TECHNOLOGICAL CHANGE IN AGRICULTURE

The Development Experience of Tamil Nadu

by

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SUMMARY

This thesis is a study of the process of technological change with reference to rice in the region of Tamil Nadu - an important rice-producing State of India. The continuous process of technological change is viewed through an endogenous/exogenous framework. The development experience of the region reveals that under traditional agriculture, technological change was largely endogenous, stimulated from within current knowledge. The introduction of the modern technology typified in the Green Revolution, on the other hand, initiates an exogenous phase of technological change.

Chapter II gives a historical perspective on the concept of technological change and the various attempts to measure the rate of technological change over time. It views the endogenous and exogenous dimensions of the process of technological change against Classical and neo-Classical literature.

The evolutionary and endogenous dimension of technological change is seen in traditional agriculture in Tamil Nadu in Chapter III, through analysis on historical data pertaining to rice cultivation in the region. Chapter IV examines the contribution of the exogenous dimension - the Green Revolution - through analyses of growth rates and stability of production.

Socio-economic factors determining farmers' acceptance of technological change are elicited using factor analysis in Chapter V. Farmers' response to modern technology is measured in Chapter VI on returns to input-use using Cobb-Douglas production functions, testing output-input relationships for different genetic strains in two homogenous districts of the region. Using linear programming in Chapter VII, we analyze the potential for increasing production in the area using modern technology.

The major findings of the thesis show that the potential for increasing production lies in the endogenous phase of the modern technology and can be effected through shifts to later hybrids in a continuous spiral. Exogenous change occurs only occasionally in the form of breakthroughs, but the endogenous phase of technological change is always with us, providing the impetus for increasing production in the long run.

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CHAPTER I

INTRODUCTION

The growing demand for food and other agricultural products as a consequence of increasing population, rising incomes and changes in food habits, has led governments in most developing countries to attempt to accelerate agricultural production through economic planning. Effective planning presupposes a serious consideration of the economic potential, resources and constraints of the area in order to determine the options which will promote agricultural development. The appropriate form of intervention or government strategy will depend on these available options.

If we accept that the goal of planning in agriculture is to attain increased production, three major types of strategy would lead to this result - increased input use, diffusion of known but only partially adopted techniques or introduction of new technology. The choice between these options will depend on the existing characteristics of agricultural production.

The simplest situation is where agricultural production is low, while at the same time available inputs are being underutilized; in this case, production can be increased merely by increasing input-use. The most common instance of this is extension of the area under cultivation; where additional land is available, bringing some of it under cultivation can increase agricultural output. Or, if land is scarce, then production from it can be increased by enhancing its quality through more irrigation, chemical fertilizers, pesticides and other inputs. Thus again increased production may result merely from increased input-use, even where one or more inputs are in fixed supply.

However, most densely populated countries of Asia are confronted with a short supply of the essential input, land, so that extension of the land frontier is no longer feasible. In this situation, intensive cultivation of land becomes necessary. Such intensive cultivation may be facilitated within current knowledge by increased use of inputs. When production can no longer be increased through increasing input-use, it may be stimulated through use of better techniques by the farmers or the community. Thus agricultural production may be increased by ensuring diffusion of techniques used in areas of high productivity or by 'progressive' farmers to 'less progressive' ones. This requires identification of areas of high productivity and/or of 'progressive' farmers in these areas. In this case, therefore, intervention includes two aspects: extending the area of better techniques and improving good techniques to better ones. Both these aspects are effected through diffusion.

Once the process of diffusion has been completed, any further increase in production must necessarily be induced from outside the framework of the existing knowledge available to the farmers. It is in this context that technological change assumes increased emphasis as an agent of growth.

The concept of technological change can be given a broader definition to include the process of diffusion, if we distinguish between endogenous and exogenous technological change. Technological change can be termed 'endogenous' if it involves the adoption of hitherto unused but known techniques and inputs. This conforms to the standard definition of technological change as it produces more output from given inputs. Thus in areas, where cultivation is purely on traditional lines, some type of seed selection or improvement in known techniques of cultivation can increase agricultural output. Such change can be brought about from within the existing field of knowledge through the process of trial-and-error. However, from the view-point of the farmers it involves use of 'different' techniques from those already in use.

On the other hand, if improved seed and techniques of cultivation are already in widespread use, further increases in output require a technological breakthrough or the introduction of new inputs like hybrid seed. This type of technological change can be termed 'exogenous', as it originates from outside the existing framework of knowledge.

We can view Indian agricultural development in this framework of endogenous and exogenous technological change. Up to the eighteenth century, increases in agricultural production were largely brought about by extending the land frontier. Once this frontier had reached its limits, pressure of population necessitated intensive cultivation of land. This intensive cultivation coupled with the progressive adoption of better techniques was an endogenous form of technological change through the process of diffusion. Thus, within the framework of traditional agriculture, increased production was achieved through adoption of improved techniques, by the process of trial-and-error. During this phase, research and experimentation centred on improving local strains and concentration on improved local varieties for increased production.

However, since land is a major constraint, after a limit, no further increases in production could be attained under traditional technology. The continuing pressure of population required a technological breakthrough to initiate and sustain any further increase. This breakthrough was inaugurated with the introduction of the Green Revolution.

We will view the breakthrough in Indian agriculture initiated with the Green Revolution as an exogenous change - a movement to new inputs and techniques outside the framework of traditional agriculture. The Green Revolution technology depends on the genetically tailored hybrid seeds accompanied by an intensive use of agricultural inputs (water, fertilizers, pesticides, research and extension services). The modern technology not only heralded the introduction of hybrid seed, but also emphasized the importance of using the appropriate 'package' of inputs and techniques. Recognizing land as a scarce input, the new technology facilitates multiple cropping through the use of modern inputs particularly the early-maturing, short-duration hybrids. It is a major departure from the traditional technology inasmuch as it relies heavily on new inputs developed by modern technology - hybrid seed, chemical fertilizers and pesticides, and is, in this sense, 'exogenous' change.

While distinction between endogenous and exogenous technological change provides a useful framework for considering agricultural development, distinction between the two phases is not clear-cut. Within the endogenous phase, farmers not only adopt known techniques but also adapt them to immediate circumstances. This on-going process of adoption and improvement means that even in the endogenous phase, technology is not static. Moreover, although the Green Revolution can be termed exogenous technological change, once its diffusion gains momentum it too takes on an endogenous aspect. We will see how in recent years, the Green Revolution has already entered on this endogenous phase through the continual movement from early hybrids to later ones.

In the same way, while we may consider the Green Revolution as a technological breakthrough, it is not a complete break with the past. The peasants in India have had a long tradition of seed selection, intensive use of water and manures, careful weeding and other associated practices. Some farmers were also familiar with research stations which date from 1786.* These research stations were experimenting on improved varieties of seed and animal breeds as far back as 1799 (Royle, 1840, p.90). Many of these improvements in traditional practice or technology came into use largely as a result of the laborious, time-consuming process of trial-and-error. Extension services in India were widely established even during the early nineteenth century, bringing the fruits of research to the farmers. In this sense, the Green Revolution technology was merely an extension and intensification of practices with which the farmers were already familiar.

It is for this reason that one would expect a reasonably high level of response from farmers to new developments. After all, many peasants, in India as well as in many other developing countries, took to cultivation of new crops (sugar, tea, coffee, indigo, cotton and groundnut) in the nineteenth century. This was in response to the markets being opened up, because of the steam revolution in transport (railways and steamships). In many cases, these crops were taken up without much promotional effort by the government.

Now that considerable experience and know-how in scientific and technological research has been accumulated, the process of 'learning by trial-and-error' can be either

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* The history of experimental work in India is said to have begun with the establishment of the Botanic Gardens in Calcutta in 1786, though systematic research on Indian vegetation dates as early as 1769 (Sinha, 1973, p.16).

altogether avoided or at least, the period over which such a process goes on can be significantly reduced by proper guidance and advice from experimental stations and the extension services. The importance of diffusion strategies therefore, becomes evident, while population pressure now makes change more urgent.

Yet, before the process of 'learning by trial-and-error' can be eliminated or reduced, a lot more information on the nature and pace of adoption is necessary. For instance, one has to know how quickly the farmers adopt a new technology. One has to answer questions such as: Are non-adopters really 'conservative' or do they suffer from serious constraints which force them to adhere to the 'traditional' technology? If this is so, what can be done to eliminate these constraints? Further, for those who readily adopt the modern technology, is it an individually rational, maximizing decision or do they adopt just because others have adopted? Do these adopters optimize input use? These are some of the issues we will consider as we examine technological change in the development experience of Tamil Nadu.*

Our choice of Tamil Nadu is guided by the fact that this region of India is a large producer of rice. It is also one of the few net rice-exporting States in India. Our analysis of the data centres on the impact of technological change in a developmental perspective on rice productivity and productive efficiency of farmers in the area.

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* Tamil Country - formerly known as Madras State.

FIGURE I

THE REPUBLIC OF INDIA

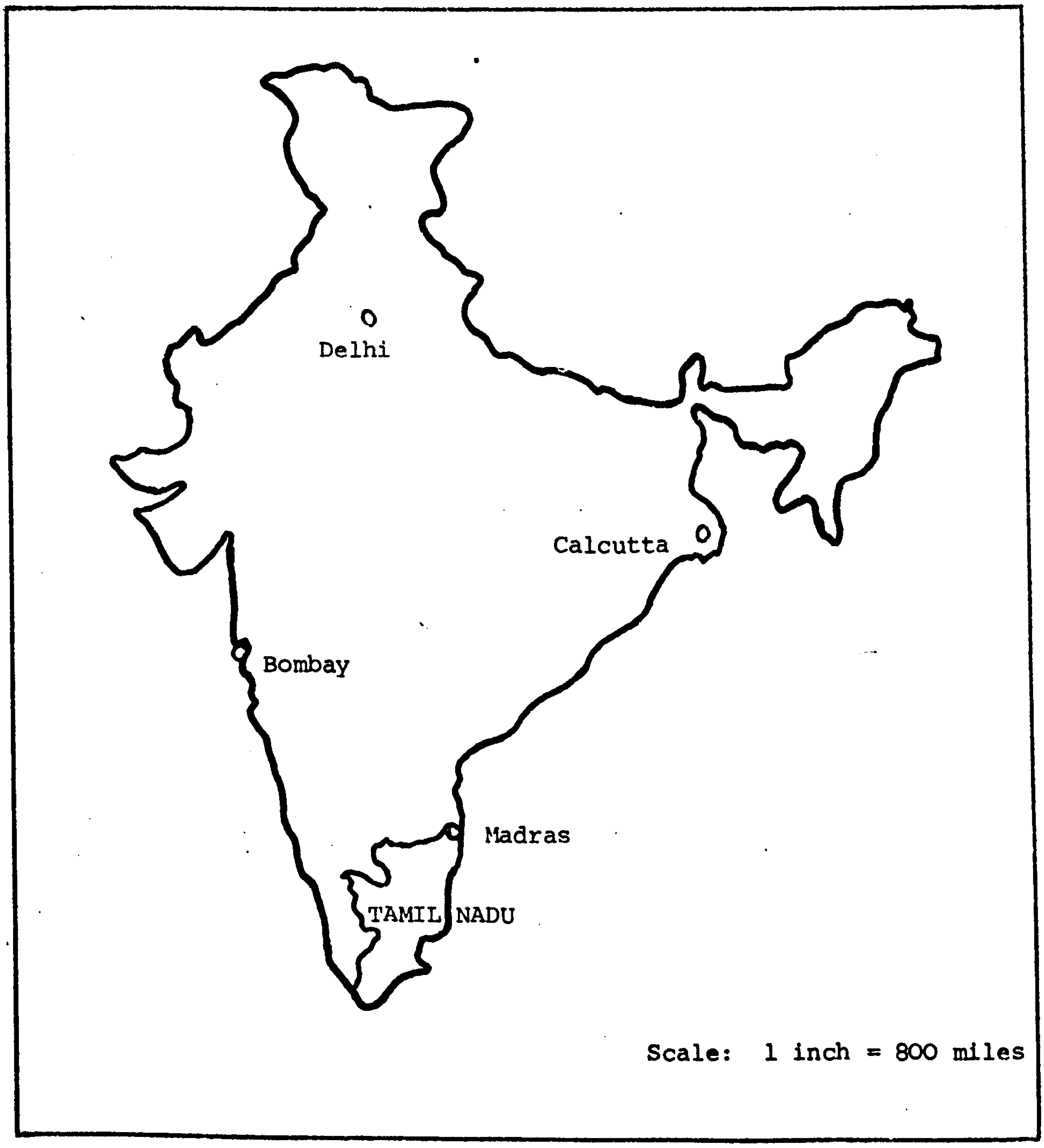
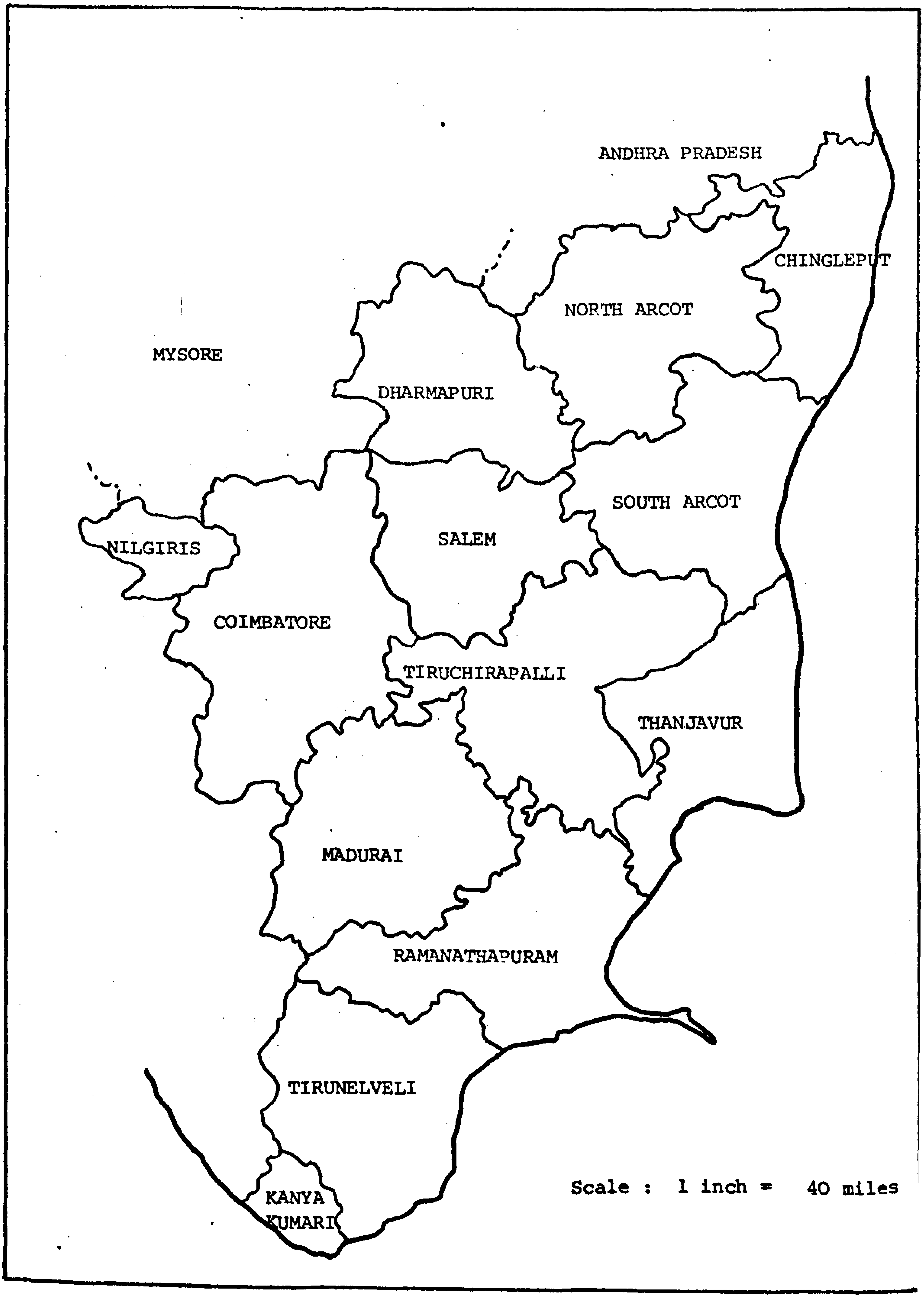


FIGURE II

THE STATE OF TAMIL NADU



The results of the analysis may have important policy implications for the future of rice strategy in the region.

One of the major objects of the exercise is to emphasize the importance of area-specificity in any consideration of technological change and particularly in relation to agriculture. Varying climatic, soil and crop conditions cause difficulty in assessing the response to modern technology. Moreover, different genetic varieties are suitable to different areas and it becomes difficult to establish their genuine technological relationships on aggregate data.

In view of the specificity of technological knowledge, we aim to concentrate our analysis to a single crop - rice, grown on a homogenous canal-irrigated tract in two districts of Tamil Nadu - Coimbatore and Thanjavur. These two districts were purposely selected because Coimbatore has been associated with progressive traditional agriculture, while Thanjavur has been associated with progressive modern agriculture. Thanjavur is one of the first districts selected by the Government for the implementation of the Intensive Agriculture District Programme (IADP). Regular farm records maintained at the IADP Office at Thanjavur provide the required disaggregated farm data for Thanjavur. In Coimbatore, the absence of such records led us to collect our data by personal interview with a sample of farmers.

We also examine the appropriateness of the existing methodological tools for the analysis and measurement of technological change. Attempts to quantify and measure technological change over time reveal the inadequacy of the currently practised methods of economic analysis to conceptualize and include the whole range of factors which constitute this phenomenon.

In dealing with historical data on traditional agriculture, such methodological problems are accentuated. Quality of inputs change over time; this makes it difficult to isolate the impact of technological change to economic growth. We will first place traditional agriculture in its historical perspective and examine it in terms of inter-country comparisons of productivity in the nineteenth century. Our analysis will be conducted on district-level data in order to minimize the effects of climatic changes which tend to bias national or regional analyses. At a lower level of aggregation, these results should be more meaningful.

However, as technological change is a continuous process, its impact is best seen in the long run. Using time-series data on average yields of rice, we will examine whether productivity has been increasing, decreasing or static over time. The effect of developmental factors like planning and irrigation on the growth rates and stability of rice production will be analyzed.

Yet, even at the district-level, the response of farmers to technological change are influenced by several socio-economic factors. These factors will be isolated through factor analysis on our survey data. These determining factors indicate the various socio-economic constraints hampering increased production. Elimination of these constraints could therefore be an effective government strategy.

We define progressive farmers on the basis of their adoption of the recommended 'package' of inputs and practices. However, adoption of the package need not necessarily imply that 'progressive' farmers obtain higher returns to input use. We therefore test whether farmers who adhere to the recommended package of the Agricultural Department are in fact, obtaining higher returns to input use than our so-called 'less progressive' farmers. We also examine the area-specificity of different genetic rice hybrids using production function analysis on data collected in the two districts - Coimbatore and Thanjavur. Thus response to technological change will be measured in terms of returns to input use.

Finally, we use linear programming techniques to examine the potential for further increasing productivity, through changes in crop pattern and input use. We test whether our 'less progressive' farmers could improve their production by altering the input-mix, or whether they are optimizing returns given their resource constraints.

The plan of the study is as follows :

Chapter II describes the historical development of the concept of technological change and the various attempts to measure the rate of technological change in industry. The difficulties of measuring technological change in agriculture using these techniques will be examined. Consequently, within this theoretical framework, the process of technological change in agriculture will be viewed in its endogenous and exogenous dimensions. Both these aspects are implicit in earlier literature, though they are unrelated to empirical analysis. We find that most of the theoretical models for measuring technological change in agriculture, tend to ignore the evolutionary and endogenous nature of the phenomenon.

Any consideration of change would however be lacking in foundation without at least a brief historical view of the past. In Chapter III, therefore we develop a framework for evolutionary and endogenous technological change which is particularly relevant in the Indian agricultural experience, where the foundation of agricultural technology is firmly rooted in tradition and past experience. The state of traditional agriculture in Tamil Nadu is examined in its qualitative and quantitative dimensions in relation to other countries. Access to late nineteenth century data on China and Japan, the two leading rice producing countries in Asia, enables us to put traditional agriculture in Tamil Nadu in an international perspective. The historical data has been obtained from agricultural records held at India Office (London) and Tamil Nadu Archives (Madras). Much of this data is in the form of impressionistic evidence and hence does not permit any formal statistical testing, but we explore the hypothesis that traditional agriculture in Tamil Nadu was already at a relatively high level in the nineteenth century. We are fully aware that such inter-country comparisons do not produce definitive answers, partly because of the limitations of historical data, but they do serve as broad indicators of the level of agricultural technology in the nineteenth century.

Chapter IV deals with the contribution over time of several forms of agricultural change - extension of area, irrigation and the introduction of modern technology. Much of this analysis is carried out en an inter-district level to emphasize variations in productivity at a lower level of aggregation. Using data on average yields of rice collected from the Season and Crop Reports for Tamil Nadu, we examine the impact of technological change and particularly the Green Revolution, on growth rates and stability of rice production in the region. We also examine the hypothesis that districts of high productivity under traditional technology maintain a 'leading role' in the long period.

Having selected 'progressive districts' on the basis of the analysis in the earlier chapters, factors promoting technological progress will be identified and evaluated in Chapter V. This analysis will be conducted on the basis of farm-level data pertaining to the agricultural year 1973-74, collected by us in personal interviews with 180 farmers in Coimbatore. The important socio-economic variables governing farmers' response to technological change will be elicited through factor analysis. It is felt that such factors can be extremely relevant in evolving a diffusion strategy.

In Chapter VI, we examine the response of farmers to modern technology in terms of returns to input use, using production function analysis, with a view to test whether there have been significant shifts in such functions for the different areas under investigation. Such a shift is most effectively measured at the lowest level of aggregation, to bring out the genuine technological relationships between inputs and outputs. Recognizing the specificity of input-output relationships for different areas and for different strains, we test the level of technology for genetic rice strains separately, using the Cobb-Douglas production function.

The relative profitability and productive efficiency of the different strains in Coimbatore will be explored vis-a-vis similar strains in a corresponding homogenous 'progressive' district, Thanjavur, in order to test the area-specificity of different rice strains. The level of technology for each strain as well as the more optimal varieties for the region will be identified. Concentration on the more optimal varieties in the area can be a positive step towards increasing rice production. We also compare levels of technology, resource use and allocative efficiency of our progressive and 'less-progressive' farmers using production function analysis.

However, this analysis does not test for optimality under the current constaints. In Chapter VII therefore, we examine the potential for increasing output under the new strategy using linear programming techniques. The simulated programme will explore the possibility of optimising output by changing the crop pattern subject to the resource constaints faced by the farmer, and enable us to determine whether or not 'less-progressive' farmers are optimising returns under their resource constraints. Thus policy strategies aimed at optimising resources by altering the input-mix through changes in crop pattern and choice of the more optimal varieties can have a positive effect in increasing productivity, as also in isolating and, later, eliminating the constraints which affect farmers' response to modern technology.

We conclude with a brief discussion of the policy implications which arise from the analysis.

CHAPTER II

PERSPECTIVE ON TECHNOLOGICAL CHANGE IN AGRICULTURE

Introduction

Any consideration of technological change requires a clear understanding of the nature of the phenomenon and its importance in the context of development. In this chapter, we shall therefore consider the historical development of the concept of technological change in an attempt to examine its contribution in a dynamic framework of growth.

However, technological change is a complex phenomenon. Consequently, attempts at measuring the rate of technological change over time become difficult. This we shall see in the various attempts at isolating the contribution of technological change in the industrial sector. Much of this difficulty stems from the fact that technological change is a continuous process. The specific problems of measuring technological change in agriculture lead us to consider the process of technological change in the context of the development experience of the region in two distinct aspects - endogenous and exogenous.

Before we enter into the development of the concept, it is necessary to clarify certain ambiguities surrounding the phenomenon. Much of this ambiguity stems from misconceptions in terminology. Terms like technology and technique, technical change, and technological change, invention and innovation are often treated as synonymous,* tending to give a confusing picture of the growth process. It is essential that the nature of technological change is properly understood. This becomes explicit in the development of the concept.

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* A definition of these terms is fundamental to any empirical analysis. A technique is defined as any bundle of inputs which yield a given output or a "method of producing a given good or service" (Schmookler, 1966, p.2); technology is a much wider term including all the techniques currently available or "the social pool of knowledge of the industrial arts" (Schmookler, 1966, p.1). Thus technical change is the change in the production methods out of the existing technology, while technological change involves the creation of a new set of production alternatives. Technological change necessarily implies invention which is the creation of new production methods, while innovation is merely the first adoption of a new technique and is therefore more related to technical change. Ruttan (1959) sums up the links between invention, innovation and technological change: "Invention in some manner is antecedent to innovation and innovation is in turn antecedent to technological change" (Ruttan, 1959, p.598). Technological progress on the other hand, indicates the <u>effects</u> of changes in technique or technology; it therefore embraces not only invention and innovation but also the process of diffusion.

Development of the Concept

The concept of technological change dates in essence as far back as the Classical economists. Although the Classical economists made no attempt at measuring technological change, the phenomenon featured quite prominently in their treatment of economic growth. The whole focus of the Classical economists was on the problem of growth in a macro-economic context. Their concern with allocative decisions and maximization were viewed in a dynamic framework of growth. Both Smith's (1776) Wealth of Nations and Mill's Principles* present the mechanism of resource allocation within the framework of changing technology and changing resources. The Classicists were concerned primarily with situations in which technology, tastes and incomes were not fixed and with problems developing from these dynamic variables. Though the term 'technological change' was not explicitly used, we shall see that the implications of changing technology in the growth process were quite clear to the Classicists.

For Smith, division of labour was the great cause of increases in productivity. To him, such increases in productivity were achieved because division of labour gave rise to invention of machinery. These increases in productivity would contribute to the growth of an

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* Cf. Smith (1776) Book I & Mill (1865) Book I.

agricultural surplus.*

The core of Smith's theory centred round the doctrine of trade and growth in which technological change played a vital role. The stimulation of wants involved in the development of trade was all-important as supplying the motive for further division of labour, further exertion and technological change. Smith's stress on the links between capital, division of labour and trade foreshadowed the relationship suggested by modern writers between capital accumulation, technological advance and trade advantage.**

Yet, Smith also realized that despite technological advance, there was no infinite horizon for economic growth and therefore, economies would ultimately reach a stationary state. Although Smith introduces the concept of the stationary state, he does not indicate the process by which the economy would reach the stationary state.

In Ricardo, the stationary state assumes greater clarity as a technological production frontier.

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* It is significant that the 'Digression on Silver' is an interesting application of the theory of economic development. Smith clearly shows how price movements largely determine production; he recognized that price trends in many primary products were likely to be less favourable than in manufactured goods.

** Such trade advantage would indicate technological leadership which could lead to transfer of technology through imitation or import. This idea is implicit in Classical literature, but comes to the fore in McCulloch as we shall see.

The introduction of machinery or any new invention pushes the production frontier outwards. In this way, Ricardo visualizes a postponement of the stationary state through introducing machinery into production.

It is in Lauderdale's (1804) writings that another aspect of the concept of technological change emerges in terms of an equilibrium limit. The theory of an equilibrium limit states that despite an economy's capacity to absorb increasing amounts of capital over time with changes in technology, there is a limit to how much capital can be profitably employed at any given time with a given level of technology. This given level of technology according to Lauderdale (1804) is set by the "existing state of knowledge".* Thus Lauderdale distinguishes between increased investment at a given level of technology and increased investment in response to technological advance - in other words, a distinction between movements along the marginal product of capital curve

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* "In every state of society, a certain quantity of capital, proportioned to the existing state of the knowledge of mankind, may be usefully and profitably employed in supplanting and performing labour in the course of rearing, giving form to, and circulating the raw materials produced. Man's invention, in the means of supplanting labour, may give scope, in the progress of society, for the employment of an increased quantity; but there must be, at all times, a point determined by the existing state of knowledge in the art of supplanting and performing labour with capital, beyond which capital cannot profitably be increased, and beyond which it will not naturally increase: because the quantity when it exceeds that point, must increase in proportion in the demand for it, and its value must of consequence diminish in such a manner as effectually to check its augmentation." (Lauderdale, 1804, as quoted in Sowell, 1972, p.83).

and shifts of the curve outwards.* This distinction will be further elucidated when dealing with production functions.

Later, the thinking of Mill expressed in his Principles, shows striking similarity to Lauderdale's theory of an equilibrium limit applied to agriculture. According to Mill, the limited quantity of land and its limited productiveness set the limits to increase in production.

Yet, even before Mill, Ricardo and other classical writers recognized that the operation of diminishing returns could be interupted by technological change. Senior was perhaps the most emphatic on these grounds when he stressed "agricultural skill remaining the same"** as a pre-condition for the operation of diminishing returns.

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* It is significant that Malthus and Sismondi present the same idea in their writings. Cf. (Malthus (1832); Sismondi (1827) vol. I. as quoted in Sowell, 1972, pp. 90-91).

** "That agricultural skill remaining the same, additional Labour employed on the land within a given district produces in general a less proportionate return, or, in other words, that though, with every increase of the labour bestowed, the aggregate return is increased, the increase of the return is not in proportion to the increase of the labour." (Senior as quoted in Schumpeter, 1954, p.584).

In other words, a given and constant technological horizon was for Senior an important and necessary condition for diminishing returns. Technological change would shift this horizon thereby delaying the operation of diminishing returns.

However, Mill went a step further in his Principles, enumerating the different ways by which technological change could be introduced into agriculture - through advances in agricultural technology, better implements, improved communications and other factors. Nonetheless, Mill also recognized that these forces could only stave off the stationary state. We find in Mill's writings, the full implications of technological change in agriculture spelt out at length for the first time. We shall return to this point in greater detail later as our treatment of technological change in traditional agriculture leans to some extent on Mill's contribution.

The Classical contribution to technological change would not be complete without a consideration of McCulloch whose stress on machinery and invention as a stimulant to growth supplements early Classical literature. In their emphasis on division of labour, Smith, Malthus and many of the other Classical economists paid scant attention to invention. McCulloch recognized invention as opening up almost limitless possibilities for growth, and therefore extending the technological horizon.

It is significant that McCulloch was far ahead of his contemporaries in emphasizing investment in human capital and diffusion of knowledge to promote growth. He realised that education accelerated invention and productivity increased with knowledge. As early as 1837, McCulloch insisted that the greater competitiveness of the Americans arose partly from their better education.

McCulloch realized that the full benefits of education could only be achieved through diffusion of knowledge. Besides, he also recognized the importance of encouraging foreigners, who often brought with them technological improvements. Mill was probably to some extent, influenced by McCulloch's writings, in emphasizing the importance of progress in agricultural knowledge and good communications to stimulate progress.

To sum up, the Classical economists were keenly aware of the contribution of technological change in the dynamic macro-economic situation. Without technological change, a country would reach the stationary state. In this way, technological change was largely responsible for extending the technological horizon (or what modern writers refer to as the production frontier) either through invention or improvements in knowledge.*

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* The Ricardian Socialists and Karl Marx while recognizing the benefits of technological change were also keenly aware of its disadvantages. The most striking of these is the problem of unemployment arising from the substitution of capital for labour. More recently the employment aspects of changing technology have been highlighted by Sen (1975).

However, the Classical writers thought of technological change exclusively as impinging upon the productive process from outside, that is, through some invention that revolutionized the technological horizon of producers. They were unable to follow the effects of technological change through the economic system as a whole, yet their view of technological change as a dynamic phenomenon is in itself a significant contribution.

This dynamic view of economic phenomena was largely lost sight of during the marginal revolution of the 1870s and had to be revived by Schumpeter and other modern writers. Schumpeter's (1928) contribution resumed interest in inventive activity and its long-run growth implications, but it is in his Business Cycles (1939) that his concept of technological change emerges more clearly.

Recognizing the deficiencies of Classical thinking on the concept of technological change, Schumpeter presents several facets of the concept. The Classical thinking was restricted to the first aspect alone - namely, improvements or inventions that extended the technological horizon. Schumpeter examined other aspects of technological change which have different consequences primarily because they do not extend producers' horizons. For instance, the introduction of machines which are not necessarily new inventions, but could not hitherto be profitably employed. A change in relative factor prices could make their introduction profitable.* So too, when output expands beyond a certain point, introduction of machinery may become profitable (this was recognized by Smith).

Schumpeter's major interest was in discovering the effect of variations in the rate of technological change on economic development. Though Schumpeter concentrated primarily on innovation, his definition of innovation is very similar to current thinking on technological change in the form of the production function, brought about either through the introduction of new inputs, new forms of organization or different production methods.**

In dealing with innovation, Schumpeter was concerned with the effect of technological change operating through the production function on economic growth. However, he did not attempt to measure these effects through changes in the production function. Schumpeter recognized that

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* This aspect of technological change bears striking resemblance to Salter's (1960) contribution which we shall discuss later.

** "We will now define innovation more rigorously by means of the production function.... This function describes the way in which quantity of products varies if quantity of factors vary. If, instead of quantity of factors we vary the form of the function, we have an innovation..... We will simply define innovation as the setting up of a new production function. This covers the case of a new commodity as well as those of a new form of organization or a merger, or the opening up of new markets..." (Schumpeter, 1939, vol. I, pp. 87-88).

changes in prices and non-neutrality of innovation do not permit any accurate measurement of innovation. Since production functions change over time, the introduction of any innovation destroys the original production function and sets up a new one. Thus, for Schumpeter, technological change is characterised by discontinuous changes over time. *

Any change in the technological horizon either through invention or innovation would therefore destroy this production function and replace it by another. It would seem therefore, as Schumpeter puts it that "... the full logical meaning of the concept of production functions reveals itself only if we think of them as "planning" functions in a world of blueprints where every element that is technologically variable at all can be changed at will, without any loss of time and without any expense." (Schumpeter, 1954, p.1031). In this context, the difficulties of measuring technological

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* Departing strongly from the Classical tradition, Schumpeter elucidates his theory of economic development in terms of such discreet jumps, enumerating 5 distinct cases through which discontinuous change is manifested (Schumpeter, 1949, p.66).

change through the production function become explicit.*

Theoretically therefore, Schumpeter visualized the difficulties that could arise in attempts to measure technological change. Yet, his main interest was in the effects of changes in technology on innovators and not on the rate of technological change. Efforts at measuring the rate of technological change highlight some of the main difficulties that Schumpeter had already anticipated.**

Attempts at Measuring Technological Change

Early attempts to quantify technological change concentrated largely on its productivity-increasing

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* Such difficulties are amplified in agriculture, particularly when we have to deal with observational data which prevent any consideration of "logically pure" production functions. Experimental data on the other hand, would permit the formulation of pure functions due to the effective controls on such farms.

** Much of this effort has been concentrated on industry (Abramovitz, 1956; Solow, 1957); the only attempt on agricultural data is Griliches' (1957a) study on hybrid corn, tracing the pattern of adoption of hybrid corn in various areas.

effects. Productivity indices were used as the quantitative expression of technological change. The simplest form used was an arithmetic index obtained by dividing an index of output by some form of input index. Initial efforts concentrated largely on measuring productivity in terms of one factor alone - usually labour.

However, such 'partial' productivity indices were unrealistic and inadequate as a measure of technological change. The inadequacies of productivity indices of labour as a measure of the rate of technological change become evident if we distinguish between growth in production caused by :

(i) employing more inputs
(ii) increasing productive efficiency.

If the initial level of technology is low, productivity can be increased merely by employing more inputs; this would also apply where the level of technology is high, but where there is unutilized capacity. Thus intensive use of inputs would result in increased productivity; but where there is no unutilized capacity, productivity can only be increased by increased efficiency of inputs. However, in using productivity indices as a measure of technological change, such differences cannot be distinguished. Besides, it is important to recognize that not all increases in productivity are brought about by technological change.

Recognizing that 'partial' productivity indices are unrealistic in a world of more than one factor, it became more popular to measure technological change in terms of total factor productivity. Total factor productivity for n factors is measured by the equation :

$$P = \frac{Q}{\Sigma_i W_i X_i} \qquad \Sigma_i W_i = 1$$

where Q = index of output

X_i = input of the i-th factor

W_i = share of i-th factor in total in the base year.

Although total productivity indices are an improvement over the 'partial', heterogeneity of inputs, makes definition and measurement of the X_i's difficult. There is also the index number problem with W_i, caused by change in relative factor prices or non-neutrality of technological change.

Following on the inadequacies of productivity indices, the production function approach was used to measure technological change. As we have seen, Schumpeter had much earlier concerned himself with the effect of technological change operating through the production function on economic growth. However, Schumpeter was primarily interested in changes in the production functions of the technological leaders - the innovators, who stimulated growth. His interest was not in explaining the process or in measuring technological change.

On the other hand, much of the applied research led by Solow (1957) has till recently been centred on the aggregate production function as a measure of technological change. Attention was therefore focussed on the production function which describes the average performance of the economy or industry.*

The rationale of the aggregate production function can be stated as follows: If the level of technology is expressed in terms of an aggregate production function

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* In agriculture, physical production functions such as fertilizer functions on experimental data were already being used as early as 1855, though no attempt was made to measure technological change in agriculture through the production function.

whose parameters reflect all the technical production possibilities currently available, technological change can be viewed as a change in one or more parameters of the aggregate production function resulting from the addition of new techniques to the existing stock. The Solow (1957) model treats technological change almost as a catch-all expression* to include all increases in output per man that cannot be explained by increases in capital per man.

As a measure of the rate of technological change, the Solow (1957) model presents certain conceptual problems which render it inappropriate in empirical analyses of agricultural data. Much of the difficulty is due to the problem of bias arising primarily from the dynamic nature of technological change. Since increases in productivity are effected by a number of factors, including technological change, a major problem consists in isolating the contribution of technological change to increasing productivity from the contribution of other factors. In the long-run, bias is introduced into estimates of technological change due to certain fundamental factors:

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* Solow admits that he is "...using the phrase 'technical change' as a shorthand expression for any kind of shift in the production function. Thus slowdowns, speedups, improvements in the education of the labour force and all sorts of things will appear as 'technical change'" (Solow, 1957, p.312).

(a) firms/farms may not be operating at equilibrium in both periods;

(b) prices of factor and/or prices of products do not remain unchanged relative to each other;

(c) constant returns to scale do not hold;

(d) technological change need not necessarily be neutral.*

Bias also results from omitted variables; for instance, the labour input measured in man-hours conceals varying degrees of efficiency which are not quantifiable except in terms of increased output. Similarly, time and labour expended in research and experimentation often tends to be omitted.

A second major problem comprises the criterion of input-output measures. All too often, agricultural out-

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* The two most common definitions of neutrality are those attributed to Hicks (1932) and Harrod (1948). According to Hicks (1932) an invention is 'neutral' when with given factor proportions, the marginal product of labour rises in the same proportion as the marginal product of capital. Harrod (1948) defined technical progress as neutral, if with a constant rate of interest, it left the capital-output ratio unchanged. Inasmuch as the isoquant shifts in favour of one or other of the factors, labour-saving or capital-saving bias follow.

put has been measured in terms of total value of farm products produced or in terms of value added (Stout and Ruttan, 1958). The difficulties caused by the inclusion of prices and the existence of bias are not far to seek. Price fluctuations over the time period render the estimates inaccurate. To avoid distortions caused by the inclusion of prices, measures of technological change are best confined to purely technical relationships in physical units.

Even in dealing with physical units, one cannot ignore the fact that the quality of inputs changes over time. These changes in quality include improvements in capital inputs and improvements in efficiency in resource allocation consequent mainly upon improvements in the quality of the labour force. Schultz (1956) is inclined to restrict technological change to include only changes in the quality of capital. But one is confronted with the problem of identifying total productivity gains contributed by changes in quality of capital as distinct from changes in quality of labour. Even were it possible to separate the two, exclusion of quality changes in labour would not be valid particularly in agriculture, where improvements in human investment reflect the whole aspect of research and experimentation leading to changes in technique and improved inputs.

This latter point is of particular significance in our consideration of the development of agricultural technology in Tamil Nadu, where the experience of several centuries has resulted in a set of traditional techniques and practices.

Thus we see that the whole problem of isolating the contribution of technological change is not an easy one. Attempts to measure technological change in the industrial sector present certain interesting points. Massell's (1960) method of apportioning historical increases in output between increases in capital and technical change in U.S. manufacturing between 1919-1955 concludes that 90 per cent of the increase in average labour productivity may be attributed to improvements in technology. However, within this estimate of technological change are included both improvements in quality of the labour force and improvements in efficiency in resource allocation.

Later, in an attempt to improve upon the estimates, Massell (1961) extends the analysis by refining the catch-all technological change category to distinguish among several component industries. His analysis does not demonstrate any relationship between technological levels and percentage rates of technical change in the various industries, but throws light on the advantages of disaggregation. The results indicate that the shift in the aggregate function exceeds the weighted average of the shifts in the industry functions by nearly one-third of the change in aggregate technology. Such discrepancies between aggregate and disaggregate analyses are a warning that aggregate results can be misleading. The effect of disaggregation yields additional information regarding productivity change. It shows the dispersion around the average of industry rates of technological change. The analysis therefore emphasizes the importance of disaggregation in any consideration of technological change (Massell, 1961, p.547).

From the foregoing considerations, we see that the production function concept is open to challenge if it is not a stable physical function and its usefulness as a measure of technological change becomes questionable. Such problems are minimised within the framework of microeconomic analysis on disaggregated data which is what we attempt later. Yet, the problem of measuring technological change over time, is not easily overcome.

One valid approach to include the time factor, is the isolation of technological epochs - periods of time within which technological change is neutral. Only between epochs can the effect of non-neutral technological change be evaluated (Brown, 1966). Though a tenable hypothesis, the isolation of technological epochs is also fraught with many problems.

In any epoch, different technologies can be identified. This is particularly significant in agriculture where technology in cultivation could differ for different crops. Traditional methods of cultivation often exist side by side with more modern techniques. Even in industry, the introduction of machinery need not necessarily imply the elimination of traditional methods. Thus, inasmuch as technological change does not necessarily involve a break with the past, differentiation of epochs may not be easy.

Salter (1960) attempted to overcome this problem by adopting an interpretation according to which the production function includes "all possible designs" which can be developed with the present state of knowledge. In other words, Salter's production function envelops not only techniques immediately available to the entrepreneur but also the "much wider range of techniques which could be designed with the current stock of knowledge". Salter makes a distinction between techniques developed in detail and those developed from existing technical knowledge in response to changed factor prices. If we accept that firms have to commit resources to establishing new optimal input combinations following change in relative factor prices, then clearly the search involved in determining the new optimum could be termed technological change, rather than factor substitution as Salter implies.* Rosenberg (1976) very concisely points out: "Today's factor substitution possibilities, in other words, are the product of yesterday's technological explorations". (Rosenberg, 1976, p.63).

Later, Salter (1960) attributes the observed differences in interindustry productivity movements largely to technological change - shifts in the production function. These shifts indicate a new set of techniques or the introduction of new elements into the set of existing techniques. Within the Salter framework, such shifts necessarily imply research and invention generating a shift in the production function.

In the context of development therefore, technological change is a continuous process. During certain periods, technological change may be subtle, almost concealed, resulting merely from factor substitution. In other periods, it may be more pronounced. The former may be regarded as an evolutionary and endogenous dimension of technological change (leaning on Mill's framework). The latter resulting in distinct shifts in the production function may be viewed as exogenous, similar to

* "Thinking in these terms it could be argued that our fundamental technical knowledge has changed very little (the fundamental production function of each industry is substantially unchanged), but that the majority of new methods are simply new designs within the fold of existing knowledge. Pressed by changing relative prices, engineers have simply rearranged knowledge into designs which save labour. This hypothesis would imply that much of what we call technical progress is really a sham - a disguised form of factor substitution." (Salter, 1960, p.130).

the Schumpeterian framework. The analytical justification for the notion of distinct shifts in well-defined production functions seems to be that some breakthroughs in scientific knowledge bring with them whole new <u>ranges</u> of more efficient factor combinations for producing a commodity.

The Salter (1960) model stimulated thinking along the lines of a technical change frontier. Also referred to as an "innovation-possibilities frontier", such a frontier embodies the range of possible alternatives under the current state of knowledge. Thus the existing knowledge provides the constraint defining the limits of the frontier. Consequently, any new technique or extension of knowledge would tend to push the frontier outwards.

The idea of a technical change frontier has been largely associated with evolutionary theories of economic growth. In such a model, there is no production function - only a set of physically possible activities. The frontier envelops not only currently available techniques but the much wider range of techniques possible under the existing state of knowledge. Hence techniques may change over time as a result of search for increased efficiency, causing movement towards the frontier.

This potential for increased efficiency or X-inefficiency according to Leibenstein (1966) suggests that in reality, firms do not operate on the production possibility frontier consistent with their resources. Rather they operate on a production surface well within that outer bound. Consequently, any movement from a lower production surface to a higher one increases X-efficiency. The similarity of the 'frontier' concept with Classical thinking becomes quite evident. Thus even in the early eighteenth century, these more recent developments were already implicit in Classical literature.

The framework of a technical change frontier can be suitably applied to agriculture. The frontier for traditional agriculture can be identified as a 'best practice frontier'. With given factor prices, the single best practice input-output combination on the frontier can be determined. The best technique therefore would be the result of interaction between changes in technical knowledge and changes in factor prices (Salter, 1960, p.26). Hence any diffusion of existing knowledge or change in techniques would cause movement towards the best practice frontier. The two forces therefore determining the direction of the "technological change path" can be identified as technological change and X-efficiency.*

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* Shen (1973) expresses these two forces very concisely: "the principal impact of technological change is on factor intensity and the principal impact of X-efficiency improvement is on productivity." (Shen, 1973, p.279).

Therefore, the contribution of technological change to increasing productivity requires a consideration of a whole series of factors generated by the complex and dynamic character of the phenomenon. Following on dissatisfaction at efforts to quantify technological change, economic analysis has shifted to a consideration of the path assumed by technological change to promote economic development. In the sphere of agriculture, two major constraints set by the inelastic supply of land and labour determine the choice between alternative paths of land-saving and labour-saving technology.

Process of Technological Change - Endogenous and Exogenous

The breakthrough in Indian agriculture effected through the Green Revolution is an illustration of the choice to loosen the constraint caused by the inelastic supply of land. Much attention has till now focussed on the superiority of the modern technology over the traditional, but not enough emphasis has centred on the on-going process of technological change in agriculture.

It is precisely this on-going process of technological change that we shall consider in the development experience of Tamil Nadu. We shall treat technological change in agriculture in two distinct dimensions:

(i) an endogenous dimension in which technological change is largely brought about through changes in techniques and improvements within traditional agriculture;

(ii) an exogenous dimension in which technological change is effected by extending the horizon of traditional agriculture through use of modern inputs.

It is interesting that these two dimensions can be gleaned from Mill's (1865) and Schumpeter's (1939) contributions. In emphasizing improved agricultural knowledge as an effective means of progress, Mill proceeds to classify these improvements:

(i) those enhancing productivity of land without increasing the labour input. These include changes in techniques of cultivation - rotation, fallows, improved knowledge of manures or techniques of improved ploughing and draining to improve the quality of the soil;

(ii) those reducing the labour cost of cultivation such as introduction of winnowing and threshing machines or increased efficiency in ploughing. Also included in this category are improved means of communication; in Mill's opinion: "Good roads are equivalent to good tools." (Mill, 1865, p.113).

Mill recognized that improvements in other industries could facilitate technological change in agriculture; for instance, improvements in the process of melting iron will tend to cheapen agricultural implements and consequently promote their use. In this way, technological changes in agriculture can be induced through improvements in other related industries.

The Schumpeterian framework on the other hand, can be regarded as an exogenous dimension of technological change. Schumpeter viewed technological change in terms of discreet jumps - a break with the past through introduction of new inputs or production methods from outside.

Technically speaking, these two dimensions could also be expressed in terms of a technological horizon or frontier. We shall see that under traditional agriculture in Tamil Nadu, any change was restricted to changes in techniques like rotation, manuring, and other practices within the framework of traditional knowledge. It will be seen that desire for progress in traditional agriculture prompted changes in agricultural techniques. Such changes were probably largely effected by what is now termed the 'learning by doing' process. In Salterian terminology, this process could be identified with factor substitution, while in the Leibenstein framework, the process of movement towards the technological frontier results in a reduction in X-inefficiency. We shall see to what extent traditional agriculture in Tamil Nadu bears evidence to this aspect. Thus progress under traditional agriculture can be largely seen as movement towards the technological frontier leading to greater efficiency.

Both the qualitative and quantitative dimensions of traditional agricultural technology in Tamil Nadu will be discussed at length in the following chapter, but here it suffices to mention that though apparently static, traditional technology was constantly evolving. This feature is not exclusive to Indian agriculture; traditional societies of several countries bear evidence to this evolutionary aspect of technological change (Smith, 1959; Boserup, 1965; Ishikawa, 1967; Geertz, 1963).

However, once this frontier of traditional agriculture has been reached, any further increases in productivity require exogenous change. Latent in the Indian agricultural experience is the reality that significant and sustained growth in productivity could not be brought about merely by the reallocation of resources in traditional agriculture (Schultz, 1964; Hopper, 1965). This led us to examine the hypothesis that evolutionary and endogenous technological change in traditional agriculture in Tamil Nadu had reached its limits in the late nineteenth century, necessitating exogenous change which was introduced through the Green Revolution in the 1960s.

Yet, if traditional technology in agriculture was at a high level in the nineteenth century, with its consequent decline in the early twentieth century, it is likely that the modern technology will also follow a similar pattern in the long run. This would depend on the pace of technological change, the rate of diffusion, research and innovation, and the speed with which the frontier can be reached.

Hence, in the long run, exogenous change initiates a process which develops endogenously. This endogenous process can be seen in early hybrids being replaced by later ones, the former having reached their limits of productivity. However, to examine this hypothesis requires disaggregated data on different genetic hybrids. Consequently, our study is related to a specific region to emphasize the importance of disaggregation in dealing with technological change.

The necessity of specificity is particularly important in a consideration of technological change in agriculture. Various genetic hybrids are area-specific and perform best under specific soil and climatic conditions. Consequently, any such study to be really worthwhile, much consider the genuine technological requirements of each variety. We have therefore restricted our analysis throughout to a consideration of a single crop - rice, in the region of Tamil Nadu, thus fulfilling the requirements of area and crop-specificity.

Conclusions:

We have seen from a definition of the concept that technological change is a complex phenomenon, but it is nonetheless vital in the growth process. It is significant that its contribution to increasing productivity was recognized even by the early Classical economists. In particular, Mill's (1865) contribution requires special mention for its specificity and precise coverage of technological change in agriculture.

Though later neo-classical thinking concentrated on the measurement and quantification of technological change, attempts at empirical analyses of technological change in industry present certain problems which are still with us. The basic problems of technological change stem from its dynamic nature and tend to give misleading results of aggregate data. Consequently, any treatment of the concept is best seen in a developmental perspective, as a continual process and analysis conducted at a low level of aggregation.

This is what we set out to do in our consideration of technological change in the development experience of Tamil Nadu. We see this development experience as comprising two distinct phases :

(i) An evolutionary endogenous phase in which traditional agricultural technology experienced change from within the agricultural sector through changes in already existing techniques or through the 'learning by doing' process;

(ii) an exogenous phase characterised by the Green Revolution through the introduction of modern inputs and techniques.

Hence to form a clear picture of the whole concept of technological change in agriculture in Tamil Nadu, we shall first examine historical data to analyse the evolutionary and endogenous nature of technological change which for a considerable length of time has remained concealed. Yet, such analysis is vital in the growth experience. It is this evolutionary endogenous dimension which we shall consider in our analysis of historical evidence of agricultural conditions in Tamil Nadu in the nineteenth century, in an attempt to lay the foundation on which the present-day technological change has developed.

CHAPTER III

ENDOGENOUS TECHNOLOGICAL CHANGE IN TRADITIONAL AGRICULTURE

Introduction

In the preceding chapter, we have seen that technological change in agriculture is best viewed as a continual process. In this chapter we shall examine the evolutionary endogenous aspect of technological change in traditional agriculture. Such an examination will give us some idea of the continuity of technological change in the development experience of Tamil Nadu.

A consideration of technological change as an evolutionary process, cannot be built on a total disregard of the past. Yet, deliberate 'disregard of the past' is not uncommon and is often justified on the facile assumption that traditional agriculture is a static, inefficient process responsible for the 'underdevelopment' in which developing countries find themselves.

In the densely populated Asian countries like China and Japan, such an assumption, explicit or implicit, is not really valid. Our hypothesis is that such an assumption is not valid in the Indian context either, but this can only be established through historical research into traditional agricultural techniques and productivity.

In a vast country like India, inter-regional and even inter-district variations in agricultural productivity and technology are to be expected. Consequently, any consideration of agricultural technology has to be restricted to a specific area or region. This is precisely what we shall do in examining the condition of traditional agricultural technology in Tamil Nadu. For our point of reference, we have selected the late nineteenth century (specifically 1860-1890) period as representative of traditional technology.

Our basic aim is to examine how traditional technology in this region compares with other traditional societies during the same period. Hence our major hypotheses consider both qualitative and quantitative dimensions of traditional agriculture. On the qualitative aspect, we will test the hypothesis that traditional agriculture is at a reasonably high level in its use of available inputs and resources, that productive efficiency of farmers in Tamil Nadu was broadly at par with other countries. Undoubtedly, in dealing with qualitative evidence of this nature, one is confronted with the dilemma as to how representative such information is. While a large part of this evidence is expressed purely in terms of evaluatory judgements, there is also the problem of generalizations, which do not permit any systematic statistical analysis.

However, we are fortunate with our choice of region. Tamil Nadu is one of the few Provinces in India that is reputed to have had fairly reliable data for the period under study; hence reasonably valid conclusions can be obtained from the analysis. Nonetheless, conclusions from qualitative evidence are always open to scepticism, unless backed by quantitative data. For this reason, we place more weight to testing our second hypothesis that rice productivity under traditional agriculture in Tamil Nadu does not compare unfavourably with prevailing yields in other parts of the world.

We have divided this chapter into two broad sections. The first part deals with the qualitative evidence to establish the level of traditional agricultural technology in Tamil Nadu. The second part deals with the quantitative evidence to establish the productivity of rice in the area under traditional technology and effects inter-country and inter-temporal comparisons of rice productivity. Basically, therefore, our assessment of traditional technology in Tamil Nadu is made through inter-country comparisons.

We have directed our attention to comparisons at the district-level in order to minimize aggregation errors. Further, in dealing with inter-country comparisons, we have restricted our choice to two major rice-producing countries in Asia - China and Japan. For China, yield data for rice in the nineteenth century have been available only at the Province level;* hence, our analysis is limited to that extent. For Japan however, we have fairly detailed figures on rice yields to effect a comparison between districts in Tamil Nadu and the Japanese prefectures in the nineteenth century. However, first we shall examine the evolution of traditional agricultural technology in Tamil Nadu.

Evolution of Traditional Agriculture in Tamil Nadu

Extensive research has shown that descriptions of agricultural operations are to be found in ancient Hindu literature, from which it can be gathered that the practices of manuring, rotation, fallows and other techniques were well-known (Gangopadhyaya, 1932, pp. 58-67). Though the science of agriculture was not highly developed at the time, the Indian ryots (farmers) knew by experience the principles of good cultivation and had recourse to them to the best of their ability. Traditional agricultural custom was built up through practices over the years. These customs often find expressions in agricultural proverbs which are still current in the rural community. Though unexpressed and unexplained, traditional agriculture concealed deep scientific principles, the reasons

* Yield data on various crops in China are to be found in Buck (1937). These however, pertain to the period 1929-1933.

for which are only gradually being elucidated. The Royal Commission on Agriculture in India (1938) reporting on the condition of Indian agriculture remarks that the system of traditional agriculture in India had "a marked degree of perfection and the wisdom of many agricultural proverbs stands unchallenged by research." (Report of the Royal Commission on Agriculture in India, 1928, p.14).

Historical records and inscriptions also bear evidence that Indian agriculture has been rooted in a strong tradition based on a solid experience of the past. It would not be necessary here, nor is it possible, to trace the whole evolution of traditional agriculture, but it will suffice to show that traditional agriculture reflects a whole process of development. Initially, this process may have been painfully slow, achieved solely through the method of 'trial and error'. Later in the nineteenth century, the opening of research stations and experimental farms is likely to have accelerated the pace of agricultural development. Bearing in mind therefore, that traditional agriculture reflects a whole process of growth, we shall examine first the qualitative and then the quantitative evidence in order to gain some idea of the level of traditional agricultural technology in Tamil Nadu.

Qualitative Evidence on Traditional Agricultural Technology in Tamil Nadu

In dealing with qualitative evidence of this kind, we are confronted with certain problems. Much of this evidence is in the form of evaluatory judgements; consequently, the tendency to subjective bias is high. Another major problem lies in determining the criteria to assess the level of traditional agricultural technology in the area. Historical data give us no indication of resource availability in order to effectively measure input use. Any inferences drawn from qualitative evidence, therefore, are limited to that extent.

Within the confines of available qualitative evidence, we seek to assess the level of traditional technology on the basis of two major criteria:

(a) adequate and appropriate use of available inputs and resources;

(b) application of techniques such as rotation of crops, fallows and methods of manuring.

The types of indigenous implements and their suitability to traditional agriculture are also considered a fair indication of the level of technology. We shall deal with each of these in turn.

Manuring Techniques

Manures were the principal input available to the ryots to enhance the fertility of the soil; of these, cow-dung ranked foremost because of its ready availability. A major criticism levelled against traditional Indian agriculture has been that farmers did not appreciate the value of cow-dung as manure using it for fuel instead, leaving their lands inadequately manured. Our evidence suggests that the ryots fully appreciated the value of manure; great care was taken to procure every scrap of manure and great pains were taken to manure the land well. Writing of Chingleput, the then Collector Price says:

> Nearly the whole of the area of cultivable ground is manured every year. The exception is principally in the case of virgin soil and that which has lain fallow, and then it is only dry land which is thus treated. Wet land is invariably manured; under the Red Hills Tank, where manure is brought from Madras, and where there is more farming than elsewhere, the proportion as I ascertained when there some time ago, is about one ton of strong manure per acre and half to three-quarters of a ton of leaves and weeds." (Report of the Indian Famine Commission, 1881, Vol. III, Appendix, p.170, emphasis mine).

Similar manuring practices are recorded in Tanjore, though the quantity of manure used is greater; in Madura, three to five tons of manure per acre are stated as common.

Forms of manuring varied according to the location of the district and the means of the ryot. Wet (irrigated) lands were usually manured with cow's and sheep's dung, ashes, house sweepings and branches and leaves of all kinds of plants. This latter is held to be a practice peculiar to South India (Martin, 1838). The Collector of Madras states that three or four days after the paddy was sown a quantity of varagoo straw or other manure was thrown over the land. (Proceedings of the Board of Revenue, hereafter referred to as B.P., 16 Jan. 1866, No. 372). Lands watered by rivers were poorly manured, as the rich silt was found to be adequate. The value of silt was fully recognized and was extensively used especially in manuring sandy and brackish soils (B.P. 13 Sept. 1865, No. 5660; Voelcker, 1893, p.110).

Along with leaves both dry and green, silt from dried up tanks and low pits was scraped up and spread over the fields (B.P. 14 Aug. 1865, No. 4853). Bushes and plants especially valuable as green manure were in great demand (B.P. 22 Aug. 1865, No. 5104). In parts of Madras, trees were specially grown by ryots on the dams of tanks and on waste lands to provide leaves and tender twigs for use as green manure (Hunter, 1907). Rice irrigated from tanks was extensively manured in this way. From these accounts, the ryots' experience of the value of green manure is amply evident.*

It is interesting to note that in Salem the use of night-soil is reported for manuring wet paddy lands (B.P. 28 Mar. 1865, No. 223). Its use is also mentioned in Madura (Voelcker, 1893, p. 121). In the absence of artificial fertilizers and the insufficiency of existing

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* "Mr. Robertson (Director of Agriculture in Madras) points to the value of green manure as a conservator of nitrogen in the soil; the ordinary practice of the ryot in this respect, therefore, founded on the experience of ages, is in strict accordance with the teaching of science." (Annual Report of the Department of Revenue, Settlement and Agriculture for 1882-1883, No. 40).

manures, the non-use of this manure was claimed to be a great loss to Indian agriculture, though this loss is often exaggerated. Voelcker (1893) confirms that the ryot was perfectly well aware of the fertilizing value of this manure and that a good deal of human excreta did indirectly return to the land, is seen from the fact that the land around village sites was rented at a much higher value than other land due to its increased fertility (Voelcker, 1893).

An investigation by the Board of Revenue into the use of town refuse and sewage as manure reveals that prejudice was not universal (B.P. 12 Aug. 1887, No. 269); and in certain districts, "there has always been a very brisk demand at the night-soil depots." (B.P. 29 July 1887, No. 196). Further evidence shows that "it is largely (emphasis mine) used for paddy crops in the neighbourhood of Madras, especially below the Red Hills Tank in a fresh state and the ryots there evince no reluctance in dealing with it."* Details on the extent of use in each district show that except in a few towns, sewage, town refuse and night-soil were not entirely utilized for two reasons outlined by the Board:

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* Government Order, (hereafter referred to as G.O.) 23 Sept. 1874, No. 1201. See also G.O. Revenue 6 Aug. 1887, Misc. No. 4598: "It is believed that in the town of Conjeevaram, manure of this description (town refuse, etc.) is purchased at high prices and eagerly sought after by the ryots."

Prejudices against it are very strong, and there are difficulties attending its use as a manure except in localities where the crops to which it is applied can be watered ... At Tanjore, it is coming into demand, whilst at Trichy, the amounts realized show that it is extensively used, ... At Tinnevelly and Palamcottah, the value of this refuse is so well known that the people refuse to allow the municipalities to remove it from private cess-pools." (B.P. 9 Mar. 1888, No. 123, emphasis mine).

As the foregoing evidence was obtained only from towns and large villages in which sanitary establishments existed, it is limited to that extent, but it does give a fair indication of the extent of use of this important resource in Madras.

The refuse of oil-mills,* indigo factories and tanneries were also used as manure. On irrigated nurseries, bats' guano is reported to have been in use in Madura with great success (B.P. 20 Dec. 1865, No. 8181). Milk hedge, horses' and asses' dung were used largely to neutralize brackishness in soils. Instances of soil-mixing as a means to enhance the productivity of the soil were to be found in some parts of the region (Stuart, 1879; Voelcker, 1893). Correction of soils through the use of appropriate manures was not unknown and was common

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* Buck (1968) states that even if the oil-cakes were first fed to animals, as was the case in India, 80 per cent of their fertilizing value would still be returned to the land in animal manures.

especially in the case of saline soils.* In parts of Salem, Coimbatore and Tinnevelly, the use of prickly-pear as manure was widespread. In Salem, the ryots burnt prickly-pear and used its ashes as manure while in Tinnevelly, the prickly-pear was cut and buried in deep pits covered with a thick layer of earth and kept for two or three years when it rotted and was fit for manure (Benson, 1908).

However, the same standard of cultivation did not prevail all over the Presidency. Inter-district variations are only too evident, while even from field to field in the same part of the district, vast differences are to be seen due to soil conditions and their consequent tillage variations. This is particularly evident in Coimbatore, which presents an interesting feature as showing "miserable tillage operations on poor upland soils by poor ryots, side by side with excellent culture on the better lands by a better class of ryots, the empirical skill of men unlearned save in the experience of centuries..." (Nicholson, 1887, p. 184).

Such differences are seen in the extent of manuring in various parts (Cox, 1895). In North Arcot, manure is

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* In Chingleput, Basuti is used as a green manure for this purpose and in South Arcot, it is believed to be beneficial for crops blighted or diseased and in several districts it is spread over paddy nurseries. (Kenny, 1922, p. 275).

sparsely used on the plateau and is quite rare in the south and east. In South Arcot, about 750 pounds of oil-cake are required for a rice crop and for other crops about 6 cart-loads of indigo refuse or stable manure, or 12 of rubbish are required per acre (Garstin, 1878). In Tinnevelly, the average quantity of manure to the acre is 15 cart-loads (Stuart, 1879).

These disparities probably explain the reasons for the mistaken notion attributing a "primitive" level of technology to pre-modern agriculture in the State. The area under cultivation being large, the average is brought low by farmers of poor means, but it would be misleading to judge the level of technology from the average in such circumstances. Such factors account for the wide divergence of opinion among those connected with agriculture in Madras at that time. Thus, while Benson (Assistant Director of Agriculture in Madras) holds that agriculture lacks the very essential techniques of manuring, rotation and fallows and consequently is primitive, Nicholson and several other Collectors of the districts, hold the opposite view.

Our examination of the evidence shows that though scientific principles were unknown, the art of agriculture was quite advanced. Nicholson remarks:

... the art is both excellently known and practised by the average and substantial ryots. Even on the black soil and richer loams or in localities favoured by rain... upland cultivation is comparatively subsidiary to that on wet and garden lands; it is to these that the ryot looks for sure and certain crops, and it is these therefore that get his most devoted attention... To ascertain therefore what is really known of agriculture the ryot's practice on these better lands must be examined, and it is doubtful if he will much suffer by comparison with any farmer anywhere. (Nicholson, 1887, p.184).

As to the controversy of burning cattle-dung as fuel, much has been said and written on this score, but nowhere is there evidence to show that in Madras, dung was preferred to other fuel. In fact, Nicholson goes into this matter at considerable length, stating that dung was never used as fuel except in towns, and that Robertson was wrongly informed when, in one of his reports, he said it was. (Nicholson, 1887).

Even where dung was used as fuel, Nicholson claims that "not a hundredth part of the cattle-dung is so used, partly because its value is perfectly known, partly because fuel for the few wants of the raiyat is supplied by hedge and tree loppings, cotton and kambu stalks and so forth." (Nicholson, 1887, p.190; Voelcker, 1893). Concluding this part, Voelcker's (1893) report based on empirical evidence is worth noting, for he states quite categorically:

As a result of my enquiries, I feel that I may safely assert that where the practice of burning dung as fuel prevails among genuine cultivators, it arises, in eight cases out of ten, from the scarcity of firewood. (Voelcker, 1893, p. 103).

Leather (1897) who also undertook to re-examine the case during the course of his tour in 1896, fully agrees with Voelcker's (1893) conclusion on this matter. Similarly, Slater (1918) in his findings on agriculture in South Indian villages, expresses the view that a very small fraction of dung is used as fuel (Leather, 1897; Slater, 1918). In any case, when dung was burnt as fuel, the ashes were returned to the land. In some instances, the ryot deliberately chose to use the ashes rather than the dung, due to the distinct mineral constituents in the ashes.*

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* "But that the cultivator when he does prefer ashes to dung, or else the whole dung to the mere ashes, does so simply from fancy or ignorance, I am by no means ready to allow, but assert that quite the contrary is the case. A cultivator from Tinnevelly, whom I interviewed, described to me his practice thus: "I would use ashes for my nursery beds, and raw dung to get 'produce'". He added that for heavy land he would use the raw dung, and the ashes for his lighter land. This use of dung for opening heavy land quite agrees with English experience. At Madura, the cultivators said to me: "the Native knows the unburnt dung is better; there is more 'force' in it." I often think of the answer given to me by two cultivators, one at Salem, the other at Avenashi, when, after they had complained to me of the difficulty of getting firewood, I said to them, for the purpose of testing them, "But why don't you make the dung into cakes and burn them? Then you have the ashes left; what more do you want?" The one replied, "What is that? It's only a little; that's not enough." The other said, "If I burn the dung what shall I have for manure? How can I live if I burn my cattle-dung? I want it all for my garden." (Voelcker, 1893, p.103).

The evidence on manuring practices therefore shows that the Tamil Nadu peasant was fully aware of the value of manure and used every scrap that he could lay his hands on. However, in the absence of sufficient capital, he had to make good with his limited organic manures, the chief of which dung, served also as fuel in the absence of firewood.

Rotation of Crops

The technique of rotation of crops such as is understood in Western countries, is not to be found in Madras in the nineteenth century, but through experience, the ryot had worked out a built-in system of cropping, which had the same effect as rotation of crops. This implies that the ryot knew the fundamental principle underlying rotation.*

The general consensus on rotation is that it is not practised on irrigated lands, except in very rare circumstances, but is common on dry lands. Irrigated lands are largely devoted to rice cultivation and it has been established that rotation is not essential on rice lands

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* "There is no established system of rotatory crops, but the principle of not overstraining the resources of the soil is fully understood by the ryots. A crop requiring little nourishment generally succeeds an exhausting crop and fallows are common in the case of inferior soils." (Maclean, 1879, p.208).

(Howard as quoted in Blyn, 1966; Buck, 1968). However, regular systems of rotation are mentioned on irrigated lands of certain districts. In Salem such a system was in use:

> ...rotation of crops exists in this district. On wet and dry garden lands various sorts of paddy are sown in rotation ... When the water is insufficient (for two paddy crops) dry grain, viz. cholam, cumbu, yelloo or ragi are sown as the first crop and paddy as the second crop. (B.P. 28 Mar. 1866, No. 2223).

A kind of triple rotation is said to have prevailed in Tinnevelly, which is believed to have been quite common (Stuart, 1879).

However, these are only isolated instances of regular systems of rotation. In all the districts, on the other hand, there is an implicit or rather concealed system of rotation, due to the practice of growing mixed crops. Not many are aware of the benefits of the system of mixed cropping, which has led to the opinion expressed by several Collectors at the time, that rotation was not practised in Madras. Though the scientific principles underlying rotation were not understood, the ryots knew by experience that certain crops like sugar cane, indigo, varagu and betel are very exhausting and hence they were always alternated with other less exhausting crops.

Voelcker (1893) is convinced from his enquiries that rotation was practised in Madras, a cereal crop being alternated with a legume (Voelcker, 1893). In the districts of Coimbatore and Tinnevelly, he cites details of the systems practised. The Collector of North Arcot expresses similar views in his report:

> ... although there is no recognized system of rotation, our farmers are not wholly without appreciation of its principles and advantages ... the leaning in practice is to follow up a cereal with a pea crop, and a pea with an oil seed ... (B.P. 20 Nov. 1865, No. 7430).

Lest one should doubt the validity of this system as an effective means of rotation, the Collector's empirical evidence is worth noting:

> ... I cannot learn that the existing system exhausts the soil; on the contrary the Ryots affirm that though fallows are rare, the land improves the longer and more steadily it is worked. (B.P. 20 Nov. 1865, No. 7430).

Instances of rotation are numerous and varied. In Trichy, the Collector alludes to a regular system of rotation (B.P. 28 Nov. 1865, No. 7604), and Benson (the Assistant Director of Agriculture) acknowledges some system of rotation in the Cuddapah and North Arcot districts (Benson, 1879). Buchanan (1803) mentions a peculiar system of rotation in Pollachi (Coimbatore) specially noting that the cropping practice there is conducted with more judgement than generally in India. In all the districts of Tamil Nadu, mixed cropping was resorted to, both with paddy and other dry crops, but an ingenious system was rotation under mixed cropping. This system led Voelcker (1893) to commend the Indian ryot for his keenness in devising methods to fit in with his meagre circumstances. On the above evidence therefore, one cannot deny that though the Western principles of rotation are not adhered to, the Indian ryot had worked out a practice from very early times similar in its essence and effects.

Fallows

The principle of fallows was well understood, but was used only as the last resort in the case of rich lands. Inferior soils were normally left fallow for definite periods, though these periods varied with the circumstances of the ryot and the urgency of cultivation. The pressure of population and the increasing demands made upon the soil reduced the extent of fallows, but its value as a means of restoring soil fertility was well-known.

The practice of fallows such as it prevailed in Madras, was another indication of the poverty of the cultivator;* the two major criteria being the insufficiency of manure or non-availability of water-supply. Thus irrigated lands were rarely left fallow, as they

* "Rich dry lands are never left fallow, nor are wet lands allowed to do so, ... Letting land lie fallow is simply a cheap way of manuring; ..." (B.P. 28 Mar. 1866, No. 2223).

had first claim to manurial resources. As a Tahsildar (Revenue Collector) expressed: "If it were possible to manure all Punjah (dry land) fallow would be unnecessary; ..." (B.P. 20 Dec. 1865, No. 8181 Encl. No. 2), but as we have been the dearth of manure made fallows an imperative necessity.

Implements

In dealing with traditional agricultural implements, one must bear in mind the prevailing agricultural set-up, namely poor capital resources and abundant cheap labour. Early sources give the impression that tools and implements of agriculture in India were crude but effective.* On no point of traditional agricultural practice, has so much criticism been levelled and the history of the Madras Department of Agriculture bears witness to the fact.

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* "Perhaps in no direction have efforts at improving Indian agriculture been pushed more than in that of introducing new or so-called "improved" implements. Even at the present time it is not unusual, among people who speak of the raiyat's farming as being "primitive" to say, "What can you expect when he uses a plough which merely scratches the soil?" After seeing for myself what is used, and what have been suggested for use, I am obliged to conclude that there is not much scope for improved implements under the existing conditions." (Voelcker, 1893, p.217).

The chief point of attack has been the native plough criticised on the grounds that it merely "scratches the surface of the soil", but experiments tried with other "improved" implements have shown the effectiveness of the indigenous plough. The Indian plough is similar to the English cultivator and its action is akin to that of a pointed stick stirring and loosening the soil a few inches below the surface, but not inverting it. Such action has definite advantages in the Madras climate, as it preserves the much-needed moisture in the soil and does not bring inferior soil to the surface. This necessity is so great that "Indian tillage implements of all kinds are made simply for stirring the soil without inverting it." (Wallace, 1889, p. 174). This fact is particularly evident in the absence of a mould-board on the indigenous plough.

Attempts to introduce improved implements have brought home the effectiveness of the simple indigenous plough under prevailing conditions. Of the numerous 'improved' ploughs experimented in Madras, only very few proved to be successful after they had been adapted to local needs, and even these were not generally suited to all parts of the Presidency. For paddy cultivation especially, the native plough excels even the lightest improved plough. The empirical evidence coupled with the personal experience of Scott from Madura on this score is worth noting:

In efforts of this nature (viz. introducing improved implements) it is not, I fear, sufficiently borne in mind, that in selecting or designing agricultural implements which operate on the soil, two distinct sets of implements are required, one for nunjah and the other for punjah cultivation; that, as a rule, no implement of English husbandry is suited to the cultivation of nunjah (wet land). I have tried to use on nunjah land the lightest American plough procurable, in fact a pony plough; one of Prouty & Mears Patent Centre Draft No. 13, light enough for a strong cooly to carry about, but have found it impracticable for a pair of bullocks, even in well-moistened clayey soils, and it appears to me that in nunjah cultivation, so essential is lightness in implements, that almost everything must be sacrificed to it, and it is useless to attempt to introduce such an implement as a plough into nunjah lands ...

I have observed that the European plough can never be used on nunjah lands, because apart from weight, the idea of a mould board turning up, and twisting over the soil, so as to raise the subsoil more or less completely to the surface, is essential to the idea of a European plough; such an operation on nunjah land, especially on lands which are gravelly, is ruinous to a rice field; it destroys the fine coat of Alluvial deposit on the surface of the field, without which the seed-paddy will scarcely germinate, and the past gradual formation of which is pre-eminently the advantage which old and highly productive rice-fields have over newly formed ones." (B.P. 21 Mar. 1870, No. 1923, Encl. No. 2).

Variations in the ploughs used in different soils are to be found all over the Presidency. On black cotton soil, heavy ploughs drawn by 8 to 12 bullocks are common and the ploughing is said to be so thorough that if the land is kept free from weeds, it does not need to be deeply ploughed for another 20 years (Madras Revenue Proceedings, 28th May 1866, No. 489). In paddy-growing districts, such heavy ploughs were not used due to their unsuitability, but where deep ploughing was advantageous to the crops cultivated, the ryots did not hesitate to take the trouble to plough deeply, even in the absence of suitable implements and at great cost. Robertson, when Director of Agriculture, reports on having seen, during his tour of Coimbatore, black cotton soil being opened up by means of crowbars; he admits: "the cultivation is, I think, very perfect, and leaves but little to be desired." (Robertson, 1878, No. 119).

For paddy, the emphasis was on producing a fine tilth through numerous ploughings. Thus the Collector of Madras reports 8 to 12 ploughings (B.P. 16 Jan. 1866, No. 372) while the North Arcot reports also affirm 6 to 12 ploughings lengthways and crossways before paddy was sown (B.P. 20 Nov. 1865, No. 7430). The Royal Commission (1928) on examining indigenous implements came to the conclusion that the "ordinary Indian plough is the best type of general purpose implement for his (the ryot's) needs..."* That the Indian ryots were slow to adopt

* "By repeated use the Indian plough can reduce the soil to the same physical condition as is secured by the inverting implement in a single operation. Support is given to this view by the fact that the fellaheen of Egypt, who are remarkably successful cultivators adhere to an implement of the Indian type." (Royal Commission on Agriculture in India, 1928, Vol.I, No. 107).

the new plough therefore is not surprising.

Thus we see that the Madras ryot was certainly aware of the effectiveness of indigenous implements and consequently sceptical of costly innovations which were not definitively proved successful. His eagerness to learn new methods cannot be denied and is borne out in several reports. His scepticism is often attributed to conservatism and prejudice, but experience in agricultural techniques and his excellence in the art have contributed to this attitude. The Madras ryot is not more conservative than his contemporaries in other countries;* poverty is likely to have made him more cautious than his counterparts.

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* "Farmers in all countries adopt with much difficulty what seem to be obvious improvements; of English farmers, Mr. Prothero writes as follows:-

> By immemorial custom in Gloucestershire, two men and a boy with a team of six horses were employed for ploughing. Mr. Coke sent a Norfolk ploughman into the country, who, with a pair of horses and a Norfolk plough, did the same amount of work in the same time. But though the annual expenses were thus diminished by £120, it was 20 years before his neighbours profited by the lesson. In 1780, a Norfolk farmer settled in Devonshire where he cultivated turnips on the newest methods. His crops were larger and finer than those of other farmers; yet, at the close of the century, none had followed his example."

Benson also mentions an apt story of the small English farmer who, ploughing with four horses in a line, was shown how to do the same work with only two horses by harnessing the two abreast, but objected that "these new fangled improvements are too expensive for a poor man." (Report of the Agricultural Committee, 1878, p.88).

From the foregoing considerations of qualitative evidence, it can be seen that traditional technology in Tamil Nadu was at a reasonably high level in its use of traditional inputs and practices. However, in large districts, wide disparities are to be found between the best and the average. In certain districts like Coimbatore, traditional agricultural technology reached a very high level.

Farmers in most districts were conscious of procuring every available manure for their land; nonetheless poverty was an effective constraint, limiting the use of manure often to the best lands. The subtle use of techniques of rotation, mixed cropping and soil correction reveal the ryot's experience and progress in the art of cultivation. The traditional implements in use also bear evidence to the ingenuity of the Tamil Nadu ryot.

However, one cannot ignore the wide disparities between the best and the average. Such disparities are evident not only between districts, but also within the same district. This is to be expected because of inter-individual variations stemming from differences among farmers and their resource constraints. Naturally such differences are greater in larger districts.

Before we turn to the quantitative data, we shall consider briefly how our qualitative evidence compares with techniques of rice cultivation in Meiji Japan. However, any inter-country comparisons must be exercised with considerable caution to draw any plausible inferences. To compare countries of vastly different size, climatic conditions, geographical location and crop culture would lead to questionable results. For instance, to compare the Indian sub-continent despite its vast size and regional diversities with Japan may not be very fruitful. On the other hand, a comparison between selected rice-growing areas in Japan and India could provide more meaningful information on levels of rice technology.

Besides, the practice of agriculture is such a 'fine art' dependent on several economic variables, that any attempt at general conclusions could be seriously misleading. Thus comparisons of traditional agricultural techniques and practices do not take us very far. Soil and weather conditions in one area may compel farmers to resort to techniques which may be quite impractical in other areas. Hence, we will attempt to examine whether traditional agricultural techniques and practices in rice-growing areas of Japan and Tamil Nadu were broadly similar and whether farmers in the two areas were attempting to use traditional inputs and practices to the best advantage.

Qualitative Evidence on Traditional Agricultural Technology in Japan

Not much has been published in English on agricultural technology in Japan during the Meiji era, but a 'fairly honest description of the conditions of agriculture at that time', (Ogura, 1963, p.300) can be gathered from the following account by Michaelovich Gorovnin, during his two year enforced residence (1811-1813) in Japan:

> The farms in Japan are very small. The farmers grow some crops between the rows of another crops. Thus the use of farmland is complicated and greatly intensified. Since the main crop and the catch crop are grown according to a rotation system, the field work has to be done by hand. It is quite difficult to use larger farm implements that are employed with the help of animals. As a result, the tilth is not deep. For fertilizer, night soil, fallen tree leaves, and green grass are used most commonly;... (Ogura, 1963, p.299).

From this short extract, several characteristics of Japanese agriculture emerge, of which the most striking seems to be the small size of the farms. Agriculture in Japan, has always been associated with small holdings, and even today, intensive cultivation is carried on, on small plots. Nicholson, Collector of Coimbatore district in the 1880s, returning from a visit of Japan, sees a striking similarity between the 'petite culture' of Japan and the market gardens of Coimbatore and Salem (Nicholson, 1907).

Official records state that the average area of the paddy field in Japan is 1.14 se or an area of only 31 by 40 feet. Excluding Hokkaido and Formosa, it is believed that 58 per cent of the irrigated rice lands were in allotments smaller than ¼ of an acre and 74 per cent of other cultivated land were less than ½ of an acre (King, 1949). These plots therefore, had to be intensively cultivated to provide food for the whole population. This sort of 'petite culture' is not uncommon in Tamil Nadu even today, reminiscent of the sub-division and fragmentation of the land.

A brief glance at the traditional indigenous practices in Japan would suffice to give us an idea of the prevailing technology. Japanese agriculture relied heavily on application of natural manures, of which night-soil was the most common. The excelleoce of Japanese paddy culture has been largely attributed to the fact that from very early times, all human waste was utilized for the enrichment of the soil (Department of Agriculture, 1910). It has been generally believed that due to prejudice, Indian agriculture largely neglected this cheap but valuable means of restoring soil fertility. As we have seen in the previous section, this prejudice was not universal, and "the ryot was perfectly aware of the fertilizing value of this manure." (Voelcker, 1893, No. 137).

Along with night-soil, Japan placed heavy reliance on farm manure, ashes of plants, oil-cake, rice bran and compost, all of which were being used in Tamil Nadu in the nineteenth century. Whereas in Japan, even before the Meiji era, fertilizers like phosphate rock and bean cake were already being imported to supplement traditional manures, in Madras reliance was solely on indigenous supplies. It was the short supply of labour rather than manure, that ushered in the early advent of chemical fertilizers in Japan.

Green manuring was the most popular form of restoring nitrogen to the soil in Japan and it is interesting that this practice was well-known in Madras, where even today, sesbania (glyricidia auriculata) is very popular on rice fields. This technique of using leguminous plants to fix nitrogen in the soil appears to be a well-known experience in the pre-modern system of agriculture (Voelcker, 1893, No. 304).

Pre-modern Japanese paddy technology and farm operations were very much similar to those in Madras, where the most simple implements were in use (King, 1949). Ploughing was performed by a hoe or an animal-drawn plough, but an efficient plough was introduced in the middle of the Meiji era. Inter-tillage and weeding operations were done by hand or with a hoe or Ganzume (long-nailed rake). A rotary ship-type weeder and a revolving hand-cultivator were devised only after 1900.

Thus the farm implements of the first half of the Meiji era (1868-90) were nothing but hand tools (Ogura, 1963). There is no indication of any seed-drills or any contrivance for sowing paddy in Japan, and the sophisticated seed-drill of South India holds its own even against its Chinese counterpart (Sinha, 1973). From the above considerations, there is no evidence that Japanese traditional implements were any more sophisticated than those in use in Tamil Nadu in the nineteenth century. The ploughs of Meiji Japan too, "did not effect a deep tilth in the soil" (Ogura, 1963, p.299), which raises anew the question: Is deep tillage essential in rice cultivation?

To complete the picture of agriculture in Meiji Japan, we shall consider briefly the attitudes of the Meiji farmer to change. The Meiji farmer appears no different from his Madras counterpart in his scepticism to accept new innovations. No conclusive evidence exists on this point, but instances can be cited in support. It took nearly ten years for the new high-yielding variety of rice - Shinriki, to attract sufficient notice and it took another decade before it was commonly accepted. Salt water sorting of paddy seed was discovered in 1882, but only came to be commonly used by the end of the century.

From the above evidence therefore, one can infer that in terms of traditional agricultural technology, there was not much difference between Madras and Japan in the nineteenth century. Yet this inference would not be justifiable without a consideration of yields under the prevailing technology. Our qualitative evidence suggests that traditional technology in Madras and Japan was indigenous; certain similarities are seen between traditional techniques and input use. However, this does not tell us much without a consideration of the output obtained under traditional technology in both countries. It is this aspect that we shall examine in the following section after considering the accuracy of our statistical data.

Quantitative Evidence on Rice Yields under Traditional Technology

Considerable controversy persists over the accuracy of pre-modern statistics and more so, figures of agricultural output. In Madras, official output figures are fairly accurate, having been recorded by Collectors assisting at crop-cutting experiments in different districts. Output reported by farmers was likely to be under-estimated to avoid increased taxation; hence actual yields may be taken to be higher than reported.

This fact is very much evident in the nineteenth century Revenue and Settlement Records of Madras, where great disparity is to be seen between results of crop-cutting experiments conducted by the Revenue Department and those conducted by the Settlement Department on each class of soil (G.O. Rev. Dept. 6 April, 1881, No. 591). In assigning grain values, we have clear evidence of a down-rating of yields from statements such as the following:

> ...though an average by the statement for best black loam is not less than 1479 MM.* per acre and is an average on 214 experiments, I consider not more than 1200 MM. (2760 lbs/ac) should be taken... for the grain value to be thus adjusted to the classification requires to be so rated as to be applicable to the whole district ... the grain values as thus proposed for lands irrigated by sources rated as first class are lower than the average outturn in respect to each taram (class) as regards the settlement kyles (experiments) and the total. (G.O. 6 Apr. 1881, No. 591).

A careful examination of the tables accompanying this report reveal that the average outturn on 188 experiments on best black loam of the first class in North Arcot yielded 3573 pounds per acre (G.O. Rev. Dept. 6 Apr. 1881, No. 591, Table II, p. 17). It was normal for settlement purposes to adjust the grain values to represent the entire district, and district-wise comparisons were made on this basis.

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* MM. denotes Madras measures; each MM of paddy is equivalent to 2.3 pounds; hence 1479 MM works out to 3402 pounds per acre.

Evidence is to be found that no less than 6000 experiments were conducted by reaping crops in the Godavari, Tinnevelly, Coimbatore and North Arcot districts and in parts of Kurnool and Cuddapah and another 6000 experiments in Ganjam, Chingleput, Nellore and South Arcot (G.O. Rev. Dept. 6 Apr. 1881, No. 591, p. 76). The best land was always looked upon as yielding 2760 pounds per acre or 21-fold in each harvest, yet there were lands yielding 25-fold too, which "Mr. Puckle expressly leaves out of count as exceptional, though they are met with in several villages of the river valley." (G.O. Rev. 31 Jan. 1908, No. 304). From an earlier account, the Collector of Tinnevelly, Banbury, in his statements, reports much higher crop yields, even as high as 3958 pounds per acre.* Hence the average outturn on the best lands is probably nearer 2990 than 2760 pounds per acre (G.O. No. 304, Rev. Dept. 31 Jan. 1908). The report from Salem gives the outturn of the best lands in Namakkal taluk as 2990 pounds per acre.

Another instance of disparity is evident in that the Collector of North Arcot gives the average yield of paddy in his district as 2500 pounds which is a high yield; yet experiments conducted by the Deputy Director of Revenue Settlement in three taluks of this district give higher results of 2693 pounds (Report of the Indian Famine Commission, 1881, p.88). For Madura the rate of

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* B.P. 1 Aug. 1865, No. 4528; B.P. 26 Oct. 1865, No. 6879.

yield is 1930 pounds of rice or 2990 pounds of paddy.* In Tanjore, the average yield of paddy is given as 1404 pounds per acre, which appears low compared with the other districts (Row, 1883).

However, the average is a misleading figure, as it does not represent the technology at its best. If we consider the maximum yields obtained, a different picture emerges. Experiments with Carolina paddy gave yields of 4377 pounds in Coimbatore (Liotard, 1880, p. 72); but even for the country variety of paddy, the outturn in Coimbatore is very high. The maximum outturn for Karur paddy ranges from 3000 to 4300 pounds per acre on well-irrigated lands. The average maximum yields as stated by the ryots themselves was 3000 pounds per acre in certain taluks of Coimbatore (Nicholson, 1887, pp. 208-211). The district Manual for Tinnevelly ascertains the yield on an acre of fair land at 3360 pounds for the first crop of paddy and 2520 pounds for the second crop (Stuart, 1879, p.24).

Since yields vary largely from field to field because of soil conditions, an attempt was made in Tinnevelly to ascertain the yield of each variety of soil, the results of which are given in Table I.

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* Paddy indicates unhusked rice; on the basis of a husking loss of 33 per cent, the weight of rice is reduced to that extent.

TABLE I

Yields on different types of soil in Tinnevelly

Soil	Class	Yield as estimated by ryots	Yield as per experiments
Best permanently improved soil	1	3120	2820
Good permanently improved soil	2	..	2750
Inferior permanently improved soil	3	2280	2460
Good black or red loam	4	2040	2100
Ordinary loam or best sand	5	1680	1680
Good sand	6	1500	..
Inferior loam or ordinary sand	7	1080	..

Source : Stuart, 1879, p.126. Yield figures have been indicated in pounds per acre to facilitate comparison.

Even as early as 1864, experiments conducted in different parts of South India gave high average yields for most crops, especially rice. Thus, best white rice, when fully irrigated, is reported to have averaged 2400 pounds per acre, while the maximum shown by the experiments was 3650 pounds (Greenaway, 1864, p. 37). Considerably high average yields are reported for Tinnevelly in 1865, the highest for paddy being 3958 pounds in

Ambasamudram taluk. This is the yield on good land; the lowest average on such land is given as 3263 pounds. The accuracy of these figures are assured, as the experiments were conducted under the superintendence of the Collector (B.P. 26 Oct. 1865, No. 6879). He gives two reasons for yields being below average - the unfavourable season and the fact that this was the second crop.

The limitations of historical data do not permit a complete assessment of yield in Madras for any given year in the 1880s, so one has to be content with the available data. Extensive research conducted on the early agricultural records in Madras (Rathnam, 1966), substantiate our earlier hypothesis that rice yields in Madras were at a high level in the nineteenth century. According to early reports, the average rice yield in India during Akbar's time (A.D. 1556-1605) was about 2333 pounds per acre which is approximately equal to present rice yields in China. On the basis of a husking loss of about $^{1}/_{3}$, the yield per acre of paddy during the above period can be estimated approximately at 3500 pounds per acre.

Pre-modern average and maximum yields in districts of Madras will put the right perspective on the level of traditional agricultural technology in the State.

TABLE II

Paddy Yields under traditional technology in Madras

District.	Year	Paddy yields lbs/ac (tons/ha)	
		Average	Maximum
Chingleput	1788(a)	2610 (2.93)	2809 (3.15)
Chingleput	1881(b)	1932 (2.17)	-
North Arcot	1881(b)	2760 (3.10)	3594 (4.04)
South Arcot	1881(b)	1932 (2.17)	-
South Arcot	1819-20(a)	2547 (2.86)	-
Tanjore	1774(a)	2538 (2.85)	-
Tanjore	1883(c)	1404 (1.58)	-
Trichy	1872(g)	2484 (2.79)	-
Madura	1796(a)	2647 (2.97)	-
Madura	1881(d)	2900 (3.26)	-
Tinnevelly	1881(b)	2760 (3.10)	-
Tinnevelly	1879(e)	2520-3360 (2.83-3.77)	-
Tinnevelly	1865(f)	-	3958 (4.44)
Salem	1872(g)	2484 (2.79)	2990 (3.36)
Coimbatore	1807(a)	6522 (7.32) I crop	-
		4919 (5.52) II crop	-
Coimbatore	1869(h)	-	4377 (4.91)
Coimbatore	1887(i)	3000 (3.37)	4300 (4.83)

Sources : (a) Rathnam, 1966.

(b) G.O. Rev. Dept. 6 Apr. 1881, No. 591.

(c) Row, 1883.

(d) Report of the Indian Famine Commission, 1881.

(e) Stuart, 1879.

(f) B.P. 26th Oct. 1865, No. 6879.

(g) G.O. Rev. 3 May 1872, No. 716.

(h) Liotard, 1880.

(i) Nicholson, 1887.

To assess productivity under traditional technology, it is essential to have some yardstick of comparison. We shall therefore see how nineteenth century rice yields compare with yields in other countries during the same period. We shall also examine how rice yields in Tamil Nadu in the nineteenth century compare with yields in the twentieth century (pre- and post-Green Revolution periods). The first involves a comparison of traditional technology in terms of inter-country comparisons; the second tests traditional technology over time. We shall deal with each of these aspects in turn.

Inter-Country Comparisons of Nineteenth Century Rice Yields

The limitations of data compel us to confine our comparisons to two leading rice-growing countries in Asia for which nineteenth century rice yields were easily available - Japan and China. Turning to Japan, although data on paddy yields are more reliable than other crops, the problem of under-estimation causes difficulties in comparison (Nakamura, 1966). Recent research on Japanese agricultural development in the Tokugawa and Meiji eras, is bringing more and more to light "how important 'national average yields' are ... at least until the 1930s" (Torre and Tacke, 1970).

Hayami and Yamada (1968) have confirmed the reliability of the Government per hectare rice yields on the basis of their consistency with the relevant series of inputs, but this could be done only as far back as 1893-97. Assuming that the earlier figures are also consistent we can take the yield for 1878-82 as 1.166 koku per tan, or 1.7 metric tonne.* However, by 1885-89, yields had considerably increased and the greater part of Japan was producing more than 2.0 metric tonnes of paddy as seen from the following table :

TABLE III

Paddy Yields in Japan 1885-89

Number of Prefectures	Paddy Yields (tonnes/ha)
4	0-1.67
11	1.68-2.09
21	2.10-2.50
8	2.51-2.64
2	2.65-3.35

Source: Torre and Tacke, 1970 as quoted in Sinha, 1973, p.30.

Comparing these statistics with the yields in Tamil Nadu in the nineteenth century, one can gather that in most of the districts of Tamil Nadu, paddy yields compared favourably. Paddy yields were on a par with Japan,

* Nakamura (1966), p. 66. Rough Calculations suggest that one koku per tan is equal to 1.5 metric tonnes of paddy. See also Appendices Tables 5 and 7.

especially in the districts of Madura, Tinnevelly and Coimbatore, where the yields were over 3.0 metric tonnes on good lands. To present a clearer picture, we have taken statistics of paddy yields in districts of Madras over the period 1872-1887, to effect a comparison with the Japanese data.

Against the Japanese figures (table IV), the Madras districts compare very favourably indeed; only one district registered average yields below 2.0 metric tonnes and only three below 2.5 metric tonnes. It is of significance that 6 out of 9 districts record average yields of over 2.75 metric tonnes. In Japan, between the years 1885-89, only two prefectures record average yields of 2.65 - 3.35 metric tonnes.

If we compare nineteenth century rice yields in Madras with the corresponding Chinese figures, a less favourable picture emerges. However, we must recognize that our Chinese data pertain to a longer period, namely, the whole of the nineteenth century. It is highly probable that even in Madras, average yields in the early nineteenth century were considerably higher than later in the century; Coimbatore is a case in point. An average of 7.32 metric tonnes is reported on the first paddy crop in 1807, whereas by 1887 the average had fallen to 3.37 metric tonnes. Table V presents average yields of paddy for China between 1800-1899.

TABLE IV.

Paddy Yields in Madras Districts 1872-87

District	Paddy Yields (tons/ha)
Chingleput (1881)	2.17
North Arcot (1881)	3.10 (max. 4.04)
South Arcot (1881)	2.17
Tanjore (1883)	1.58
Trichinopoly (1872)	2.79
Madura (1881)	3.26
Tinnevelly (1881)	3.10
Salem (1872)	2.79
Coimbatore (1887)	3.37 (max. 4.83)

TABLE V

Average Paddy Yields in China 1930-1939

Province	Paddy Yields (tons/ha)
Kiangsu	3.75 (8)
Kiangsu (north)	3.17 (64)
Hunan	3.50 (50)
Hupei	4.10 (2)
Swatow	9.70 (6)
Kwantung (entire)	7.75 (19)
Szechwan	1.90 (15)

Source : Perkins, 1969, Table G-2, p.315.

(Figures in brackets indicate the number of observations used in arriving at the average figures in the table.)

At least two of the Chinese provinces, Kwantung and Swatow report very high yields, which perhaps none of the Madras districts had registered in the nineteenth century, though gauging from the early Coimbatore figures, it is possible that some districts came very close to it.

On the whole therefore, it could be inferred from a comparison with China and Japan, that rice yields in Madras in the nineteenth century were on a par with these two Asian countries and in fact, compares very favourably with Japan. Having therefore examined the level of traditional technology in Madras through inter-country comparisons, we shall now consider how productivity under traditional technology compares with present-day productivity.

Inter-Temporal Comparisons of Rice Productivity in Tamil Nadu:

By attempting inter-temporal comparisons, we seek to test whether traditional technology had reached its limits in the nineteenth century. Consequently, any further growth could not be brought about merely by allocation of resources within traditional agriculture. In the development experience of Tamil Nadu, this gives us an illustration of the exogenous phase of technological change, which was heralded by the Green Revolution. We have chosen two points of reference 1959-60 prior to the introduction of the Green Revolution and 1972-73 indicating productivity under the new strategy. Table VI presents productivity under traditional and modern technology in perspective.

Except in the case of South Arcot and Tanjore, average yields seem to have declined considerably in the early half of the twentieth century as seen from table VI, thereby making a technological breakthrough almost imperative. Such a breakthrough effected by the introduction of the new strategy staged a recovery to nineteenth century standards, as seen from the 1972-73 figures. It is interesting that Tanjore does not record a decline. As this is a monoculture rice district, favoured with assured canal-irrigation, our results reflect the importance of the irrigation factor in rice technology.

However, our comparisons are based on a single year and are to that extent limited. Besides, although in terms of averages, it can be inferred that the Green Revolution has significantly improved rice productivity, it is contended that rates of growth have not been significantly accelerated by the new strategy. It is this aspect of change that we shall explore in the following chapter.

TABLE VI

Inter-Temporal Comparisons of Paddy Yields in Tamil Nadu

(tons per hectare)

District	1872-1887	1959-60	1972-73
Chingleput	2.17	1.78	2.60
North Arcot	3.10	2.19	2.86
South Arcot	2.17	2.23	3.45
Tanjore	1.58	2.25	3.11
Trichinopoly	2.79	1.98	2.74
Madura	3.26	2.47	3.35
Tinnevelly	3.10	2.72	3.26
Salem	2.79	2.70	3.22
Coimbatore	3.37	2.71	3.45

Conclusions

As a result of the evolutionary and endogenous process of technological change, rice cultivation in Tamil Nadu had reached a high level. Our examination of available qualitative and quantitative evidence reveals that the traditional Madras farmer exploited all possible manurial resources and his application of the techniques of crop rotation and fallows enhanced productivity of land. The traditional agricultural implements were also well-suited to his purpose. Thus we see that through trial-and-error, the farmers had reached the frontier of traditional agriculture.

A comparison of traditional inputs and techniques of rice cultivation in Japan and Madras shows that indigenous technology in these two countries was broadly similar. The traditional Madras farmer was no more conservative or lacking in initiative than his Japanese counterpart. If we accept that nineteenth century rice cultivation in Japan was efficient, we have no basis to consider traditional technology in Madras as inefficient.

The quantitative evidence on rice yields obtained under traditional technology in Madras confirms our hypothesis that traditional technology in rice cultivation was at a reasonably high level. Rice yields in nineteenth century Madras compare very favourably with prevailing yields in Japan. In Madras, between 1872-1887, 6 out of 9 districts registered average rice yields of over 2.75 tonnes per hectare. In Japan, on the other hand, between 1885-1889, only 2 out of 54 prefectures recorded rice yields of 2.65

to 3.35 tonnes per hectare. Comparisons with Chinese data are less favourable as they refer to a longer period 1800-1899, though gauging from our earlier evidence, some of the Madras districts like Coimbatore registered very high yields in the early nineteenth century comparable to the Chinese figures.

When we turn to our inter-temporal comparisons of rice yields in Madras, we find a decline in all except 2 districts (South Arcot and Tanjore) in 1959-1960 from the late nineteenth century figures. These findings confirm our second hypothesis that average rice yields declined considerably in the early twentieth century. However, as our comparisons are limited to a single year, we treat these findings with some caution. We will examine whether similar results are obtained over a longer time period. The time period is a crucial factor, because technological change is a dynamic, evolutionary process, effecting significant productivity changes. Hence we shall consider to what extent rice yields were affected by the process of technological change. This process includes the introduction of the Green Revolution - the exogenous dimension of technological change - in Tamil Nadu. It is this dynamic process that we shall now consider, evaluating the contribution of exogenous technological change on rates of growth and stability of rice production in the region.

CHAPTER IV

INTER-DISTRICT VARIATIONS IN RICE PRODUCTIVITY

Introduction

Since we emphasize the view that technological change is a continuous process, a dynamic analysis of technological change is necessary. As we have indicated in Chapter II, this dynamic analysis may be characterised by two broad phases - an endogenous phase in which growth is relatively slow and an exogenous phase or breakthrough in which growth is more pronounced. However, these two phases need not always remain distinct - once the exogenous change has gained sufficient momentum, it could take on an endogenous aspect.

In the development experience of Tamil Nadu, we could see this exogenous phase in the introduction of the Green Revolution technology which initiated a breakthrough in agriculture in the mid 1960s. Over a decade since its inception, the endogenous phase of the modern technology is becoming evident in the cultivation of later hybrids replacing earlier-released strains. Yet, the impact of this breakthrough - the Green Revolution, is still evident. This impact can be viewed in two distinct dimensions - the contribution of the Green Revolution to improving growth rates of rice yields and its effect on increasing stability in yields over time.

The emphasis on technological change as an agent of growth would depend on the extent to which it contributes to improving growth rates; we shall therefore examine in detail whether the Green Revolution has in fact improved growth rates of rice yields in Tamil Nadu. Moreover, as the pace of agricultural development is seriously affected by fluctuations arising from climatic factors, we shall examine whether the Green Revolution has increased stability in rice production. Even if the impact of the Green Revolution did not result in significant increases in the annual growth rates, if these year to year fluctuations are reduced, the contribution of the new strategy towards achieving stability in production may be considered significant.

To assess the impact of technological change effectively, we require time-series data on a disaggregated level. Growth rates vary in different districts. Consequently, regional data often conceal distortions caused by inter-district variations.

It is true that potential growth rates depend on the initial levels of productivity. It is easier for low productivity areas to manifest high growth rates within given techniques than high productivity areas. In view of this to combine both high and low productivity areas and to calculate a growth rate gives us results that are meaningful only if interpreted with considerable caution. It would seem more legitimate in this context to select districts where levels of productivity are established and calculate their rate of growth separately. This sort of exercise would enable us to determine the impact of the new technology on rice yields. Such analysis could have important implications for policy strategy. This is what we shall do in this chapter by examining the impact of technological change on growth rates of rice yields and whether districts of high productivity under traditional technology maintain a leading role under the new technology.

However, our comparisons of rice yields in Tamil Nadu in the late nineteenth and twentieth century indicate a decline in average rice yields in the early part of the twentieth century and a recovery to nineteenth century levels is effected through the Green Revolution as seen in Chapter III. This unexpected decline needs to be explored to provide some reasonable explanation. It could indicate the divergence between static and dynamic analyses. Our earlier comparisons of rice yields in the late nineteenth and twentieth century are based on data for a single year. Although the years of reference chosen are 'normal' years, comparisons of a single year are limited. We need time-series data to assess if such a decline is evident over a period of time. This would confirm whether this unexpected decline in yields is purely due to single-year comparisons. On the other hand, this unexpected decline could reflect the inadequacy of developmental factors to increase yields over time. It is this point that we shall examine first.

Developmental Factors Promoting Increased Yields

In Japan, some developmental factors conducive to increasing rice yields are evident following on the Meiji Restoration (1868). Improvements in transport and communication, diffusion of the results of research stations, coupled with the efforts of the gono (veteran farmers) who travelled round the country sharing their experience of farming techniques with other farmers, all these were responsible in improving rice productivity in Japan.

In Tamil Nadu, similar developmental factors were also in operation. Although the main network of the railways was installed by the end of the nineteenth century, development of branch rail-roads connecting towns and villages continued throughout the early twentieth century. So too, the canal and road system established links between rural and urban areas. The influence of the price mechanism was thus facilitated, prices in the world market for commodities like cotton, jute and sugar were beginning to affect the rural countryside.

The development of the transport and communication network accelerated the diffusion of knowledge of improved techniques of rice cultivation. The benefits of research stations and experimental farms such as the Saidapet Farm were conveyed to the farmers with much greater ease and speed. Farmers tended to travel more frequently and to more distant places. Thus the lag between experimental research and adoption by the farmers was considerably reduced.

Coupled with these developments came the development of the irrigation systems. One of the oldest irrigational systems in the country in Thanjavur enabled multiple cropping of rice. Thus single-crop areas came to be converted into double-crop lands enhancing gross output. The extension of the irrigational system, the establishment of major and minor irrigation works, was a vital factor in reducing the dependence of the rice farmers on the vagaries of rainfall. Storage projects, enabled better control of water, double cropping and increased productivity.

All these developmental factors, together with the advent of chemical fertilizers would lead us to expect a steady increase in rice productivity in the late nineteenth century and into the twentieth. However, our inter-temporal comparisons of rice yields in Chapter III show that rice yields declined in the region and in most individual districts in the early twentieth century. We shall therefore examine the possible causes for this decline.

Reasons for the Declining Rice Yields in the Early Twentieth Century.

Intuitively, this decline could be attributed to a loss of soil fertility. In the case of rice, this need not necessarily follow because of the existence of a built-in fertilization process. Due to the fixation of nitrogen in the rice fields while the land is under water, there is no evidence of gradual loss of fertility, even in mono-culture rice lands (Aiyer, 1949; Blyn, 1966).

Rainfall shows itself to be another factor influencing both area under rice as well as yield per acre, so increases in rice acreage could be due to increased rainfall. This would permit growth of rainfed rice whose yields are generally lower. Thus the correlation may work through rainfall variation. It is highly probable that during the early twentieth century, in good years, rice yields on well-irrigated lands were much higher than average.

Another reason for declining rice yields could be the cultivation of more remunerative cash crops on better land, while rice cultivation is shifted to marginal lands. In this case, acreage under rice cultivation is not effectively altered.

Yet, it must be emphasized here that soil and climatic conditions which render an area suitable for growing rice make it unsuitable for other crops (Aiyer, 1954). Hence choice between alternative cash crops is limited to those cultivable on irrigated land, chief among these being sugarcane and turmeric.

Since a positive association has been found between rice area and yield per acre in Madras during the first half of the twentieth century* (Narain, 1965), declining yield per acre may be attributed to declining total area. All we can say is that as marginal land was brought into cultivation of rice, more fertile land was shifted to other crops. We have no statistical evidence that this was in operation, but during the year of survey (1974-75), several farmers reported that they had cultivated turmeric and sugarcane on their irrigated rice land; in some cases, only a small acreage was devoted to rice cultivation, often sufficient only for home consumption.

No conclusive evidence can be obtained for the earlier period, but some research has been done on regional data for the period 1939-40 to 1957-58 (Parthasarathy, 1959). The evidence shows that "there is no conversion taking place on paddy land to sugarcane in any absolute sense," but in another sense, "the potential higher growth of irrigated paddy is arrested by the expansion of acreage under sugarcane" (Parthasarathy, 1959, p.38), emphasis mine). This would imply that as irrigated acreage increased, sugarcane occupied this newly irrigated area. However, unless new paddy area was relegated to unirrigated land, this phenomenon need not necessarily affect productivity, due to the built-in fertilization process in rice lands.

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* This study relates to the Madras Presidency for the period 1900-1940. It is highly probable that the same conclusions are applicable for its southern districts which now comprise Tamil Nadu.

The shift to more remunerative crops therefore seems the most probable reason for declining yields in the early twentieth century. Data on irrigated and unirrigated paddy area would enable us to assert this finding more fairly. However, we do not have separate time-series data for irrigated and unirrigated paddy and hence we have to be content with analysis on average yields, which indicate a decline in the early twentieth century. This decline together with increasing population pressure called for an urgent response from the Government to meet food requirements.

With the situation reaching a crisis, urgent measures were required to improve the situation. In response, the Government launched a massive Grow More Food (G.M.F.) Campaign which aimed at exploiting every available resource to increase foodgrain production by:

(i) switching over from cash crops to food crops;

(ii) intensive cultivation of land through irrigation, better seeds, manure and improved techniques;

(iii) extensive cultivation of lands by bringing current fallows, culturable waste and water-logged lands into use.*

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* Report of the Grow More Food Enquiry Committee, Government of India, 1952.

Following shortly after Independence, the introduction of planning in 1950, set a new impetus to rice cultivation by emphasizing the importance of irrigation works as a 'leading input' in agriculture. A breakthrough however, came in 1966-1967, with the introduction of the new technology - the High-Yielding Varieties Programme (HYVP). Commonly referred to as the 'Green Revolution', the new strategy has introduced a whole new technology into foodgrain production, which would enable the country to be independent of reliance on food imports.*

The Effect of the Green Revolution on Production: A Macro View

Scarcely ten years since its inception, the contribution of the new strategy is being questioned. It is contended that on a national level, the new technology has not resulted in improved growth rates of foodgrain production in India (Sen, 1974; Srinivasan, 1972). Challenging the view that the Green Revolution has effected a major improvement in long-run growth rates, Sen (1974) contends that the annual rate of growth for foodgrains

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* Much alarm was raised in the 1960s by 'prophets of doom' that India would have to be sacrificed to save other 'deserving' nations (Paddock and Paddock, 1968). The dependence on imports from the U.S. meant having to make political concessions as in a 'low profile' in the Vietnam war.

during 1949-50 would have been maintained even without the new technology. His data shows that rates of growth of output of rice have fallen from 3.47 during 1949-50 to 1964-65 to 3.26 per cent during 1949-50 to 1970-71. Similarly, rates of growth of yield of rice fell from 2.12 to 1.94 per cent over the same period (Sen, 1974).

However, any attempt to measure growth rates of foodgrains on an aggregated basis, must take into account the relative weights of each crop. Such weights would vary for each region. So too, climatic differences in various regions could cause such an exercise to give misleading results. Consequently, we are inclined to treat Sen's (1974) conclusions with considerable caution.

Another limitation in an assessment of the contribution of the Green Revolution strategy is the short time span, since the new strategy has been introduced only in 1965-66. In his analysis, Sen (1974) omits the years 1971-73 because of their unfavourable weather conditions, in order to avoid downward bias in trend rates. With the exclusion of 1965-66 and 1966-67 (drought years), his evidence is based on only four years 1967-68 to 1970-71. Srinivasan (1972) comes to similar conclusions on data for 1967-68 to 1969-70. The inadequacy of so short a time span - three to four years - to assess the contribution of the new strategy to growth rates must cast doubt on their conclusions.

Our analysis is to some extent also limited, because our data relates from 1967-68 to 1972-73. However, as our analysis is conducted on an inter-district level, for a single crop - rice, climatic conditions in the area are more or less standardized. Thus variations in coverage, climatic factors and acceptance of the new technology which may tend to distort the true picture will be avoided. Hence on a district-level, it may be more reliable to assess the contribution of the new strategy. Our analysis is based on district-level data on area, production and yield per hectare of rice from the Season and Crop Reports of the State of Tamil Nadu from the earliest date available - 1904-05 to 1972-73.*

In any analysis of long-term agricultural trends in India, one is confronted with problems posed by comparability of data and differences in methods of estimation which may bias the inferences. We will therefore consider these first before we proceed to any further analysis.

Problems of Measurement

Inconsistencies in early agricultural data in India

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* Yields for the years 1900-1901 to 1904-05 were the same as these years were considered to be 'normal' years. The system of yield assessment will be discussed later.

have been widely recognized in most of the literature (Panse, 1952; Thorner, 1960; Shah, 1961; Blyn, 1967; Shetty, 1969). These inconsistencies arise from variations in coverage of the crop and differences in the method of estimation.

Up to 1906-07, reported rice yields covered only _ryotwari_ (peasant owned) land but after that, _zamindari_ (feudal) lands were also included (Blyn, 1966). This does not however, affect our analysis as we have restricted ourselves to a consideration of yield and not total output. For all purposes of assessment, yields in _zamindari_ lands were assumed by the Board of Revenue to yield the same as other lands in the Province.*

As regards non-comparability of data caused by changes in methods of estimation, these pose a more difficult problem. The traditional method in use at the time estimated production by the formula :

> Area multiplied by Standard yield per acre
> multiplied by the Seasonal Condition Factor.

Area under the crop was taken to be area sown, regardless of whether the crop came to maturity. The Standard Yield

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* If anything, yields under feudal tenure can be expected to be lower. For, with tenants paying an average of 50 per cent of the gross output as rent without the landlord contributing inputs, the yield would not be the optimum.

was a constant in each district, at least for five years at a time. Though the standard yield was not well defined, it was the yield on land of average quality, under normal climatic conditions.

Usually, the standard yield was fixed by village officials on the basis of crop-cutting experiments. The seasonal condition factor was the proportion of current yield to standard yield and was also determined by village officials. As both the standard yield and the seasonal condition factor were determined by village officials, it is probable that they were prone to downward bias, due to the association of land revenue assessment with yield and weather conditions.*

Recognizing the deficiencies of the traditional method, the scientific crop-cutting method of estimating production of foodgrains was initiated around the year 1943-44. However, the change from the traditional to the crop-cutting method was gradual, each district and each province adopting it in turn. Madras began to switch over to the crop-sampling method for estimating yields of rice in 1955-56 (Blyn, 1966). For some crops, the shift was more rapid than others, coverage reaching 100 per cent of output as early as 1958-59.

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* Adverse crop conditions could lead to remission of land revenue.

While we are aware that changes in the method of estimation tended to bias yield figures, there is no reliable method of determining in which direction this bias was likely to be. Further, as the crop-sampling method was introduced gradually, there is no recorded evidence as to when each district or each area adopted the method. Besides, even in the late nineteenth century, Collectors in some districts ensured accuracy in statistics by insisting on being present at crop-cutting experiments. These experiments formed the basis on which average yields were determined as we have shown earlier in Chapter III.

The difficulty of determining whether changes in the method of estimation have caused a significant difference in yield estimates is illustrated in earlier analyses on similar data. These analyses demonstrate that the results are largely relative to the area and time period for which they have been conducted (Shah, 1962; Shetty, 1969). Shah (1962) found that the changes in the method of estimation of rice yields in Bombay in 1951-52 did not result in significant differences in average yields over the preceding and following five years. Shetty's (1969) analysis for Bombay confirms this on the basis of district-level data.

On the other hand, Panse (1963 and 1964) finds significant difference in average yields, which he attributes to changes in the method of estimation. However, Panse's (1964) analysis is made at the Province level, using comparable data collected by the Indian Council of Agricultural Research (ICAR) for various Provinces. Any analysis therefore testing differences in average yields is relative to the area and period during which such change was effected.

However, despite inconsistencies caused by changes in the method of estimation, we have certain advantages of statistical accuracy in our choice of area:

> Madras is one of the provinces which have the reputation of supplying fairly accurate data. When the reorganization of the forecasting methods took place after the war (1914-18), Madras had a very efficient Director of Agriculture in G.A.D. Stuart..... Madras was also the first Province to give effect to the recommendation of the Board of Agriculture in India regarding the appointment of a qualified statistician to help in this work. (Thomas and Sastry, 1939, p.38).

Having considered the various possible causes for declining rice yields, we shall now proceed to test our two hypotheses, so as to determine the contribution of the Green Revolution to increasing growth rates of rice and stability of production in the district of Tamil Nadu.

Rates of Growth

The rate of growth of rice productivity was calculated by fitting the exponential trend

$$y = ae^{bt}$$

Transformed into logarithms, this equation can be written as :

$$\log y = \log a + bt$$

where y = yield per hectare of rice

t = time measured in years.

b then measures the average (or trend) annual growth rate of rice yields.

We measured growth rates in the pre-plan (1904-05) to 1950-51), plan (1951-52 to 1966-67) and Green Revolution periods (1967-68 to 1972-73). Table 7 gives the rates of growth and fluctuations around the trend for each of the periods. These fluctuations around the trend give us a measure of instability with which we shall deal later in this chapter.

The purpose of our analysis is twofold:

(i) to examine the rate of growth of yields in each district since the introduction of the Green Revolution and to test if the new strategy has significantly improved these;

(ii) to identify districts with high growth rates and to examine if these have been sustained over time. These districts could then serve as 'leading' districts in a micro-analysis of rice technology for the diffusion of the new technology from regions of high productivity to regions of low productivity.

Analysis of the Rates of Growth

It is evident from the analysis (Table 7) that rates of yield growth steadily increased in the States and in most individual districts of Tamil Nadu in each of the three time periods. In the pre-plan period, a very low growth rate (below 1.00 per cent per annum) is seen in the region as well as in all districts except Mordurai* which records a growth rate of 1.37 per cent. However, in the plan period (1952-67) growth rates of rice yields improved considerably in the region and all districts except the Nilgiris. This indicates that the development factors had a significant positive effect in increasing rice yields over time. In the Green Revolution period (1968-73) rates of growth of rice yields improved in the State and in all districts except Coimbatore, which again reinforces the positive effect of the new technology on increasing rice yields.

Our analysis therefore indicates that both the developmental factors and the Green Revolution increased rates of growth of rice yields. In other words, these forms of

* Names of districts are those currently in use. Some of these differ slightly from nineteenth century records. Thus Madura, is now referred to as Madurai, Tanjore-Thanjavur, Trichy - Tiruchirapalli and Tinnevelly - Tirunelveli.

TABLE VII

RATES OF GROWTH AND INSTABILITY INDICES FOR RICE YIELDS

District	1905-51		1952-67		1968-73	
	R	I	R	I	R	I
CHINGLEPUT	0.37	26.8	3.21	9.2	8.99	17.5
SOUTH ARCOT	0.21	15.0	1.97	13.5	6.38	6.91
NORTH ARCOT	0.04	14.5	1.81	16.6	12.28	14.6
SALEM	0.59	12.9	2.90	11.8	5.44	6.4
COIMBATORE	0.02	10.8	3.26	11.9	3.04	15.8
TIRUCHIRAPALLI	0.29	11.0	1.61	11.9	5.21	8.9
THANJAVUR	0.40	8.9	2.45	7.8	6.33	8.5
MADURAI	1.37	21.7	2.47	11.9	10.57	14.9
TIRUNELVELI	0.81	15.9	1.16	17.7	7.69	15.2
NILGIRIS	0.98	13.4	-2.47	20.4	3.23	25.1
STATE	0.41	13.1	2.05	8.3	7.21	4.9

R = Rate of growth (per cent per annum)

I = Instability index (percentage)

technological change facilitated the movement of the frontier outwards. Our findings also emphasize the importance of a dynamic treatment of technological change. Static inter-temporal comparisons such as in Chapter III could give a misleading picture. The importance of dis-aggregation is also seen in our results - not all districts record steady increases over time. Our two exceptions Coimbatore and the Nilginis are a case in point.

In Coimbatore, while an increase in growth rate is evident in the plan period (1952-67) from 0.02 per cent to 3.26 per cent, a slight decline is to be found in the Green Revolution period (1968-73) from 3.26 per cent to 3.04 per cent. It is to be noted that in the pre-plan period (1904-51) Coimbatore shows the lowest growth rate (.02 per cent). This is not surprising as one would expect an area of high traditional technology to record a slow growth for average yields. However, the increase in rates of growth in the plan period (1952-67) could indicate that the impetus given to irrigation under the plans coupled with other developmental factors like the introduction of chemical fertilizers and improved seed gave a tremendous spurt to growth rates in Coimbatore.

On the other hand, it is found that the impact of the new technology has not resulted in an increase in growth rates in Coimbatore. Rather, growth rates have declined from 3.26 per cent between 1952-67 to 3.04 per cent between 1968-73. This could be due to one or other of the following factors. Either rice technology had already reached its high in the period 1952-67 and no further increase in growth rates could be brought about even with the introduction of modern technology or the short time period has not enabled us to find any significant increase in growth rates due to the introduction of the Green Revolution.

In the Nilgiris, a negative rate of growth is found in the plan period (-2.47 per cent). This could indicate that already in the nineteenth century, rice technology had reached its peak and the various developmental factors did not result in any improvement. It must be emphasized here that the area under rice cultivation in this district is very small and much of the rice is cultivated under unirrigated conditions which accounts for the decline in productivity over time. It is also probable that much of the more productive lands in this district were shifted to other remunerative crops resulting in declining growth rates of rice over the plan period. However, with the introduction of the Green Revolution and the use of hybrid seed, a definite improvement in growth rates is to be found from -2.47 per cent in the plan period to 3.23 per cent in the Green Revolution period. We shall see later that there has also been a slight increase in area under rice cultivation in this latter period.

Thus we see that in the region as a whole and in most individual districts, the effect of technological change has been positive, effecting a steady increase in growth rates, both in the plan period (1952-67) and in the Green Revolution (1968-73) period. Having examined the overall effect of technological change, we shall consider if there are any 'leading' districts - districts with high growth rates which have been sustained over time and could serve as 'leaders' in the diffusion of new technology to regions of low productivity.

Identifying districts of high productivity

In the pre-plan period (1904-51), the highest rate of growth is recorded in Madurai (1.37 per cent) followed by the Nilgiris and Tirunelveli (.81 per cent). Coimbatore shows the lowest rate (0.2 per cent) which is to be expected in an area of high traditional technology, as mentioned earlier.

In the plan period (1952-67) however, the highest rate of growth is recorded in Coimbatore (3.26 per cent) followed by Chingleput (3.21 per cent) and Salem (2.90 per cent). It is not surprising that Coimbatore records a leap from 0.02 per cent to 3.26 per cent rate of growth. If we accept that Coimbatore was a 'progressive' district under traditional technology, then the introduction of irrigation and improved inputs such as improved seed and fertilizers, enabled farmers to increase their rate of growth of rice yields. So too, Chingleput and Salem which have a large percentage of irrigated rice were able to benefit from the developmental factors under the plans manifesting an increase in growth rates.

However, we find that Madurai, the Nilgiris and Tirunelveli which recorded high rates of growth in the pre-plan period, do not register high growth rates in the plan period. This could indicate that these districts had not reached their peak under traditional technology and maintain their steady growth rate with the introduction of irrigation and improved inputs in the plan period. In fact, Tirunelveli records the lowest growth rate (1.16 per cent) in the plan period after the Nigliris which records a negative rate (-2.47 per cent). It is likely that the district of Tirunelveli reached its peak under traditional technology in the plan period.

In the Green Revolution period (1968-73), the highest rate of growth is to be found in North Arcot (12.28 per cent) followed by Madurai (10.57 per cent) and Chingleput (8.98 per cent). This is due to the fact that these districts only started benefitting from the introduction of the new strategy in the early 1970s. On the other hand, Coimbatore ranks lowest in its growth rate for this period (3.04 per cent). It would seem to indicate that in this 'progressive' district, slow rates of growth are expected over a longer period, as in the initial years of its inception, already high growth rates had been experienced.

Several general points emerge from the above analysis. The most striking is the effect of disaggregation. Our analysis shows a steady upward trend in yields in the State and in most of the individual districts in the pre-plan period (1904-1951) though not to the same extent in each district. At the regional level, growth rates of rice yields maintain their upward trend from the pre-plan period to the plan period and a further rise is seen in the Green Revolution period. This increase in growth rates is significant and illustrates the contribution of technological change in the region.

At the district-level however, one can notice that all districts with the exception of the Nilgiris, increased their growth rates in the period 1952-67, but districts with high growth rates in the pre-plan period had a relatively low growth rate compared to other districts which had a low growth rate in the earlier period. So too, in the Green Revolution period, 1968-73, all districts improved their rates of growth from the plan period, with the exception of Coimbatore. This could imply that rice technology had reached its peak in Coimbatore and even the introduction of the new technology could not improve rates of growth.

Before we conclude this section, it would be worthwhile to consider the case of Thanjavur - a monoculture rice region. Due to the availability of irrigation, and the lack of competition from other crops, the impact of technological change on increasing productivity would be clearest in this district. In the pre-plan period, Thanjavur records a growth rate of 0.40 per cent, which is very close to the State average. However, in the plan period (1952-67) the rate of growth increases to 2.45 per cent which is above the State average, and a further increase in growth rates is recorded in the Green Revolution period to 6.33 per cent. On the basis of our analysis therefore, we can conclude that the contribution of technological change to increasing growth rates of rice is significant.

It is further significant to note that this increase in growth rate has been largely due to increased productivity rather than increased acreage under rice cultivation. On the basis of State-level analysis of area, production and yield per hectare of rice between 1964-65 and 1970-71, it has been found that Tamil Nadu claims the highest percentage change in production and yield per hectare of 31.4 and 28.4 per cent respectively (Bansil, 1972). We shall test the extent and direction of this change in each of the districts, with a view to determine which districts contribute most to increased productivity in the region. Identifying these areas could be a vital factor in using these districts to diffuse modern rich technology.

Area under rice declined in four districts in the Green Revolution (Table 8) - Chingleput, North Arcot, Salem and Tiruchirapalli. The decline is particularly high in Salem (-33.03 per cent). This becomes clear when we realize that much of the new district of Dharmapuri was formed in 1965-66, from a large part of Coimbatore. However, all the other districts indicate an increase in rice acreage after the introduction of the new technology.

Yet despite a decline in area under rice cultivation after the introduction of the Green Revolution in the above four districts, there is no indication of a decline in yields in these districts. (Table 9). All the districts record an increase in yield with the introduction of the new technology, though not to the same extent.

Ranking districts according to changes in productivity levels since the Green Revolution, Tinnevelly ranks highest followed by South Arcot, the Nilgiris, Ramanathapuram and Chingleput, all of which rank above the State average (Table 9). Dharmapuri district records the lowest productivity (11.24 per cent). Though our findings are relative to the year of reference they give a fair indication that significant increases in rice yields per hectare have resulted from the adoption of the new technology in Tamil Nadu.

TABLE VIII

CHANGE IN AREA UNDER RICE CULTIVATION 1964-65 to 1972-73.

(million hectares)

DISTRICT	1964-65	1972-73	Absolute change.	Percent change.
CHINGLEPUT	339.2	326.4	-12.8	- 3.78
SOUTH ARCOT	305.2	329.8	24.6	8.08
NORTH ARCOT	305.5	290.4	-15.1	-4.93
SALEM	135.2	90.6	-44.6	-33.03
DHARMAPURI*	37.1	57.1	20.0	54.05
COIMBATORE	112.3	134.0	21.7	19.30
THIRUCHIRAPALLI	235.1	190.9	-44.2	-18.77
THANJAVUR	601.9	623.1	21.2	3.53
MADURAI	155.1	167.9	12.8	8.26
RAMANATHAPURAM	240.5	296.6	56.1	23.33
TIRUNELVELI	136.1	160.6	24.5	18.07
NILGIRIS	3.5	3.6	.1	0.54
KANYAKUMARI	56.6	61.7	5.1	8.99
STATE	2626.1	2732.7	106.6	4.06

* Data for the district of Dharmapuri refer to 1965-66.

TABLE IX

CHANGE IN RICE YIELDS 1964-65 to 1972-73

(tonnes per hectare)

DISTRICT	1964-65	1972-73	Absolute change.	Percent change.
CHINGLEPUT	1.32	1.73	0.41	31.45
SOUTH ARCOT	1.57	2.30	0.73	46.06
NORTH ARCOT	1.57	1.91	0.34	21.40
SALEM	1.82	2.15	0.33	17.73
DHARMAPURI*	1.76	1.96	0.20	11.24
COIMBATORE	1.82	2.30	0.48	26.00
THIRUCHIRAPALLI	1.48	1.83	0.35	23.20
THANJAVUR	1.73	2.07	0.34	20.02
MADURAI	1.83	2.23	0.40	22.10
RAMANATHAPURAM	0.86	1.25	0.39	45.18
TIRUNELVELI	1.43	2.17	0.74	52.10
NILGIRIS	0.93	1.35	0.42	45.37
KANYAKUMARI	1.78	2.22	4.40	24.66
STATE	1.54	1.96	0.42	27.78

* Data for the district of Dharmapuri refer to 1965-66.

A state-wise analysis of rice productivity in India during the Green Revolution period shows that Tamil Nadu ranks highest. Compound growth rates of rice productivity in Tamil Nadu increased significantly from 1.14 per cent to 5.78 per cent (Singh and Sirohi, 1974). This figure is not the highest for the country as a whole but productivity in the pre-Green Revolution period in Tamil Nadu was already high as compared to other Southern States (Minhas and Vaidyanathan, 1965). Singh and Sirohi (1974) maintain that even before the introduction of the Green Revolution, Tamil Nadu recorded the highest productivity for rice followed by Mysore and Kerala. There is no doubt that the extent of progress has been largely conditioned by the extension of irrigation (Raj, 1972). To that extent, Thanjavur is singularly favoured and has benefitted from the High-Yielding Varieties Programme.

While much emphasis has been placed on the trend rate of growth of foodgrain production, there is a tendency to overlook the contribution of the new strategy to stabilizing productivity. Short-term fluctuations due to climatic or other factors, shifts to other more remunerative crops, tend to vitiate long-term production. We shall therefore examine the contribution of the new technology in reducing such fluctuations and stabilizing rice production in Tamil Nadu.

Technological Change and Stability of Rice Production

Stability in agricultural production is an important dimension of agricultural strategy. Year to year fluctuations in agricultural production cause uncertainty in planning and affect long-term economic policy. Bad harvests in consecutive years increase reliance on food imports with the concomitant political implications. One of the major goals of economic strategy in India is to attain self-sufficiency in foodgrain production. Hence a consideration of stability becomes important.

Since the introduction of the Green Revolution, Tamil Nadu has become one of the major net rice exporting States in India. We shall consider whether developmental factors like planning and its emphasis on irrigation have contributted to stability or whether the Green Revolution has been a major factor in stabilizing rice yields.

There is no doubt that certain intrinsic qualities of the new rice hybrids reduce instability. The hybrid rice strains are genetically tailored to irrigated conditions and hence could not be grown on unirrigated soil. Moreover, hybrid rice is not photosensitive. This implies that these hybrids reach maturation after a definite period (varying for each strain) and can be harvested even under cloudy conditions.* Traditional rice varieties on the other hand, being photosensitive can be harvested only under certain conditions of light and heat. Changes in climate therefore affect traditional varieites more than hybrids. To this extent, hybrid seed is less dependent on weather conditions and consequently, increases stability of rice yields.

We shall now examine to what extent the new strategy has succeeded in reducing the effects of short-term fluctuations thereby effecting greater stability in rice yields.

We have defined these fluctuations as percentage changes from the trend-line often referred to in the literature as 'instability indices' (Coppock, 1962; MacBean, 1966; Casley, Simaika and Sinha, 1974). Several measures of calculating the instability index have been used, each with their relative merits, the simplest form being the average percentage deviation from the five-yearly moving average centred on the mid-year (MacBean, 1966), but this has the disadvantage of losing out on the first and last observations.

As our index of instability, we use the ratio of the average deviation around the trend line to the trend growth rate. To measure the average deviation, we use the standard

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* Hybrids harvested when there is a cloud cover require to be dried mechanically. This involves higher costs but against these costs is the certainty in cultivation.

error (root mean square deviation) of the fitted equation. Expressed in percentage terms, this ratio gives our instability index. This measure is analogous, for a trend line, to the coefficient of variation for univariate data, and has the advantage of measuring the deviations after allowance for the trend change in yield levels. It has the disadvantage that over a small time period, a single observation could affect the instability index very significantly, a disadvantage shared by other methods as well such as moving averages.

Analysis of Instability

From our analysis (Table 6) it is evident that a greater stability is noted in the State as a result of technological change. Instability indices in the pre-plan period fall from 13.1 per cent to 8.4 per cent in the plan period and a further decline is to be found as a result of the Green Revolution to 4.9 per cent. On the basis of these results therefore, the contribution of technological change to stability in rice production cannot be doubted.

However, when we look at the individual districts, we see that Coimbatore and the Nilgiris record a steadily greater instability over time. In Coimbatore, the instability index rises from 10.8 per cent in the pre-plan period to 11.9 per cent in the plan period and further increases to 15.8 per cent in the Green Revolution period. In the

Nilgiris, instability indices increase from 13.4 per cent in the pre-plan period to 25.1 per cent in the Green Revolution period. In the other districts, on the other hand, instability indices fluctuate and no definite pattern can be established. Thus in five districts - Chingleput, South Arcot, Salem, Thanjavur and Madurai, a greater stability is recorded in the plan period, while in the other five districts, a greater instability is evident in the plan period.

Such variations in instability indices in the individual districts are to be expected, due to inter-district variations and price fluctuations which are not reflected in the State indices. Thus good or bad harvests in a single year could cause the instability index to increase drastically. Such variations are not reflected in the State indices, as good harvests in one district may compensate for bad harvests in another. Hence instability is large in smaller areas and tends to get smaller and smaller with increasing size of the region.

From the foregoing considerations, it would seem logical to consider the contribution of technological change to increasing stability in rice yields on the basis of the State indices. There is little doubt that from our findings, greater stability in rice yields results from the introduction of technological change. The contribution of technological change to stability in rice yields therefore, is significant.

One interesting result that follows from our analysis is that Thanjavur records the lowest instability index in each of the three time periods. As this is a predominantly rice-growing district, this result is significant. It reflects the contribution of technological change on stability in rice yields, without the necessity of discounting for competition from other crops. On the basis of this finding, the contribution of technological change to increased stability in rice yields becomes more emphatic.

Looking at the relationship between instability indices and growth rates, we find no evident relationship emerges. Districts with low instability and high growth rates could be 'leaders' in the diffusion of modern technology, but from our analysis, no such 'leaders' can be identified. High instability accompanies high rates of growth in North Arcot and Madurai (Table 6), as well as low rate of growth as in the Nilgiris (Table 6). The complexity of factors responsible for instability of production clouds the issue, hindering any effective measure of the efficacy of the Green Revolution in stabilizing fluctuations in rice yields.

Conclusions

In this chapter, we have seen the impact of developmental factors on rice productivity in Tamil Nadu. The decline in average rice yields in the region led us to examine the impact of technological change effected through planning and the Green Revolution on growth rates and stability of rice production.

We recognize that over a period of six years, any conclusions arrived at will be severely limited. However, as our analysis is conducted on district-level data, the effects of disaggregation are very clear. While in the region as a whole, the impact of the Green Revolution is evident in increasing growth rates of rice yields in certain districts like Coimbatore, there is a decline seen in the period following the introduction of the new technology.

Our analysis does not agree with previous findings (Sen, 1974; Srinivasan, 1972) that the Green Revolution has not contributed significantly towards increasing growth rates of rice. On the other hand, our findings attribute a significant positive contribution made by the new strategy to increasing rice productivity in almost all districts of Tamil Nadu.

In analyzing the contribution of the Green Revolution to stability of rice production, we have not been able to arrive at any definite conclusions. In the region as a whole, the new strategy has reduced instability in rice production, but in certain districts, instability has increased with the Green Revolution. This is to be expected, since in a short period any remarkable increase in productivity would be likely to reflect a high instability. However, over a longer period, these short-term fluctuations may be ironed out.

We have examined the contribution of exogenous technological change - the Green Revolution - on rates of growth of rice production and instability. However, we have assumed throughout this analysis that a large proportion of the farmers have adopted the new technology. This may not be the case. Several factors govern the response of farmers to technological change which are often ignored. Yet, they form an important ingredient of development strategy. It is to this that we shall now turn, examining the socio-economic factors which influence response of farmers to technological change.

CHAPTER V

SOCIO-ECONOMIC FACTORS INFLUENCING TECHNOLOGICAL CHANGE

Introduction

While the impact of exogenous technological change is evident in analyses of growth rates and stability of production, such analysis does not give us a complete picture. The effect of exogenous change varies in different districts due to several factors which are not reflected in analysis of trend. There are physical factors which result in one district growing faster than others. Factors such as irrigation, favourable soil, climatic conditions and access to input supplies could cause some districts to have higher growth rates. Historical factors such as the initial level of agricultural productivity could also result in faster growth in some districts.

Ultimately however, the growth rate is a function of farmers' behaviour. Farmers do not all behave the same way. Between districts and even within the same district, farmers behave differently. Their response to new technology, new inputs and new crops are varied, even given similar physical and historical conditions. The pace of exogenous technological change depends on farmers' adoption of modern technology. If efforts of the state are to result in maximum development and quickest response, it is necessary to understand and isolate the factors that make some farmers more alert, flexible and innovative (in short, more 'progressive') than others. To the extent to which these factors are promoted, the pace of adoption and consequently, the exogenous phase of technological change is accelerated.

This cannot be done on an aggregate level because of differences between individual farmers. Hence we have to look at individual farmers in a single district. This is what we do by examining the socio-economic factors which affect response to technological change of our sample farmers in Coimbatore. These factors will give us some important guidelines for diffusion strategy.

Criterion of Technological Progressiveness

On the basis of their response to technological change farmers have been termed 'progressive' or 'non-progressive'. The criteria for distinguishing between progressive and non-progressive farmers is important, if any valid results are to be obtained for effective agricultural policy. Too often progressive and non-progressive farmers have been distinguished solely on the basis of adoption of hybrid seed. Consequently, adopters were labelled 'progressive' and non-adopters 'non-progressive'.

However, such a distinction is incomplete; it does not take into account use of other inputs, nor reasons for non-adoption of hybrid seed. Farmers who chose to cultivate traditional varieties or locally improved strains because of their better cooking quality or taste would fall into the non-progressive category. Yet, their input use and techniques of cultivation for these strains may in fact, be 'progressive'.

We found that from our sample of 180 farmers, 26 (14.4 per cent) had not grown hybrid rice in the year of survey. Most of these expressed preference for local improved varieties because of their taste or cooking quality. As 22 of these farmers had paddy area below 1.75 acres, they were growing paddy mainly for home consumption. Their choice of local varieties seems therefore reasonable. Thus, from the above considerations, it would appear that farmers' decisions to adopt new inputs or techniques depend on several factors which determine his technological efficiency. Underlying all these decisions however, is farmers' rationality.

Rationality as a Determinant of Technological Efficiency

The concept of rationality in the rural context refers to various choices or decisions in farming. Viewed in this perspective, rationality involves the use of deliberation, planning and the best available sources of information and advice in arriving at decisions as a means of achieving maximum economic ends. Even as early as the 1940s, the recognition of economic rationality as a key variable in economic progress was emphasized but research was confined to its restrictive context of distinguishing between adopters and non-adopters of improved practices (Gross, 1949) or between cultural groups accepting a recommended practice (Pedersen, 1951).

It was only in the early 1950s, that the breakthrough was evident in the analysis of the relationship between rationality and adoption of improved farming practices. The Subcommittee on the Diffusion and Adoption of Farm Practices of the Rural Sociological Society (1952) in the United States suggested that the greater the degree of economic rationality in farming matters, the greater the likelihood of accepting improved farm practices. This finding stimulated fresh interest in adoption research which had hitherto been confined to establishing the association between various socio-cultural variables and adoption, in an effort to determine the factors promoting speedy adoption of new techniques and practices (Fliegel, 1957; Wilkening, 1958). The emphasis remarkably rested on the time factor with various socio-cultural variables enhancing or retarding the time of adoption. Thus farmers were categorized as innovators, early adopters, early majority, late majority and laggards on the basis of time of adoption of improved practices (Rogers, 1958).

Besides socio-cultural variables, sources of information emerged as another important variable affecting rate of adoption, calling for a closer look at adoption in relation to time of contact with new techniques, thus making diffusion closely allied to adoption (Mason, 1964; Kivlin, Fliegel and Roy, 1968; Sinha and Mehta, 1972). Such close association between adoption and diffusion is remarkably accentuated in the following definition of the process of diffusion as "the (1) acceptance (2) over time, (3) of some specific item - an idea or practice, (4) by individuals, groups or other adopting units, linked to (5) specific channels of communication (6) to a social structure and (7) to a given system of values or culture..." (Katz, Levin and Hamilton, 1963, p.240).

It became apparent therefore, that in diffusion studies, the measurement of the time variable is crucial; the adoption model too, recognizes this factor in distinguishing five consecutive stages in the adoption process - awareness, information, application, trial and adoption. Viewed against time, it is generally accepted that the pattern of adoption follows an S or growth curve.*

> "Ordinarily adoptions are slow at first. After an initial slow start, they increase at an increasing rate, until approximately half of the potential adopters have accepted the change; after this, acceptance continues but at a decreasing rate." (Lionberger, 1960, p.33).

The similarity of this idea with the Schumpeterian concept of innovation is interesting. Schumpeter recognized the importance of stimulating innovations through technological leaders, so as to ensure speedy adoption. On the implication that adoption follows a normal distribution,

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* This view has been challenged in economies highly conditioned to technological innovations such as the U.S., where the diffusion curve resembles a J curve rather than an S curve (Perry, Sullivan, Dolan and Marsh, 1967). In 1958, Roger's research on Iowa indicates a bell-shaped adoption curve

Rogers (1962) classified adopters into early adopters, majority and late adopters on the basis of the three segments of the distribution.

Two points emerge from the foregoing consideration, which are particularly pertinent to our study. Firstly, the consideration of time as a crucial variable. Recall of time of adoption or contact can be subject to considerable error and specifically in agriculture may lead to subjective bias. Where the lag between first propagation of the practice and date of survey is large, error may be considerable; so too, with a large majority of farmers in the older age bracket, when recall of time may be more difficult and less reliable. Earlier research shows that the diffusion period was found to become progressively larger with each successive survey (Coughenour, 1965).

Secondly, assuming the rationality criterion, the concept of stages breaks down; even at the awareness and acquaintance stages, farmers' rationality may opt for non-adoption in which case subsequent stages are rendered redundant. Some researchers have attempted to minimise this problem by considering only three stages - awareness, acquaintance and adoption (Shetty, 1967) - which simplifies analysis but nonetheless remains arbitrary as a means of classification.

Besides, though reducing the magnitude of the problem, it does not wholly eliminate it. Two possibilities can be distinguished in this respect: firstly, farmers' rationality may interrupt the sequence of the stages by leaps from one stage to another or secondly, farmers' rationality may result in immediate adoption, merging stages into a single phase. This is not uncommon and reflects the 'demonstration effects' of an experiment. A farmer 'learning' of an improved technique from his peers is much quicker in adopting. This ties up with sources of information which we shall discuss later.

To minimize the above difficulties, we decided to assess technological efficiency of farmers in Coimbatore, in relation to their response to the package of inputs and practices recommended by the Agricultural Department for the new High-Yielding Varieties Programme. Insofar as these inputs and practices achieve best results only in combination (hence the term 'package'), a weighted index of technological efficiency has been used in assigning scores to the relevant inputs and techniques on the basis of their relative importance in the package. The relative importance of various inputs and the assigned scores are outlined in Appendix III.

Earlier studies have used indices to measure the rate of adoption or innovativeness (Bose, 1967; Presser, 1969;

von Fleckenstein, 1974). Our index differs slightly from most of the earlier studies in that it avoids the time factor considering technological efficiency at a point in time rather than in the whole change continuum.

If we assume technological efficiency of the farmer is measured by the extent of his adoption of the modern package of inputs and practices, we can analyze the factors enhancing or reducing this efficiency. We are primarily interested in the socio-economic variables affecting response of farmers towards technological change. Socio-economic factors and farmers' inherent qualities sometimes account to a large extent for differences in progress both between areas and between groups of farmers. We maintain that these factors did play an important role under traditional technology and our examination of historical evidence in Chapter III bears out this claim that the Coimbatore farmer was far superior to his peers in other districts in his use of traditional resources and techniques. We therefore proceed to identify the major socio-economic factors facilitating response to technological change, but first a few points on our index of technological efficiency are necessary.

Basically, it has been argued that success under the new strategy is best achieved by the adequate and timely use of modern inputs and practices. This being particularly essential in rice cultivation, the importance of the 'package' of inputs and techniques cannot be overemphasized. Assuming then, the interdependence of inputs within the package, any index of efficiency must consider two dimensions - quantity and timely application of inputs; a change in the quantity of one input causes imbalance in the package, consequently decreasing production and lowering efficiency. In the same vein, an untimely application of certain inputs or techniques reduces efficiency. In considering our index for rice cultivation therefore, we have considered both these aspects.

Index of Technological Efficiency

The index we have chosen has been based on the package of inputs and practices for rice cultivation recommended by the Agricultural Department for the area. For convenience of analysis, certain basic assumptions have been made:

(i) In the case of plant protection chemicals, homogeneity has been assumed, so as to avoid difficulties in price fluctuations entering into the analysis. The index was based on the recommended number and times of application of these chemicals rather than on the type or chemical composition.

(ii) For fertilizers,* the recommended dosage was measured in terms of plant nutrients in the ratio of N + 2.29P + 1.20K. Different fertilizer mixtures and different brands were thus aggregated in terms of plant nutrients. In keeping with the accepted view that overdosage of fertilizers results in negative yields, farmers applying more than the recommended dose were given less than the full score assigned for this input, thereby lowering their index.

Having thus fixed our index for each farmer on the basis of scores for each item of the package (as indicated in Appendix III), it was found that only 14 farmers (7.8 per cent) had an index below 50 and only 44 (24.4 per cent) had an index less than 70. From this, it seems that at first sight, most of the farmers in this area may be termed technologically progressive - the majority (32.3 per cent) having an index between 70 and 79. This brings us to a consideration of the vital factors which produce this response .

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* For convenience of analysis, research studies usually aggregate different fertilizers in value terms (Govt. of India, Farm Management Studies, (various, (1956-73)- Khusro, 1964); the incongruence of the inclusion of prices in a consideration of technical efficiency are obvious (Farrell, 1957; Bharadwaj, 1974). The legitimate way is to measure fertilizer input in terms of plant nutrients. The same procedure is not ideal for pesticides as the composition of plant protection chemicals is not reduced to standard units. We have instead used the number of applications as an index of the farmer's input. Implicitly it means the more often the farmer uses pesticides, the less pests his crop suffers from and the higher the output. This seems a reasonable assumption.

Socio-Economic Variables Affecting Technological Change

Of the various factors influencing technological efficiency, we have confined ourselves to the socio-economic variables. Our framework establishes the relationship between the index of technological efficiency and 18 variables divided into three broad categories :

(i) farmer characteristics - age, education, farming experience, subsidiary occupation, assets, contacts with extension agencies and town influence;

(ii) family characteristics - family literacy, family level of education, family size, farmers' position in the family;

(iii) farm characteristics - scale of rice cultivation, percentage of land under tenancy, total land owned, fragmentation, information sources, sources of inputs, experience with hybrids.

We shall test several allied hypotheses through this analysis, but for convenience, they will be grouped into the composite variables: farmer characteristics, family characteristics and farm characteristics, but these cannot be strictly separated because of links between the variables. Age is usually positively associated with traditionalism; it would be reasonable to assume that the older a farmer, the more set he is in his farming ways and consequently less progressive. However, the influence of education, contact with the town and efficiency of extension agencies often reverse the hypothesis.

Similarly, it is generally maintained, with regard to education that "the illiterate, uneducated farmer with his social obligations to fulfill and in a situation of social and economic immobilities, cannot but be conservative and sceptical of any improvement in farming methods" (Thamarajakshi, 1969, p.381) but this is not necessarily true to facts. In fact, two contradictory hypotheses can be cited with reference to education and technological efficiency in agriculture which our experience in the sample villages emphasized:

(i) the higher the education, the more disinterested the farmer in his land; this feature was most prominent in the case of professionals who delegated responsibility of the farm either to less educated relatives or leased out the land, in which case technological efficiency sometimes diminished;

(ii) the higher the education, the greater the interest in use of modern inputs and consequent increase in technological efficiency.

Status of the farmer and his subsidiary occupation are closely interrelated with education and determine the influence that education is likely to have on the technological efficiency of the farmer. Higher status results in either of two conflicting reactions - greater innovativeness stimulated by the desire for prestige and power or fear of risk involved and consequent loss of status (Cancian, 1967, pp.912-913).

While subsidiary occupation may be taken to be inversely related to technological efficiency, size and influence of the family may have a positive effect on this relationship. In a joint or extended family, the need to support extended cousins and relatives (very common in the Indian family structure) often prompts farmers to supplement farm income by a subsidiary occupation. Depending on farm size, this need not necessarily affect technological efficiency, provided interest in farming is sustained. In the present situation of rising wages to farm labour and scarcity of hired farm labour, an extended family can be a positive means of increasing profitability of the farm.

It is therefore difficult to isolate the influence of these interrelated socio-economic variables on the technological efficiency of farmers. This interrelationship is evident both within the 'package' and between independent variables. Such inter-relationships are not surprising, as in any technology, it is found that each part has positive connections with many other vital parts. Hence if one adds some new element, not just one old part but perhaps many of the other parts of the old technology will also have to be modified. Thus the addition of a new element affects the other parts, sometimes for the worse or for the better. Bearing these facts in mind, we shall consider which of our socio-economic variables have a significant influence on the technological efficiency of our sample farmers.

Since the early 1950s, several research studies have been undertaken into the socio-economic and socio-psychological factors affecting the adoption of one or other of the modern inputs and techniques (Gross, 1949; Fliegel, 1957; Bose, 1961), but for want of more sophisticated techniques, these studies had to be limited to chi-square tests to distinguish between adopters and non-adopters. In a few later studies (Van Den Ban, 1957; Shetty, 1967), multiple regression analysis was employed to establish the relationship between the rate of adoption and several socio-economic variables. However, it is not possible to obtain reliable estimates of the parameters using multiple regression because of the inter-correlation* between variables. Hence we use factor analysis to identify the underlying socio-economic factors on 'source' variables which influence farmers' response to technological change.

Factor Analysis

The basic rationale of factor analysis derives from its data reduction quality. The contribution of an

* The problem of inter-correlation between variables (multicollinearity) will be dealt with in Chapter VI.

individual regressor remains ambiguous in multiple regression when the variables are inter-related. Factor analysis performs precisely this function - by reducing the regressors to a set of hypothetical orthogonal (non-correlated) components known as factors the precise contribution of each of these factors can be isolated (Gordon, 1968). To this extent the misleading effects of interpretation of multiple regression* can be avoided by reducing data to more manageable constructs.

As a technique, factor analysis, has only recently been introduced into economic analysis, though its use in fields of psychology and sociology** has been widespread for several decades (Fruchter, 1968). The first applications of the technique of factor analysis into economics were introduced via rural sociology in the analysis of socio-economic variables and their influence on economic phenomena. The contribution of several highly intercorrelated variables which hitherto could not be meaningfully measured in quantitative terms in economic analysis was thus facilitated.

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* Such misleading effects of interpretation of multiple regression are dealt with at length in Ezekiel and Fox, 1959, particularly in Chapter 25.

Choice of Method

With the facility of digital computers, several methods of factoring have been developed but by far, the principal components method still remains the best for several reasons:

(i) it does not require any assumptions about the general structure of the variables;

(ii) the extracted principal components can be defined as exact mathematical transformations of the original variables, since the main diagonal of the correlation matrix is not altered;

(iii) following from the above advantage, this method facilitates the processing of highly correlated variables, which cannot be processed by other factoring methods requiring the inversion of the correlation matrix.

The object of the Principal Components Method is the construction of new variables or empirical constructs (Z_i) from the data set of independent variables (X_j; $j = 1,2 \ldots k$); these new variables are linear combinations of the X's and are called principal components:

$$Z_1 = a_{11}X_1 + a_{12}X_2 + \ldots\ldots + a_{1k}X_k$$

$$Z_2 = a_{21}X_1 + a_{22}X_2 + \ldots\ldots + a_{2k}X_k$$

$$\vdots$$

$$Z_k = a_{k1}X_1 + a_{k2}X_2 + \ldots\ldots + a_{kk}X_k$$

The a's, called loadings, are the coefficients on the original variables; their choice requires the fulfillment of two basic conditions:

(i) the principal components should be orthogonal (that is, uncorrelated);

(ii) the first principal component absorbs and accounts for the maximum possible proportion of the total variation in the original variables; the second principal component is orthogonal to the first and absorbs the maximum of the remaining variation in the X's (after discounting the variation accounted for by the first component).

Thus each of the principal components is orthogonal to each other and together account for the total variation in the original variables. By the principal component method therefore, a set of variables is reduced to n components.

However, our main interest is not in the mere mathematical transformation alone, but in finding whether some small number of components account for most of the variance in the data. We have therefore applied a modification of the principal components method - the principal factoring method which varies slightly from the principal components method in that it replaces the main diagonal of the correlation matrix by estimates of communality.

As the term implies, communality is defined as the proportion of a variable sharing something in common with other variables in the set. There is no agreed upon method of calculating communalities, but the principal factoring method makes use of an iteration procedure to improve upon the estimates of communality. The advantages of this method can be summarised thus:

(i) each factor extracts the maximum amount of variance (that is, the sum of squares of factor loadings is maximized on each factor) and gives the smallest possible residuals;

(ii) the correlation matrix is condensed into the smallest number of orthogonal factors;

(iii) this method also has the advantage of giving a mathematically unique (least squares) solution for a given table of correlations (Fruchter, 1968).

To obtain neater and more meaningful results, we have employed orthogonal rotation of the varimax type, (that is, each of the factors is rotated till the maximum amount of variance in the data is extracted). The advantagesof rotation greatly facilitate interpretation of the results :

(i) it simplifies factor structure;

(ii) each variable is accounted for by a single significant common factor; consequently, the rotated factor loadings are conceptually simpler;

(iii) rotated factors are more stable; loadings of unrotated factors depend heavily on the number of variables and consequently deletion of a variable alters the relative loadings on the unrotated factors drastically.

We shall now turn to the contribution derived by the use of factor analysis to elicit the source variables affecting farmers' response to technological change.

Tests of Results

The loadings on each factor represent the regression coefficients of factors describing the given variable; hence the reliability of these estimates calls for statistical tests of significance. However, there is some doubt about the tests of significance of the loadings of the factors. It is not surprising therefore, that earlier studies (Rao and Shetty, 1968; Shetty, 1969; Pareek and Trivedi, 1965; Kivlin and Fliegel, 1968; Greene, 1973) have made little attempt to test the significance of the loadings.

If we accept that the loadings are in effect the coefficients of the variables then to identify the 'source' variables without any statistical tests of significance could lead to unreliable conclusions. Thus Shetty finds in both of his studies (1968 and 1969) that land oriented and farmer oriented variables load heavily on his first factor which he identifies in his initial study as access to information and supply of modern inputs. This type of ambiguity is to be expected from unrotated factors, as all the factors other than the first (which tends to be a general factor) tend to be bipolar,* which makes interpretation difficult, as every variable is accounted for by two significant common factors.

On the basis that the loadings are similar to the correlation coefficients, it has been suggested that the tests of significance for the loadings could be the same as for the Pearson correlation coefficients (Child, 1970). However, while the critical values for the significance of the coefficients vary with different sample sizes, this test does not take into account the number of variables or the order of extraction of the factors. The Burt-Banks test (Koutsoyiannis, 1973) is an improvement on Child's (1970) by considering the number of variables

* One of the main advantages of rotation in factor analysis is to simplify factor structure. Consequently, each variable has high loadings on only one factor. Bipolarity indicates that variables load heavily on two or more factors; this makes identification of the factors difficult.

and the order of extraction of the factors in assessing the significance. We have used the Burt - Banks test and the results for each variable are indicated in Table XI.

Interpretation of the Results

Interpretation of the factors is a subjective feature of factor analysis and is determined to a large extent on what identity is ascribed to the different factors. In order to assess the substance and structure of the factors, as well as its meaning, one should keep in mind the content of the factor, its relationship to the other factors and the manner in which its content relates to technological efficiency; it must be noted that cross-sample differences are bound to occur at each step, which account largely for the divergencies between different research studies, rather than the purely 'subjective' aspect of identifying the factors. Thus from our analysis, six distinct factors or 'source variables' account for the underlying relationship between technological efficiency and socio-economic variables of which 3 could be termed as major and 3 minor factors. Two criteria have been used in making this distinction:

(i) Kaiser's criterion (Koutsoyiannis, 1973, p.423) which considers only those principal components having eigenvalues* greater than one as essential

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* The sum of the squares of the loadings of each principal component is called the latent root or eigenvalue of this component.

to be retained in the analysis. Though this criterion is most reliable when the number of variables in the analysis is between 20 and 50, we have retained it for our 19 variables, as we are merely using it for purposes of distinguishing between factors rather than as independent variables in a Regression on Principal Components.

(ii) The first three factors account for the major portion of the variance in the data (78.4 per cent; Cf. table 10) which is a substantial part of the total variance.

We shall now turn to the identity and interpretation of the factors.

Factor 1: Economic Status

Factor 1 loads significantly and positively on three variables - scale of rice cultivation, value of assets, total land owned by the farmer and negatively on one variable - proportion of land under tenancy. Considering the nature of these variables, we interpret this factor as economic status of the farmer. As a general factor, it has a significant bearing on his technological efficiency and ability as well as willingness to undertake risk.

TABLE X

CONTRIBUTION OF 'FACTORS' TO EXPLAINING VARIANCE IN VARIABLES

Factor	Eigenvalue	Percent of Variance	Cumulative Percentage
1	3.887	37.3	37.3
2	2.409	23.1	60.4
3	1.885	18.1	78.4
4	0.882	8.5	86.9
5	0.835	8.0	94.9
6	0.529	5.1	100.0

TABLE XI

FACTORS AFFECTING TECHNOLOGICAL EFFICIENCY

Variables	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	h^2
Technological efficiency	.140	.787**	.167*	.117	-.061	.100	.695
Size of farm	.765**	.013	.068	.111	.065	.033	.608
Assets	.706**	.137	.257**	.133	.112	.122	.629
Owned Land	.704**	.304**	.259**	.111	-.017	-.017	.668
Tenancy	-.171*	-.056	-.013	.051	.042	.104	.048
Sources of Inputs	.033	.797**	.054	.034	-.057	.072	.648
Extension Contact	.170*	.714**	.049	-.067	-.027	-.100	.556
Sources of Information	.121	.621**	.087	-.110	.066	.111	.436
Family Schooling	.295**	.144	.831**	.004	.071	-.162	.830
Education of Farmer	.084	.089	.766**	-.301**	.088	.176*	.731
Family Literacy	.033	.172*	.642**	-.213*	.081	-.116	.508
Subsidiary Occupation	.127	-.058	.443**	-.035	-.057	.232**	.274
Experience with Hybrids	.093	.113	.146	-.007	-.035	.070	.049
Farmer's Age	.116	.000	-.116	.979**	.053	-.105	.999
Farming Experience	.091	-.025	-.355**	.807**	.007	-.154	.810
Fragmentation	-.003	.013	.007	.022	.860**	.013	.740
Contact with Town	.269**	-.292**	.196*	.053	.394**	-.186*	.389
Farmer's Position in Family	-.065	.082	.056	-.147	-.083	.566**	.363
Size of Family	.403**	.216**	.070	-.088	.140	.453**	.446

* Significant at 5 per cent probability level.

** Significant at 1 per cent probability level.

h^2 = communality of the variable.

It is important to note that none of these variables load highly on any of the other factors and are to that extent distinct. Possession of land is much associated with prestige and power in rural Indian communities; in our study villages, land ownership undoubtedly has a high status symbol and it is significant that both value of assets and extent of land ownership load heavily on this factor.

It may seem surprising that status of the farmer should emerge as the primary factor influencing technological efficiency, but experience of the implementation of the Green Revolution strategy presents the stark reality that in practice the theoretical neutrality-to-scale* argument of the modern technology collapses (Ladejinsky, 1973). Wealth commands easy access to sources of modernization; this is borne out in our analysis (table 11) by the significant loading of this factor on contact with extension agencies (.170) and contact with the town (.269). That the level of schooling in the farmer's family loads significantly on this factor is not surprising; except in rare cases, rural families are quite 'open' to the benefits of education and every

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* Scale-neutrality of the new technology implies that the modern technology can be suitably applied to any farm size - large or small. However, though theoretically this is possible, it is found that in practice small farmers very often cannot adopt the modern technology for want of certain vital inputs like fertilizers or credit facilities.

attempt is made to avail of the opportunities offered by the Government in this direction. Government-directed schemes to provide free schooling have been a tremendous boon to the uplift of rural areas.

In this connection, the size of the farmer's family has a significant bearing on the family level of schooling, which is reflected in our analysis, from the significantly high loading on family size on this factor (.403). With the present scarcity of hired farm labour and consequent high wage demands, family labour increases profitability of the farm; consequently, an extended family while contributing to the profitability of the farm, increases wealth of the farmer in the long run, while also determining the family level of schooling. As the number of farm hands increases, the number of family members released for education also increases.

An interesting sociological dimension also emerges in this context - despite family planning propaganda, farmers of lower socio-economic status have larger families with a larger percentage of second and third generation illiterates, while farmers holding high status have smaller families often nuclear, of first and second generation learners. Wealth and status therefore presents an important feature in rural technological progress reflected in the fact that this factor accounts for 37.3 per cent of the total variance in the variables (table X).

In this respect, our findings differ significantly from previous factor analytic studies (Pareek and Trivedi, 1965; Greene, 1973) as our primary factor accounts for more than a third of the total variance in the variables. For Pareek and Trivedi (1965) social influence emerges as the primary factor which agrees with our concept of status as a symbol of power and influence in rural life, but while they consider land being largely inherited, under the factor 'caste' we differ in our concept of land whether inherited or acquired as an integral part of farmer's wealth and status in Indian rural communities.

<u>Factor 2 : Modernization</u>

Our second factor loads heavily on three interrelated variables - contact with extension agencies, sources of information and sources of modern inputs. It must be noted that the index of technological efficiency loads heavily on this factor alone; we interpret this factor as the 'modernization' factor. While wealth and status facilitates technological progress in the sense that it puts the farmer in a more advantageous position to have access to modernization, ultimately it is the influence of this factor that determines technological efficiency. This is implicit in the significant positive relationship between the loadings of index of technological efficiency, extension contact and sources of information and inputs. Certain curious but nonetheless interesting facts are evident in the loadings of other variables on this factor. The extent of land ownership loads significantly on this factor justifying our argument that land ownership is a considerable prestige symbol facilitating easy access to modernization.

On the other hand, contact with the town loads significantly yet negatively on the modernization factor. This finding may seem contradictory at first sight, as it differs from earlier findings - Greene (1973) found in his factor analysis study on fertilizer adoption data and 34 socio-economic variables that farmer's use of fertilizer was closely related to contacts with the town, either through visits of relatives from the town or through farmer's visits to the town (Greene, 1973, p. 30). In our analysis, this curious relationship can be explained through the interplay of several interconnected variables:

(i) the efficiency of extension agencies overrides the influence of the town as an integral means of promoting modernization. Our experience in the study villages and the results from this analysis bear evidence that in villages farthest away from the town, where contacts with the town are as infrequent as once or even less a month, technological efficiency as measured by our index is on a par or even better than in the case of farmers who have frequent contacts with the town. Undoubtedly, the introduction of communications media and special radio broadcasts for farmers through the agricultural extension services has substituted for visits to the town, which formerly provided the only means of contact with the forces of modernization;

(ii) the negative relationship between town contact and index of technological efficiency in agriculture can best be expressed in terms of interest in farming. Contact with the town is highest in the case of farmers residing in the town pursuing a trade or profession having relegated responsibility of the farm to less educated relatives or having leased out the land.

Insofar as residence in the town reflects disinterest in agriculture (ownership of the land being retained only as a means of security), technological efficiency diminishes (Thamarajakshi, 1969).

On the other hand, the significant loading of family literacy as a contributing component in modernization reflects the mutual assistance received from members of the farmer's family in promoting efficiency. The increasing literature on technique and practices to effect a greater productivity through the High-Yielding Varieties Programme presupposes farmers' literacy. The higher the proportion of literate members in the farmer's family, the greater the incidence of exposure to these sources of modernization.

Factor 3 - Education

This factor is most obviously an 'education' factor, as it loads highly significantly on four inter-related variables - family level of schooling, farmer's education, family literacy, and subsidiary occupation. In relation to the first two factors, the contribution of this factor is obvious; we have already seen how farmers of high status tend to be more educated themselves and give high priority to education in their families. This feature is reflected in the significant loadings on value of assets and extent of land ownership. Its relationship with the second factor 'modernization' is expressed in the significant loading on index of technological efficiency. As expected, this education factor loads heavily on subsidiary occupation, which is also significant at the one per cent level, and justifies our earlier inference that higher education leads to a shift to other occupations, farming becoming only of secondary interest. Further evidence of this point is found in the significant loading of contact with the town. It is generally accepted that one of the most conspicuous effects of increasing education in the rural areas is the mass exodus from these areas into the towns, leaving the business of farming to the older, less educated generation. This fact is reflected in two distinct ways in the analysis:

(i) significant loading on town contact - the more educated are known to seek more prestigious employment in the towns;

(ii) significant negative loading on farming experience - the higher the education, the lower the experience in farming.

Experience with hybrid rice strains loads highest on this factor but as this coefficient is not significant, we do not intend to ascribe much importance to it, but just one remark in passing would be valid in this respect. It seems to indicate that the more educated farmers adopted rice hybrids earlier and consequently have a higher technological efficiency than later adopters. This finding is in keeping with earlier research on rates of adoption (Bose, 1961; Gross, 1949; Rajagopalan, and Singh, 1971; Sen, 1974); contradictory evidence has been cited however for Thanjavur in which it was found that the degree of progressiveness of the farmer is independent of his or his family's educational status. (Thamarajakshi, 1969). We are sceptical of the above conclusions arrived at by chi-squared tests,because of the inherent inter-relationship between the variables. From our analysis, this factor accounts for 18.1 per cent of the total variance (table X), which indicates that education is a significant contributing factor to technological efficiency of farmers in our sample.

Minor Factors

The three minor factors will be considered together as their individual contribution is relatively small, yet collectively these factors account for 21.6 per cent of the total variance (table X) and therefore cannot be totally ignored. Age and farming experience have high coefficients on factor 4, which we interpret as farmer's age. As expected, the older the farmer, the greater his experience in farming; this is a foregone conclusion in typically farming communities. Significant negative loadings on education and family literacy are also indicative of the early concept of farming as a way of life, in which education or literacy had little place.

Closely allied to this concept is factor 5, which loads significantly on only two variables - fragmentation and contact with the town. At first sight, it is difficult to conceive the relationship between these two variables, but if we consider contacts with the town as an indication of relative disinterest in farming, a quite different picture emerges. The more disinterested the farmer, the more likely he is to subdivide and apportion his land either leasing it in small plots or distributing it among his family.

Factor 6 has been termed decision-making, as only two variables have high coefficients on this factor - farmer's position in the family and size of the family. The extent to which decision-making is centred entirely in the farmer can be significant to technological efficiency. The effect of family size is obvious; the influence of extended cousins and older members of the family affects farmer's decision-making, other contributory factors being education and subsidiary occupation. In more developed rural communities, family decision-making does not necessarily affect adoption of improved practices (Wilkening, 1953; Fliegel, 1956); however, in Indian rural communities, the influence of the family still plays a considerable role in affecting farm decisions.

Conclusions

From the analysis, it follows that three major factors or 'source' variables affect technological efficiency of farmers - economic status, modernization and ecuation,which throw light on several points of Green Revolution strategy. We are inclined to place greater emphasis on the modernization and education factors because of their significant links with the index of technological efficiency.

Though economic status emerges as the primary factor, its importance stems largely if not solely from the fact that it provides the precondition for access to the sources of modernization. Our experience in the sample villages shows that the farmers with small paddy acreage were excluded from the lists of the Village Level workers (VLWs) who distribute the fertilizer rations. In some villages, this discrimination has been justified on the grounds that small farmers are usually of a lower caste and hence have less farming experience. In our sample area however, this is not necessarily so. In the present context, of development of rice cultivation therefore, there is no reason to believe that certain inherent qualities in the farmer rank high in contributing towards his technological efficiency. On the contrary, progress is facilitated through forces external to the farmer and evoking his response. Extending this analysis therefore, given equality and facility of access to the sources of modernization - inputs, techniques, extension services and education, overall efficiency in rice productivity could be accelerated. Hence efforts aimed at removing such constraints would be a more positive contribution to governmental rice strategy; our analysis suggests these efforts could be more efficacious in two main directions:

(i) Non-discrimination between farmers to include even small rice farmers under the prevailing lists for distribution of modern inputs. At present, experience in the sample villages has shown that in practice, farmers owning less than one acre of irrigated land are discriminated against and excluded from the lists of the village level worker (VLW) who administers the fertilizer rations. Evidence of research in different areas of India suggests that "the small farmers use modern inputs more intensively on a per acre basis and that they are eager to try out and accept an innovation if it is demonstrably superior and profitable". (Sen, 1974, p.54).

The present tendency to concentrate attention on large farmers or on farmers growing later hybrids of rice might well call for a re-thinking of policy in rice research and extension. To date, there is no positive evidence to suggest that larger farmers are more efficient in their use of resources than smaller farmers. Malone (1971) summarizing evidence from nearly 5000 IADP farms concludes that there are no significant differences in the way farmers on different size farms respond to opportunities to modernize their production methods... What is documented is that the very small and small farmers, many of whom are known to be tenants participate in the early adoption of the HYVs where they are profitable.*

(ii) Diffusion of existing resources on extension and education to include a wider coverage, attention being focussed first on potential for further rice development.

Throughout this section, the analysis has been based on farmers' technological efficiency as measured by the 'package of practices' for rice cultivation recommended

* This evidence is confirmed by studies in individual districts - Thanjavur (Harrison, 1970) and West Godavari and Raipur (Bouton, 1969).

by the Agricultural Department. A basic assumption has been the 'optimal' nature of this recommended package, which presupposes a constant review by research agencies of this package to suit different areas.

In the early years of the new strategy, differentials in rice productivity arose largely from resource constraints; more recently, it is believed the lag in the development of adaptable varieties is accountable for these differentials. In the two areas of our study, the lag has been reduced to a minimum - Thanjavur, an IADP district, has for the past ten years been inundated with the benefits of research; Coimbatore, within easy access of the Tamil Nadu Agricultural University, also similarly favoured.

While the pace of farmers' response to exogenous change can be promoted by providing the three major pre-conditioning factors - economic status, access to the sources of modernization and education, response of farmers still varies according to their input use. Through production function analysis, we shall examine the returns to input use for different genetic rice strains in Coimbatore and Thanjavur. The results of our analysis will indicate farmers' response to technological change and determine the more productive and profitable rice strains for the region. We also examine whether our 'progressive' farmers are obtaining higher returns than the less progressive ones. It is this aspect of exogenous technological change that we shall now consider.

CHAPTER VI

INPUT USE OF FARMERS UNDER THE MODERN TECHNOLOGY

Introduction

Our consideration of the socio-economic factors influencing technological change has emphasized three primary factors - economic status, modernization and education - which largely determine the response of farmers towards technological change. While these may be termed pre-conditioning factors, in the ultimate analysis, it only gives us some idea for diffusion strategy. It does not indicate the response of farmers in terms of input use, nor the specific contribution of each input. Thus though in the area of study, these determining factors may be in operation, we may find that the apparently 'progressive' farmers may not be those showing the highest levels of productivity in terms of returns to input use. This is what we shall examine in this chapter in terms of returns to input use of progressive and less-progressive farmers in order to assess their response to technological change.

One of the most evident effects of the introduction of the Green Revolution technology has been the movement from traditional inputs to modern inputs, from traditional and locally improved strains to hybrids. This trend initiated by the Green Revolution is a continuing one, farmers moving from the cultivation of earlier hybrids to newly developed varieties. Such a movement could be viewed as the endogenous phase of technological change. We shall examine this endogenous phase in returns to inputs using production function analysis.

In order to establish the genuine technological relationships between inputs and outputs, a rigorous analysis is called for on a highly disaggregated set of data. A crop level production function enables us to establish these relationships. We shall therefore test for the effects of technological change through resource allocation and input use. Our production functions of different genetic varieties of rice will allow us to examine returns to inputs for different rice strains - hybrids and local improved varieties.

It is fast becoming recognized that different genetic rice strains are location-specific. By location-specificity is meant that due to varying soil, water resources and climatic conditions, rice varieties that prove suitable and highly productive in one region may not be equally productive in another region. Such varying conditions often exist not only in adjacent districts but also in different areas within the same district. This may account for the numerous varieties of rice cultivated in India.

It is believed that there are over 600 improved varieties of rice in India (Grist, 1975), but attempts are being made to reduce this number by concentrating on varieties which are adaptable to different regions. We shall test for this location-specificity of rice strains by a comparison of the production functions of different strains cultivated by our sample farmers in Coimbatore and Thanjavur.* We intend to test two major hypotheses through our use of production function analysis in the above districts:

(i) that the marginal productivity of land under rice cultivation is higher in Coimbatore than in Thanjavur;

(ii) that the marginal productivity of land in the same area varies for different rice strains; consequently, choice of the more productive strains would have important implications for the increasing output in the area.

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* Input-output data on 114 progressive farmers in a comparable canal-irrigated tract in Thanjavur were collected from farm records for the year 1973-74 from the IADP Office, Thanjavur. Criteria for selection were based on farmers' consistency in adhering to the recommended IADP package; hence only those farmers are classified by the Department as "progressive" who satisfy the above criteria stipulated by the Office.

Type of Function

We have selected a purely technological function of the Cobb-Douglas type with inputs and outputs measured in physical units:

$$Y = A \prod_{i=1}^{n} X_i^{b_i} e$$

where :

Y = level of output

X_i = level of the i-th input

b_i = production elasticity of the i-th input

A = constant which can be used to give a measure of the level of technology

e = random error term.

Our choice of the Cobb-Douglas model is guided by its flexibility to extend to any number of inputs. The computational facility accompanying its use has promoted its widespread application in agricultural research. The relative ease with which returns to scale are measured has caused the Cobb-Douglas production function to be popularly used in establishing the scale-neutrality of the new agricultural strategy. The logarithmic transformation of the function:

$$\log Y = \log A + \sum_{i=1}^{n} b_i \log X_i + \log e$$

permits the estimation of the parameters by standard linear regression techniques. However, one of the basic requisites of production function analysis is to ensure its application to purely technological relationships. This involves determining the level of aggregation for the function, the choice and specification of the variables entering into the function.

Level of Aggregation:

Our level of aggregation is determined by the very real genetic differences between different types of rice species. Our hypothesis seeks to determine the productivity of land for different strains of rice in an attempt to effect a measure of technological change resulting from the shift to hybrid strains from improved local varieties. Ever since the introduction of the Green Revolution technology, attention has been concentrated on the profitability of the new hybrids vis-a-vis traditional or improved local varieties. Farm-level production functions distinguished between 'progressive' and 'non-progressive' farmers.

Such farm-level aggregation could hide differences between crops grown by the same farmer. Bardhan (1973) attempted to overcome this problem by restricting analysis to monoculture farms. If we accept that input levels vary significantly between different genetic varieties depending on their duration and biological structure, aggregation even at the crop level conceals to some extent the basic technological relationships between inputs and outputs. Hence allocation of resources differs for various strains even of the same crop. Consequently, it is best to avoid grouping heterogenous strains to obtain accurate results. This we shall do by using production functions for each variety.

Specification of Variables

Having eliminated the problem of aggregation by our choice of variety-level production functions, we attempted to maximise accuracy of the estimates by proper specification of the variables. According to Griliches (1957b) two main causes for specification errors are quality differences in inputs and exclusion of the management input. We shall deal with each of these in turn.

In our model, quality differences in inputs have been kept at a minimum. No doubt, land is a heterogenous input and differences in soil fertility are to be expected. However, to some extent, such differences in fertility are offset by assured irrigation facilities. Our sample has been selected from a homogenous canal-irrigated tract in Coimbatore and Thanjavur. Consequently, quality differences in land have been reduced to a minimum.

Turning to inputs, quality differences in fertilizers have been standardized by aggregating different fertilizers in terms of plant nutrients.* On the other hand, quality differences in manure are almost impossible to measure depending upon the composition of manure, method of preparation and gestation period. So too, quality differences in pesticides are difficult to estimate for want of adequate detail on chemical composition.

With regard to labour, quality differences are more complex and more difficult to quantify arising both within and between different categories of labour. Male and female labour are assigned distinct functions in rice cultivation; female labour is largely sought for transplanting, weeding and harvesting operations while men perform the functions of ploughing, bunding, threshing and other more arduous farm operations. Despite their separate functions, substitution of male labour for female labour is not uncommon for jobs like harvesting during periods of scarcity. For want of separate data,** we have aggregated the two

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* Earlier studies (Gopalakrishnan, 1969) aggregated fertilizers of differing chemical composition on the basis of nitrogen units, nitrogen being the most effective plant nutrient. Such a procedure is not wholly satisfactory; with the shortage of chemical fertilizers, farmers often substitute large doses of phosphatic fertilizers, to make up for deficiency in nitrogen. Hence aggregation in terms of plant nutrients is a more effective measure. The ratio is given as : N + 2.29P + 1.20K (Jensen and Williams, 1963).

** Although our questionnaire was intended for separate data on male and female labour, at the interview stage, we found that most farmers employed farm labour in groups comprising both male and female. The proportion of male and female in each group varied depending on availability at peak seasons.

categories as the human labour input as distinct from plough labour.*

While differences in qualities of inputs can to some extent be minimised, the exclusion of the management input introduces bias in the parameter estimate (Griliches, 1957b). Returns to all inputs which have a positive correlation with entrepreneurial skill tend to be biassed upward. In dealing with hybrid rice, the importance of the 'package' of inputs and practices cannot be overemphasized. The perfect implementation of the 'package' involves not only optimum levels of input use, but also timing and quality of inputs such as hybrid seed, chemical fertilizer and pesticides, which reflect the efficiency of the 'manager'. However, influences such as timing and quality of inputs especially fertilizers and pesticides will not be evident in the production function which allows only for level of input use; hence it is likely that the exclusion of the management input will be most apparent in overestimated elasticities for hybrid seed, pesticides and other inputs closely associated with managerial ability.

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* Heady and Dillon (1961) indicate two general rules for the aggregation of inputs:

1. "The inputs within an individual category should be as nearly perfect substitutes or perfect complements as possible.
2. Relative to each other, the categories of inputs should be neither perfect substitutes nor perfect complements."

(Heady and Dillon, 1961, p.220).

Variables in the Production Function

Output has been measured in physical units in terms of kilograms per acre.*

Land is measured in acres;

Seed is measured in kilogrammes;

Manure is measured in cartloads;

Fertilizer measured in kilogrammes of plant nutrients;

Pesticides measured in number of times of spraying;

Human labour measured in eight-hour days;

Plough labour measured in eight-hour days.

Our functions consider allocative efficiency of farmers for different genetic rice varieties in each of our sample districts separately.

In attempting to estimate the parameters of the Cobb-Douglas production function using the traditional technique of Ordinary Least Squares (OLS) regression, we found the reliability of the parameter estimates seriously imparied by the presence of multicollinearity. We shall therefore examine the problem of multicollinearity and the method used to tackle it.

Multicollinearity

The problem of multicollinearity arises from inter-

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* To some extent, the returns to inputs will be underestimates as the quantity of fodder is not included in the output figures.

relationships between explanatory variables. When variables are inter-correlated, it becomes difficult to separate out the true contribution of each independent variable using OLS. (Ezekiel and Fox, 1959; Gordon, 1968; Haitovsky, 1969; Johnston, 1972). The presence of multicollinearity produces large standard errors on the estimated coefficients; consequently if conventional tests of significance are applied it becomes difficult to reject the null hypothesis of the non-significance of the estimated coefficient. Moreover multicollinearity results in highly unstable parameter estimates; as the number of explanatory variables or the observation period is altered, the estimated coefficients are liable to change markedly, sometimes even with a change of sign.

The degree of the multicollinearity present determines the extent to which precision and stability of the OLS estimates are affected. Some econometricians (Klein, 1962) consider that multicoolinearity need not necessarily pose a problem unless it is high relative to the overall degree of multiple correlation, but we agree with Farrar and Galuber (1967) on the instability it causes to parameter estimates.

> "However real the dependency relationship between y and each member of a relatively large explanatory variable set X may be, the growth of inter-dependence within X as its size increases, rapidly decreases the stability of each independent variable's contribution to explained variance. (Farrar and Glauber, 1967, pp.94).

The extent of multicollinearity between the independent variables in the regression can be established by the values of the correlation coefficients for each pair of explanatory variables, or by the value of the determinant of the regression. Though the exact effects of collinearity have not been theoretically established, the problem tends to be severe when the reliability of parameter estimates is impaired. Multicollinearity is typically a data problem, originating in the nature of the sample observations to be used for example, in time-series of trended variables. In our case however, the problem is more fundamental, originating in the structure of the analysis. In a recent paper, Doll (1974) asserts that the Cobb-Douglas model implies exact multicollinearity in the independent variables and hence that the presence of multicollinearity in the data confirms the theoretical validity of the Cobb-Douglas production function. This arises from certain fundamental assumptions :

(i) identical production coefficients for all farms;

(ii) each farmer attempts to maximize profit;

(iii) input-output prices are the same for all farmers.

If the above assumptions hold, then all parameters in the model cannot be estimated by ordinary least squares techniques (OLS).

"...Thus, users of the Cobb-Douglas model who are dismayed to find multicollinearity among the independent variables should be pleased because the presence of multicollinearity serves as a verification of their economic model." (Doll, 1974, pp. 557-558).

Although the presence of multicollinearity in the Cobb-Douglas production function is inevitable from Doll's (1974) analysis, until recently more attention was paid to emphasizing the problems involved and the consequent inappropriateness of the model rather than attempting to eliminate multicollinearity. Ishikawa (1967) stated that complementarity in agricultural inputs was the main cause of the inappropriateness of the Cobb-Douglas model. He tried to overcome the difficulty by running separate regressions on individual inputs. However, this is not a very satisfactory procedure, as it does not touch the fundamental problem of multicollinearity which accounts for the unreliability in parameter estimates.

It might seem therefore, that the existence of multicollinearity rules out the possibility of using the Cobb-Douglas model since the OLS method requires that independent variables be less than perfectly correlated in order to ensure reliable estimates of the coefficients. However, today factor analysis offers a way out of the multicollinearity problem as we have seen, (Chapter V). While in Chapter V, we merely identified the 'source' variables causing inter-correlations, here we also need to estimate the structural parameters between inputs on one hand and output on the other. We do this using the Regression on Principal Components (RPC) techniques.

Regression on Principal Components

Basically, the Regression on Principal Components is an extension of the Principal Components method which we have discussed earlier (Chapter V). Its application to economic data is fairly recent (Scott, 1966, Pidot, 1969; Nieuwodt, 1972; Pingle, 1976). Having extracted a set of orthogonal principal components from the inter-correlated independent variables, the dependent variable is regressed on the extracted principal components by OLS and by transformation the coefficients of the original variables in the model can be obtained.

Each principal component explains a part of the total variance in the independent variables, while the first principal component explains the maximum variation. Usually the number of principal components which are extracted from the original variables is smaller than the number of original variables. The problem therefore arises as to the selection of principal components for inclusion in the analysis. If we retain all the extracted principal components, the coefficients of the original variables would be identical to those obtained from the OLS regressions, thereby defeating our purpose of eliminating multicollinearity.

Several criteria have been put forward for selecting the number of principal components (Massy, 1965; Koutsoyiannis, 1973). We have restricted ourselves to the first principal component to derive the relationship between the independent variables and the dependent variable. In a few cases, where the first principal component does not explain a large percentage of variation, we have employed the first two components.*

The method of principal components has certain definite advantages over ordinary least squares:

(i) inasmuch as it eliminates the problem of multicollinearity it gives more accurate estimates of the coefficients.

(ii) It has the added advantage of economizing on degrees of freedom so that the Regression on Principal Components (RPC) technique can be used even when OLS regression is inapplicable. However, the actual error distribution of the estimates obtained by the RPC method cannot be established with any certainty, though it has been noted (Massy, 1965) that the standard errors rise as the number of principal components

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* We have used the BMDO2M package of the Health Sciences Computing Facility of the University of California, Berkeley (Dixon, 1971).

used in the analysis increases. Besides, the coefficient of multiple determination (R^2) is lower than those obtained by OLS. However, it is generally accepted that the RPC functions give better estimates of the coefficients than the OLS (Massy, 1965; Scott, 1966; Nieuwoudt, 1972). This is because the coefficients obtained by the RPC method are more reliable.

Analysis of the Results

We find in both Coimbatore and Thanjavur, that the determinant for each of our functions is zero or approaching zero (Tables XII and XIII), indicating a high degree of multicollinearity among the variables. Our use of the RPC method is therefore justified. Recognizing that the RPC method produces more reliable estimates of the parameters, we shall now examine three allied hypotheses determining:

(i) the level of technology for similar strains of rice in the two selected districts, as well as the level of technology for the same strain grown by progressive and less-progressive farmers in Coimbatore;

(ii) the elasticities and the marginal physical products of land for the same strain in each district;

TABLE XII

ELASTICITIES OF INPUTS FOR DIFFERENT RICE STRAINS IN COIMBATORE

Strain	Constant	Land	Seed	Fert.	Manure	Pest.	HLAB	PLAB	Σb_i	$\bar{R}^2$	DET	N
Karuna	3.485	.177	.195	.152	.064	.198	.175	.081	1.042	.90	.000	13
Co.25	1.845	.196	.108	.094	.130	.101	.186	.179	.994	.95	.0000002	16
IR20	3.009	.210	.205	.185	.069	.016	.203	.112	1.002	.94	.000002	134
Kannagi	1.580	.210	.215	.153	.008	.139	.116	.204	1.045	.95	.000006	36
Co.32	1.914	.206	.213	.061	.076	.147	.195	.086	.984	.94	.000008	61
Co.29	2.723	.215	.222	.102	-.006	.055	.211	.215	1.014	.96	.000002	31
Bhavani	1.593	.206	.224	.188	.146	.156	.105	.031	1.056	.96	.000	15
Kanchi	2.021	.205	.196	.161	.042	.092	.203	.136	1.035	.93	.000002	73

Abbreviations and Notes :

LAND in acres
SEED in quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

Σb_i = Sum of elasticities of inputs
$\bar{R}^2$ = Co-efficient of determination
N = Number of observatior

TABLE XIII

ELASTICITIES OF INPUTS FOR DIFFERENT RICE STRAINS IN THANJAVUR

Strain	Constant	Land	Seed	Fert.	Manure	Pest.	HLAB	PLAB	Σb_i	$\bar{R}^2$	DET	N
Karuna	3.420	.207	.166	.159	.199	.012	.191	.169	1.012	.90	.00007	83
Co.25	2.301	.240	.243	.095	.036	.089	.221	.125	1.049	.96	.0001	37
IR20	3.280	.206	.160	.145	.029	.041	.213	.197	.991	.92	.00006	25
Kannagi	2.724	.218	.189	.119	.137	.140	.123	.093	1.019	.74	.000	12
Karikalan	2.612	.211	.194	.219	.072	.052	.206	.101	1.064	.96	.0000009	14
Ponni	3.440	.210	.189	.169	.015	.059	.208	.202	1.053	.89	.00004	100

Abbreviations and Notes :

LAND in acres
SEED in quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

Σb_i = Sum of elasticities of inputs

$\bar{R}^2$ = Co-efficient of determination

N = Number of observations

(iii) the marginal value products of inputs for different strains of rice to estimate the most profitable variety for the district.

Level of Technology

By the very nature of the Cobb-Douglas model, the intercept 'A' which maintains the dimensional consistency in the equation is indicative of the level of technology.

On the basis that rice technology varies for different genetic rice strains, a comparison of the level of technology for different strains is meaningless. On the other hand, a comparison of the level of technology of the same strain in the two districts could be interesting. Our results (Table XIV) show that for the two strains - Karuna and IR20, the level of technology is high and does not vary much between the two districts. However, for Co.25 and Kannagi, a significant difference is noted between the level of technology in Coimbatore and Thanjavur. For Co.25, a much higher level of technology is evident in Thanjavur than in Coimbatore, while for Kannagi, the level of technology in Coimbatore is much higher than in Thanjavur (Table XIV).

Having considered the level of technology of the same strain in the two sample districts, we shall now examine the level of technology of the same strain grown

TABLE XIV

ELASTICITIES OF INPUTS IN RICE PRODUCTION : A COMPARATIVE ANALYSIS IN COIMBATORE AND THANJAVUR

Strain	Constant	Land	Seed	Fert.	Manure	Pest.	HLAB	PLAB	Σ^{b}_{i}	$\bar{R}^2$	DET	N
Karuna (C)	3.485	.177	.195	.152	.064	.198	.175	.081	1.042	.90	.000	16
Karuna (T)	3.420	.207	.166	.159	.109	.012	.191	.169	1.012	.90	.00007	83
Co.25 (C)	1.845	.196	.108	.094	.130	.101	.186	.179	.994	.95	.0000002	16
Co.25 (T)	2.301	.240	.243	.095	.036	.089	.221	.125	1.049	.96	.0001	37
IR20 (C)	3.009	.210	.205	.185	.069	.016	.203	.112	1.002	.94	.000002	134
IR20 (T)	3.280	.206	.160	.145	.029	.041	.213	.197	.991	.92	.00006	25
Kannagi (C)	2.724	.218	.189	.119	.137	.140	.123	.093	1.019	.74	.000	12
Kannagi (T)	1.580	.210	.215	.153	.008	.139	.116	.204	1.045	.95	.000006	36

Abbreviations and Notes

(C) = Coimbatore
(T) = Thanjavur
LAND in acres
SEED in quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

Σ^{b}_{i} = Sum of elasticities of inputs

$\bar{R}^2$ = Co-efficient of determination

N = Number of observations

by our progressive and less-progressive farmers* in Coimbatore. The two most popular strains among the less progressive farmers were Co.32 and Co.29. For want of adequate observations for the latter strain, analysis of the comparative level of technology of progressive and less-progressive farmers had to be restricted to only one strain - Co.32.** During the survey year, Co.32 was cultivated by 17 less-progressive and 44 progressive farmers in Coimbatore.

As expected, our results indicate a higher level of technology for the progressive than for the less-progressive farmers (Table XV). This is not surprising as the progressive farmers adhere more rigorously to the package of inputs recommended by the Agricultural Department. Consequently, their allocation of resources would be more efficient and returns to inputs higher than the less progressive farmers. This could be further substantiated from a consideration of the marginal value products of inputs for progressive and less-progressive farmers.

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* Our distinction between progressive and less-progressive farmers is the same as that used in the previous chapter, based on adherence to the recommended package of the Agricultural Department.

** Though one of the earlier improved varieties of rice, this strain is preferred by a large percentage of farmers in the region because its cooking quality and taste come nearest to the traditional rice varieties.

TABLE XV

ELASTICITIES OF INPUTS IN PRODUCTION OF Co.32 COMPARATIVE ANALYSIS OF PROGRESSIVE AND LESS PROGRESSIVE FARMERS

Group	Constant	Land	Seed	Fert.	Manure	Pest.	HLAB	PLAB	Σb_i	$\bar{R}^2$	DET	N
Progressive	2.061	.209	.217	.069	.043	.185	.192	.120	1.035	.97	.000002	44
Less Progressive	1.671	.202	.214	.052	.092	.113	.199	.086	0.958	.93	0.0	17

Abbreviations and Notes

LAND in acres
SEED in quintals
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

Σb_i = Sum of elasticities of inputs
$\bar{R}^2$ = Co-efficient of determination
N = Number of observations

In calculating the marginal value products, we realize that we can only determine ex post rationality of farmers in input allocation. Ex ante rationality is difficult to examine. Since in dealing with irrigated cultivation, yields are relatively independent of random weather conditions, the difference between expected yields and realized yields is likely to be small. Yet, we cannot ignore the difference between expected and realized prices for output. Farmers rationality may be guided by prices at the sowing or harvesting seasons; if he is only producing for home consumption it is difficult to say what price he is using implicitly as a basis of his decisions. In our analysis, we have chosen the average annual price of output.

With these points in mind, we consider the allocative decisions of progressive and less-progressive farmers in Coimbatore, on the basis of their marginal value products. It is not surprising that the marginal value product for land used by the progressive farmers is higher than for the less-progressive (Table XVI). For most other inputs too, marginal value products of progressive farmers is higher. However, manure is an exception. Higher marginal value product for manure input is reasonable for less-progressive farmers, as they tend to allocate more to manure owing to their inability to procure adequate quantities of fertilizer.

TABLE XVI

MARGINAL VALUE PRODUCTS OF INPUTS FOR Co.32 COMPARATIVE ANALYSIS OF PROGRESSIVE AND LESS PROGRESSIVE FARMERS IN COIMBATORE

(Rupees per unit)

Group	Land	Seed	Fert.	Manure	Pest.	HLAB	PLAB	Price *
Progressive	60.253	37.113	1.140	.050	30.942	7.333	7.248	49.55
Less Progressive	56.685	20.712	0.545	.149	23.176	6.541	5.748	49.55

* price in rupees per quintal (100 kilogrammes)

Abbreviations

LAND in acres
SEED in quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

Our findings (Table XV and XVI) therefore, substantiate our earlier results (indicated in Chapter V) that progressive farmers are more efficient than the less-progressive in terms of returns to input use and allocative efficiency. We shall now move on to test our second hypothesis on returns to scale and allocative efficiency in each district and for separate strains.

Elasticities of Production and Returns to Scale

The early years of the Green Revolution saw much attention focussed on returns to scale in an attempt to resolve the issue whether small farms were more 'productive' and 'profitable' than large farms. The facility of the Cobb-Douglas model to obtain returns to scale extended its use, as the sum of the elasticities of production of inputs indicate the returns to scale. The coefficient of an independent variable denotes the percentage increase or decrease in the dependent variable due to a one per cent increase in the given independent variable provided the quantities of other independent variables remain unaltered. Depending on whether the sum of the elasticities of production is less than, equal to or greater than unity, returns to scale would be at a diminishing, constant or increasing scale respectively. In other words, if all the inputs are increased by one unit each, output will be increased by the sum of the elasticities.

The rationale of returns to scale assumes importance when we recognize that farmers' choice allows for the cultivation of a wide variety of rice strains of differing biological structure, maturation and output. Thus even in a monoculture rice area, various options are available to farmers such as the cultivation of three short-duration hybrids or one long- and one short-duration variety. A major factor governing farmers' choice between different strains could be returns to scale. Insofar as returns to scale of different strains vary owing to differences in optimal seed input, fertilizer dosage and per acre output, a comparison of the returns of different strains could indicate potential for increased output in each district.

In Coimbatore, we find that returns to scale for all strains are constant* (Table XII), with the exception of <u>Bhavani</u> which is operating at increasing returns to scale. This implies that on average, most rice varieties in Coimbatore yield at constant returns to scale. The case of <u>Bhavani</u> is interesting; this strain is one of the later hybrids of 130-140 days duration and reinforces our emphasis of technological change as a continuous phenomenon. The fact that potential for increased output lies almost solely in increasing cultivation of <u>Bhavani</u>

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* We have taken the range between plus and minus 5 per cent of unity to indicate constant returns.

reflects the endogenous phase of technological change in which after a point further increases in output are obtained through replacing earlier hybrids by later ones. With the exception of Karikalan and Ponni which are operating at increasing returns to scale, all other strains indicate constant returns (Table XIII). Here again, Karikalan and Ponni are classed as later hybrids, again emphasizing that potential for increased output in Thanjavur lies in promoting cultivation of these later hybrids.

On the whole therefore, our technological relationships reveal that constant returns to scale extend to most rice varieties in Coimbatore and Thanjavur. While such a consideration of returns to scale is valid, it is limited, because it does not indicate productivity of inputs. It is this aspect that we shall now consider.

Productivity of Inputs

Land being the scarce input in Indian agriculture, it is logical to consider which rice strains yield highest output on land. The elasticities for the land input in our functions indicate the net effect of a one per cent increase in land on output. Consequently, those strains with high elasticities for land would result in larger output response.

Of the different rice strains in Coimbatore, Co.29, IR20 and Kannagi show high elasticities for the land input (Table XII). In Thanjavur, on the other hand, Co.25 shows a high elasticity (Table XIII). While elasticities for land are higher in Thanjavur than in Coimbatore, in each of the two districts, there is not a large divergence from the average.

However, elasticities only indicate potential for increased output. To determine the productivity of inputs, we have to calculate the marginal products of inputs using these elasticities. The Cobb-Douglas model gives us constant elasticities of production throughout the range of observations, but as the constant term is included in the function, the marginal product will vary according to the point at which the marginal products are measured. Heady (1947) and Tintner (1944) in their early application of the Cobb-Douglas model estimated the marginal products at the geometric mean*, and this is now generally acceptable.

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* Heady and Dillon (1961) maintain that the choice of the geometric mean enhances reliability by ensuring that errors in the variance estimates of the marginal products are negligible (Heady and Dillon, 1961, p.231). Both for purposes of accuracy and facility, we find the selection of the geometric mean more suitable.

When we consider the marginal physical products of different varieties of rice, we find that in Coimbatore, the newly released Bhavani has the highest marginal physical product for land (2.007) followed by Co.25, Kannagi (Table XVII). In Thanjavur, Karikalan, Kannagi and Co.25 have much higher marginal physical products for land than other varieties (Table XVIII). It is interesting to note that a comparison of the two districts shows that for most strains marginal physical product of land is higher in Coimbatore than in Thanjavur. As our sample in both districts are selected from a homogenous canal-irrigated region, a valid comparison of marginal physical products can be made of similar varieties in the two districts. Our results (Table XIX) indicate without doubt that the marginal physical products of all the rice strains is higher in Coimbatore than in Thanjavur. This would seem to explain the fact that Coimbatore district at present records the highest productivity for rice in the State of Tamil Nadu.

Certain important factors contribute to this high productivity in Coimbatore, chief of which is the superior quality of land* enhanced by the cultivation of other

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* It is generally accepted that drainage problems in Thanjavur are responsible for the comparatively low productivity of rice farms in the area.

TABLE XVII

MARGINAL PHYSICAL PRODUCTS* OF INPUTS IN COIMBATORE

RICE STRAIN	LAND	SEED	FERT	MANURE	PEST	HLAB	PLAB
KARUNA	1.439	1.315	.084	.170	.156	.131	.126
Co.25	1.956	1.586	.059	.082	.283	.134	.110
IR20	1.434	1.606	.021	.011	.104	.159	.146
KANNAGI	1.692	1.492	.091	.041	.417	.169	.145
Co.32	1.196	1.057	.014	.002	.602	.143	.124
Co.29	1.013	1.054	.065	.139	.541	.156	.142
BHAVANI	2.007	1.522	.111	.071	.460	.154	.171
KANCHI	1.310	1.419	.093	.091	.293	.152	.125

* Calculated at geometric mean levels

Abbreviations :

LAND	in acres
SEED	in quintals (100 kilogrammes)
FERT.	=Fertilizer (kilogrammes of plant nutrients)
MANURE	in cartloads
PEST.	=Pesticides (number of applications)
HLAB	=Human Labour (8-hour days)
PLAB	=Plough Labour (8-hour man-animal days)

TABLE XVIII

MARGINAL PHYSICAL PRODUCTS* OF INPUTS IN THANJAVUR

RICE STRAIN	LAND	SEED	FERT	MANURE	PEST	HLAB	PLAB
KARUNA	.874	1.557	.118	.120	.054	.150	.129
Co.25	1.150	1.446	.074	.045	.461	.153	.144
PONNI	.783	1.456	.113	.047	.240	.146	.127
IR20	.802	2.058	.102	.080	.315	.160	.117
KANNAGI	1.159	1.739	.052	.138	.434	.168	.119
KARIKALAN	1.256	1.408	.076	.104	.402	.127	.101

* Calculated at geometric mean levels

Abbreviations

LAND in acres
SEED in quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

TABLE XIX

COMPARATIVE ANALYSIS OF MARGINAL PHYSICAL PRODUCTS* OF INPUTS IN COIMBATORE AND THANJAVUR

(Quintals)

Strain	Land	Seed	Fert.	Manure	Pest.	HLAB	PLAB
Karuna (C)	1.439	1.315	.084	.170	.156	.131	.126
KARUNA (T)	.874	1.557	.118	.120	.054	.150	.129
Co.25 (C)	1.956	1.586	.059	.082	.283	.134	.110
Co.25 (T)	1.150	1.446	.074	.045	.461	.153	.144
IR20 (C)	1.434	1.606	.021	.011	.104	.159	.146
IR20 (T)	.802	2.058	.102	.080	.315	.160	.117
Kannagi (C)	1.692	1.492	.091	.041	.417	.169	.145
Kannagi (T)	1.159	1.739	.052	.138	.434	.168	.119

* Calculated at geometric mean levels.

Abbreviations

(C) = Coimbatore
(T) = Thanjavur
LAND in acres
SEED in quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

crops like sugarcane,turmeric and banana. Thanjavur, on the other hand, is a monoculture rice region. Water-logging and drainage problems are the main impediments to the attainment of the full productivity-increasing effects of the Green Revolution in rice.

While it is widely recognized that assured irrigation facilities are a pre-condition for the successful implementation of the Green Revolution in rice, it is found that in the Telengana region of Andhra Pradesh, well-irrigation is more effective than canal- or tank-irrigation for the growth of hybrid and improved rice strains under the new strategy (Pingle, 1976), owing to the possibility of more effective control of water-supply under well-irrigation. If the same were true of Thanjavur, shift to rice cultivation under well-irrigation could be the answer to increasing productivity in Thanjavur.

From our comparative analysis of marginal products of land in Coimbatore and Thanjavur, it seems logical to concentrate on extending the High-Yielding Varieties Programme for rice in Coimbatore. However, such a policy measure would have to be based on the relative profitability of rice vis-a-vis other commercial crops like turmeric and sugarcane. The relative profitability of turmeric over rice in Coimbatore has led many farmers in the area to shift to turmeric in the earlier seasons cultivating sufficient rice only for home consumption.

Nevertheless, output can be increased by the cultivation of the more productive strains of rice such as Bhavani in Coimbatore and Karikalan and Ponni in Thanjavur.

As we are primarily interested in increasing productivity of land, we have so far concentrated on the returns to land under different rice strains in Coimbatore and Thanjavur. A brief look now at the returns to other inputs. We find that the marginal physical products of the seed input are very high for all strains of rice both in Coimbatore and Thanjavur (Tables XVII and XVIII). Such high marginal products suggest under-utilization of seed, as a one per cent increase in seed input would increase output by the amount of the marginal physical product provided the quantities of other inputs remain unchanged. Under-utilization of seed can hardly be realistic since in most cases farmers are using more than the recommended dosage of seed in order to avoid risk through non-germination. However, under-utilization of seed can only be justified on a consideration of the price paid for the input. We shall examine this point when dealing with marginal value products of inputs. Another possibility is that the high marginal product for the seed input may reflect the element of management which is not included in the production function.

The relatively high returns for pesticides are particularly evident for the longer duration hybrids like

Co.25, IR20, ADT-27 (125-180 days) than for the shorter duration hybrids (90-110 days). Returns to labour are also found to be higher for hybrids than for local improved varieties and for later hybrids than for earlier ones. This would imply possibilities for wage bargaining in favour of farmers of later hybrids.

A consideration of the marginal physical products gives us an indication of the possibilities for increasing output or improving resource allocation. This is another aspect of farmer's rationality which has a direct effect on the speed and direction of technological change by determining the choice of rice variety so as to increase productivity of land. However, farmer's choice of rice strain is guided not only by expected yields but also by price of output. It is in this respect that the marginal value products of inputs derive importance in decision-making.

Thus farmers might decide to cultivate an earlier hybrid because of the certainty that the market for the strain will maintain the same price or in anticipation of a rise in price for that strain due to growing demand. At the same time, stability in expected yields is also a vital factor that influences a farmer's choice of rice variety. So too, returns to inputs can only be accurately assessed through a consideration of the marginal value products. Thus if the marginal value of an input exceeds the price paid for it, this could give an indication of excess utilization. With these points in mind, we shall examine the marginal value products of inputs in Coimbatore and Thanjavur.

Marginal Value Products of Inputs

The inclusion of prices necessarily introduces difficulties caused by price fluctuations and price variations. Such price variations are not only inter-regional and inter-district but extend to differences between villages as well. Then there is also the problem of which price to select - current price at the time of sowing or harvest prices. When dealing with a single crop, one may be tempted to think that such variations are negligible, but in terms of farmers' rationality, choice between later hybrids, early hybrids or locally improved varieties is considerable, as the 'package' of inputs and practices for each strain varies markedly. As our main concern is to determine marginal value products of land for different strains, we have selected the average annual price of the sample farmers.

From our analysis, it is evident that Bhavani has the highest marginal value product for land in Coimbatore followed by Ponni and Co.25 (Table XX). This substantiates

TABLE XX

MARGINAL VALUE PRODUCTS OF INPUTS IN COIMBATORE

(Rupees per unit)

RICE STRAIN	LAND	SEED	FERT	MANURE	PEST	HLAB	PLAB	PRICE
KARUNA	96.341	88.039	5.624	11.382	10.444	8.770	8.436	66.95
Co.25	131.267	106.436	3.959	5.503	18.992	8.992	7.382	67.11
IR20	102.933	115.279	1.507	0.789	7.465	11.413	10.479	71.78
KANNAGI	117.239	103.381	6.305	2.841	28.894	11.710	10.047	69.29
Co.32	59.262	52.374	0.694	0.099	29.829	7.086	6.144	49.55
Co.29	62.482	65.011	4.009	8.574	33.369	9.622	8.759	61.68
BHAVANI	146.792	111.319	8.119	5.193	33.644	11.264	12.507	73.14
KANCHI	91.766	99.401	6.515	6.375	20.525	10.648	8.756	70.05

* price in rupees per quintal (100 kilograms)

Abbreviations

LAND In acres
SEED In quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrients)
MANURE In cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

our hypothesis that later hybrids are more remunerative than earlier hybrids, which gives further weight to our evolutionary endogenous model. Insofar as the initial breakthrough in technological change sustains productivity for a short period, in the long run further productivity increases are initiated and sustained from within by the rationality and productive efficiency of farmers.

In Thanjavur, Karikalan has the highest marginal value product for land followed by Kannagi and Co.25 (Table XXI). The highest average annual price is offered for Ponni (Rs. 74.85) followed by Bhavani (Rs. 73.14). It can be misleading to infer on the basis of our analysis, that it would be more profitable to shift to Bhavani in Coimbatore and Karikalan or Kannagi in Thanjavur. Certain allowance must be made for the duration of different strains - Ponni is clearly suited to the second season in Coimbatore or Samba season in Thanjavur, requiring a maturation period of 130-140 days; Co.25 falls likewise into the same category. On the other hand, varieties like Karuna and Kanchi have a much shorter duration of 90-110 days. Consequently, in Coimbatore farmers' rationality extends to choice of two long-duration crops or three short-duration crops in the agricultural year.

Conclusions

In this chapter, we set out to examine farmers'

TABLE XXI

MARGINAL VALUE PRODUCTS OF INPUTS IN THANJAVUR

(Rupees per unit)

(in Rupees)

RICE STRAIN	LAND	SEED	FERT	MANURE	PEST	HLAB	PLAB	PRICE *
KARUNA	58.541	104.241	7.900	8.034	3.615	10.043	8.637	66.95
Co.25	77.176	97.041	4.966	3.019	30.938	10.268	9.664	67.11
PONNI	58.608	108.982	8.458	3.518	17.964	10.928	9.506	74.85
IR20	57.568	147.723	7.322	5.742	22.611	11.485	8.398	71.78
KANNAGI	80.307	120.495	3.603	9.562	30.072	11.641	8.246	69.29
KARIKALAN	83.549	93.660	5.055	6.918	26.741	9.448	6.719	66.52

* price in rupees per quintal (100 kilogrammes)

Abbreviations

LAND in acres
SEED in quintals (100 kilogrammes)
FERT. = Fertilizer (kilogrammes of plant nutrient)
MANURE in cartloads
PEST. = Pesticides (number of applications)
HLAB = Human Labour (8-hour days)
PLAB = Plough Labour (8-hour man-animal days)

response to technological change in terms of returns to input use and to compare the response measured by the level of technology of progressive and less-progressive farmers. We found that progressive farmers had a higher level of technology and greater allocative efficiency than less-progressive farmers in Coimbatore. Inasmuch as efficiency of farmers is largely dependent upon access to the sources of modernization, economic status and education of the farmer (Chapter V), allocative efficiency of farmers can be improved by governmental effort in that direction.

We tested the hypothesis that marginal productivity of land varies in each district and for different rice strains. The results (Tables XVII and XVIII) show that the marginal productivity of land under rice cultivation is higher in Coimbatore than in Thanjavur, while the marginal products of certain late hybrids like Bhavani and Co.25 in Coimbatore and Karikalan, Kannagi and Co.25 in Thanjavur are higher than marginal products for other rice strains.

Certain vital implications follow from our analysis, chief of which is the necessity of micro-studies at a low level of aggregation to facilitate effective policy strategies at the grass-roots. The experience of the Green Revolution in rice with its wide choice of strains bears evidence to the process of endogenous technological change with later hybrids replacing earlier ones in a continuous spiral to effect increased production. Thus speedy and effective propagation of the newly-released strains from the research stations to the farming community is vital. This result substantiates our earlier findings (in Chapter V) that contact with extension agencies enhances technological efficiency of farmers.

Thus we see that the introduction of the Green Revolution technology is an instance of exogenous technological change as it initiated a breakthrough from traditional technology resulting in new inputs and techniques into the production process. This breakthrough has now moved into an evolutionary endogenous phase where continuing research feeds the process of technological change with farmers moving from early hybrids to newly-released strains. The pace of adoption is remarkable* and reflects the efficiency of the Agricultural Extension Services in the region.

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* In one of the sample villages, Vaigai, a newly-released rice hybrid (released by the Agricultural Research Station attached to the Tamil Nadu Agricultural University, Coimbatore in December 1973) was already beginning to be adopted by farmers in the villages in June 1974.

We have considered here the impact of the modern technology on resource allocation and input use with the help of the Cobb-Douglas model. Yet, as an average function, the Cobb-Douglas model does not give us any indication of farmers' 'efficiency' or 'optimality' under the current technology. Policy strategies aimed at achieving the full productivity-increasing effects of the new technology require some measure of efficiency to determine whether resources are being optimised. Any increase in output effected merely by increasing efficiency, without absorbing further resources would represent the potential for increased production.

At the individual farm level, potential for increased production can be assessed by examining farmers' optimality under the current resource constraints. To some extent, farmers' efficiency could be reflected in relation to the theoretical optimum indicated by the linear programming technique. This is what we shall examine in the following chapter on a 10 per cent random selection of our sample farmers in Coimbatore and Thanjavur. We also consider optimality of our less progressive farmers to ascertain whether they are all in fact inefficient.

CHAPTER VII

OPTIMISING RETURNS FROM MODERN TECHNOLOGY IN RICE

Introduction

We have so far examined the effects of technological change introduced through the Green Revolution and returns to inputs under modern technology for different genetic rice strains. The location-specificity of different strains was examined and it was found that hybrids which are more productive and profitable in Coimbatore are not equally productive in Thanjavur. This finding substantiates our hunch that micro-studies at a low level of aggregation are essential to promote increasing productivity at the grass-roots. Here we examine the efficiency of farmers under the modern technology to assess the potential of the Green Revolution in its endogenous phase.

Much of our analysis so far has been based on the observed behaviour of our sample farmers in Coimbatore and Thanjavur. This observed behaviour is largely determined by the 'package of inputs' and practices recommended by the Agricultural Department. The 'optimality' of the recommended package is now being brought into question on the grounds that the effective control exercised on experimental farms does not prevail at the individual farm level. Thus the recommended package, while being 'optimal' under effective control, could well be sub-optimal for farmers in the region.*

In this chapter, we shall examine the potential for increasing output under modern technology, using linear programming techniques. Linear programming allows us to estimate more effectively the maximum attainable output from a given set of resources whereas production function analysis relates actual output to actual input use. Although production function and linear programming are not mutually exclusive techniques, they have certain basic distinctions. Production function analysis assumes an infinite number of possibilities along the isoquant; linear programming on the other hand operates on a finite number. Thus linear programming recognizes that given the resource constraints, output can be increased by altering the input-mix or changes in the cropping pattern. Since we are solely interested in the rice crop, changes in cropping pattern would be confined to choice between alternative rice strains.

The object of the exercise is thus to determine if farmers in the area are maximizing output. If we can

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* Other climatic and soil conditions could well be responsible for sub-optimal output at the farm level.

accept our hypothesis then it follows that the full productivity-increasing effects of the new technology have already been achieved and any further increases would necessitate improvements in technological knowledge and application. On the other hand, to reject the hypothesis would imply further potential under modern technology by fuller or optimal utilization of existing resources.

We shall also test the hypothesis that our 14 less-progressive farmers are not maximizing output and consequently are in fact less efficient than the progressive farmers. It is not uncommon to find that farmers who are labelled 'non-progressive' due to their low adoption index are in fact more efficient in their allocation of resources than some 'progressive' farmers. This is what we propose to analyze using linear programming techniques.

The Linear Programming Model.

The utility of the linear programming technique in determining maximum returns to a combination of inputs and resources has been well-established; in principle, the model is based on the inter-relationships between inputs and output, expressed by means of a production function. If we consider the production function as representing all technologically feasible combinations of inputs and outputs, the problem of maximizing output would consist in selecting the optimal or most profitable point on the production function.

Basically therefore, the logic of the linear programming model follows from the choice between different processes or levels of activity; to a large extent, farmers' decisions are determined by his knowledge of the available options or alternative opportunities open to him and bounded by his resource constraints. Thus essentially, the linear programming concept is "that of a 'process', or 'activity', which we define as a set of ratios obtaining among rates of consumption of various inputs and rates of production of various outputs". (Dorfman, Samuelson and Solow, 1958, p.132).

Certain fundamental assumptions accompany the linear programming model; their validity to our data justifies our application of the technique in our analysis. It is assumed that the farm has a large but finite set of processes or activities. Each process can be operated at any positive level provided the necessary inputs are available. This presupposes that each process is independent of the other and that inputs are divisible, for changes in the level of a process imply changes in rates of consumption of all inputs and rates of production of all outputs in the same proportion. Yet, "the quantities of inputs and outputs of the firm cannot be altered directly, but only indirectly by means of changes in the levels of various processes. Thus linear programming does not seek to determine directly the optimal quantity of each factor and product but, instead, the optimal level of each activity" (Dorfman, et al., 1958, p.133).

The assumption that the levels of a process can be varied need not necessarily be exactly true; it implies constant returns to scale which does not always apply. But from the results of our production function analysis (Chapter VI) we find that in the case of both Coimbatore and Thanjavur, most rice varieties are producing at constant returns to scale; hence our use of the linear programming technique is amply justified.

In our model, we considered different levels of activity for each of the different strains of rice. For certain locally improved varieties, fertilizer is sometimes not used at all but is substituted by manure; so too, pesticides may not be used for certain strains. Thus the number of processes was increased to include all possible activities for each of the different rice strains. We shall now proceed to define our model.

We have selected output maximization as the criterion of efficiency in the model, with a view to determining potentialities for increasing output under the present strategy. In linear programming terminology, the criterion of efficiency is defined as the 'objective function', since the optimal solution varies depending on the objective function used. Thus if the problem were concerned with determining potentialities for increasing employment, the function would be defined as employment maximization. While both output and employment maximization are recognized state objectives, the former is a priority in agriculture; hence our choice was unambiguous. However, the limits to the attainment of the objective function are set by the availability of inputs, which in linear programming terminology, can be expressed as effective constraints. In our model, these input levels are the actual amounts of inputs used by the individual farmer which determine the limit of his output maximization.

Definition of the Model

The basic linear programming model is expressed for each farm as follows :

$$\text{Maximize} \quad Z = \sum_{i=1}^{n} c_i X_i$$

Subject to

$$\sum_{i=1}^{n} a_{i1}X_i \leq A_1$$

$$\sum_{i=1}^{n} a_{i2}X_i \leq A_2$$

....

$$\sum_{i=1}^{n} a_{ij}X_i \leq A_j$$

and all $X_i \geq 0$

where X_i (i=1,n) is the level of the i-th crop activity; a unit of activity is equal to an acre of a crop.

c_i (i=1,n) is the gross output per acre of the i-th activity.

The inputs in the model are given as :

A_1 = land capable of growing only one short-duration rice crop per year.

A_2 = land capable of growing either one long-duration rice crop or two short-duration rice crops per year.

A_3 = Quantity of seed

A_4 = Quantity of manure

A_5 = Fertilizer

A_6 = Pesticide costs

A_7 = human labour in 8-hour days

A_8 = plough labour in 8-hour days.

For the purpose of estimating the coefficients, we relied on the results of the production function analysis for the different strains of rice (Chapter VI), all the variables were standardized in terms of the fixed input - land. Then the different activities for each strain were determined. For some rice varieties, fertilizer is substituted by manure, and pesticides are not found to be necessary. Hence the number of activities is not restricted to the number of different rice strains only, but includes different combinations of inputs for the same rice strain; these latter represent different and distinct crop activities. Our simulated plans therefore, will indicate not only which of the strains are the most optimal, but also the activities which result in optimizing output.

Variables Used :

Maximands:

Z_1. Output: Gross output from crop activities.

Constraints:

A_1. Land 1: Single crop land; that is, area producting only one short-duration (90-110 days) rice strain per year.

A_2. Land 2: Double crop land, that is, area producing two short-duration (90-110 days) or one long-duration crop (120-180 days) per year.

A_3. Seed input in kilograms.

A_4. Manure in cartloads.

A_5. Fertilizer input in kilograms of plant nutrients.

A_6. Pesticides in value terms (Rs.)

A_7. Human labour in 8-hour days.

A_8. Plough labour in 8-hour days.

For each sample farm the resource constraints were measured by the actual level of inputs used by the farmer in the survey year 1973-74. By means of linear programming technique therefore, we simulated the effect on output by reallocating the inputs used by the farmer; the simulated output will indicate the 'optimum' that can be achieved by the farmer under the given resource constraints. Thus a comparison of the farmers' actual output with the simulated 'optimum' will give the potential for increased output. To facilitate the analysis of farms of different sizes, all input variables were standardized on a per acre basis.

Results of the Analysis

The results of the simulated plan giving the optimal output in Coimbatore are indicated in Table XXII. It is found that 6 out of 18 farmers in Coimbatore have higher levels of output than the simulated plans. This shows that these 6 farmers are in fact doing 'better' than if they followed the programme. The other 12 farmers would obtain higher output if they followed the simulated plan; in this case, the simulated output indicates the potential for increased output. Hence our results show that there is still further scope for optimising output under the modern technology in Coimbatore.

In Thanjavur (Table XXIII), the simulated plan indicates that all our sample farmers have lower output than if they followed the simulated programme, pointing to a large measure of potential for increased output.

Not only does the simulated plan give the potential for increasing output, but the net profit derived for the programme is also greater than actual net profit. This derived net profit was obtained by deducting from the 'optimum' output, the cost of the non-land input 'used' by the programme; a common set of prices was used to weight inputs for all farms. To a large extent, these prices can be considered as the opportunity cost of inputs. To the extent, that inputs are left 'slack' or unutilized by the programme, these represent excess capacity which could be alternatively employed.

TABLE XXII

EFFECT OF OUTPUT MAXIMIZATION ON TOTAL OUTPUT AND NET PROFIT IN COIMBATORE

(tons or Rupees)

Farm	Actual Output	Optimum Output	Actual Net Profit	Derived Net Profit
C1	136.80	181.95	7923.61	8312.30
C2	34.80	39.89	984.88	1071.90
C3	57.60	63.70	2718.08	3649.39
C4	90.60	111.98	3014.00	4473.87
C5*	20.40	18.80	574.17	579.12
C6*	167.60	142.92	8756.72	8875.29
C7	69.30	71.28	2917.22	3414.46
C8	48.13	51.28	1380.84	1484.03
C9*	65.40	59.85	2063.49	2073.58
C10*	42.40	41.27	1255.69	1460.26
C11	38.40	40.80	1097.98	1344.77
C12	15.60	20.77	489.71	622.88
C13	19.80	19.97	137.51	156.86
C14*	86.40	81.90	3868.87	4052.31
C15*	48.00	27.91	1353.32	1679.26
C16	12.60	13.50	353.29	459.82
C17	57.00	63.70	2718.08	3000.13
C18	53.28	57.50	2315.96	2373.38
Total	1064.11	1108.97	43923.42	49083.61

* Indicates farms with actual output higher than the 'optimum'.

TABLE XXIII

EFFECT OF OUTPUT MAXIMIZATION ON TOTAL OUTPUT AND NET PROFIT IN THANJAVUR

(tons or Rupees)

Farm	Actual Output	Optimum Output	Actual Net Profit	Derived Net Profit
T1	85.18	99.57	3672.15	4731.51
T2	96.09	125.02	2876.50	4072.83
T3	66.68	83.44	2083.40	3113.11
T4	109.80	132.63	1602.47	3011.39
T5	201.56	343.87	9022.00	10926.26
T6	52.17	107.13	2198.55	2839.54
T7	113.97	117.39	5405.80	8018.09
T8	159.14	196.63	8732.50	10868.21
T9	14.82	27.44	419.26	971.34
T10	191.62	246.88	9926.64	11242.36
T11	293.91	391.26	14899.25	17014.60
TOTAL	1384.94	1871.26	60838.52	76809.24

It is significant that both in Coimbatore and Thanjavur, for most farms, fertilizer input features as being in excess by the programme. This could be explained by 2 factors:

(i) fertilizer dosage varies for different rice strains. However, for purposes of convenience, the Agricultural Department recommends an average dose for all varieties. Consequently, certain varieties may well be receiving excess fertilizer,

(ii) farmers are inclined to increase fertilizer doses on the mistaken notion that 'more fertilizer yields greater output'.

It is generally accepted that excess fertilizer leads to reduction in output; hence the optimum output may well be obtained by lowering the fertilizer dosage, thereby also reducing the cost of cultivation.

While it is relatively easy to cost all non-land inputs, it is important to realize that in many cases, land is also left unutilized by the programme. This is due to the fact that the programme is restricted by a fixed set of coefficients, but it does not have the same flexibility as the farmer, who though limited by his resource constraints, allocates his inputs and selects the type of rice strain so as to cultivate all his land.

Land being a scarce input, his major priority is to maximize returns from it.

It is interesting to note that in Coimbatore district, in the case of 4 farms, the land left 'idle' by the programme is of significance, namely, over half an acre. In 2 out of these farms, the flexibility of farmers in allocating inputs results in a better farm plan having an output higher than the 'optimum' generated by the programme. In the other 2 farms, 'optimum' output as indicated by the programme is much above the actual, inspite of a large portion of unutilized land. In Thanjavur too, we find that in 5 farms, a sizeable area of land is left 'unutilized' by the programme and in each case, the optimum generated by the programme is well above the actual inspite of the unutilized land input.

The reasons for land being left unutilized by the programme could be explained by the fact that farmers may face effective constraints by the seasonal use of labour. Moreover, the fear of 'idle' land being taken over by the government could force farmers into cultivating all their land allocating their resources over a wider area, thereby reducing efficiency.

From our analysis therefore, it can be inferred that substantial increases in output and profit can be obtained from following the simulated plans which indicates the potentialities for increased productivity in the area. It would seem that this potential is much greater in Thanjavur than in Coimbatore, where at least a third of the sample farmers are maximizing output.

When we consider the optimal varieties of rice selected by the programme, we find that in Coimbatore, IR20 emerges as the most optimal strain, appearing in 13 out of the 18 simulated plans. Kannagi, Karuna and Co.32 also figure prominently in a few farm plans, but on smaller acreages of the farm. When we compare these varieties with the strain actually cultivated by the farmers, we find that IR20 is the most popular strain in Coimbatore followed by Co.32, Kanchi, and Karuna. As Ponni has a longer duration (130-140 days) compared to IR20, Kanchi and Karuna (90-110 days) only a few farmers cultivate this strain and mostly in the second season. These findings substantiate our earlier results (indicated in Chapter VI) in which IR20 registers high marginal products for land in Coimbatore.

For Thanjavur, on the other hand, the most optimal rice strain seems to be Karuna which features prominently in 10 out of 12 simulated plans; IR20 also emerges in 9 simulated plans, while Co.25 only in 3. This would seem to indicate that although our production function analysis shows that Karikalan has the highest marginal product for land in Thanjavur, under the resource constraints faced by our sample farmers, it would not necessarily optimise output. It is interesting to note that IR20 emerges as an optimal strain both in Coimbatore and Thanjavur. Though superceded by many later hybrids like Kanchi, Karuna, Karikalan and Kannagi, IR20 is still very popular in the Coimbatore and Thanjavur rural scene.

Efficiency of Less-Progressive Farmers

To determine the efficiency of our less-progressive farmers we tested the actual output of these 14 farmers against the simulated output obtained from the programme. We found (Table XXIV) that 4 farmers had obtained higher output than the simulated output, which indicated that the actual performance of these 4 farmers is 'better' than if they had followed the simulated plan. However, the other 10 farmers would do better by following the simulated plan thereby increasing their output.

When we turn to 'net profit' figures, in the case of 2 farmers, the actual and derived net profit is the same, indicating no excess capacity. For the other 12 farmers on the other hand, derived net profit is slightly higher reflecting that some inputs were left 'idle' under the simulated plan. To sum up therefore, we can conclude that not all less-progressive farmers are inefficient. Some are in fact, following plans better than the simulated plans.

TABLE XXIV

EFFECT OF OUTPUT MAXIMIZATION ON TOTAL OUTPUT AND NET PROFIT OF LESS-PROGRESSIVE FARMERS

(tons or Rupees)

Farm	Actual Output	Optimum Output	Actual Net Profit	Derived Net Profit
N1	21.60	21.94	416.06	423.57
N2*	23.80	23.33	436.37	446.83
N3	32.20	33.39	797.10	960.00
N4*	15.65	14.90	364.37	638.33
N5	24.38	25.14	666.40	666.40
N6	31.80	32.46	918.70	940.64
N7	6.24	6.78	156.62	160.32
N8	45.30	50.42	1408.90	1422.81
N9	6.24	7.41	582.15	584.40
N10	17.28	22.38	634.45	806.69
N11*	20.40	18.80	574.17	579.12
N12	36.00	41.04	900.38	900.38
N13*	65.40	39.85	2063.49	2073.58
N14	5.92	6.71	170.20	351.74
TOTAL	352.21	344.55	10089.36	10954.81

While at the farm-level, individual farmers could optimize returns by following the simulated plan, it will be interesting to analyze whether on an aggregate, there is any significant difference between the actual and simulated plans in terms of output and net profit. This involves comparisons in standard units - for convenience, we have indicated the results of our model in per acre terms (Tables XXV to XXVII).

Comparing the means of actual output and optimum output in Coimbatore, we find no significant* difference nor is there any significant difference in means of actual and derived net profit. Similar conclusions were arrived at for Thanjavur and for our sample of less-progressive farmers.

However, if we examine differences in means between the two districts and between progressive and less-progressive farmers, a different picture emerges. There is a significant difference in means of actual output between Coimbatore and Thanjavur farmers. On the other hand, there is no significant difference in actual net profit. This would imply that although Coimbatore farmers may have higher productivity than Thanjavur farmers, their actual net profit is not significantly different.

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* Our tests of significance refer to the 95 per cent level of confidence.

TABLE XXV

RESULTS OF OUTPUT MAXIMIZATION MODEL IN PER ACRE TERMS FOR COIMBATORE

(tons or Rupees)

Farm	Actual Output	Optimum Output	Actual Net Profit	Derived Net Profit
C1	15.20	20.22	880.40	923.59
C2	17.40	19.95	492.44	535.95
C3	19.20	20.82	906.03	1192.61
C4	15.95	20.43	530.63	816.40
C5	17.00	17.09	478.48	526.47
C6	20.95	18.47	1094.59	1146.68
C7	19.80	20.37	833.49	375.56
C8	19.25	20.51	552.34	593.61
C9	16.35	14.96	515.87	518.40
C10	21.20	20.64	627.85	730.13
C11	19.20	20.40	548.99	672.39
C12	15.60	20.77	489.71	622.88
C13	19.80	20.37	134.75	160.06
C14	21.60	26.18	653.01	960.08
C15	24.00	20.52	676.66	634.75
C16	16.80	18.00	471.05	613.09
C17	15.20	20.95	724.82	986.88
C18	22.20	23.96	964.98	988.91
AVERAGE	18.71	19.12	643.12	755.46

TABLE XXVI

RESULTS OF OUTPUT MAXIMIZATION MODEL IN PER ACRE TERMS FOR THANJAVUR

(tons or Rupees)

Farm	Actual Output	Optimum Output	Actual Net Profit	Derived Net Profit
T1	15.92	19.80	686.38	940.66
T2	16.02	20.84	479.42	678.81
T3	12.92	20.45	403.76	763.02
T4	18.30	22.11	267.08	501.90
T5	21.60	26.14	966.99	1171.09
T6	10.69	21.95	450.52	581.87
T7	16.28	24.10	772.26	1646.43
T8	17.19	23.75	943.03	1312.59
T9	10.44	22.68	295.25	802.76
T10	14.85	19.13	769.51	871.50
T11	17.25	22.96	874.37	998.51
AVERAGE	15.59	22.17	628.05	933.55

TABLE XXVII

RESULTS OF OUTPUT MAXIMIZATION MODEL IN PER ACRE TERMS FOR LESS PROGRESSIVE FARMERS IN COIMBATORE

(tons or Rupees)

Farm	Actual Output	Optimal Output	Actual Net Profit	Derived Net Profit
N1	14.40	14.63	277.37	282.38
N2	14.88	14.58	272.73	279.27
N3	16.10	16.95	398.55	487.31
N4	15.35	15.20	364.37	651.36
N5	16.25	16.80	444.27	445.45
N6	15.90	16.39	459.35	475.07
N7	15.60	16.95	391.55	400.80
N8	15.10	17.47	469.63	493.00
N9	15.60	18.53	455.38	461.00
N10	14.40	18.97	528.41	683.64
N11	17.00	17.09	478.48	526.47
N12	14.40	16.42	360.15	360.15
N13	16.35	19.93	515.87	518.40
N14	14.80	16.78	425.50	879.35
AVERAGE	15.44	16.91	417.25	495.97

When we test for differences in means between progressive and less-progressive farmers, we find a significant difference in means of actual output as well as actual net profit. There is also a significant difference in means of optimum output and derived net profit. This would indicate that there is potential for increased production in Coimbatore, if less-progressive farmers become more progressive.

Conclusions

Our simulated plans using the output maximization model indicate that there is still further potential for increased output in both Coimbatore and Thanjavur districts. This potential is to be seen in terms of output as well as net profit. Both the productivity and profitability of the simulated plans is better than the actual performance of the farmers. One significant result from the analysis shows an excess use of fertilizer input which could well be responsible for sub-optimal output in the area.

In terms of the more optimal strains, IR20 holds its own both in Coimbatore and Thanjavur, and its popularity among the farmers is indicated in their choice of this strain rather than later hybrids, because of its cooking quality and taste which come closest to traditional rice varieties. Among other strains which also produce optimal output under the simulated plans are Ponni and Co.32 in Coimbatore and Karuna in Thanjavur which bears important policy implications for the region.

If we accept output maximization as a priority for policy strategy, a shift in the cropping pattern to include the more optimal strains like IR20 and Ponni in Coimbatore or Karuna and IR20 in Thanjavur would increase output in the region. Besides, net profit to farmers would also be enhanced while economizing on scarce inputs like land and fertilizer.

An interesting finding from our simulated plans is the excessive use of fertilizer; in a period of fuel-energy crisis, an economic use of chemical fertilizer can go a long way towards augmenting overall productive efficiency.

A consideration of the performance of less-progressive farmers indicates that 4 out of 14 farmers obtained higher output than the simulated plan, although their net profit would be higher if they followed the simulated plan. Two of the less-progressive farmers obtain higher net profit than if they followed the simulated plan and therefore, have no incentive to change their plan in favour of the simulated one.

The results of the analysis therefore reveal that not all less-progressive farmers are inefficient, as some are in fact getting better results than would have resulted from the simulated plans. However, a significant difference is observed in means of actual output and net profit between progressive and less-progressive farmers which indicates the potential for increased productivity and profitability in less-progressive farmers. This potential may be exploited by shifting to later hybrids, economizing on fertilizer usage without incurring any additional costs. Thus increased productivity could be achieved through the endogenous phase in which modern technology has now entered.

CHAPTER VIII

CONCLUSIONS

In this study we have used an endogenous/exogenous framework to examine the process of technological change in agriculture. While these two dimensions of technological change have been implicit in economic literature for nearly two hundred years, their application in the study of agricultural development has not been usefully exploited.

Endogenous and exogenous change is implicit in Classical literature. The early Classicists were concerned about technological progress. Mill in particular recognized its importance in agriculture, emphasizing clearly how technological progress can be brought about by changes within the current knowledge of agricultural techniques or through the process of diffusion, which extends the frontier of current knowledge. To our mind, such change is evidently endogenous. On the other hand, the Schumpeterian concept of innovation which views technological change in discrete jumps, gives us the framework of exogenous technological change.

We have found in the experience of Tamil Nadu, an impressive illustration of endogenous and exogenous technological change in the case of rice. Early historical records for this important rice-producing State reveal the continual process of technological change over time. Under traditional agriculture, change was largely endogenous through the process of trial-and-error, within known techniques or through diffusion of better techniques between areas and/or farmers.

The Green Revolution on the other hand, illustrates the exogenous dimension of technological change. Through the introduction of modern inputs and techniques, the Green Revolution initiates a new phase quite distinct from traditional agriculture. Yet, while distinct, the acceptance of the modern technology has been prepared by a long tradition of research and to that extent may be termed part of the continual process of technological change.

Moreover, once exogenous change has been sufficiently adopted, it too gains momentum, assuming an endogenous aspect. We found this endogenous phase remarkably evident in the continuous process of shifts from earlier to later-released hybrids. To the extent that this continuing spiral reaches the farmers at the grass-roots through the extension agencies, the full potential of technological change is achieved.

Our analysis highlights certain important aspects of technological change, chief of which is the importance of specific, disaggregated, micro-level studies. Technological knowledge is often highly specific to a particular area or region. This calls for micro-level studies. At a regional or district-level, quite different results are often obtained than at an aggregated national level.

Our analysis of growth rates dismisses the view of some economists that the Green Revolution has not made any significant contribution to improving yields of rice. On the contrary, in most districts of the region, a significant increase in growth rates of rice yields are to be found. Moreover, at the regional level, greater stability is also evident since the introduction of the modern technology.

Significant in our findings also is the varying pace of growth at the micro-level. Districts which have already reached a high level of growth under traditional technology have not registered a high increase in growth rates since the introduction of modern technology. We found this to be the case in Coimbatore. In the same vein, areas that are well-provided with the necessary vital inputs - irrigation-like Thanjavur, record a steady increase in both growth rates and stability of yields. Thus differences in natural resources or socio-economic characteristics of farmers give rise to different rates of growth in rice yields over time.

Recognizing variations in response to technological change are not only between districts but also between individual farmers, we examined how farmers had responded to the new technology in Coimbatore. An analysis on dis-aggregated farm-level data revealed that farmers who showed greater response to the modern technology ('progressive' farmers) were those who enjoyed a higher economic status, greater access to the sources of modernization and higher education than the 'less progressive' farmers.

These three socio-economic factors represent the major constraints influencing farmers' response to modern technology. Government strategy aimed at removing these constraints would promote technological efficiency of farmers and result in increasing production in the area. The most effective constraint is the lack of credit facilities and vital inputs like chemical fertilizers. There is no evidence to show that the poorer farmers or those cultivating small farms are less productive or efficient; our analysis reveals the contrary is true. Progressive farmers obtain higher returns to inputs than less progressive farmers. Hence effective government policy aimed at eliminating these constraints would promote rice production and thus accelerate the endogenous phase of technological change.

We examined the potential for increased production within the endogenous phase of modern technology in terms of returns to input use. Most earlier-released rice strains are operating at constant returns to scale, while the later-released varieties at increasing returns. This shows that increase in production can be obtained by shifting from the cultivation of the early-released strains to the later hybrids. However, this requires greater effectiveness in the Extension Services so that the newly-released strains are adopted by farmers more speedily and effectively. It also requires continuing research to develop viable hybrids for different areas. Our analysis brings out clearly that different rice strains are area-specific; that is, the same hybrid does not yield comparable returns in two canal-irrigated tracts. This finding further substantiates the relevance of micro-studies.

No doubt farmers' efficiency is evident in allocation of inputs; 'progressive farmers were found to have higher returns to input use than 'less progressive' farmers. However, in assessing the potential for further increase, we found that the full potential of the new technology has not yet been exploited. Our results show that increased productivity can be obtained by moving to cultivation of later hybrids which indicate higher marginal products for land. Again the role of the extension agencies and the government becomes important in diffusing the later hybrids.

It is also significant that reduction in the fertilizer input would effect increased output. In a period of rising demand for fertilizer due to the fuel-energy crisis, shift to more optimal strains and appropriate use of the fertilizer input could be an important direction for change. This also requires education of the farmers through the extension agencies.

Thus if the process of technological change is to continue to produce increased output, this endogenous phase has to be continually sustained by diffusion of the later-released hybrids and education of the farmers to the use of the adequate amount of fertilizer for each strain.

Our findings therefore emphasize the continuity of the process of technological change. This continuity is sometimes ignored because it is often implicit and endogenous. Our study shows the importance of this endogenous phase as an on-going process. Exogenous change in the form of a breakthrough occurs only occasionally, but the endogenous phase of technological change proceeds continuously. It therefore implicitly provides the climate for the reception and adoption of exogenous change. Consequently, the endogenous phase of modern technology assures us that the potential for increasing production through technological change is always with us.

APPENDIX I

SAMPLE DESIGN

The choice of our area was prompted by our initial research on historical evidence of traditional rice technology. In our interest to find a working model of productively efficient farmers who could be 'leaders' in the diffusion of the new strategy, our choice fell on Coimbatore for two reasons:

(i) in our analysis of historical evidence, the Coimbatore farmer presents traditional technology at its best and though for lack of adequate data his efficiency in the nineteenth century cannot be measured, he could be termed efficient on the basis of existing data as compared to his peers in other districts.

(ii) The fact that growth rates of rice productivity are significantly low in Coimbatore as compared to other districts, could suggest that technology was at a high level in the nineteenth century.

Since we are primarily interested in technological change in rice cultivation, it was essential to select an area in which rice was the predominant crop. Having selected Coimbatore district as the primary strata, two factors prompted the choice of Erode taluk as secondary strata.

(i) Erode is the only taluk in the whole district that grows three crops of rice per year;

(ii) the percentage of paddy to the total irrigated area is highest in this taluk.

Within Erode taluk, it was decided to select a homogenous tract with minimum constraints for rice cultivation. One of the major constraints that had to be eliminated was inadequate irrigational facilities - a major impediment to the spread of the new rice hybrids. To ensure therefore, an unbiassed evaluation of technological change, we have purposely selected a canal-irrigated tract, supplied with irrigation facilities for ten and a half months annually from the river Cauvery through the Kalingarayan channel.

From this homogenous tract comprising 3 panchayat unions of 13 villages, 6 villages were selected on the basis of proportional representation of the paddy acreage in each panchayat union. In each village, 30 farmers were selected by random sampling and data were collected by personal interview with the sample farmers. The collection of data related to farmer's particulars and family structure, nature and extent of adoption of the modern package of inputs and sources of information, and highly disaggregated input-output data at farm level.

APPENDIX II

QUESTIONNAIRE

Changing Agricultural Technology in Tamil Nadu

(A Study of Paddy cultivation in Erode Taluk)

SR. Merlyn D'Sa

Code: V..... G..... H......

Name of farmer:

Address:

1. Family Structure:

S.No.	Name	M/F	Age	Education	Occupation
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					

2. Size of holding: (Acres)

S.No.	Particulars	Wet	Garden	Dry	Total
1.	Area owned				
2.	Area leased in				
3.	Area leased out				
4.	Net available area				
5.	Nature of lease		Cash	/ Kind	

Experience in farming Years

3. Source of Irrigation:

S. No.	Type	J	A	S	O	N	D	J	F	M	A	M	J
1.	Canal												
2.	Wells												

4. Farm Equipment

S. No.	Name	Number	Owned	Year of purchase	Value	Hired	Hire charge
1.	Country plough						
2.	Iron plough						
3.	Ridge plough						
4.	Trampler/Puddler/ Burmese settun						
5.	Levelling Board						
6.	Bund former						
7.	Mammutty						
8.	Crowbar						
9.	Handhoes/Rotary weeder						
10.	Sickles/Bill hooks						
11.	Tractors						
12.	Cultivators/disc/ Cage wheel						
13.	Sprayers						
14.	Dusters						
15.	Electric motors/ pumpsets						
16.	Storage Equipments						
17.	Mechanical Thresher/ Winnower/Drier						
18.	Miscellaneous (specify)						

5. Livestock:

S.No.	Type	No.of owned	Value per pair	Hired	Hire charge per full team
1.	Working bullocks				
2.	Working buffaloes				
3.	Working cows				

6. Farm Buildings:

S.No.	Details	No.	Value	Total amount
1.	Farm house			
2.	Godown			
3.	Cattle shed			
4.	Pump house			
5.	Threshing floor			
6.	Others			

7. Cropping Pattern:

Year	I Season			II Season			III Season		
	Crop	Variety	Area	Crop	Variety	Area	Crop	Variety	Area
1973-74 Reasons for such a pattern									
1972-73 Reasons									

8. Crop Rotations:

What is the usual rotation you follow after paddy on same land?

S.No.	Crop	Duration (month or year)	S.No.	Crop	Duration (month or year)
1.					
2.					
3.					
4.					

Reasons for this rotation:

9. Extent of Adoption of these Improved Practices:

Name / Variety Season

a) Soil Analysis Yes What type No

b) Improved Seeds

S. No.	Quantity used	Area sown	Per Acre Seed Rate		Reasons for deviation
			Adopted	Recommended	

c) Seed Treatment, Method of Sowing:

S. No.	Type of Treatment	Method of sowing	Spacing in transplanting		Age of seedlings		Reasons for deviation
			Adopted.	Recommended	Adopted	Recommended	

d) Preparation of Nursery and Main field:

S.No.	In Nursery	Adopted	Recommended	Reasons for deviation
1.	Proportion to Mainfield			
2.	Raised bed/level			
3.	Plant protection			
4.	Manures			
5.	Fertilizers			
	Main field			
1.	No. of ploughings			
2.	Field lay-out			

e) Manures and Fertilizers:

S.No.	Name of manure/ fertilizer	Dosage		Reasons for deviation
		Adopted	Recom-mended	

f) Time and Method of Application:

S. No.	Type of Fertili-zers	Method of Appli-cation		Time of Appli-cation		Reasons for devia-tion
		Adopted	Recom-mended	Adopted	Recom-mended	

g) Plant Protection Measures:

S. No.	Type of Plant protection measures	No.of sprayings		Time of Appli-cation		Reasons for deviation
		Adopted	Recom-mended	Adopted	Recom-mended	

9. Extent of Adoption of these Improved Practices:

Name / Variety Season

a) Soil Analysis Yes What type No

b) Improved Seeds

S. No.	Quantity used	Area sown	Per Acre Seed Rate		Reasons for deviation
			Adopted	Recommended	

c) Seed Treatment, Method of Sowing:

S. No.	Type of Treatment	Method of sowing	Spacing in transplanting		Age of seedlings		Reasons for deviation
			Adop-ted.	Recom-mended	Adop-ted	Recom-mended	

d) Preparation of Nursery and Main field:

S.No. In Nursery	Adopted	Recommended	Reasons for deviation
1. Proportion to Mainfield			
2. Raised bed/level			
3. Plant protection			
4. Manures			
5. Fertilizers			
Main field			
1. No. of ploughings			
2. Field lay-out			

e) Manures and Fertilizers:

S.No.	Name of manure/ fertilizer	Dosage		Reasons for deviation
		Adopted	Recom-mended	

f) Time and Method of Application:

S. No.	Type of Fertili-zers	Method of Appli-cation		Time of Appli-cation		Reasons for devia-tion
		Adopted	Recom-mended	Adopted	Recom-mended	

g) Plant Protection Measures:

S. No.	Type of Plant protection measures	No.of sprayings		Time of Appli-cation		Reasons for deviation
		Adopted	Recom-mended	Adopted	Recom-mended	

9. Extent of Adoption of these Improved Practices:

Name / Variety Season

a) Soil analysis Yes What type No

b) Improved Seeds

S. No.	Quantity used	Area sown	Per Acre Seed Rate		Reasons for deviation
			Adopted	Recommended	

c) Seed Treatment, Method of Sowing:

S. No.	Type of Treatment	Method of sowing	Spacing in transplanting		Age of seedlings		Reasons for deviation
			Adopted	Recommended	Adopted	Recommended	

d) Preparation of Nursery and Main field:

S.No. In Nursery	Adopted	Recommended	Reasons for deviation
1. Proportion to Mainfield			
2. Raised bed/level			
3. Plant protection			
4. Manures			
5. Fertilizers			
Main field			
1. No. of ploughings			
2. Field lay-out			

e) Manures and Fertilizers:

S.No.	Name of manure/ fertilizer	Dosage		Reasons for deviation
		Adopted	Recommended	

f) Time and Method of Application:

S. No.	Type of Fertilizers	Method of Application		Time of Application		Reasons for Deviation
		Adopted	Recommended	Adopted	Recommended	

g) Plant Protection Measures:

S. No.	Type of Plant protection measures	No.of sprayings		Time of Application		Reasons for deviation
		Adopted	Recommended	Adopted	Recommended	

h) Improved Implements:

S. No.	Implement	Type of operation	No. of Operations		Reasons for deviation
			Adopted	Recommended	

i) Source of Inputs:

S. No.	Particulars	Own	Private sources	Co-op. Society	Govt.	Total cost
1.	Purchase of seeds					
2.	Purchase of manures					
3.	Purchase of fertilizers					
4.	Purchase of Implements					
5.	Purchase of Pesticides					
6.	Others (Specify)					

10.A. Attitude/Opinion on New Technology:

S. No.	Item	Year of adoption	Source of learning					Opinion on New ~~features~~ technology			
			News Papers	Radio	Mag.	Neigh.	Ext.	Convinced	Not Con.	Satis.	Not satis.
1.	Improved seeds										
2.	Fertilizer										
3.	Plant protection										
4.	Implements										
5.	Improved cultivation practices										

B. Non-Adoption:

S. No.	Item	Reasons for non-adoption						Willingness to adopt if obstacles are removed
		No knowledge	Not convinced	High cost	Not avail.	No money	Not suitable	
1.	Improved seed							
2.	Fertilizer							
3.	Plant protection							
4.	Implements							
5.	Improved practices							

Supplementary Questions:

1. Do you prepare FYM or Compost?

2. Do you use all cattle dung for paddy field?

3. Do you get required quantity of fertilizer on time?

4. In the absence of the desired quantity of fertilizer what strains would you cultivate?

   I Season   II Season   III Season

5. Which variety do you consider as the most efficient in the use of fertilizer and plant protection measures?

Cost of cultivation of Rice   Variety:

Wage per man   Woman   Child   pair   per acre

S.No.	Particulars	No.	Labour days											Materials used			Remarks
			Pairs		Men			Women			Children			Quantity	Unit cost	Total cost	
			Hired	Owned	FL	PL	CL	FL	PL	CL	FL	PL	CL				
1.	Preparatory cultivation																
	a. Ploughing with iron plough																
	b. Ploughing with country plough																
	c. Levelling																
	d. Thinning and rectification of bunds																
2.	Manures and Manuring																
	a. Green manures																
	b. FYM or Compost																
	c. Carting, transporting and spreading																
	d. Fertilizers																
	Amm. Sulphate																
	Urea																
	Amm. phosphate																
	Super phosphate																
	Muriate of potash																
	Others: 1.																
	2.																
	Application charges																

S.No. Particulars	No.	Labour days											Materials used			Remarks
		Pairs		Men			Women			Children			Quantity	Unit cost	Total cost	
		Hired	Owned	FL	PL	CL	FL	PL	CL	FL	PL	CL				
3. Raising Nursery seeds																
Cost of raising nursery																
4. Pulling cut seedling and transplanting																
5. Interculture																
a. Hand weeding																
b. Rotary weeding																
c. Roguing																
d. Plugging bunds																
6. Plant protection																
a. Seed Treatment																
b. Spraying																
c. Dusting																
7. Irrigation charges																
a. Lifting																
b. Guiding																
c. Customary wage																
d. Water rate																
8. Harvesting and Threshing																
a. Harvesting																
b. Transporting																
c. Threshing & cleaning																
d. Processing																
Total				Yield grain straw			Per acre unit value						Total yield		Total value	

Cost of cultivation of Rice

Variety:

Wage per man   Woman   Child   pair   per acre

S.No. Particulars	No.	Labour days											Materials used			Remarks
		Pairs		Men			Women			Children			Quantity	Unit cost	Total cost	
		Hired	Owned	FL	PL	CL	FL	PL	CL	FL	PL	CL				
1. Preparatory cultivation																
a. Ploughing with iron plough																
b. Ploughing with country plough																
c. Levelling																
d. Thinning and rectification of bunds																
2. Manures and Manuring																
a. Green manures																
b. FYM or Compost																
c. Carting, transporting and spreading																
d. Fertilizers																
Amm. Sulphate																
Urea																
Amm. phosphate																
Super phosphate																
Muriate of potash																
Others: 1.																
2.																
Application charges																

S.No. Particulars	No.	Labour days											Materials used			Remarks
		Pairs		Men			Women			Children			Quantity	Unit cost	Total cost	
		Hired	Owned	FL	PL	CL	FL	PL	CL	FL	PL	CL				
3. Raising Nursery seeds																
Cost of raising nursery																
4. Pulling out seedling and transplanting																
5. Interculture																
a. Hand weeding																
b. Rotary weeding																
c. Roguing																
d. Plugging bunds																
6. Plant protection																
a. Seed Treatment																
b. Spraying																
c. Dusting																
7. Irrigation charges																
a. Lifting																
b. Guiding																
c. Customary wage																
d. Water rate																
8. Harvesting and Threshing																
a. Harvesting																
b. Transporting																
c. Threshing & cleaning																
d. Processing																
Total				Yield grain straw			Per acre unit value						Total yield		Total value	

Cost of cultivation of Rice   Variety:

Wage per man   Woman   Child   pair   per acre

S.No. Particulars	No.	Labour days											Materials used			Remarks
		Pairs		Men			Women			Children			Quantity	Unit cost	Total cost	
		Hired	Owned	FL	PL	CL	FL	PL	CL	FL	PL	CL				
1. Preparatory cultivation																
a. Ploughing with iron plough																
b. Ploughing with country plough																
c. Levelling																
d. Thinning and rectification of bunds																
2. Manures and Manuring																
a. Green manures																
b. FYM or Compost																
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Amm. Sulphate																
Urea																
Amm. phosphate																
Super phosphate																
Muriate of potash																
Others: 1.																
2.																
Application charges																

S.No. Particulars	No.	Labour days												Materials used			Remarks
		Pairs		Men			Women			Children							
		Hired	Owned	FL	PL	CL	FL	PL	CL	FL	PL	CL	Quantity	Unit cost	Total cost		
3. Raising Nursery seeds																	
Cost of raising nursery																	
4. Pulling out seedling and transplanting																	
5. Interculture																	
a. Hand weeding																	
b. Rotary weeding																	
c. Roguing																	
d. Plugging bunds																	
6. Plant protection																	
a. Seed Treatment																	
b. Spraying																	
c. Dusting																	
7. Irrigation charges																	
a. Lifting																	
b. Guiding																	
c. Customary wage																	
d. Water rate																	
8. Harvesting and Threshing																	
a. Harvesting																	
b. Transporting																	
c. Threshing & cleaning																	
d. Processing																	
Total				Yield grain straw			Per acre unit value						Total yield		Total value		

APPENDIX III

PROCEDURE FOR CONSTRUCTION OF INDEX OF ADOPTION

The major farm inputs and practices were considered in the construction of the index. A weighted index is used giving greater importance to inputs like hybrid seed, chemical fertilizers and cultural operations. For each of the inputs and practices, weights are assigned on the basis of proportion to the recommended use indicated by the extension agencies for each variety. This reflects both the intensity of use of the package of inputs as well as the efficiency of the farmer. In the case of excessive use of particular inputs, mostly in the case of chemical fertilizers, less than full scores were assigned to the respective farmers.

The weights assigned are as follows:

Components	Weight Assigned	Total
1. Improved seed		
Less than 30 per cent	5	
30 to 60 per cent	7	
60 to 90 per cent	9	
Recommended amount	10	10
2. Seed Treatment		5

Components	Weight Assigned	Total
3. Recommended number of ploughings		5
4. Use of compost and farmyard manure		5
5. Chemical fertilizers		
Less than 20 per cent	5	
20 to 50 per cent	8	
50 to 75 per cent	12	
Recommended dosage	15	
6. Intercultural operations (seed bed preparation and care, time and manner of transplanting, interculturing, etc.)		
Less than 20 per cent	5	
20 to 50 per cent	8	
50 to 75 per cent	12	
75 per cent and above	15	15
7. Improved implements		10
8. Rotation of crops		10
9. Use of green manure		5
10. Soil Analysis		5
11. Pesticides and plant protection		15
	Total	100

Under roation of crops was considered also the practice of changing different plots between turmeric, sugarcane, paddy and banana or on smaller acreages the rotation of different varieties of paddy or growing sesbania as green manure in the third season.

APPENDIX IV

LIST OF SOCIO-ECONOMIC CHARACTERISTICS AND THEIR MEASUREMENT

Characteristic	Measurement	
1. Age	Age of the farmer in years	
2. Education	Educational level of the farmer in years of schooling	
3. Subsidiary Occupation	Scores assigned as follows:	
	i) Professional occupations and village officials	5
	ii) Business	4
	iii) No subsidiary occupation	3
	iv) Artisans	2
	v) Non-farm labour	2
	vi) Farm labour	1
4. Family literacy	Percentage of literate adults and school-going children to non-literates in the family	
5. Family Schooling	Total years of schooling of the family members by number of members in the family excluding infants	
6. Size of Family	Scores assigned as follows:	
	i) Joint Family	5
	ii) Two generations	3
	iii) Nuclear Family	2
7. Farmer's Position in the family	Head of family	5
	Son	3
	Grandson	2

Characteristic	Measurement	
8. Farming Experience	Number of years experience in agriculture	
9. Experience with Hybrids	Number of years using high-yielding varieties	
10. Owned land	Amount of irrigated land owned in acres	
11. Size of farm	Area under rice in acres	
12. Tenancy	Percentage of farm under tenancy	
13. Fragmentation	Number of plots per acre of farm	
14. Farm Assets	These include farm houses, equipment, livestock in value terms (Rupees)	
15. Sources of Information	i) Extension officials	5
	ii) From neighbours	3
	iii) Radio and newspapers	2
16. Sources of inputs	i) Government sources and cooperatives	5
	ii) Private sources and black marketeers	3
	iii) Own supply	2
17. Contact with Town	i) Residence in Town	5
	ii) Twice a week	3
	iii) Once a fortnight	2
	iv) On rare occasions	1

Characteristics	Measurement	
18. Extension Contact	i) No contact with the VLW but aware of extension services	1
	ii) Has met the VLW:	
	1-2 times a year	1
	3-4 times	3
	5-7 times	6
	8 and more times	10
	iii) Contact with other extension officials	2
	iv) Had a demonstration on his farm or witnessed one	2

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