STUDIES OF SUPPLY RESPONSES IN INDIAN AGRICULTURE: SOME MODELS FOR PLANNING RATIONAL FOOD SUPPLY

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PREFACE

This thesis is about foodgrain supply responses in India. In view of the importance of regional level development of agriculture, the study is conducted at a very disaggregate level and for the southern state of Andhra Pradesh which covers some very dry districts of the country. The work emphasises the need for efficient resource use and increased market orientation in agriculture in keeping with the current economic outlook in the country. Supply decision in agriculture is examined in terms of its elementary components constituting land utilisation, acreage responses and yield rate determination. The impacts of technology and price incentive on supply are the focus. In addition to the disaggregate level study in the thesis, an all India level study is also conducted and presented in the Appendix (C) of the thesis. This work models the supply responses of the two main cereal crops of the country taking into account the role of government policy and the interrelations in the foodgrain market.

I had started this work while associated with a Planning Commission project 'Regional Analysis of Agriculture' at the Indian Statistical Institute. I sincerely thank my supervisor Dr. K.C.Majumdar (formerly of Planning Commission and Indian Statistical Institute) for his patience and support. While at I.S.I., Calcutta, I had useful suggestions and help from Dr. N.Chattopadhyay, Ms. A.Dhar, Dr. Bimal.Roy and Sri. Buddhadeb Ghosh. Words can scarcely express my deep gratitude towards Prof. N.S.S. Narayana and Prof. Dipankor Coondoo of Indian Statistical Institute, Bangalore and Calcutta respectively. This work would have lost its course mid way without their help. I sincerely acknowledge the guidance and support I got from Prof. Narayana for the entire empirical work presented in this thesis while I worked at I.S.I., Bangalore. I thank Prof D. Coondoo for his expert advice and support which I readily received whenever in difficulty with any theoretical or empirical issue in the work. In addition, I had the fortune of getting his comments on the write up . I also thank the anonymous referees for their comments and suggestions towards a more complete study of supply responses. I am indebted to the Indian

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1. INTRODUCTION

1.1. INTRODUCTION

This thesis deals with food supply in a less developed country.

In a world where social awareness together with technical progress is offering advances in all spheres of life, the persisting presence of hunger and malnutrition in any corner of the earth casts a shadow on all human achievements. It is said that over 800 million human beings in this world are suffering from hunger and a great majority of them live in Asia. Food problem has many dimensions (Timmer et al, 1983), but the solution lies mostly in adequate supply of foodgrains and proper distribution of the same. Any shortfall in food supply in a low income country has profound impact on the economy and is borne mostly by the poorer people through drastic reduction in their intake of basic nutrients (Ahmed and Mellor, 1988). In a free economic regime, foodgrain supply can come from both domestic and global sources, and imports/exports take place according to comparative advantage. In most countries, however, foodgrain trade has been largely regulated until recently and the emphasis is on domestic food sufficiency. Imports are resorted to when felt absolutely essential and exports are viewed as possible threat to internal food security. Moreover, in large and essentially agricultural countries, agriculture is usually the leading source of employment and a policy which favours uncontrolled import of foodgrains is viewed as a possible threat to the people's entitlement to a livelihood. Above all, globalisation can mean subjecting food security to the unpredictabilities of the world grain market and the production conditions of a few major exporters. Buffer stocks (and not just foreign exchange) are usually held by developing countries to bridge years of abundance with those of shortage. Export orientation of agriculture is considered appropriate only when the subsistence agriculture transforms into a market oriented one at the farm level. In spite of apprehensions toward free trade in foodgrains, globalisation has started off since the WTO agreement (1995). There are divergences in view point, but for a country with reasonable potential for agricultural production, a developed and productive agriculture is essential anyway, for meeting domestic requirements as also exports when the global market is favourable.

In the decades following 1960, the supply of foodgrains in the world as well as in the less developed countries grew under the impact of the green revolution. However, the rate of growth in the case of less developed countries as a whole was only marginally higher than the growth rate of population (Paulino,1988). Many developing countries turned into grain importers while some others, through successful use of technology supported by land reforms and price policies, managed to maintain self sufficiency.[1] The concept of self sufficiency however has more to do with market conditions than food security of the people. Essentially, it implies equality of demand and supply at given income levels and at acceptable price levels. Income levels and thereby the purchasing power in most of the LDCs are low and self sufficiency has not always meant food security in the sense of adequate nutrition for one and all.[2] Economic development which raises income levels can cause rapid increases in food demand. In the coming years *the green revolution, now at the verge of a saturation, will possibly have little to offer even in countries that have achieved self sufficiency.* Population in many of these LDCs continue to grow despite population policies. With this growth rate being only marginally less than that of foodgrain output, immense effort would be necessary to stay away from a Malthusian predicament or in any case, a helpless dependence on imports would be unavoidable towards the middle of the next century.

Most of the LDCs with growing population pressure are faced with an alarming increase in the man-land ratio. This puts the onus on land augmenting technologies to ensure the required growth in foodgrain output. However, intensive use of land and excessive application of inputs have already led to problems that raise doubts about the *sustainability* of the growth in the sector. Encroachment into forest covers and its environmental impact on agriculture, depletion of ground water reserves, drainage problem and land submersion, depletion of soil nutrients are some of the observed outcomes of agricultural development. Besides, the agrarian technology costs dearly in terms of subsidies and foreign exchange. Obviously, these represent sacrifice of other developmental projects and public investment which could lead to significant development in the agricultural sector in the long run. Thus, it is important that supply in agriculture must also grow in a way which will not compromise the same growth in future. Essentially, what is necessary is efficient use of inputs including land, to increase food supply.

Agriculture in LDCs are thus in a difficult cross road. On the one hand, it must respond to the growing need for domestic food security as also to the changes in world order. On the other, with a post green revolution era having set in, the response must be in a way that is sustainable in the future decades. Any agricultural development programme for an LDCs must therefore primarily focus on economic use of resources. Such a programme would surely depend on the understanding of how foodgrain supply is essentially determined and the factors to which it responds. We will first take up the second issue in 1.2. The process of supply determination is analysed in 1.3. In sections 1.4 and 1.5 we present an overview of Indian agriculture and discuss various issues relevant for the ensuing work. After reviewing the literature on supply responses in 1.6, we will lay down the objectives and the plan of the present thesis in 1.7.

1.2 FACTORS DETERMINING FOODGRAIN SUPPLY

Prices have been the central focus in most of the literature on foodgrain supply responses, whether empirical, theoretical or methodological. The long lag involved in agricultural production and the consequent importance of expectations in supply decisions have added to the interest shown towards the price variable in modelling exercises. Various models have been formulated to explain the expectation generation process and to model supply. These range from the simple Cobweb model to the informed predictions of the Rational Expectations model. The most popular of them is the Adaptive Expectations model with Partial Adjustment of supply which has been extensively used to model agricultural supply (Askari and Cummings, 1977). The Box-Jenkins method (Box and Jenkins, 1970), which essentially observes the stochastic process followed by the prices has also been applied in modelling agricultural supply in India and Kenya (Narayana and Parikh, 1981 and Narayana and Shah, 1984). Econometric methods of estimating these models also evolved simultaneously. The focus on prices as determinants of supply also had serious policy significance. In most mixed economies agricultural prices are administered through public policy encompassing a large number of operations like procurement, imports, stocking and public distribution of grains. Thus, when supply is price responsive, government policy can be used to influence prices and thereby encourage and guide the supply decisions in agriculture. There have been differences in opinion regarding farmers' responses to price incentives. Some social scientists and even several economists themselves were sceptical about a positive price response in the context of a subsistence agriculture. On the other hand, scholars like Schultz (1964) who were emphatic in contradicting the possibility of a non-responsive or a perversely responsive agriculture in LDCs. But it was recognised that the effect of price changes on supply can be small due to various restraints working in these economies. Markets in developing countries are particularly imperfect and farmers may be reluctant to risk their own subsistence needs and switch to other crops. In most LDCs facing population pressure, responses in supply can be limited by the inelasticity of available land and only technological progress can help. In the pre-green revolution days, when yield rates were more or less stagnant, acreage responses were often considered as a proxy to supply responses (Nerlove, 1958, Behrman, 1968). With technical progress, supply was expected to become more price responsive through greater use of modern inputs. Development of transport and marketing facility and other institutional measures which help the farmer to be more market oriented is likely to improve price response of crop supply and crop acreage. In fact, a high price response of supply can be taken as indicative of a progressive agriculture with less of institutional and infrastructural restraints. It is also of significance for a sound agricultural price policy. But in any case, the food sector is so large in most developing countries that the government has limited power to influence and maintain food prices at variance with the forces of demand and supply. The price policy also has several objectives which are at conflict with one another and farmers' incentive is just one of them. Budgetary limitations also constrain governments' ability to administer prices significantly. Thus too much emphasis on prices as determinant of foodgrain supply may be rather undue.

With the launch of the new agrarian technology, use of inputs, specifically fertiliser and irrigation has been the major source of growth in output. Supply responses to input use therefore deserve as much attention as price in planning agricultural development The governments of many LDCs played a dominant part in promoting input use through measures like public investment, subsidies and field level extension services. It is pointed out that non- price factors have been of greater relevance in increasing input use in agriculture in the last three decades (for example, Desai, 1988). Improvement of the infrastructural and institutional facilities coming through new irrigation projects, restoration and maintenance of existing irrigation sources, credit facilities, distribution networks for inputs, better power supply etc. have been more important than crop or input prices for the adoption of technology and the success of the green revolution. However, desirable technologies in agriculture need to be worked out since (i) inputs can have varying effects on different crops which differ in their biological requirements, (ii) there can be interactions among the inputs while determining supply and (iii) agricultural inputs are usually costly in terms of their impact on the budget, foreign exchange reserves and the eco-system..

Agricultural inputs are expected to have favourable effect on supply but the issue is not always simple due to the immense complexity involved in agricultural operations. Crops differ in their requirements and the effect of additional doses of an input depends on the nature of the crop and the input, the level of application of the same input as well as that of other associated inputs, weather and other aspects of agro-climatic situation. Agrarian inputs are often associated with some undesirable developments too. Irrigation is said to be the 'leading input for agricultural productivity in Asian countries' (Ishikawa, 1967). But the impact of irrigation on agriculture and rural life has not been above controversy . The *Favourable effects* of irrigation are well recognised: Irrigation increases the yield rates of crops, alters the cropping pattern in favour of high value crops, makes multiple cropping possible and stablilises output per hectare. But it is also important to be aware of the possible afflictions that arose from irrigated agriculture like (i) water-logging and salinisation in canal commands, (ii) lowering of the water table with rapid depletion of ground water, (iii) widening disparities between dry and irrigated tracts, between income classes of farmers and between regions endowed with irrigation facility and drier regions of the country, (iv) reappearance of malaria in irrigated country side and (v) adverse effect on deprived crops like pulses, oilseeds and coarse cereals. Above all, it is important to note that irrigation is hardly a homogeneous input and different sources of irrigation vary in their reliabilty, perenniality, adequacy and their favourable and unfavourable effects. Chemical fertiliser is the crucial input in the agrarian technology, but its effects and desirability has been much debated especially for its environmental implications. Besides, fertiliser is costly and requires huge imports and budgetary support. It is also sometimes alleged that intensive use of fertiliser impoverishes the soil by rapid depletion of nitrogen and is in the long run harmful for production.

The effectiveness of the fertiliser intensive technology is said to rest heavily on the irrigation status. In other words, the impact of each of the two main inputs is not independent of the other, and these complex interractions are of great importance in determining the supply responses to these inputs.

The possibility of a substitution or a complementarity relation occurring between the two inputs is of great relevance in view of the exhaustible nature of resources (Chopra,1985). Thus any study of supply responses of foodgrains to input use can be meaningful if it takes into account the *interactions among inputs.*

One of the most important determinants of foodgrain supply is weather. The vagaries of weather is often held responsible for the instability of supply. Weather related instability is said to increase with input use. But since weather is a factor beyond the contol of either policy makers or the farmers, the attention given to it has been limited in studies of supply responses. Yet, *the level and pattern of rainfall is of crucial importance in deciding the effectiveness of technology which is in the control of farmers.* Greater intensity of fertiliser use can increase production provided there is adequate moisture to help the absorption. Thus response to fertiliser depends on the availability of irrigation as well as on rainfall. Poor rainfall can lower the quality of irrigation in many cases but may be beneficial to high yielding cultivation when assured and controlled irrigation is possible. Thus rainfall can influence the effect of irrigation depending on the type of irrigation practised. For either input rainfall can act as a favourable associate input (or a complement) in certain circumstances but as a substitute in others, when too much rainfall has an adverse effect on the input productivity. Above all, in dry regions where irrigation is either not possible or is traditional such as from tanks, an appropriate technology must make full use of the scarce rain water available. Such a technology may also save other scarce inputs for which rain water can substitute. Thus weather conditions must surely be given appropriate importance when deciding the technology to be used.

Apart from technology, price and weather, there are innumerable other factors which influence foodgrain supply and these factors are often profound and not quantifiable. The soil and geographical can have significant bearing on decision and ultimate realisation of supply of various crops. Institutional factors like agrarian relations and farm size, credit, transport, input distribution, marketing and other services are all influences on supply. So are the infrastructure provided in the form of irrigation works, roads, power and even education and health facilities. Another factor of great importance embraces prevalent customs and cropping practices covering aspects like preferences for crops and food habits, crop rotations and manuring traditions, community actions in land improvement, drainage and maintenance of village water bodies and other such functions. It is most important to realise that all these factors can vary greatly among nations and among different regions of a large nation and their differences are likely to be reflected on the supply responses to inputs, prices and rainfall. An *aggregate level study of supply responses for a country characterised by agro-climatic diversity can say very little about the true responses which get hidden in the averaging process.*

1.3 COMPONENTS OF SUPPLY DECISIONS

Supply response is often represented by the response of overall production level (or acreage) of foodgrains or of individual foodgrain crops, mostly the dominant cereal rice or wheat, to the factors of interest (Behrman, 1968, Krishna, 1963 etc.). However, it is appreciated that output is a product of acreage and yield which are determined separately and, therefore, a decomposed analysis of foodgrain supply is more desirable . In fact, in pre-green revolution days it was common to use acreage response as a proxy to supply response considering yield as invariant and beyond the control of farmers. It was later recognised that yield was becoming the major source of growth. Also, the farmers did have control over yield rates through their decisions on input use. In fact there have been instances where input intensive cultivation compensated for reduction in acreage. Yield responses therefore deserve attention when studying the supply response in a progressive agriculture.

However the treatment of supply response as constituted of acreage and yield responses is also a simplified perception and does not really capture the entire process of supply determination in agriculture. Although acreage and yield rate of foodgrains have been considered as the main sources of growth in output, the latter having been more important in recent years, the very complexity of agricultural production process compels a deeper look into the elementary components of growth in agriculture. These sources essentially comprise components of supply decision taken by the farmers at large. Farmers' behaviour with respect to each of these components is important for the determination of supply which is ultimately the net result of these behaviours. In the words of Minhas and Vaidyanathan (1965)(also Vaidyanathan, 1994),

The principal elements of the decomposition scheme are so chosen that their contributions to output growth are determined by more or less independent sets of factors. Increase in gross sown *area, for instance, can be derived partly from extension of cultivation to new areas through reclamation of virgin lands or reduction of fallows and partly from increases in double cropped areas made possible by the spread of irrigation, adoption of better crop rotations and moisture conservation practices .... what happens to yield on the other hand depends entirely on the technological relation between inputs and output and the quantum of inputs (including fertiliser, water, seed and labour) used. Aside from availability of irrigation, shifts in crop pattern are a function of relative prices and profitability of crops.*

Thus we can view supply decision in agriculture as comprising the following stages of decision making:

(a) The primary input in agriculture is land. Given the availability of cultivable land the farmers decide how much land will be put under plough during the year;

(b) Given the seasonal nature of cultivation, the farmers also decide what crops will be grown in the different seasons and the number of crops to be grown in a sequence during the year. The intensity with which the land is sown along with the net sown area decided in (a) then determines the gross cropped area;

(c) Now, the gross cropped area consisting of different soil composition and irrigation facility can be sown with a variety of crops and in different seasons. The choice can be food versus non food crops and within the former, among the various foodgrains or other food crops like oil seeds and vegetables. Crops vary in their requirements and the choice of crop is constrained or influenced by soil climatic conditions, availability of irrigation, expected prices etc. The allocation of the total cropped acreage among different crops, or the cropping pattern is a determinant of the ultimate supplies of different grains (i.e., total supply as well as its composition) in the country;

(d) The acreage devoted to a crop is however not enough to determine its supply unless the yield rate is stagnant and known. After sowing a crop farmers use their own resources and the institutions and infrastructure created by the government to apply different inputs to the various crops, which combine with the weather factor to determine the yield levels per unit area of individual crops. Thus the total output that we observe at the national level is the outcome of several stages of decision making each with its own importance. At each stage certain variables are important and supply response is essentially the sum total of the responses to these variables at each stage.

The present work takes account of the above view of supply determination and addresses itself to *identifying the factors to which supply of foodgrains responds in India and the nature of these supply responses. Since the country is characterised by immense agro-climatic diversity, the supply responses need to be related to different regions. The study therefore is conducted at a disaggregate level to bring out the differing supply responses of foodgrains in India.*

1.4 INDIAN AGRICULTURE: PERFORMANCE AND POSSIBILITIES

India is a less developed economy which has shown commendable achievement in food production by adopting the new technology in the sixties.[3] India's large agriculture feeds the world's second largest population and is also the source of livelihood for 65% of the same population, a majority of whom is poor. Besides, agricultural development is essential for the broad based success of industrial development in India. Further, with WTO's conditions on trade liberalisation, India faces the prospect of emerging as a major grain exporter. An assured supply of foodgrains is essential if investment, industrial growth and a high standard of living are to be attained and sustained without giving rise to large imports, inflation and balance of payments problem (Vaidyanathan, 1995). The Government of India (GOI,1993) in its programme of economic reforms also acknowledged that 'broad based agricultural development is critical for raising general standard of living, alleviating food security, generating a buoyant market for expansion of industry and making a substantial contribution to national export effort.'

In the last three decades, the agrarian technology and the price policy promoted by the government combined with the toils of millions of farmers to increase foodgrain production from 72 million tonnes in 1965-66 to 190 million tonnes in the mid nineties. Though population has been growing, the per capita net availability went up from 460 grams to 511 grams per day. Self sufficiency was achieved while the public distribution system was taking care of the food entitlements of the poor. There is ground for satisfaction in our past achievement in the food front as (a) imports became minimal, (b) physical access to food improved through better transportation system and higher per capita availability, (c) economic access to food also improved (Tyagi, 1990) and (d) wide spread famines did not occur. Although agriculture 'occupies the pride of place among the achievements of independent India', (Swaminathan, 1997 (a)) , the burning question today is whether a high growth rate in food production can be sustained in coming years to match the growth in population. India faces the following concerns relating to food security some of which are shared by many other LDCs as discussed so far:

(i) The trend growth rate of output so far has been around *2.6% a year* which is somewhat higher than the population growth rate in India. But this is significantly *less than the target growth rate of 4% visualised in the plans.* There is also no tendency for the growth rate to pick up. While the growth achieved has so far been able to reduce imports and even generate exports in some years, it must be noted that (a) India's population is growing at about 2% per annum, and (b) increase in income in a low income country is likely to bring about significant increases in food demand. To meet the estimated demand of the next decade (projected 220 million tonnes in 2000 (Parikh,1991)) the growth rate must be well over this 2.6%[4]. The productivity of Indian agriculture is still quite low compared to international standards [5].

(ii) Although the agrarian technology practised in India served well in preventing food crisis, the *sustainability of the development* has become an extremely important issue. The growing population has been exerting its pressure on land resources and its onslaught on forest resources poses a danger to agricultural development in future by increasing soil erosion and silting of irrigation sources. Farming on tank beds have disturbed a traditional mode of irrigation which had many ecological advantages (Reddy et al,1993). Such undesirable effects in the face of an inelastic supply of arable land can be avoided by full utilization of whatever land is available for cultivation and by land augmenting technologies. Irrigation has raised productivity but created many new problems mostly arisisng from water management and drainage related issues (see 1.5.1). Fertiliser is an expensive input in India but its distribution has been very uneven among crops and regions. Moreover there is now a scepticism that more of fertiliser has been used relative to the gains achieved (see 1.5.3). Chemical fertilisers are environmentally harmful and their application must take into account the external costs involved. Intensive and excessive use of irrigation and fertiliser have depleted the soil of valuable micronutrients that get reflected in the plants grown

(Swaminathan, 1997 (b)). The input intensive techniques of farming now call for review if agricultural growth is to be sustainable.

(iii) The *growing burden of subsidies* is another problem of Indian agricultural development related to its sustainability. Subsidies on fertiliser and irrigation are both patent and latent in India and the enormous pressure on the budget is a hindrance to the overall development plan for the country and is possibly even responsible for the low investment flowing to agriculture. The subsidies are also said to be a cheap input policy encouraging inefficient use of inputs by hiding true costs of inputs. Thus while the subsidies help production in the short term, their adverse effect on investment, both public and private, can be harmful to agriculture in the long run. Removal of subsidies is an extremely difficult decision but economic use of inputs encouraged through other means can lessen the damage.

(iv) The price policies, which are meant to encourage agricultural production as also to protect the consumers' interests and build up buffer stocks have not prevented the *terms of trade from going against agriculture.* This occurrence has been blamed for the poor investment in the sector and possibly the modest growth in supply too.

(iv) Indian agricultural development has also seen the emergence of huge imbalances. There have been significant unevenness in growth performances among crops and regions. Wheat has recorded the fastest growth rate but rice has shown a less commendable performance. Since these two crops cornered a bulk of the scarce resources, other crops benefitted much less. Rice and wheat which together account for 36% of cropped area corner nearly 60% of both irrigated acreage and fertiliser consumed. About 83% of wheat area is under HYV, well ahead of 57% for rice. *The coarse cereals which were traditional crops in dry areas performed quite poorly.* These crops comprising jowar, ragi, maize, bajra and small millets have a weight of 15% in the index of agricultural production, their cultivation having fallen in the last decades, and their productivity being just about 43% of that of developing countries (Gupta, 1996) is highly unstable. Yet these crops are rich in nutrients and deserve the appelation 'nutritious grains' rather than 'coarse cereal' (Swaminathan, 1997 (a)). These grains also have an export market. Above all they can be raised on relatively infertile tracts with very little moisture and in hard conditions. *Cultivation of inferior cereals can be source of sustenance for the poor in many parts of the country.* While public operations in rice and wheat are imposing unmanagable burden on the budget, and imports of the same are also costly, cultivation of these cereals through fuller utilisation of land and water resources available can be a cheap source of food for the poor. Involving little distribution cost, they can be a source of food security at the regional level or the farm level. Moreover, being less demanding of inputs, their cultivation can improve the sustainability of the growth process.

Vast regional differences are a characteristic of our agricultural performance in India. The growth rate per annum between the early 60s and the early 80s ranged between 1% in Bihar to over 6% in Punjab. The imbalance is also a reflection of the differences in the states of technology, infrastructure and tenurial systems besides those in weather and geography. The variations are more marked at the district level with some districts posting absolute declines in output while others grew impressively. India is a large country with tremendous diversity in climatic and soil conditions, farming practices, customs, food habits, economic well being and infrastructural and institutional endowments. The agrarian technology which marked the green revolution in India failed to take account of the vast differences in agro-climatic conditions. Its success rested mostly on the performance of a few endowed regions only. The drier areas, which constitute bulk of the agricultural acreage in the country have mostly been the losers. These areas, if properly developed, may provide a large potential for future growth in India. The limited potential of the green revolution in assuring steady and sustained growth in Indian agriculture was recognised way back in the seventies and eighties. In the words of Rudra (1982).

"The most important factor that acts as a brake on the onward march of the green revolution is of course the constraint arising from the availability of water and .... investible resources. .... The green revolution cannot obviously be extensive .."

The time has come now to look for other sources of growth which can be sustainable in ensuring food security of the country. These sources lie in the intrinsic potential of the country's resources, a large part of which is not really tapped. There is now a need to look into the supply potentials of the limited land, water and other resources at the *regional* level and work out suitable cropping patterns and technologies for crops which take account of the local requirements and conditions also. An understanding of the process of supply determination and the supply responses of superior as well as coarse cereals at the regional level can help in drawing up rational price policies and encouraging efficient use of inputs. Land utilisation is the the most basic source of agricultural growth and is possible through increases in net sown area and cropping intensity. There is limited scope for the former course, but avoidance of land wastage may be possible. It is useful to find out if variations in the extent of land use are caused by factors amenable to policy. Multiplecropping, pulling up the cropping intensity of land, mostly depends on the availability of moisture. This is a very important potential source of growth as the cropping intensity is as yet very low in many regions of the country. That is, land is left fallow and wasted for most part of the year. Foodgrain acreage particularly the acreages under the coarse cereals have been declining in India. While diversification towards commercial crops or other uses are often the reason, wastage of land due to lack of resources and water is sometimes responsible and in any case, the tendency can have unfavourable implications on food security. To encourage cultivation of foodgrains in general and specific cereals like coarse grains in particular in different regions, responses of their acreages to relative prices (based on possible substitutability among the crops), and other factors need to be examined. Finally, the yield rate can yet be a potent source of growth. The green revolution saw remarkable increase in yield rates providing the main impetus to agricultural growth, but as noted, the revolution was only confined to some regions and for some crops. *There is now opportunity of spreading a revolution across the lagging regions and the neglected crops through proper use of technology consistent with the requirements of the crops, conditions of the regions, needs of the people and limitation and cost of resources.* A regional level programme that pays adequate heed to every aspect of supply decision and to the limitations and long term costs of resources can help in paving the way towards food security and sustainable growth.

1.5 FACTORS OF SUPPLY DETERMINATION: THE INDIAN SCENE

Our interest lies in three groups of factors that are expected to influence foodgrain supply. These are (i) profitability or incentive, (ii) technology, and (iii) weather. The explanatory variables for supply response may be price, capturing economic incentive, irrigation and fertiliser, capturing technology and seasonal rainfall capturing the weather. However, other agro-climatic factors including cropping practices and institutional facilities (though not considered explicitly) are expected to influence the responses to the above variables and their effects are likely to show up in the differing regional responses. We will now briefly review the nature and importance of the variables mentioned above in the Indian context focusing on the role of policy and the contradictions they have thrown up in the course of time.

1.5.1 Irrigation

Agriculture in India has traditionally been a victim to the vagaries of monsoon. Moreover, while some parts of the country have high rainfall as well as perennial river basins, many others are arid or chronically drought prone. People have, through the centuries, attempted to hold rain water in tanks and ponds, utilised the ground water infiltration through wells and surface water through canals and resorted to other water conservation and irrigation methods. Since independence and particularly since the high yielding technology was adopted, the Government of India invested large sums amounting to about 40% of the public investment on agriculture and rural development, and also extended credit through the cooperative societies and land development banks for the build up of a modern irrigation system.. The irrigation potential thus developed was 83.4 million hectares in 1992 against the ultimate potential of 113 million. Irrigated acreage reached 60 million hectares in 1989-90, which was double the same in 1965-66. Associated with irrigation the command area development programmes, water conservation measures taken in drier regions and flood control and drainage in areas having heavy rainfall and extensive irrigation.

The national plan documents present irrigation statistics as irrigable (POTENTIAL) and irrigated ((UTILISED) gross area which are classified according to major and medium schemes with command area exceeding 2000 hectares and minor schemes . The first two plans laid emphasis on major and medium schemes but with the third plan and the advent of the new technology minor schemes especially tube wells gained importance. Major and medium schemes mostly comprise extensive forms of irrigation and are financed and operated by public authorities. Minor schemes are, on the contrary, mostly financed, owned and operated privately. Surface water sources are generally extensive in nature while wells constituting ground water irrigation are intensive. Extensive irrigation covers as large an area as possible, reaching out to dry lands and waste lands but distributional losses can be substantial. Intensive irrigation, on the other hand, maximises the output per unit of water by limiting the area covered while assuring it with adequate water preferably in all seasons. Whatever area is benefitted is likely to be fully utilised. However, unlike extensive sources, the benefit is restricted to a few with access to capital (development of a water market may increase the extent of the benefit).

There has been a continuous disagreement over the merits of ground water versus surface water irrigation. Ground water is often credited to be less expensive to the budget, more productive, especially for its effect on yield rates and cropping intensity, and ecologically safe (see Vaidyanathan,1994). But critics point out that the total expense on unsuccessful digging, capital and operational costs of electrification and diesel and the subsidies involved is not taken into account when making a judgement. The advantage of better timeliness provided by the tube well vis a vis canal is not intrinsic to the source but arises because control over water supply from canal is not vested with the individual farmer . In any case, it is not quite clear that canals backed by storage works are any less productive than ground water sources as pointed out by Dhawan (1993, pp113). The ecological hazards[6] of land submergence and water logging created by large scale irrigation projects have been criticised by environmentalists. The emphasis placed on ground water (which now accounts for half the irrigated area) through the past decades is found to have led to indiscriminate digging in many regions lowering the water table[7]. Incidentally, ground water reserves are much more limited than surface water in India (Dhawan,1993).

Irrigation also differs according to its level of dependence on rainfall or its reliability.[8] This aspect has often been of significance in empirical studies which tried to capture the quality of irrigation. Usually canals drawn from reservoir backed by dams and deep tube wells are considered as superior quality irrigation. Their supply is more or less assured even if rainfall in any one year fails and the supply is also perennial. Their presence help in planning cultivation and even in getting high yields in the dry season when cultivation would not otherwise be possible. On the other hand, tanks, bore wells and diversion canals from rivers or other water bodies serve in channelling, storing and distributing excess rain water run-offs and percolation but their performances depend entirely on the rainfall in the region. With the start of the new technology, investment flowed towards the modern assured irrigation sources while traditional modes were neglected and fell into disuse. However, it is now appreciated that the latter are also important particularly in dry areas and help in utilising rain water and in raising less demanding traditional crops. Attempts are now being made to restore the traditional sources rather than go for bigger and new projects.

1.5.2 Rainfall and Rainfed Cultivation

Although irrigation received the maximum attention in agricultural planning, it is dangerous not to appreciate the importance of rainfall and rainfed farming in India. Nearly 70% of the cropped area in the country is unirrigated, and the proportion is not likely to be less than 50% even if all irrigation potentials are realised. The unirrigated acreage contributes about 40% of the crop output of the country. Besides, irrigation planning can be of little value if the rainfall conditions are not taken into account. Even the modern irrigation methods depend on rainfall for recharge, though this rainfall can occur in a different region or at a different point of time. Where controlled and perennial irrigation is not possible due to geographical conditions and available infrastructure for traditional irrigation becomes important. Its impact depends largely on rainfall performance. The effect of technology on supply of foodgrains is found to vary significantly across regions depending on the rainfall patterns. Cropping patterns and technology need to be planned on the basis of rainfall performance of the region. For example, high rainfall in canal or tube well commands can deter high yielding technology which relies on controlled watering. An irrigation system with adequate drainage network may be useful where rainfall is high. In low or medium rainfall regions, emphasis must be on sources of irrigation that make efficient use of this natural water.

Where irrigation is not possible, the onus is on the suitable choice of crop variety and technology for attaining high yields with the given rainfall. The productivity differential between rainfed and irrigated areas vary widely in the country (e.g., 50% in Bihar and 280% in Maharashtra (Vaidyanathan, 1994)) and some districts with low levels of irrigation have shown growth rates of crop output exceeding national average (Bhalla and Alagh, 1979). It is important to note that rainfed agriculture is practised in two kinds of rainfall conditions: (i) Areas of high rainfall, above 750 mm such as in Eastern India, Maharashtra and coastal peninsula. Most of these regions have perennial river basins and alluvial geology supporting copious surface and ground water reserves. Irrigation is not pracised possibly due to the redundance of irrigation in kharif seasons; (ii) Areas with low rainfall constituting the arid, semi arid and desert lands. Bulk of this is found in the Deccan where low rainfall and rocky geology limit the scope of irrigation. A total of 90 districts, 26 of them in the south have been earmarked as drought prone. The two groups have different needs. Those under (i) call for a system to improve drainage and field level access to water while preventing water logging in low lying areas along with flood control and desilting programmes for river basins. The dry areas in (ii) require planning of suitable cropping patterns and technology and soil moisture conservation programmes including maintenance of traditional methods of rain water storage and distribution. The watershed development programme is an important measure to develop dry and hilly areas which can also help the surrounding areas.

1.5.3 Fertiliser

Fertiliser is said to have contributed 70% of the growth in productivity of Indian agriculture (Government of India, 1993). This is because the new technology involving HYV seeds are more responsive to nutrients than traditional ones. The government of India encouraged fertiliser consumption by (i)imports of fertiliser and its components, (ii) subsidising producers and farmers and (iv) promoting infrastructural and institutional facilities to improve distribution and credit facilities. As a result, consumption and intensity of fertiliser use increased impressively (from 11 lakh tonnes to 116 lakh tonnes and from 7 kilogram per hectare in 1965-66 to 70 kilogram per hectare in the early nineties). The diffusion of fertiliser use was also a response to the the spread of HYV area, development of controlled irrigation systems, field demonstrations to familiarise farmers with the technology and land reforms which provided incentives for input use. [9]

However, the use of fertiliser in Indian agriculture calls for careful reconsideration in view of the future food needs of the country, the diversity in Indian agriculture coupled with the imbalances created by past development, budgetary difficulties and sustainability of the development. Here we mention some of the contradictions facing the fertiliser based technology in India[10] :

(a) Although fertiliser consumption in Indian agriculture increased remarkably, the intensity of 70 kilograms per hectare still does not compare well with those of advanced nations and the global average of 87.3 kilograms. This has been of concern to many who advocate higher doses of fertiliser use for higher productivity.

(b) The benefit of fertiliser use has mostly gone to irrigated areas and some superior crops and have promoted the crop wise and regional imbalances in performance. Though lack of crop wise data on fertiliser use is a hindrance to studies in the field, survey data[11] available (NSSO 1970-71, NCAER surveys 1975-76 and 1988-89) showed that about 2/3 of the total fertiliser use went to irrigated farming (i.e., about 30% of total acreage only) and rice and wheat together accounted for 60% of the fertiliser consumption. This also underscores the untapped potential of fertilising dry/ unirrigated/ lightly irrigated areas as also areas which can grow coarse cereals.

(c) While the relatively low level of fertiliser use is of concern, it is also being pointed out that the contribution of fertiliser to production has been diminishing through the years. The incremental output has been consistently short of the expectation based on experimental field trials. This is curious in view of the diffusion of knowledge and experience of the technology, betterment of irrigation facility and of the nutrient balance in fertiliser. Apart from the possible effect of reaching out to rainfed and less endowed tracts, the above shortcoming highlights the inefficiency of fertiliser use. It is an indication that fertiliser consumption has been excessive relative to the gains. The policy of subsidies has been blamed for the inefficiency in fertiliser use and production as well.

The inefficiency of fertiliser use has been a subject of debate in the context of the structural reforms. Fertiliser consumption has an enormous cost in terms of subsidies and foreign exchange. Removal of subsidies has been considered dangerous for its possible effect on production and food prices and ultimately on food security and is in any case a difficult political decision. On the other hand many economists suggest that such a move will have little impact on the cost of production as more efficient use of fertiliser will be made than currently.

(d) Although factor-crop price ratio has been used as an explanatory factor in analysing the low fertiliser consumption in India in the tradition of neo-classical economics, a consistent inverse relation failed to emerge[12] possibly due to the domination of non price factors in determining its use. Efficient distribution, adequate infrastructure and timely credit are of more relevance as also the use of manures and biological wastes which are also sources of plant nutrients. The poor response of fertiliser consumption to its price and low yield elasticity (Parikh and Suryanarayana, 1992) may suggest that the effect of a subsidy reduction on production may not be significant especially if institutional facilities are strengthened. It is also suggested that the fall in fertiliser consumption may be compensated by increasing the investment on irrigation which has a low incremental capital output ratio and involves less of subsidy cost.

1.5.4 Prices and Price Policy

In India, government interferes in the food market by procuring foodgrains at pre-announced prices, by holding stocks to tide over years of shortfall and to stabilise prices, distributing grains at subsidised prices and importing grains when production falls short. There are two sides of the food policy. On the one hand it aims at protecting the interests of the consumers especially the urban poor and on the other it attempts to provide incentive to the farmers for production of foodgrains. The objects are conflicting and are politically sensitive too on both sides.

The food policy through its effect on prices of foodgrains can have profound impact on foodgrain production. In India, in spite of its market imperfections and constraints, farmers have been shown to be rational and responsive to prices . The government has taken measures such as tenancy reforms, institutional development for marketing, transport and dissemination of market information through the media to encourage farmers to behave in tune with the optimality rules of economics and respond to prices. Several studies have been undertaken to examine farmers' price responses and most have agreed on a positive response. However, these studies are mostly at the national level (e.g., Narayana and Parikh, 1981) and since price policy is formulated by the central government the results are often used for policy making. But even at the regional level it is interesting to learn how far the farmers respond to economic incentives and how far they are led by customs, weather and institutional restraints. A positive price response at the regional level points to a progressive agriculture and successful institutional development across the country and some scope for policy to alter cropping patterns.

The price policy of the government mostly involved the superior cereals rice and wheat and neglected the coarse cereals as against the rice and wheat.[13] This discrimination against the nutritious and also hardy crops is undoubtedly reflected in the regional imbalance because three states Punjab, Haryana and Uttar Pradesh contribute the bulk of rice and wheat to public pools. . A policy to encourage cultivation of coarse cereals in dry regions will be facilitated if they too respond positively to prices.

1.6 LITERATURE ON SUPPLY RESPONSES

The growth and performance of Indian agriculture since the green revolution have been examined carefully by several scholars like Bharadwaj (1974), Rao (1975), Ray, Cummings and Herdt (1979), Rao(1992). Most of these studies being at the national level mask the tremendous differences that can arise among states and regions. In an exhaustive review of the performance of Indian agriculture since independence. (Vaidyanathan,1994) makes a detailed and very interesting analysis of all the components and factors of agricultural growth and emphasises further need for such studies embracing the different components of growth and preferably at disaggregate levels.

Decomposition of changes in foodgrain output have also been attempted - first by Minhas and Vaidyanathan (1965) followed by Bhalla and Alagh (1977), Dharm Narain (1977) and more recently by Ray (1983) and Bhalla and Tyagi (989). The analyses suggest that area expansion was as important as yield increases before the 1960s, but the latter became dominant in later years. Also changes in cropping patterns towards higher yielding and higher value crops and locational shifts of crop from low to high yield areas reinforced the rising tendency of average yield level and thereby production. At a more disaggregate level, studies conducted by Bhalla and Tyagi (1989), Minhas and Vaidyanathan (1965) and Bhalla and Alagh (1979) indicated marked variation with respect to growth rates of area and yield level and their contributions to output growth among districts and states. The yield factor was found significant only in high growth districts. Vaidyanathan and Mukherjee (1980, 1987) further analysed the trend growth at the regional level by considering the contributions of inputs and input productivities. All these studies are based on distinct points of time and not on trends on the variables concerned, but nevertheless they are useful in decomposing output changes into more basic components. Vaidyanathan (1994) suggested decomposing output growth into its principal components as an useful starting point for exploring factors responsible for regional and temporal divergences. These components are - extent of cultivated area and intensity of cultivation, together constituting the area cultivated, cropping pattern and yield levels of crops.

Models for agricultural supply responses often considered acreage as a proxy for the supply decision. The Nerlovian model of partial adjustment and adaptive expectations set a trend in empirical literature. Krishna' (1963) study of rice and wheat in Punjab, Krishna and Rao's (1967) study on Uttar Pradesh, Roy and Lahiri's (1985) study on rice in India, Sawant's (1978) study on several rice growing districts in India, Bliss and Stern's (1982) comprehensive study of Palanpur in Uttar Pradesh being some of them. At the international level too a large volume of work was done and we may mention the surveys of literature on farm supply responses made by Askari and Cummings (1976, 1977), Feder et al (1982). Empirical elaboration of Indian work is concisely provided by Narayana (1988) along with a review of theoretical and methodological issues and has been very useful for the present research.. Askari and Cummings tabulated the short run and long run elasticities obtained by different scholars using the Nerlovian model for a number of crops state wise and region wise. Further these authors used the price responses collected for different countries including India for identifying different factors that affect price responses. Cummings (1975) himself studied the supply behaviour of several crops in India at the state level and at the level of some important districts and obtained negative responses in many cases including some cases for rice. Most of the literature in supply responses is concerned predominantly with price responses. Many researchers however included other variables in the supply response functions . In a valuable work on some dry districts in India, Bapna et al (1984) estimated systems of equations for supply responses as well as input demand function incorporating explanatory variables like rain, road and market densities which are beyond the farmers' control. In a different approach Madhavan (1972) estimated acreage response of rice in Tamil Nadu as a result of optimisation where acreage allocation for a crop was not independent of decisions with respect to other competing crops. Another study which also assumed supply to be a consequence of profit maximisation was a case study of rice by Houghton (1986) where several functional forms were explored to obtain 'Price based' production functions. Majumdar et al (1988) also used an alternative approach to obtain indirect yield functions of major foodgrains in a region wise study of three states as a direct consequence of joint profit maximisation. Narayana and Parikh (1981) found unsatisfactory results when applying Nerlovian model to Indian data. They considered revenue rather than price as the economic incentive to which farmers responded and argued that expectations of price or revenue should account for the process of its movement over time and the occasional random shocks. Their study of 16 major crops in India using ARIMA process expectations in relative revenues of crops indicated positive responses at the individual level which might however turn negative at the aggregate level. Narayana and Shah (1984) also applied the ARIMA specification successfully in a study on Kenya. Most of the above studies were based on some maximisation behaviour. While such concepts of maximising behaviour, competitive markets and rationality accepted by economists were viewed with doubt by other social scientists (Lea et al, 1987,) several economists themselves were sceptical and many addressed the subject in a semi commercial framework. Bhaduri (1973) studied production decisions under share cropping with credit linkage between landlords and tenants which lead to suboptimal results. Rudra (1983) noticed farmers' satisfaction in consuming home grown food and claimed that rationality and profit motives are not the guiding force for farmers. Nowshirvani (1971), Srinivasan (1972), Binswanger (1978), Jodha (1978), Malathy (1985) and Mythili (1988) incorporated risk in their studies of production decisions though some of these attempts suffer from theoretical drawbacks (Just and Pope,1978). It is suggested that supply response may be negative under behaviours of risk aversion.

Narayana and Parikh (1981, 1987) took the following approach to farm supply response: (i) In the first stage they analysed the farmers' behaviour in allocating land to defferent crops based on relative revenues and technological factor; (ii) In the second stage they considered the farmers' decisions in different seed-water-irrigation and rainfall regimes to apply fertiliser so as to obtain the optimising yield rates. Apart from Narayana and Parikh's (1987) study of yield responses for major cereals in India, there are few estimates of yield response functions in India. Lack of cropwise data on fertiliser and multicollinearity problem of data have been the constraints. Narayana and Parikh used experimental data from Simple Fertiliser Trials (SFT) for estimating quadratic yield functions which were revised to obtain consistency with national level yield rates by using a scale factor and rainfall parameter for each crop. The estimates performed well when tested for their predictive ability. Majumdar et al (1988) studied yield rates of major cereals as derived from an optimisation exercise where the yield rates were estimated simultaneously for the competing crops. Some notable estimates of yield functions are provided by Desai and Patel (1983), Grewal and Rangi (1983) etc.

Finally, most studies have included weather as a variable in the supply response models. The response is held as an uncertain effect on supply. Roy and Lahiri's(1985) study was an attempt to model the response to rainfall (besides price) by considering an optimum rainfall implying that too much or too little of rainfall may be harmful for production. However the behaviour of rainfall can have significant influence on the impact of other inputs and deserve consideration. Besides rainfall is today not an altogether unknown and unpredictable element and weather forecasts using modern technology should be a useful guide to planting as also input decisions at various growing stages.

Another approach to study supply responses which takes into account different factors in the market including policy is provided by Rational Expectations models. Several factors such as income levels and public foodgrain policy measures act on both demand and supply sides of the market and can influence foodgrain prices profoundly. The Rational Expectations Hypothesis (REH) postulates that the farmers take account of current market information and the theory behind price determination when forming their expectations. This approach can be useful in an environment of changing policies but its applications in agriculture have been few. Goodwin and Sheffrin (1982) and Huntzinger (1979) studied the US broiler market and Aradhyula (1987) studied the wheat market in India. We have developed a model for rice and wheat markets for India using REH and presented the results in the Appendix to the thesis.

1.7 THIS THESIS

The present work concentrates on certain foodgrains only, namely the important cereal crops rice, jowar, ragi, maize and bajra and seeks to understand their supply behaviour in India. We have considered for our analysis the period following the launch of the high yielding technology in India and a vigorous intervention policy of the government in food market. This is because there is likely to be a structural change at that juncture. The high yielding wheat variety developed in Mexico was experimentally grown in India in 1963 and by 1966 was being commercially cultivated in irrigated areas. In the case of rice the breakthrough came from Taiwan with the identification of the dwarfing gene and the development of the variety IR-8 at IRRI in Phillipines. The new variety was released in India in 1965-66. The ICAR developed a hybrid variety of maze in 1961. In the same way, collecting strains from all over the world research yielded hybrid jowar in 1964 and bajra in 1965 both of which withstood the droughts of 1966 and 1967 better than older varieties. Thus by 1965-66, the high yielding varieties of all major cereals were introduced in India. Although the High Yielding Varieties Programmes was started with the Intensive Agricultural Development Programme (IADP) of 1961, the drought of 1965-66 provided the necessary will power to depart from past practices. The recommendations of the Jha Committee of 1964 also provided the foundations of a strong price policy.

Since supply responses are expected to vary with the varied regional conditions prevailing in India, we consider it desirable to conduct the study at a disaggregate level to get at the true picture. A district can be regarded as a fairly homogeneous unit, but since such a work for the country as a whole would be voluminous, we have first selected a state to analyze at the district level. The *southern state of Andhra Pradesh* is selected on certain considerations. The state is not one of the prime seats of green revolution except for certain areas such as in the Godavari basin. The state exhibits remarkable heterogeneity of soil-climatic-irrigation conditions and it is thus interesting to bring out the different supply response behaviours in the various districts of the state. The dominance of coarse cereals is also one aspect of relevance in choosing the state. [14] The neglect of the coarse cereals is of concern and and their responses also deserves scrutiny for coming years. The supply responses of the cereals are studied at the district level, building up the process of supply decision from the determination of the net sown area, the cropping intensity, the cereal crop acreages to the final yield rates of the cereal crops, all potential sources of output growth as discussed in section 1.3. Different explanatory variables are chosen in the light of theoretical considerations and past research, and stochastic disturbance terms take care of other unforeseen factors present in agricultural production. We have considered a sample period of 20 years following the green revolution covering 1965-66 to 1984-85 for which district level data are .continuously and consistently available at the time of analysis.

Two points are to be noted. First, an important crop, wheat, does not appear in the study as the crop is not grown in Andhra Pradesh at all. Second, it has been difficult to explicitly incorporate government actions in the food market in our district level study. Food policy is mostly formulated in New Delhi but implemented in the states. The import of food is a central government function, the procurement and stocking of grains in central pools (as well as state pools) and distribution therefrom by central government agency at fixed prices There is a lot of interstate movement of food both on public and private account on which reliable information is not available. All this makes a disaggregated study of the supply responses to macro factors of food policy rather difficult. The study conducted in this thesis is at best partial as it considers the supply side in isolation and overlooks demand and policy related factors on supply decisions. In the Appendix C at the end of the thesis (in Chapter 8), we have built up a model for the determination of supply based on Rational Expectations Hypothesis for the two main cereals rice and wheat. This study takes into account demand and supply as well as government interventions in rice and wheat market and the interrelations between the two to look for responses of supply to technology and policy variables.

In this thesis we probe the following questions: How do farmers decide what and how much foodgrains to produce? To what extent is production determined by natural rainfall and what extent by technology and farmers' decisions? Can extent of land use be influenced through technology ? How important is irrigation in promoting intensive cultivation of land? Is the quality of irrigation important and is development of perennial irrigation system the only path to intensive land use? To what extent do the different cereal crops lend themselves to multiplecropping? Do farmers in the different regions respond to incentives? Or, are the farmers constrained by past practices and customs? Do coarse cereals too respond to incentives or are the acreages determined only by weather condition? How do the farmers form expectations ? How do rainfall and technology interact to determine productivity? Can the technology make good use of the natural rainfall in any region? Given the rainfall and other natural conditions, are irrigation and fertiliser substitutable? Given the rainfall and other conditions are farmers applying too much or little of the inputs? Do the supply responses vary with agro-climatic conditions or are the responses similar? Is there any need for decentralised or regional level planning of agriculture?

Before going into the analytical part of the thesis and following this introduction, a brief review will be made of the agriculture in Andhra Pradesh in chapter 2. For facilitating the subsequent district level studies in Chapters 2, 3, 4, 5 and 6, we have clarified how the data is handled for analysis in Appendix B of the thesis. Chapters 3 and 4 study land utilisation in AP trying to explain the extent and intensity of cropping. Acreage responses of the 5 cereal crops are modelled and studied in Chapter 5 followed by a study of the yield responses in Chapter 6. Chapter 7 gives some broad conclusions drawn from the analysis of supply responses in Andhra Pradesh. A model is also built up at the national level foodgrains supply taking account of various market relations (based on Rational Expectations Hypothesis) and the results are presented in the Appendix A of the thesis.

Notes:

[1]A list 40 less developed countries have been listed by Paulino (1988) according to their degree of self sufficiency in foodgrains between the years 1976-80. Among these only 8 countries had attained self sufficiency.

[2]In fact self sufficiency in countries where the governments intervene in the market is usually implied when requirements for public distribution are met from domestic procurement and stocks. But, the consumption of the poorest section of the people can at the same time be far below the desired level.

[3] Table 1.1 gives some statistics on the technology practised and foodgrains cultivation in India.

Table 1.1 Foodgrain cultivation and Technology used:India

YEAR	Foodgrain Area (million Ha.)	Area under HYV (million Ha.)	Power Tillers (No.)	Tractors (No.)	Foodgrain Production
1	2	3	4	5	6
1970-71	124.9	15.4	1,457	33,404	108.4
1975-76	128.2	31.9	2,540	34,402	129.6
1980-81	126.7	43.1	2,125	70,007	150.4
1985-86	128.2	55.4	3,754	76,886	169.9
1988-89	127.7	60.11	4,798	110,323	168.4

Source: Indian Agriculture in Brief,1992.

[4]Swaminathan suggests an estimate of 300 million tonnes of foodgrains by the year 2050. This is based on a population projected at 1.4 to 1.5 billions (assuming our population policies go right).

[5]The agricultural sector engages 65% of the country's workforce but contributes little more than 30% of GDP and the per capita agricultural income at 1980-81 prices is Rs 1056 as of 1988-89 (FAO statistics, IAB,1992) compared to Rs 2099 for the whole economy. The yield rates of major crops are also low by international standards. Yield per hectare in kilogram is (i) 2635 for rice compared to 6168 in Japan and 3457 at the world level (ii) 2117 for wheat compared to 6348 in France and 2381 at the world level and (iii) 1606 for maize compared to 7023 in USA and 3627 at the world level. The cropping intensity at 1.3 is also lower than that achieved by China, Korea and Taiwan (Parikh, 1991).

[6]Other ecological dangers like the possibility of triggering seismic pressures also merit caution and investigation.

[7]Conjunctive use of well irrigation in canal commands is preferred on this count. In fact the presence of surface water irrigation is a source of recharge for the exhaustible ground water stock through seepage.

[8] Table 1.2 gives some statistics on irrigation and land use in India.

Table 1.2 Irrigation and Land Use for Agricultural production:India

Year	Surface Water Irrigated Area	Ground Water Irrigated Area	Net irrigated Area	Gross irrigated Area	Net Sown Area	Cropping Intensity	Value of Agricultural product (Rs cr.at 1970-71 prices)
1	2	3	4	5	6	7	8
1965-66	15,401	8,445	26,441	30,901	136,198	1.14	12,980
1970-71	17,054	11,834	31,292	38,194	140,784	1.18	17,531
1975-76	17,761	14,346	34,491	43,363	142,224	1.2	19,372.6
1980-81	18,470	17,734	38,805	49,875	140,299	1.23	20,752.1
1985-86	19,092	20,455	42,049	54,563	140,908	1.26	23,238.6

Notes: Area in '000 Hectares.

[9]Some statistics relating to fertiliser technology in India is presented in Table 1.3.

Table 1.3 Fertiliser Use and Policy :India

Year	Consumption	Intensity	Import	Subsidy	Price
1	2	3	4	5	6
1965-66	11	7	4.13	-	76.1
1970-71	22.7	13.6	6.29		100
1975-76	28.9	16.9	15.54	26,642	214.7
1980-81	55.2	31.8	27.62	60,536	242.7
1988-89	115.7	69.3	16	320,000	288.4

Notes: Consumption and imports are in lakh tonnes, Fertiliser intensity is in kilogram per hectare, Subsidy on fertiliser in Rs lakhs, Price ia per quintal at 1970-71 prices.

Source: Fertiliser Statistics, India Data Base.

[10]The discussion is based mostly on Vaidyanathan's(1993) critical analysis of fertiliser application in India. Also see Bhide and Gulati (1992), Raju (1983).

[11] Survey data on fertiliser use is provided in Table 1.4.

Table 1.4 Crop wise Fertiliser use in India (NSSO and NCAER Survey data)

Data	Year	Rice	Wheat	Jowar	Maize	Bajra	TIR	TUR
1	2	3	4	5	6	7	8	9
%AREA FERTILISED	1	37	44	6	21	8	65	11
	2	44	55	18	35	14	67	19
	3	79	93	66	84	55	87	51
FERTILISER INTENSITY (KG/HA.)	1	42	54	37	49	44	44	-
	2	79	75	54	44	35	86	85
	3	108	128	59	69	48	121	69
% SHARE IN TOTAL	1	-	-	-	-	-	-	-
	2	36.6	22.8	2.8	2	0.9	85.3	14.7
	3	31.8	26.6	3	2.2	1.8	68.8	31.2

Notes: TIR = Total irrigated area, TUR = Total unirrigated area, Years 1 = 1970-71 from NSSO, 2 = 1975-76 from NCAER, 3 = 1988-89 from NCAER. A blank is left where figures are not available.

Source: NSSO,1978, Vaidyanathan, 1993.

[12]Similar attempt was made during course of the present work in trying to explain input use while working on the yield response functions. The study was not successful because fertiliser consumption showed no significant negative relation to its price/relative price with the data at hand.

[13]The Food Corporation of India (FCI) in charge of the foodgrain operation in India, does not procure coarse cereals since 1980-81 owing to the localised nature of their production and consumption and their perishability. The operations are in charge of NAFED which has very limited activity. The price policy has not been favourable to the producers of these grains. Procurement has been low and inefficient. Market prices often prevail below the minimum prices and lack of assured outlets and proper distribution is plaguing these grains. Possibly this preferential treatment towards rice and wheat and the consequent regional imbalance have resulted in a transfer of income from the backward regions to surplus regions, from poorer farmers to richer ones and from dry crops to those based on resource intensive and subsidised technology (Tyagi, 1990).

[14]Table 1.2 presents the importance of different foodgrain crops and the yield rates as compared with international standards.

Table 1.5 Importance of Foodgrain crops:India

CROP	Rice	Wheat	Jowar	Maize	Bajra	Pulses
1	2	3	4	5	6	7
% SHARE IN FOODGRAIN TOTAL						
Gross Area 1988-89 (Total=127.7mill. Ha.)	32	18.9	11.4	4.6	9.4	18.1
Gross irrigated Area 1988-89 (Total=42.9 mill. Ha.)	43.6	43.4	1.9	2.8	1.4	4.6
Production 1988-89 (Total=171 mill.tonnes)	43	29.1	7.5	5.7	3.8	7.5
MEAN EARNINGS (RS) PER HECTARE 1980-81 TO 1987-88 (at 1980-81 prices)						
CULTIVATOR	1,908.5	2,089.5	727.8	1,377	960.5	1,393
WORKER	463.7	193.8	161.6	106.9	153.5	80.3
YIELD IN KILOGRAMS PER HECTARES						
1965-66	1,500.5	826.8	428.8	1,005	313.6	-
1988-89	2,635	2,117	869	1,606	610	549

Notes: Pulses represented by only grams, global (WORLD) yield rate for rice, wheat and maize only as reported by F.A.O. *Source:* Indian Agriculture in Brief, 1992, Acharya,1992.

2. AGRICULTURE IN ANDHRA PRADESH

2.1 INTRODUCTION

In terms of geographical area and population, Andhra Pradesh (AP) comes fifth in India. Agriculture provides for about 70% of the state's work force. Nearly, 10% of the country's cultivated acreage is concentrated in Andhra Pradesh. Although the state accounts for only 6.3% and 6.4% respectively of national foodgrain acreage and production, it is the second largest producer of rice. It is also a major producer of jowar, ragi and maize. Andhra Pradesh lies partly in the coastal plains and partly in the Deccan plateau and displays diverse geographical characteristics. Climate and soil conditions vary widely within the state. Infrastructure is also unevenly distributed among the regions of the state.

Agro-climatic diversity is one of the chief grounds for choosing Andhra Pradesh for our study. The coastal districts are plain land with river basins and deltas of Godavari and Krishna. These also receive heavy rainfall, above 900 mm of annual average rainfall and are often subjected to cyclonic disturbances and excessive precipitation. These areas have irrigation facilities and grow mostly rice and sugarcane with modern inputs. The other regions get low rainfall, and in fact eight of the districts are considered drought prone. The soil is often rocky and irrigation facility and potential are rather limited. Some of the districts have jowar as the dominant crop and in general millets are suited for these conditions. Interestingly, some of the low rainfall districts of Telangana region have gained from irrigation projects in the last two decades and have become more progressive than others and therefore they provide more diversity in conditions. Though not a leading beneficiary of the green revolution, AP has its own strength and potential. It has some of the most fertile districts of the country and is a major producer of rice. The yield rate of rice is quite high in the state and in fact, that of all foodgrains together is higher than the national average. The poor productivity of the unirrigated stretches of land and the coarse cereal grains provide opportunities of further improvement in the face of limited resources. AP also provides a chance to study the supply responses of rice as also of the coarse cereals which demand little resource and are commonly grown here. The significance of foodsecurity in the state is also notable as about 23% of the state's population (according to the expert group headed by Lakdawala) remains below the poverty line. Problems of hunger and malnutrition are present and electoral issues like providing rice at a low prices (leading to the success of the Telegu Desam party in 1996) highlights the importance that access to food still has in this state's economy. Finally, the availability of time series data, fairly satisfactory for their coverage and consistency, is what encouraged us to take up AP as a subject while some other states seemed equally interesting.

AP consists partly of fertile plains and partly of rocky and undulated plateau. The annual rainfall is normally about 890 mm of which a little less than 70% is received in the southwest monsoon season, June to September. The rivers Godavari, Krishna and Vamsadhara are all non-perennial unlike the rivers of the north India. With the exception of the coastal districts and some interior ones like Nizamabad, Warangal and Khammam, all have rainfall less than 900 mm and many even less than 500 mm.

The state has three geo-political divisions or regions, viz.,

1.Coastal Andhra Pradesh

Srikakulam, Visakhapatnam, Vizianagaram, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore.

2. Rayalaseema

Kurnool, Anantapur, Cuddapah, Chittoor.

3. Telangana

Rangareddy, Hyderabad, Nizamabad, Medak, Mahabubnagar, Nalgonda, Warangal, Khammam, Karimnagar and Adilabad.

In the following sections we will give a brief overview of the state's agriculture (2.2) and an account of the heterogeneity among districts of the state (2.3). The variables used for the district level analyses in this chapter and the following ones and the sources of data are provided in Appendix B of this thesis. Since district level data will be used for analyses in the following chapters we have provided some summary statistics at district level for a few specific years in Appendix B. Figure 1 (B) in Appendix B gives a map of AP showing the districts and their involvement in agriculture. Table 2.1(A2) in the Appendix (A2) of this chapter gives some basic statistics on AP's agriuclture.

2.2 AN OVERVIEW OF AGRICULTURE

The rainfall pattern, irrigation intensity and the degree of multiple cropping in the above three regions are given in Table 2.1. The Coastal region gets the highest rainfall while Rayalaseema is the driest region. Certain districts in Rayalaseema and Telangana like Chittoor, Cuddapah and Nellore get plenty of rain in the north east monsoon season. The irrigation intensity and the proportion of multiple cropped area are also highest in the Coastal and least in the Rayalaseema districts.

Table 2.1 Rainfall, Technology and Land use in Regions of Andhra Pradesh 1987-88

REGION	RAINFALL SOUTH WEST-M (MM)	RAINFALL NORTH EAST -M (MM)	RAIN FALL TOTAL (MM)	IRRIGATION INTENSITY	FERTILISER (KG/HA.)	CROPPING INTENSITY	MULTIPLE CROPPED AREA (SHARE IN NSA)
1	2	3	4	5	6	7	8
COASTAL	407	548	955	0.54	118.2	1.33	0.33
RAYALASEEMA	333	438	771	0.18	45.5	1.05	0.05
TELANGANA	726	265	859	0.24	62.2	1.09	0.08
AP	475	390	865	0.34	79.5	1.16	0.16

Notes: Col. 6 gives fertiliser intensity for cereals (total fertiliser used divided by cereal area), col. 8 gives share of multiple-cropped area in net sown area. *Source:* Season and Crop Report, 1987-88.

AP produced about 12.6 million tonnes of foodgrains and 11 million tonnes of cereals in 1989-90. Several irrigation projects like the Nagarjunasagar project and the Srisailam project have led to a canal dominated irrigation pattern and improvement of the overall irrigation intensity. At the same time, about 11 lakh pumpsets have been energised as of 1990. The reservoir backed canal system and energisation of wells also helped in providing irrigation in the dry season and pushed up the gross cropped area. By 1992 the gross irrigated area (GIA) was 35.4 % of the gross cropped area (GCA) with 929 thousand hectares getting irrigation for more than one crop in a year. Fertiliser intensity also improved and according to NSSO (1978) more than 67% of the fertiliser consumed in the state went to cereal crops. About 30% of the state's electricity consumption was accounted for by agriculture. More than 5 million hectares out of a 12 million hectares of cropped area was brought under high yielding varieties (HYV) by 1987-88. HYV adoption has been highest in the case of rice, followed by bajra, while maize and jowar lag behind. While much of HYV jowar, maize and bajra are raised in unirrigated conditions, not all of the irrigated rice is under HYV. Parallel to the high yielding technology, there have been special programmes for drought prone districts with 53.4 thousand hectares being eligible for drought relief and soil conservation progammes. About 4.5 million litres of liquid pesticides and 23 thousand tonnes of dust pesticides were distributed as of 1987-88.

Table 2.2 presents some indicators of AP's agricultural performance for comparison with that at the all India level and also with the north Indian state Punjab. Although it is far behind the agriculturally most successful state in India, AP's performance compares well with the national level.

Table 2.2 Agricultural performance of Andhra Pradesh, Punjab and India

REGION	IRRIGATION INTENSITY (%)	FERTILISER (KG/HA.)	MULTIPLE CROPPED AREA(%)	CROPPING INTENSITY	ENERGY (PUMPS IN LAKHS)	YIELD RATE FOODGRAINS (KG/HA.)
1	2	3	4	5	6	7
AP	32.3	79.54	16.6	1.17	11.91	1,308
INDIA	31.6	50.81	26	1.27	835.8	1,173
PUNJAB	90.8	151.72	76.2	1.76	55.66	3,228

Notes: Cols 2 and 4 give shares in net sown area, col 6 gives number of ennrgised pumps in lakhs.
Source: IAB 1992

2.2.1 Sources of Irrigation

The main sources of irrigation in AP are wells, tanks and canals grouped under major, medium and minor schemes. The multipurpose and major irrigation projects in the state include (a) Nagarjuna Sagar, (b) Sriram Sagar, (c) Vamsadhara, (d) Godavari Barrage, (e) Somasila, (f) Singur, (g) Yeleru, (h) Srisailam, (i) Telugu Ganga and (j) Jurala etc., some of which are yet to be implemented. The major canals which are now supplying water for irrigation have among them the Kurnool-Cuddapah canal, Srisailam RBC and LBC (right and left bank canals respectively). The reservoir of Srisailam, Nagarjuna Sagar, Sriramasagar and Somasila together have a capacity of 10 tm cum. Associated with the dams are important power projects like Tungabhadra, Nagarjuna Sagar and Nizam Sagar hydel power schemes which also help to energise the 10.4 lakh pumpsets for irrigation in the state. Minor irrigation programmes mostly comprise ground water development schemes through construction of dug wells and private shallow tube wells, deep public tube wells and boring or deepening of dug wells. Certain surface water works are also included as minor irrigation like storage, diversion canals and lift irrigation. Ground water sources offer instant irrigation and are essentially people's programme calling for individual and cooperative effort based on institutional finance. Minor surface projects are financed through Plan funds and not they only help to provide water to chronically drought affected areas, but also control water logging and salinisation in canal commands. These schemes have the added advantage of being labour intensive and offer employment to the rural people.

Table 2.3: Source wise Net Irrigated Area in Andhra Pradesh ('000 Ha.)

YEAR	CNL	TNK	SW	TW	OW	GW	OS	NIA
1965-66	1,225.5	1,159	2,415	30.9	423.7	455	108	2,977
1984-85	1,794	774.2	2,568	186.7	651.7	838	117	3,522
1987-88	1,593	663	2,256	230	761	991	122	3,369

Notes: CNL=canal, TNK=tank, SW=surface water = CNL+TNK, TW=tube well, OW=other wells, GW=ground water = TW+OW, OS=other sources, NIA=net irrigated area. *Source:* Season &Crop Report

Table 2.3 brings out the growing importance of ground water irrigation and the downfall of tanks. Tanks had been the main source of water and a useful life saving device in drought prone areas of Andhra Pradesh. Their ecological importance to rural life had been immense. They served to store and conserve the rain run off and prevented wastage of water. The storage tanks also enriched the water table through percolation. There were more than 58 thousand tanks in AP in 1955-56, majority of them of smaller dimension. Of these 19 thousand were in drought prone districts, irrigating 2.8 lakh hectares of land. Although there has been some increase in the number of tanks, the area irrigated declined (see Table 2.2(A2)), possibly reflecting the deteriorating conditions of the tanks.[1]. More than half of the tanks and most of the lift irrigation projects in AP are in Telangana region. Canal irrigation is most common in Coastal region followed by Telangana. Ground water sources consist of tube wells, mostly private, and dug wells some of which are energised by diesel or electricity. Coastal AP also possesses the largest number of tube wells while Telangana has the least number. More than 90% of tube wells are in private hands but the share is much less in Rayalaseema, perhaps indicating the paucity of private capital and the greater concern shown by the government towards this less endowed region. Of the 1.3 million dug wells in the state, Telangana has the largest share, followed closely by Rayalaseema. About

70% of these wells are energised and the rate of energisation is highest in Coastal AP followed by Rayalaseema (see Table 2.3(A2)).

2.2.2 *Land Utilisation*

With the advent of the new technology and the expansion of irrigation, the gross cropped area (GCA) increased marginally from 12.09 million to 12.96 million hectares between 1965-66 to 1987-88. But the same is not observed for net sown area (NSA). The Cropping intensity (CI) is poor, although it made a modest improvement through the years. It is highest (1.33) in the Coastal region and lowest (1.05) in Rayalaseema. About 34% of the NSA in Coastal region is under multiple cropping but the proportion is meagre (16%) at the state level. Since the intensive use of land involves multi-season cultivation of crops, Table 2.4 is given to indicate the extent of kharif and rabi acreages of different foodgrain crops. Rabi season accounts for a third of the total foodgrain acreage. The share of the season in the total irrigated foodgrain acreage is roughly the same. The share of rice and ragi acreages in the kharif season are high at 70 to 75 per cent respectively. Bajra is raised entirely as a dry kharif crop. Jowar is predominantly an unirrigated crop and is grown equally in both seasons. Maize, which is mostly cultivated in Telangana is also grown in both seasons.

Table 2.4 :Seasonal Pattern of cultivation in Andhra Pradesh

CROP	RICE		JOWAR		PULSES		FOODGRAINS		SUGAR CANE
Season	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Total
1	2	3	4	5	6	7	8	9	10
AREA	2,234	973	928	802	916	593	5,155	2,413	176
GIA	2,095	973	13	7	2	18	2,275	1,005	175
FRT	-	-	-	-	-	-	486	480	-

Notes: FRT= Total fertiliser ('000 tonnes) used over all crops, GIA= gross irrigated ares, areas in thousand hectare.
Source: Season Crop Report, Andhra Pradesh, 1987-88.

2.2.3 *Cropping Pattern and Crop performance*

Foodgrains constitute 66% of the GCA of which rice is the most important followed by jowar, bajra, ragi and maize in that order. Maize is grown mostly in Telangana region while jowar and bajra are significant in Rayalaseema and also Telangana. Over time the importance of foodgrains came down. Within it, the share of rice improved but except for a slight improvement in the case of maize (and a roughly unchanged share of pulses), the other foodgrains lost importance. Rice and maize also recorded positive growth in production. Yield rate however improved for rice, maize as also jowar and ragi. Jowar and ragi suffered falling irrigation intensities and only bajra, which is essentially a dry crop, has increased its irrigation intensity but failed to improve its yield rate.

2.3 AGRO-CLIMATIC CONDITIONS AND PERFORMANCES OF DISTRICTS: A COMPARATIVE VIEW

The studies conducted at district level in subsequaent chapters seek to bring out the differing supply responses in the varied agro-climatic conditions. Broadly speaking, the districts differ with respect to (i) natural conditions, (ii) infrastructure, (iii) farming practices and customs, (iv) institutional facilities. Natural conditions or geography include topology, soil quality and rainfall pattern of the district. Infrastructure consists of sum total of all facilities of transport, storage and marketing of grains, of irrigation from various sources along with reservoir capacities, electric or diesel power availability and flood control measures etc. The type of irrigation infrastructure also has implications on drainage and conservation of water. Water logging and salinisation of land and ground water depletion all affect the productivity of agriculture. Even facilities of hospitals and schools constitute infrastructure in a broad sense as they indirectly affect the quality of work the farmers can put in. Farming practices incorporate soil preparation, labour use and mechanisation and and rotation of crops commonly adopted. Farmers may have their own ways of tilling the soil, the preferences for farm-yard manures and methods of preparing the same have a bearing on the intensity of fertiliser use and the productivity of land. Drainage and water conservation measures which add up to effective use of rain water also depend on farmers' endeavour to a large extent. Community based actions such as management of irrigation, desilting of tanks, and reservoirs and other maintenance work have impact on productivity. Finally, the active collaboration of banks and cooperative societies in providing timely and adequate credit and marketing facilities as well as inputs like fertiliser are important in determining technology and production and such facilities are often quite uneven among regions.

In this section we will make a comparative discussion of the 18 districts with respect to the above mentioned attributes and performances. We will naturally consider those aspects for which we have quantitative information and which are directly relevant for our analyses though other qualities are equally important.

The districts have been classified as High Value District or HVD and Low Value District or LVD with respect to a variable Y according as the value of Y in the district is higher (equal to) or lower than the value of Y at the state level in 1984-85 (Ganesh Kumar, 1993). Thus if Y_t^s is the the state level value of Y at period t, district j is

HVD if $Y_{jt} > Y_t^s$

and **LVD if** $Y_{jt} < Y_t^s$

Tables 2.5.(A2) and 2.6 (A2) in Appendix A2 of this chapter provide the classifications of the districts with respect to different variables.

Coefficients of variation (CV) of different variables across the 18 districts (as computed by Ganesh Kumar (1993), presented in Table 2.4(A2) are used to measure diversity. The disparity is described as severe if CV exceeds 50%, mild if CV is less than 30% and moderate if lying between 30% and 50%.

2.3.1 Natural Factors

On the whole, the coastal districts are fertile, low lying and possess alluvial soil while the other regions have mostly rocky and infertile terrains. There is significant variation in rainfall in both seasons (across districts), that of rabi rainfall (RNE) being severe. Except Guntur and Nalgonda, all the Coastal and Telangana districts are HVD in kharif rainfall (RSW), while in the whole of Rayalaseema this rainfall is short of the state level. However, in RNE , Guntur and two of the Rayalaseema districts are HVD. Normal rainfalls in AP are given in Appendix B.

2.3.2 ***Irrigation***

The basic irrigation infrastructure that determines the availability of water for cultivation is a serious constraint on farmers' behaviour. But the availability of water relative to the demand made by the various technologies depends on the types of irrigation prevalent in the region. So, more important then the extent and the intensity of irrigation is its quality, reflected by the adequacy, timeliness and controllability of water supply. A number of irrigation projects have been launched in AP to provide canal irrigation. Most of them benefit the Coastal region and also the Telangana districts like Nizamabad and Nalgonda. Rayalaseema still awaits the Teluguganga Project. The irrigation intensity (ie., NIA/NSA) of the state was 0.336 in 1984-85 (and 0.39 in 1992-93), but it varied from 0.796 in West Godavari to a mere 0.08 in Adilabad. Irrigation intensity in general is high in coastal districts and in a few Telangana districts as expected, most notably, in Nizamabad. Most of Telangana and all of Rayalaseema districts are lowly irrigated.

Ground water dominated districts consist of three Rayalaseema districts Ananatapur, Cuddapah and Chittoor and all of Telangana, barring Nizamabad, Khammam and Adilabad. All the Coastal districts have ground water intensity of irrigation less than the state level (LVD). They are all HVD in surface water. Kurnool in Rayalaseema and Nizamabad, Khammam and Adilabad in Telangana are also surface water (HVD) irrigated districts.

Within the two broad categories, the individual sources have their own differences (as discussed in 1.5.1 in Chapter 1). We find that though the Coastal districts are HVD in surface water, Srikakulam is tank dominated in contrast to the others which are canal dominated. Kurnool in Rayalaseema and Nizamabad in Telangana are canal dominated but the preponderance of tanks make Khammam and Adilabad HVD in surface water irrigation. All the ground water irrigated districts (HVD) are irrigated by other (dug) wells. Remarkably, ground water dominated districts Chittoor, Rangareddy, Medak, Mahabubnagar, Warangal and Karimnagar are also HVD in tanks. Nalgonda is HVD in canal, tank and well irrigation.

The disparity in irrigation facilities is severe (CVs exceeding 50% for overall irrigation intensity (II) as well as its constituent parts). In fact the heterogeneity in irrigation system within the state is all the more conspicuous from the fact that the CVs of all sources barring tanks, exceed that of II. Thus the disparity in irrigation intensity in the state may not entirely reflect the inequalities of facilities in terms of the quality of irrigation. The CV of II is coming down over the years mostly on account of the same in ground water irrigation, as CV of surface water irrigation is fairly stable. The CVs relating to all individual sources are also falling, the only deviation being tanks where the increasing tendency compensates for the opposite movement in the case of canal irrigation to keep CV of SW unchanged. However we note that both the assured sources, namely canals and tubewells have highly skewed distribution in the state.

Compared to irrigation, cropping intensity (CI) which is said to be determined by the availability and quality of irrigation, shows much less variation. Also, in contrast to the declining CVs of irrigation variables, that of CI has been on the rise. In other words while the districts tend towards a uniform system of irrigation, this does not reflect on the intensity of cultivation. Perhaps this suggests that different regions respond differently to irrigation facilities. All the Coastal districts (which are highly irrigated) and only Nizamabad, Nalgonda and Warangal (all of which happen to be 'other' well dominated) in Telangana are HVD while all of Rayalaseema is LVD in cropping intensity (CI).

2.3.3 *Input Intensity*

The irrigation intensities of crops (Table 2.11(A2))bring out the allocative decision of farmers. The decisions regarding the irrigation intensities of crops (i.e.., GIA/GCA of crop) are based on the importance of the crops in their subsistence, their income earning capacities, on the rainfall pattern and soil quality and nature of the crop, ie., the water requirement of the crop.

The irrigation intensity of rice is quite uniform throughout the state (evident from the low CVs in Table 2.4(A2) but the CVs relating to the other crops are very high. Rice is almost entirely irrigated except in Khammam and Adilabad. Jowar records the highest irrigation intensity of 14.7% in Chittoor and Rayalaseema is where it is raised with more irrigation intensity than elsewhere. Bajra is also mostly grown dry, but the irrigation intensity is as high as 50% in Guntur and 57% in Cuddapah and almost cent percent in Nizamabad. Ragi once again is a dry crop but its irrigation intensity of 32% is on account of the high intensities prevailing only in Guntur and the Rayalaseema districts. Maize is grown both dry and irrigated with irrigation intensity varying from 0.% in Nalgonda to 100% in Cuddapah. All the Rayalaseema districts are HVD in maize irrigation intensity but the Coastal and Telangana districts, with the exception of West Godavari, Krishna, Warangal and Karimnagar, grow maize as a dry crop mostly. Incidentally, Karimnagar and Nizamabad which are the largest maize producers in the state and also have very high yield rates of maize have only 40% and 13.6% of maize area under irrigation respectively. Fertiliser is another important input, and even here the CV of fertiliser intensity is fairly high. Only five districts have fertiliser intensity above state level, three of them being in the Coastal region. Except for the irrigation intensity of ragi all the CVs of input intensities are lower in 1984-85 than in 1965-66.

2.3.4 Yield rates

The degrees of dipersion of yield rates across districts are modertely low for all crops, with the CVs generally lying within 50%. With the exception of rice, CV of irrigation intensity of which is very low, (being entirely irrigated in most districts), the CVs of yield rates are lower than those of irrigation and fertiliser intensities and even the rainfalls.

As in the case of cropping intensities, we note the lack of correspondence between the disparities in causal factors and outcomes. Not only are the CVs of inputs more than those of yield rates, the direction of changes are in contrast with the relations. In fact, all the crops registered increasing variation of yield rates across the state with the CV having more than trebled for maize. The farmers in a region appear to find out the optimal pattern of cropping and input use and other practices in keeping with input availability to obtain yield rates comparable with other regions, possibly accounting for the greater uniformity of yield rates compared to input intensities.

Rice yield rates are high in three districts of Coastal AP, four of Telangana and also three in Rayalaseema. Jowar yield rates vary from 125 kg/Hectare to 719 kg/Hectare, both the extremes being observed in Rayalaseema. Rayalaseema districts suffer from low yield rates and this, despite the higher irrigation intensity of jowar while Telangana districts which grow mostly unirrigated jowar have high yields. The story is reverse for ragi yield rate of which is low in most of the Telangana districts but high in Rayalaseema. In the case of maize some districts have high yield rates despite poor irrigation.The Coastal districts perform impressively in respect of bajra yield although it is a dry crop except in Guntur, while Cuddapah in Rayalaseema and Nizamabad and Karimnagar in Telangana, where it is raised with irrigation, are LVD in bajra yield rates. Such a lack of correspondence indicates that irrigation, which may be a major constraining input in the state is not the only vital input for most of the crops.

2.3.5 Cropping Pattern and the importance of crops

Rice is the foremost crop of the state accounting for half of the cereal acreage, followed by jowar, and maize, ragi and bajra together claim 16% of cereal acreage. Rice is the most important cereal in all Coastal districts but only in Chittoor in Rayalaseema and Nizamabad, Nalgonda and Karimnagar in Telangana. Although jowar ranks second at the state level, it is the leading crop in a number of districts, namely Kurnool, Anantapur, Cuddapah, Rangareddy, Medak, Mahabubnagar, Warangal, Khammam and Adilabad. Maize and bajra do not rank first anywhere, but are still quite important in many districts. Ragi constitutes 20% of cereal acreage in Chittoor, but the share is rather low in other districts. Maize is important only in Telangana districts but the other three cereals are important in all regions.

In terms of production, the importance of Coastal districts in rice production is overwhelming, about 60% of state output. Rayalaseema's share is minimal and in Telangana too, besides Nalgonda and Karimnagar, no single district contributes more than 5% of state's rice production. The major jowar producers are Guntur in Coastal region, Kurnool and Anantapur in Rayalaseema and Rangareddy, Medak, Mahabubnagar, Warangal, Khammam and Adilabad in Telangana. Srikakulam and Guntur in Coastal region, Anantapur, Cuddapah and Chittoor in Rayalaseema and Rangareddy and Mahabubnagar in Telangana each contributes more than 5% of state ragi output and the principal contributors of bajra in three regions are respectively Srikakulam, Guntur, Anantapur, Cuddapah, Chittoor and Nalgonda. Only four districts of Telangana produce as much as 90% of the state's maize out turn. The **largest contributors to state crop production** are :

RICE	West Godavari	(Coastal)
JOWAR	Kurnool	(Rayalaseema)
RAGI	Srikakulam	(Coastal)
MAIZE	Karimnagar	(Telanagana)
BAJRA	Srikakulam	(Coastal)

Notes:

[1] The degeneration of tank system in dry districts has been attributed to the rise of well irrigation as a direct result of the new technology and irrigation oriented loans. The promotion of well irrigation system has led to the private capitalisation of irrigation. The wealthier farmers sought possession of an irrigation source and lost interest in the maintenance of traditional community based sources like tanks. In fact, they may have encouraged the degeneration process to get access to land holdings on tank beds or those from poorer farmers who had earlier depended on tank irrigation. In a study on tank irrigation, Reddy et al (1993) held the government responsible for continuing a colonial policy of the past century. The policy was based on the view that tanks were unproductive. Although tanks are not controllable and assured sources of water like the tube wells, they are significant sources in the dry regions, have ecological benefits and are above all, accessible to the poor. In addition, the externality provided by the recharging of ground water is favourable for well irrigation also and some form of conjunctive use of both sources may be desirable. However, the prolonged neglect of tanks and minor irrigation have brought a situation where a critical minimum investment is required for restoration of the tank system in the state. This has to be followed by maintenance in the form of desilting and reclamation, raising bunds and prevention of evaporation (by use of chemicals and deweeding) and by afforestation of shores and regulation of tank-bed farming.

Appendix A2:

Agricultural Statistics on Andhra Pradesh: State

Table 2.1(A2): Some Indicators of Agricultural performance in Andhra Pradesh

1. YEAR	**1965-66**	**1987-88**	**1990-91**
1	2	3	4
2. GEO. AREA(sq. kilometers)	275,068	275,068	27,068
3. SNDP (Total, Rs. lakhs)	207,002	298,296	450,954
4. SNDP (Agriculture, Rs. lakhs)	112,793	156,456	163,001
5. PC NDP (state, Rs)	527	625	758
6. PC NDP (All India, Rs)	559	664	810
7. GCA (lakh hectares)	120.9	129.6	131.9
8. GIA/GCA	0.29	0.34	0.41
9. FRTILISER(Kilogram/Ha.)	7.8	25	74.5
10. %FOODGRAIN AREA	7.7	7.7	6.1
11. %FOODG RAIN PRODUCTION	8.4	7.8	6.4

Notes: State net domestic product (SNDP) total and agriculture in rows 3 and 4 and per capita net domestic product (PC NDP) for state and all India in rows 5 and 6 rows are at 1970-71 prices. Rows 10 and 11 give shares of state in national foodgrain area and production respectively. *Source:* Statistical Abstract, India.

Table 2.2(A2): Tank Irrigation in Andhra Pradesh: Number of Projects and Area Irrigated

	1955--56			**1987-88**		
	NUMBER			NUMBER		
REGION	SMALL	TOTAL	AREA	SMALL	TOTAL	AREA
1	2	3	4	5	6	7
DROUGHT PRONE	15.7	18.8	276.8	20.2	22.4	145.8
STATE	49.7	58.5	1,077	77.1	85.2	662.9

Notes: Net sown area in thousand hectares, Tanks are small if irrigating less than 100 acres.
Source: Season & Crop Report, Andhra Pradesh.

Table 2.3 (A2) Number of Projects, area irrigated and intensity of irrigation of sources in Andhra Pradesh 1987-88

SOURCE	TANKS (000)		CANALS		LIFT	TUBE WELLS		DUG WELLS(000)	
NUMBER	SMALL	TOTAL	MAJOR	TOTAL	TOTAL	PRIVATE	TOTAL	WITHOUT PUMPS	TOTAL
1	2	3	4	5	6	7	8	9	10
Coastal	26.8	30	26	90	1,211	85	92	95	221
Rayalaseema	10	11	6	22	493	12	14	85	294
Telangana	40.3	43	13	53	3,194	9	10	221	817
State	77.1	85	42	165	4,898	106	116	401	1,333
GROSS IRRIGATED AREA IN '000 HECTARES									
Coastal	105	292	1,477	2,280	45	219	23	27	156
Rayalaseema	42	95	142	222	6	27	31	11	280
Telangana	175	355	273	605	34	20	23	14	601
State	322	742	1,892	3,107	83	266	285	52	1,037
INTENSITY OF IRRIGATION									
Coastal	0.06	0.06	0.41	0.36	0.05	0.2	0.2	0.95	0.44
Rayalaseema	0.17	0.22	0.14	0.17	0.26	0.4	0.4	0.07	0.24
Telangana	0.11	0.14	0.18	0.16	0.24	0.52	0.48	0.14	0.41
State	0.1	0.12	0.35	0.24	13	0.24	0.22	0.43	0.36

Notes: Tanks as small if irrigated area is less than 100 acres, Canal= Public surface water (flow) projects, Lift = lift irrigation, TW= tube wells irrigation, DW= Dug well irrigation, PVT= Private, PUB= Public, W/O= without, Intensity of irrigation is proportion of net irrigated area under the source which is irrigated more than once. *Source:* Season & Crop Report, Andhra Pradesh.

A2: Diversity Among Districts in Andhra Pradesh

Table 2.4 (A2) Disparities in Input use and Performances (Coefficients of variation %)

YEAR	1965-66	1974-75	1984-85	YEAR	1965-66	1974-75	1984-85
1	2	3	4	5	6	7	8
CV(CI)	10.43	10.88	13.61	CV(IRR)	12.1	9.7	10.2
CV(II)	67.35	65.83	62.35	CV(IRJ)	199.7	162	162.4
CV(SW)	82.14	82.66	81.43	CV(IRG)	139.2	178.1	148.1
CV(GW)	82.8	71	62.68	CV(IRM)	115.7	127.4	95.7
CV(CNL)	142.9	125	114.6	CV(IRB)	139.3	81.4	98.9
CV(TNK)	61.4	68.5	84.5	CV(FRT)	85.4	5.2	56.8
CV(OW)	94	92.3	84.3	CV(YR)	25.6	21.6	23.5
CV(OS)	87.1	78.3	62.7	CV(YJ)	23.5	21.7	36
CV(RSW)	36.1	41.85	66.41	CV(YG)	38.4	38.5	39.8
CV(RNE)	151.6	58.6	134.4	CV(YM)	8.2	16.9	30.4
CV(TW)	263	229	192	CV(YB)	29.7	45.6	0

A2: 2.5(A2): Classification of Districts according to Irrigation , Rainfall and Cropping Intensity

DISTRICTS	II	CNL	TNK	OW	SW	GW	RSW	RNE	CI
1	2	3	4	5	6	7	8	9	10
SRIKAKULAM	HVD	LVD	HVD	LVD	HVD	LVD	HVD	HVD	HVD
E. GODAVARI	HVD	HVD	LVD	LVD	HVD	LVD	HVD	HVD	HVD
W. GODAVARI	HVD	HVD	LVD	LVD	HVD	LVD	HVD	HVD	HVD
KRISHNA	HVD	HVD	LVD	LVD	HVD	LVD	HVD	LVD	HVD
GUNTUR	HVD	HVD	LVD	LVD	HVD	LVD	LVD	HVD	HVD
KURNOOL	LVD	HVD	LVD	LVD	HVD	LVD	LVD	LVD	LVD
CUDDAPAH	LVD	LVD	LVD	HVD	LVD	HVD	LVD	HVD	LVD
ANANTAPUR	LVD	LVD	LVD	HVD	LVD	HVD	LVD	LVD	LVD
CHITTOOR	LVD	LVD	HVD	HVD	LVD	HVD	LVD	HVD	LVD
RANGAREDDY	LVD	LVD	HVD	HVD	LVD	HVD	HVD	LVD	LVD
NIZAMABAD	HVD	HVD	HVD	HVD	HVD	LVD	HVD	LVD	HVD
MEDAK	LVD	LVD	HVD	HVD	LVD	HVD	HVD	LVD	LVD
MAHABUBNAGAR	LVD	LVD	HVD	HVD	LVD	HVD	HVD	LVD	LVD
NALGONDA	LVD	HVD	HVD	HVD	LVD	HVD	LVD	LVD	HVD
WARANGAL	HVD	LVD	HVD	HVD	LVD	HVD	HVD	LVD	HVD
KHAMMAM	LVD	LVD	LVD	LVD	HVD	LVD	HVD	LVD	LVD
KARIMNAGAR	HVD	LVD	HVD	HVD	LVD	HVD	HVD	LVD	LVD
ADILABAD	LVD	LVD	LVD	LVD	HVD	LVD	HVD	LVD	LVD

A2: Table 2.6(A2): Classification of Districts according to Input intemsities and Yield rates of crops

DISTRICTS	FRT	IRR	IRJ	IRG	IRM	IRB	YR	YJ	YG	YM	YB
1	2	3	4	5	6	7	8	9	10	11	12
SRIKAKULAM	HVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	HVD
E. GODAVARI	HVD	HVD	HVD	LVD	LVD	LVD	HVD	LVD	HVD	HVD	HVD
W. GODAVARI	HVD	HVD	HVD	LVD	HVD	LVD	HVD	LVD	HVD	HVD	HVD
KRISHNA	HVD	HVD	LVD	LVD	HVD	LVD	HVD	HVD	LVD	LVD	HVD
GUNTUR	HVD	HVD	HVD	HVD	LVD	HVD	LVD	LVD	HVD	LVD	HVD
KURNOOL	LVD	LVD	HVD	LVD	HVD	LVD	LVD	LVD	HVD	LVD	LVD
CUDDAPAH	LVD	HVD	HVD	HVD	HVD	HVD	HVD	LVD	HVD	LVD	LVD
ANANTAPUR	LVD	HVD	HVD	HVD	HVD	LVD	HVD	LVD	HVD	HVD	LVD
CHITTOOR	LVD	LVD	HVD	LVD	HVD	HVD	HVD	HVD	LVD	LVD	HVD
RANGAREDDY	LVD	LVD	LVD	LVD	LVD	LVD	HVD	HVD	HVD	LVD	LVL
NIZAMABAD	HVD	LVD	LVD	LVD	LVD	HVD	HVD	HVD	LVD	HVD	LVD
MEDAK	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD
MAHABUBNAGAR	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	HVD	LVD
NALGONDA	LVD	HVD	HVD	HVD	LVD	LVD	HVD	LVD	HVD	LVD	LVD
WARANGAL	HVD	HVD	LVD	LVD	HVD	LVD	LVD	LVD	LVD	LVD	LVD
KHAMMAM	LVD	LVD	LVD	LVD	LVD	LVD	LVD	HVD	LVD	HVD	LVD
KARIMNAGAR	HVD	HVD	LVD	LVD	HVD	HVD	HVD	LVD	LVD	HVD	LVD
ADILABAD	LVD	LVD	LVD	LVD	LVD	LVD	LVD	HVD	LVD	LVD	LVD

Notes to Tables 2.4, 2.5 and 2.6: HVD= high value district (with respect to state level), LVD= Low value district, IRR= irrigation rice, IRJ= irrigation jowar, IRG=irrigation ragi, *IRM=irrigation maize, IRB=irrigation bajra, FRT= fertiliser,* YR= yield rice, YJ=yield jowar, YG= yield ragi, YM= yield maize, YB= yield bajra; CV=coefficient of variation across districts(%), , CI=cropping intensity, II=irrigation intensity (net), SW=surface water, GW= ground water, CNL=canal , TNK=tank, OW=other wells, OS=other sources, RSW=rainfall from south west monsoon, RNE= rainfall from north east monsoon, all irrigation and fertiliser variables are intensities

Source: A. Ganesh Kumar, (1993), Season and Crop Report, Andhra Pradesh.

3. LAND UTILISATION: EXTENT AND PATTERN

3.1. INTRODUCTION

Since land is the primary input for agricultural production, overall level of land utilisation in agriculture is important in deciding the foodgrain suppy in the country. On the one hand, land utilisation incorporates extension of cultivated acreage and preventing land from falling fallow , it involves intensive cultivation of whatever land is already ploughed on the other.

In India the possibility of extending the sown area is limited by the paucity of land relative to the population pressure and due to the hazards of environmental degradation. On the contrary, the scope of making fuller use of the available land is immense. The climate in most regions permit crop growth thoughout the year, provided moisture can be supplied. Roughly, this amounts to two to three crops a year in a sequence depending on the lengths of growing periods, of course. The cropping intensity given by the ratio of the gross cropped area to the net sown area can therefore theoretically be almost 3. In actuality, however, the cropping intensity is only about 1.3 at the all India level. This underscores the possibility of increasing food supply via more intensive use of available land area. In the present situation, with land being demanded by many different alternative activities, the most effective use of land for food production amounts to getting an adequate food supply out of a minimum amount of land devoted to that purpose and releasing the rest for other uses. This brings into focus issues such as cropping intensity of land, wastage of land, choice of crops and seasonal pattern of cultivation.

Availability of water limits the scope of extending cultivation over culturable tracts as also the opportunity of growing crops in multiple seasons, especially the dry season. Poor rainfall can cause wastage of land and other resources. Since water has been the most important ingredient for bringing about acreage expansion in India, be it by extending the net sown area or by stepping up the cropping intensity, the infrastructure for irrigation facility deserves some emphasis when studying land utilisation.

To reiterate, overall utilation of land in agriculture has two dimensions. One is the 'land' acreage cultivated or the net sown area (NSA) as it is called, and on the other, is the 'cropped' acreage or gross cropped area (GCA) which depends on the net sown area as well as the cropping itensity .(see Dhawan 1988). *In this chapter we are mostly concerned with the most essential and basic of all determinants of foodgrain supply, namely the extent of land cultivated*.

Net sown area is the number of hecatres of 'land' area a farmer actually puts under the plough at least once during a year. Whether all or a part of the land is multiple cropped is of no relevance to its measurement. Not all land is cultivable. The geography of a region primarily determines the availability of arable land. In a land scarce and labour surplus country like India, where an enormous food requirement vies for land with other competing demands like foddar, timber, fuel, habitation and industrial and other activities, (not forgetting the importance of forests and other natural resources), it is expected that as much land will be brought under crop cultivation as *possible*, given the weather and resource conditions.

Over time, net sown area in India changed gradually. With the availability of irrigation and other inputs and with the government coming up with active support towards agricultural growth, more and more barren wasteland were reclaimed in many regions. Counterforces in favour of environmental conservation and the growing need for fuel and grazing ground, encroachment of cities, industries and other activities like pisciculture acted to check the growth or even bring down the net sown area in different parts of the country. Irrigation development encouraged extension of cultivation but is also sometimes said to have inhibited it via salinisation and submersion of land or simply through its superior productive or land augmenting effect on agriculture. Thus, it is possible that population growth and the general development process acted slowly to change net sown area in any direction in the long run.

Some data on net sown area (NSA) for Andhra Pradesh state and its districts are given in Table 3.1. We find that NSA shows no increase over time, with NSA (in '000 Hectares) for the state having gone down from 10994.5 in 1965-66 to 10486.3 in 1984-85 and to 10466.0 in 1992-93. The patterns at the district level are not uniform with some improvement in Coastal region and decline in nearly all of Telangana. In a point to point comparison of years, between 1965-66 and

1984-85 NSA increased only in seven districts -: 2 in the Coastal region, 1 in Rayalaseema and 4 in Telangana and between 1965-66 and 1992-93 also in 7 cases but 3 in Coastal region, 2 in Rayalaseema and only 2 in Telangana.

Table 3.1: Net Sown Area ('000 Hectares) in Andhra Pradesh Districts

District	1965-66	1984-85	1992-93	District	1965-66	1984-85	1992-93
1	2	3	4	5	6	7	8
SRIKAKULAM	824.4	891.1	1,015	RANGAREDDY	323	334.7	293.5
E.GODAVARI	379.4	374.8	445.4	NIZAMABAD	289.2	299.9	240..4
W.GODAVARI	409.8	404.7	440.1	MEDAK	478	443	395.7
KRISHNA	484.4	473.5	477.7	MAHABUBNAGAR	905.4	761.3	678.3
GUNTUR	1,519	1,532.9	1,489	NALGONDA	647.8	629.7	473.5
KURNOOL	1,089	824	901	WARANGAL	501	417.4	393.4
ANANTAPUR	872.8	851.2	976	KHAMMAM	404	430.8	457.3
CUDDAPAH	406.7	352.4	365.9	KARIMNAGAR	487.9	420.4	387.1
CHITTOOR	435	468.2	462.4	ADILABAD	538	576.3	574.3

Source: Season and Crop Report, Andhra Pradesh

In the ensuing analysis we shall seek to answer the following questions about net sown area in the districts of Andhra Padesh.

(1) Has there been a significant long term trend in NSA? If so, in which direction?

(2) What are the factors that influence or constrain the farmers' decisions about the acreage they sow in a year?

(3) What changes have taken place in land utilisation for foodgrain cultivation? Is land resource being fully utilised?

For the econometric analysis, time series data for 20 years following the launch of the green revolution, 1965-66 to 1984-85 are used for 18 districts (groups) as mentioned in Appendix B. This is followed by a discussion on land utilsation. Data on various attributes of land use, rainfall for the two major seasons and irrigation intensity are used for the analyses.

The ecconometric analysis begins in section 3.2. We first look for a long term time trend in net sown area in 3.2 and then examine the factors that actually determine the net sown area in 3.3.

We shall also try to evaluate the utilisation of land for foodgrain production on the basis of some state level indicators and other research work in the field in 3.4 before drawing some conclusions in 3.5.

3.2 TREND ANALYSIS

As discussed in the earlier sections, while the irrigation and fertiliser based agricultural technology tends to bring new land under cultivation, factors like environmental conservation, growth of population, cities and industries and other non agricultural activities can also have profound impact on net sown area in the reverse direction over time. The presence of a time trend in the NSA can indicate secular increase/decrease of NSA over the time horizon owing to such factors.

We therefore fitted for each of the 18 districts and district groups of Andhra Pradesh the following two trend equations where NSA_T stands for net sown area in hectares and T for time running from 1 to 20.

$$NSA_T = a + bT + u_T \text{ ....} \mathbf{3.2.1}$$

$$NSA_T = a + bT + cT^2 + u_T \text{ ....} \mathbf{3.2.2}$$

The first equation (3.2.1) is the linear trend equation while the second (3.2.2) is a quadratic one. The latter allows for an increasing or a decreasing rate of change through the squared or quadratic term. Growth rate of NSA in both specifications, however is allowed to be variable, given by $(b / NSA\ T) * 100$ and $(b + 2cT)/ NSAT) * 100$ respectively. In the linear equation net sown area is increasing, falling or is constant over time according as b is positive, negative and zero respectively. For the second, the direction of trend depends on the magnitude of $\mathbf{(b+2cT)}$. When $\mathbf{b>0}$ and $\mathbf{c<0}$, NSA has a finite maxima and when $b<0$ and $c>0$ it has a minimum.. When b and c have the same sign there is no turning point in the sample period since the latter occurs at $\mathbf{T = -(b/2c)}$. Here we only reported only whichever equation has shown a better fit (Table 3.1(A3)).

Out of all the 18 districts only seven revealed any trend at all, but the fit of these regressions are rather poor. The only exceptions, districts Kurnool and Cuddapah, both in Rayalaseema region, show declining trend in net sown area. (Among the others, the trend in Karimnagar is also negative while in Chittoor and Adilabad, net sown area encountered a maxima towards the middle of the sample period. Only in Warangal, the trend, after a turning point, has been positive in the last years of the sample period.) Moreover, a Dickey-fuller test conducted on the variable could not reject the possibility of a unit root[1] in the cases of Mahabubnagar and Adilabad (in fact, analysis indicated that in both instances the variable NSA might be following a random walk with no deterministic trend).

3.3 MODEL FOR DETERMINATION OF NET SOWN AREA

The results of the preceding section fail to bring out perceptible long term changes in net sown area in a positive direction in most parts of the state. If anything, the declining tendency seems to be stronger. We shall next try to examine the year to year variations in NSA and try to explain how net sown area is determined at any point of time. In any year, the farmers would like to sow as much land as possible for them. However, the availability of cultivable land is not the only constraint. The input that makes cultivation possible is water obtained from rainfall or irrigation. The farmers take planting decision only when they are assured of water. Of course, the choice of crops will be made on the basis of the quantity and assurance of water required by the individual crops relative to the water available. But the decision of the area to be sown must depend on the expectation about water availabilty at the time of sowing.

Since both kharif and rabi crops are grown in Andhra Pradesh, the rainfall in both seasons can be important in determining the farmers' decisions. We shall therefore consider total rainfall in south west monsoon (kharif) season and the total rainfall in north east monsoon season (roughly rabi) as possible factors influencing the decision to sow, assuming that farmers have an anticipation about rainfall at the time of sowing. Normally one should expect the effects of the rainfall variables to be positive, implying that a poor rainfall in any season will bring down the sown area.

Besides rainfall, irrigation is also a source of water. However, the availability of irrigation water is not always assured unless there is some rainfall to recharge the source. Surface water irrigation from tanks depend mostly on rainfall. Ground water also goes down in a year of drought making this form of irrigation unreliable. Tube wells are anyway insignificant in this state. Only in the presence of reservoir backed canals supplying water, is there some degree of assurance of water availability[2] independently of rainfall to enable the farmer to sow land. The expansion of the canal system and the proliferation of tube wells have, at the national level brought a large amount of uncultivated land under plough. Though this expansionary effect tapered off subsequently, yet at the regional level, the tendency of increasing NSA following an assurance of irrigation may still be present. Now, to the extent that canals reach out to unsown tracts, this form of irrigation is expected to have positive impact on the net sown area. On the other hand, where canal irrigation becomes available to already cultivated dry/ rainfed acreage only, it is only likely to effect changes in the cropping pattern and the technique of farming. But apart from replacing rainfed crops by irrigated ones it has little effect on net sown area. At the other extreme, the assurance of water in canal commands can lead to pooling of resources and efforts to raise more lucrative crops. This can let some unirrigated land move out of cultivation in the process and actually have a negative effect on net sown area. Similarly, development of canal systems can have an adverse impact on net sown area and land utilisation when some land falls waste due to waterlogging, submersion or degradation.

In the present analysis, we will consider two rainfall variables RSW and RNE measuring the rainfall during the two main seasons and canal irrigation (CNL) as the explanatory variables for net sown area. CNL measures the proportion of net sown area which was under canal irrigation in the previous year. The implicit assumption is that a farmer expects the proportion of net sown area which receives canal irrigation to be the same as that in the preceding year. It may be presumed that expectation is based on previous experience in which case the previous year's proportion serves as a proxy for this year's expectations. Finally, we acknowledge the limtation of considering only variables for water input in the econometric analysis. Perhaps, there are other relevant factors (mostly institutional), that may affect NSA which are not included in the following study.

Our model for net sown area is thus as follows:

$$NSA_t - f(RSW_t, RNEt, CNLt\text{-}1) \quad \text{.....3.3.1}$$

where NSA = Net Sown Area in thousand hectares,
RSW = Rainfall in millimeters from June to September,
RNE = Rainfall in millimeters from October to December
and t = time.

Equations 3.3.1. is assumed to be linear and is estimated by multiple regression method. Due to the time series nature of the data, serial correlation of errors may be expected. Autocorrelation of first order (AR1) is corrected while estimating the equation by Hildreth and Lu's (HILU) method The Durbin Watson (DW) statistics presented are generally close to 2 . The residuals have also

also been subjected to Dickey-Fuller test[3]. With two exceptions (Mahabubnagar and Warangal), the hypothesis of a unit root is rejected at 5% level of significance. The estimated equations are reported in the Appendix (Table 3.2.(A3)). We selected equations for reporting on the basis of significance of estimated parameters and the goodness of fit. Equations showing variables having absolute value of estimated coefficients smaller than their standard errors are not included in the reported equations (COV criterion, see Maddala,1989, pp 243). We note that not all equations come out with satisfactory $\bar{R}^2$ and in some cases no equation is worth reporting. The summary results are presented in Table 3.1. What is remarkable about these estimated equations is the presence of RSW in all of them except for Adilabad (in Kurnool, RSW appears with a parameter insignificant even at 15% level). In fact, RSW alone determines NSA in 3 Coastal and 2 Rayalaseema districts. On the other hand, RNE appears only in 7 districts and along with other variables.[4] The rainfall variable always has a favourable effect on NSA. Canal irrigation appears as a variable in three out of the 18 districts, (namely Karimnagar, Warangal and Adilabad) and in all three it appears with a negative coefficient. Thus supply of assured water may be leading to pooling of resources having a negative effect on land utilisation.

Table 3.2 Variables determining Net Sown Area in districts of Andhra Pradesh

VARIABLE	DISTRICTS
1	2
RSW	Srikakulam, East Godavari, West Godavari, Cuddapah, Chittoor,
RSW AND RNE	Guntur, Kurnool, Anantapur, Nizamabad, Mahabubnagar,
RSW AND CNL	Warangal
RNE AND CNL	Adilabad
RSW, RNE AND CNL	Karimnagar

3.4. SOME IMPLICATIONS ON LAND UTILISATION

Despite technological development (see section 2.2), it is intriguing to find no positive trend in NSA in the districts of AP. In fact, it has been declining during the sample period in some districts. Perhaps the demand for land for non agricultural purposes proved too strong and agriculture was relatively unprofitable. Also, the net sown area in any year is seen to depend on rainfall. Technolgy (as canal irrigation) is not found to have any favourable effect on the extent of cultivation (this would possibly have shown up in a positive trend also). In view of the declining trend of the NSA and the perverse effect of irrigation observed in some of the districts, the whole issue of land utilisation for agriculture in the state deserves careful examination. A brief look at some information on land use at the state level in Table 3.3 may throw some light. The table gives time series data on some aspects, but for comparability we have chosen the years 1969-70, 1978-79 and 1983-84, all of them being good years in respect of rainfall and crop performance.

Table 3.3 Land Use statistics: Andhra Pradesh

YEAR	NSA (000 Ha)	II (%)	MCA (000Ha)	TF (000Ha)	CW (000Ha)	NAU (000Ha)	LU(%)
1	2	3	4	5	6	7	8
1965-66	10,994	29.8	1,096	3,372	1,420	1,969	0.69
1967-68	11,367	30.9	1,427	2,990	1,373	2,067	0.72
1969-70	11,510	31.9	1,635	2,588	1,222	2,081	0.75
1970-71	11,735	33.1	1,612	2,654	1,116	2,122	0.75
1977-78	10,918	33.1	1,618	3,759	908	2,126	0.7
1978-79	11,349	36.4	1,772	3,287	888	2,134	0.73
1979-80	10,533	32.5	1,748	5,073	883	2,149	0.63
1980-81	10,735	34.6	1,543	3,914	871	2,168	0.69
1981-82	11,324	36.9	1,722	3,386	889	2,184	0.72
1982-83	11,034	35.3	1,735	3,650	901	2,216	0.7
1983-84	11,435	38.9	1,957	3,219	894	2,217	0.73
1984-85	10,486	35.6	1,726	4,550	870	2,236	0.65
1987-88	10,425	35.4	1,730	4,641	864	2,260	0.65
1990-91	11,022	39.1	2,170	3,862	780	2,307	0.7

Notes: II=Irrigation intensity (%NIA/NSA), MCA=Multiplecropped acreage, TF=Total fallows(=current and other fallows), CW=Culturable wastes, NAU=Land put to non agricultural uses, LU=Land utilised (=%NSA/(NSA+TF+CW)).

The net sown area, which fluctuated over the time period, has declined from 1969-70 to 1983-84. The implication of this observation on land utilisation is not simple. The net irrigated area (and the irrigation intensity of land ie., NIA/NSA) made steady improvement. The same is noted for land put under multiple cropping. So, while extension of cultivation may have diminished, intensification of land use has taken place. We shall examine this in Chapter 4. We also notice that a large amount of cultivable wasteland has been claimed during the sample period, so that culturable wastes (CW) which include waterlogged or such waste land which can be brought under cultivation, came down by 37% (Table 3.3). But since the statistics on net sown area fails to bring out this favourable effect, it appears that land must have been put to alternative uses away from cultivation. Do these observations suggest that the benefits of technology came at the cost of some land parting from the plough? Is land being underutilised? We shall look into the data for possible answers.

The dwindling net sown area need not imply underutilisation of land, on the whole, if the land went out to serve more useful or remunerative purposes. To some extent this is confirmed by the increase registered by land put to non agricultural uses (NAU). But as Table 3.3 readily reveals, although culturable wastes(CW) was declining, and non agricultural uses of land (NAU) increasing, the incidence of fallow land (TF) was on the rise. The total fallow land includes *current fallows* (CF) which lie idle mostly on account of variations in rainfall, and *other fallows* (OF) that are untilled upto 5 years due to soil-climatic conditions and/ or lack of resources and/or unprofitability of farming in the region. The percentage of total cultivable land (TCL) underutilised ((TF+CW)/TCL) has also gone up between the two years. The total proportion of utilised land in total cultivable land moved from 75% in 1969-70 to 73% in 1983-84 and to 65% in 1987-88. Even if CF is excluded from underutuilised land, considering it unavoidable, the share of underutilised land was still 15% in 1987-88.

We have not conducted any rigorous econometric study of land underutilisation. In this study we shall briefly review the works of other scholars on this subject, particularly Reddy's (1991) econometric analysis and examine some changes in land use pattern in AP to understand the implications.

Although the cropping intensity (GCA/NSA) of land *actually cultivated* is most widely employed in land use statistics and in literature as an index of land utilisation, this is perhaps not a perfect indicator for utilsation of *total available cultivable land.* Nadkarni (1984), in a critique of the role of irrigation in rural development takes a slightly different approach to study land utilisation. In his study based on survey data of south Indian states Tamil Nadu, Karnataka and Andhra Pradesh, he examines how the proportion of fallow land can be explained by weather, irrigation and farm size. He suggests that the availability of irrigation has led to concentration of resources and time on the privileged land depriving the dry cultivable tracts, and that this tendency increases with farm size. As Table 3.3 reveals, alongside the decline (or reclamation) of waste land, the incidence of fallow land (current fallows and other fallows) has increased in Andhra Pradesh. This curious phenomenon in a land hungry climate can perhaps also be explained partly by the failure of land reforms. Concentration of holding in the hands of well off farmers who employ their resources on lucrative activities like trading or the presence of uneconomic holdings and lack of resources in the hands of poorer farmers can be responsible for land underutilisation.

The possibility of irrigation having some unfavourable implications on land use has also been considered by Dhawan (1988). In a discussion providing valuable insight into the external effects of irrigation, he cites Gadgil's (1948) study of Maharashtra where introduction of irrigation led to changes in cropping pattern towards heavily manured crops (use of chemical fertiliser was not common those days). A large part of the demand for farm yard manures was met from dryland outside the canal command. This naturally led to a setback to yields of dryland crops. Such diversion of inputs and resources from dryland to irrigated land is not unlikely to have its toll on dry cropped acreage too. Scarlett Epstein's (1962) study of the villages of Karnataka too indicated the diversion of inputs, labour inputs of male inhabitants in this case. Even within the land holding of an individual farmer, introduction of irrigation facility to part of the holding may lead to concentration of limited productive resources in the irrigated portion, depriving the rainfed part of its share. It is however suggested that over the years the tendency may be reversed when the accummulation of wealth from irrigated farming improves the treatment given to the rainfed tracts.

A detailed study of land utilisation in Andhra Pradesh by Reddy (1991) considers a period of 33 years from 1956 to 1988, breaking it up into pre and post green revolution periods 1956 to 1969 and 1970 to 1988, respectively. Net sown area is shown to have a negative linear growth rate for the state and this is owing to the faster rate of fall in post green revolution years. Both categories of fallow land (current and other) registered positive growth rates in both the periods, particularly in the later period, while culturable waste land kept declining, although the process slowed down in the second period. Further, Reddy divided the state into drought prone and non drought prone groups of districts and found the extent of underutilisation more in the former and the gap between the two widening. However the difference is more in degree and at least in the post green revolution period both showed significant trends, negative for net sown area and culturable wastes and positive for the fallow lands. Reddy too finds positive effect of irrigation, especially well irrigation on land under-utilisation.

Thus the possibility of adverse effect of irrigation on land utilisation has been noted in earlier researches. But how far the intensification of land use makes up for the underutilisation and the consequent loss is difficult to say. Further, the process is always accompanied by other changes like those in cropping pattern. Sugar cane is found to corner much of the resources available when canal irrigation is introduced as in Maharashtra (Dhawan, 1993). The shift in preference towards cash crops has its toll on foodgrain acreage. Even within the acreage allotted to foodgrains, reallocation of land among different foodgrains is likely. Since many of these associated changes in land use pattern have far reaching effects on food production and rural welfare and since land utilisation must be viewed in the wider context of welfare issues, it is pertinent to examine such changes for their implications on land utilisation for foodgrain production.

Table 3.4 Seasonal pattern of Cultivation and its Change in Andhra Pradesh

	1969-70			1983-84			% CHANGE 1			% CHANGE 2		
crop	KHARIF	RABI	TOTAL	KHARIF	RABI	TOTAL	KHARIF	RABI	TOTAL	KHARIF	RABI	TOTAL
1	2	3	4	5	6	7	8	9	10	11	12	13
Rice	2,561.7	907.3	3,469	3,048	1,115.6	4,163.6	16.3	10.2	14.7	19	23	20
Jowar	1,272	1,338	2,610	1,976.6	999.1	1,975.7	-12.6	-7.8	-10.2	-23.2	-25	-24.3
Ragi	237.8	89.9	327.7	199.9	55.4	255.3	1.7	-22.6	-4.9	-15.9	-38.4	-22.1
Maize	203.5	43.3	246.8	282.7	58.2	340.9	30.2	16.6	28	38.9	-34.4	38.1
Pulse	852.1	618.9	1,471	968.6	529.7	1,498.3	-2.2	-478	-36	-15.6	-65.2	-16.3
Bajra	580.3	9.2	589.5	489.9	3.2	493.1	0.35	-8.5	-3.4	13.6	-14.4	1.8
FG	6,382	3,187	9,569	6,338.7	2,831	9,169	5.7	-8.9	0.8	0.11	-11	-.3.6
GI	---	---	---	2,930	1,244	4,174	---	---	---	1.63	8.7	3.6

Notes: %CHANGE 1 relates to period 1969-70 to 1978-79, %CHANGE 2 relates to 1969-70 to 1983-84, Area in thousand Hectares, Season wise data for GI not available for 1969-70, % CHANGE 2 for GI is for period 1978-79 to 1983-84, FG area for 1987-88 respectively for KHARIF, RABI and TOTAL are 5155, 2413 and 7568 thousand hectares.
Source: Season and Crop Report.

As net sown area declined, foodgrain acreage (gross) as a whole also fell over the years (by 3.6% between 1969-70 and 1983-84). This is partly owing to a tendency towards diversification to other crops (the share of foodgrains in gross cropped area came down) as also due to the increased fallowing of land. The fall in foodgrain acreage is seen to be accompanied by a change in cropping pattern[5]. Rice, which is mostly a kharif crop and enjoys a high irrigation intensity, underwent improvement in acreage in each of the two seasons. So did maize, which is raised as a dry kharif crop in the state. Jowar, a 50% rabi crop, suffered losses in both seasons. Pulses are grown entirely as rainfed crops with 40% acreage in in the rabi season. The rabi acreage has been going down through the period though the kharif acreage improved. Clearly, although total acreage under foodgrains came down, even within the foodgrains there has been a movement towards more lucrative crops with opportunities of higher yields, like rice and maize and away from inferior and coarse grains which have been traditionally grown in the state under conditions of water scarcity. There have been changes in the seasonal orientation of foodgrain cultivation too. Before examining Table 3.4 we must point out that the total multiple-cropped acreage is considerably less than the non kharif acreage under foodgrains alone in all the years of the period 1965-66 to 1987-88. For example, in 1987-88 rabi acreage of foodgrains at 2413 thousand hectares was more than the multiplecropped acreage of 1730 thousand hectares (see Tables 3.3 and 3.4). This seems to suggest that the cultivation of non kharif grains is not merely supplementary to its kharif counterpart. A significant amount of land is monocropped in the rabi season. This is partly because of the predominance in the state of strong crops like millets and pulses that can be raised in dry conditions and a bulk of these are grown as rabi crops. The relatively reliable and sunny weather of the rabi season which also receives about a third of the annual rainfall also accounted for the importance of the dry season in Andhra Pradesh agriculture. But the rabi season, which accounted for about 33.3% of foodgrain acreage in 1969-70, witnessed a decline in its share to 31.2% in 1978-79 and further to 30.7% in 1983-84. Although the kharif acreage of foodgrains increased marginally, the 11% fall in the other season brought down foodgrain acreage as a whole. Incidentally, the down fall of rabi cultivation occurred despite a marginal redirection of irrigation towards the dry season (30% of gross irrigated area was in the rabi season in 1983-84 compared to 28% in 1978-79) [6].

Since the fall in NSA between 1969-70 and 1983-84 is accompanied by an increase in irrigated area, it is obvious that the introduction of additional irrigation facility did not only convert some dry acreage into irrigated acreage, but some amount of dry farming was displaced in the process.

To sum up the above discussion, we note the following behaviour:

(a) The total foodgrain acreage in the state fell by about 3.6% between the years 1969-70 and 1983-84. The share of foodgrains in the gross cropped area also came down from 73% to 69% showing signs of diversification within agriculture.

(b) The blow has been more severe in the dry season. In fact, even the increased cultivation of crops like groundnuts, fruits, vegetables and condiments and spices which are also grown as rabi crops did not make up for the losses of foodgrains and other crops in the dry season (calculations based on data of 1969-70 and 1983-84 supports this contention of a decline in rabi cultivation). It appears that the growth of multiplecropped acreage came about more from expansion of kharif acreage than rabi acreage in the state.

(c) The fall in foodgrain area is on account of the decline in unirrigated acreage. Even within the irriagated acreage, we noted the diminution of the traditional tank irrigated acreage. All these naturally hurt the crops usually grown under rainfed or lightly irrigated conditions. These are the less demanding coarse cereals, affordable to the poor, which gave way to high yielding crops like rice and maize and to some fallow land as well.

Although the above changes did not imply a drop in either total cropped acreage (Table 4.2) or production, but, whether the movement benefited all sections of the population or left some worse off is not easy to decide. Such implications are important for drawing conclusions about the utilisation of land in a developing country. The change of land use pattern, the tendency to diversify and reorient cropping pattern, is itself not very reassuring in the Indian context, as the commercial gains of some sections of the rural households who switched to non food crops or higher value crops (or other activities) may not really help those who are deprived of the basic food requirement (Dreze and Sen, 1989). Such changes may be a sign of some food insecurity at the (poor) household level (more investigation is however needed to arrive at any firm conclusion). On the other hand, in spite of the reallocation, total food production can very well gain from greater intensity of cultivation and input use. While there can be differences of opinion about the implication of a falling net sown area or a falling foodgrain area, the increased wastage of limited land as evident from the incidence of fallows, cannot be taken for granted. Also, whether the evolving cropping pattern which sometimes results in mounting public stocks of superior grains (in the face of hunger among the masses) and involves high cost public distribution of these grains also constitutes land wastage is a question which needs review.

3.5 CONCLUSION

In conclusion we make the following observations:

(1) There is little effect of time in the long term movement of net sown area. Possibly the various forces acting on land allocation to agriculture cancelled one another out. In the districts where some trend is noticed, net sown area has shown a declining tendency.

(2) In almost all the districts, it is the rainfall from south west monsoon that is found to guide the farmer in deciding the net sown area. Only in 7 district covering all three regions, the rainfall in the north east monsoon season also plays a part. Of these, except for one case (Adilabad) both the rainfalls determine the net sown area. The rainfall variables have positive impacts in all cases.

(3) The proportion of land with assured irrigation shows little impact on net sown area and even where it does, it is an unfavourable one. In these districts the assurance of water in canal command areas displace some sown land out of cultivation (possibly they are dry land which lie fallow while irrigated tracts draw away resources). The poor contribution of canal irrigation (which grew to prominence in the state over the last few decades) towards net sown area may also be due to the fact that even in the pre-green revolution years, farmers in Andhra Pradesh were already cultivating most of the available land. As we know, hardy and less water intensive crops like jowar and other millet crops were widely cultivated in this state. This could mean the rainfall alone decided how much land could be sown and the growth of canal irrigation only served to change the cropping patterns in favour of more water intensive crops and perhaps enabled some multiple cropping of land.

(4) At a state level review of land use statistics, a lot of changes are observed. The net sown area of the whole state came down marginally with the decline of unirrigated rainfed cropping traditionally prevalent in the state. The cropping pattern went against foodgrains in general and in favour of high yielding crops while acreages under inferior grains came down in absolute terms. Curiously, in spite of improvement in irrigation, the cultivation in the rabi season declined. The implication of all these to the welfare of poorer section of rural population who can not afford cultivation or consumption of superior cereals is not clear. Also, there has been increased tendency to leave land fallow which certainly is not desirable.

We may now ask: Can there be any policy towards net sown area? From the above investigation it emerges that net sown area has largely been stationary and some times declining over time. If the rainfall wavers between bad to good, net sown area is likely to be unstable and not much can be done to prevent it. Provision of assured water through irrigation to substitute for uncertain rainfall is of little use in stabilising net sown area. It may influence the cropping pattern, cropping intensity and cropping techniques but it can in the process even lead to some wastage of cultivable land. Perhaps, nothing can be done in the way of technology to attain any desired net sown area. In fact such a desired net sown area is itself difficult to ascertain since it would depend on relative prices or returns and welfare implictions from alternatve uses of land and the implicit values attached to requirements including habitation, fuel, fodder and environmental conservation. However, in view of the growing demand for land for different purposes, it is desirable to extract the most out of any piece of land by improving the cropping pattern, cropping intensity and yield rates of crops through appropriate policies in keeping with the regional conditions and demand pattern. What is really of concern is to ensure that no land is wasted due to lack of resource, enterprise and faulty planning and to see that no section of the population suffers owing to the technological development in agriculture. Finally, we acknowledge the shortcoming of the present study for not taking explicitly into account variables like demographic pressure, resource position including easy access to credit, land reforms, urbanisation and education. These factors possibly have a greater relevance in deciding the movement of net sown area over a long period of time. Farm level studies can also be useful to explain farmers sowing behaviour with respect to their resource position and other socio-economic factors.

Notes:

[1] The presence of a stochastic trend in the variable can make the estimation of a time trend equation (as in the text) meaningless, as this would mean that any shock would have a permanent effect. In fact, its presence can show up as a deterministic trend when none actually is present. A search for a stochastic and deterministic trend would involve consideration of the following equations.

$$Y_t = A_0 + A_1 t + PY_{t-1} + . \in_t \; ..1.1(n)$$

$$\Delta Y_t = A_0 + A_1 t + A_2 Y_{t-1} + \in_t \; .....1.2(n)$$

$$\Delta Y_t = A_0 + A_2 Y_{t-1} + \in_t \; .....1.3(n)$$

$$\Delta Y_t = A_2 Y_{t-1} + \in_t \; ....1.4(n)$$

where Y is the variable studied, t is time and $\in$ is noise. Coefficient $A_2 = P-1$ where $P=1$ would imply a unit root. The null of $A_2 = 0$ is tested using critical values of Dickey-Fuller test. The rejection of the null hypothesis confirms the deterministic trend but otherwise the hypotheses $A_1=0$, $A_2=0$ and $A_0=0$ are tested and accordingly the stochastic process is selected. Equation 1.3(n) shows a random walk process with drift (which *can* spuriously show up as a significant time trend) and equation 1.4(n) shows a pure random walk (see Enders, 1995). Equation 1.2(n) estimated for Mahabubnagar and Adilabad are as in equations 1.5(n) and 1.6(n), where ΔNSA is change in net sown area.

Mahabubnagar

Δ NSA = 551185.8 - 3521.24 t -.5464 NSA_{t-1} ..... 1.5(n)

(1.8953) (-1.6348) (-1.8021)

RESIDUAL SUM SQUARED = 52446064042

Adilabad

Δ NSA = 223311.6 - 492.4 t -.3887 NSA_{t-1} .... 1.6(n)

(1.8969) (-.4995) (-1.8296)

RESIDUAL SUM SQUARED = 6339122162

we note from the t-statistics of variable NSA_{t-1} that unit root is a possibility (Dickey-Fuller critical value at 95% level is (3.57)) and in the above equations the time variable too has an insignificant parameter.

[2] The level in storage tanks ultimately depend on rainfall again. But since this storage may be charged from rainfall recorded in previous years or even that in other states, we will not reject the possibility of its influence on sown area even if rainfall cannot be trusted.

[3]Dickey-Fuller test (without trend) for unit root has been conducted on the stimated residuals for all cases at 95% level (using MICROFIT software).

[4] The districts where RNE appears as a variable seems to comprise a belt stretching from Guntur in the east to Kurnool and Anantapur in the west as also the northern districts of Nizamabad, Mahabubnagar, Karimnagar and Adilabad all in Telangana (see Figure 1(B) map of Andhra Pradesh).

[5]Foodgrains comprise of major cereal crops rice, jowar, ragi, maize and bajra as also other coarse cereals and pulses. In most part of the thesis (chapters 4,5 and 6) we are concerned with the major cereals. A trend line fitted to data on acreages under the five major cereals over sample period 1965-66 to 1984-85 failed to show any trend while the plot over time brought out large swings. The increase in acreage in rice and also maize mostly made up for the loss in major millet crops. But the acreages under minor millets too came down sharply.

[6]This is in contrast to findings and views expressed by economists with respect to northern India. The cropping intensity is ususally said to gain from perennial or at least dry season directed irrigation via greater cultivation in rabi season. The departure is undoubtedly due to the bimodal rainfall pattern in the state which traditionally had led to a cropping pattern and seasonal pattern of agriculture which was more balanced to start with. The effect is reinforced by the contribution made by rainfall dependent sources like tanks and wells in either season (also to cropping intensity as noted in Chapter 5).

Appendix A3: Estimated Regression Equations

Table 3.1 (A1) Trend Equations for Net Sown Area

DISTRICT	CONSTANT	T	T^2	$\bar{R}^2$	DW	DFT	T*
1	2	3	4	5	6	7	8
KURNOOL	110.8640 (50.180)	-13.262. (-7.190)		0.73	2.08	-4.52	
CUDDAPAH	442.24 (47.440)	-31.17 (-4.076)		0.45	1.77	-3.57	
CHITTOOR	419.32 (27.080)	11.5 90 (3.413)	-0.49 (-3.16)	0.35	2.3	-3.57	1,976 MAX
MAHABUBNAGAR	900.33 (25.470)	19.40 (2.503)	-1.09 (-3.05)	0.37	1.66	-3.21	1,973 MAX
WARANGAL	527.19 (21.970)	-13.68 (-2.599)	0.55 (2.27)	0.24	2.2	-3.59	1,977 MIN
KARIMNAGAR	497.75 (36.050)	-2.91 (-2.524)		0.22	2.2	-4.25	
ADILABAD	535.05 (34.440)	9.45 (2.770)	-0.33 (-2.15)	0.37	0.97	-2.34	1,978 MIN

Note: *T*-statistics are given below the coefficients. T* gives the turning point year marking a maxima (MAX) or a minima (MIN) in Net Sown Area.Sample period is 1965-66 to 1984-85. DFT is Dickey-Fuller Test Statistic (t-statistic with trend) of variable NSA, where the critical value at 95% confidence level is -3.57.

Table 3.2 (A3) Regression Equations for Net Sown Area

DISTRICT 1	CONSTANT 2	RSW 3	RNE 4	CNL 5	$\bar{R}^2$ 6	DW 7	DFT 8
SRIKAKULAM	712.545 (17.958)	0.284 (4.896)			0.48	1.9	3.93
E. GODAVARI	350.32 (25.775)	0.08 (4.17)			0.48	1.94	3.88
W. GODAVARI	366.84 (28.88)	0.06 (3.674)			0.33	1.7	-3.49
GUNTUR	1,390.22 (24.68)	0.33 (3.46)	0.08 (1.05)		0.32	1.96	-4.08
KURNOOL	824.84 (11.59)	0.12 (1.39)	0.24 (2.165)		0.57	2.3	-4.81
CUDDAPAH	364.7 (15.246)	0.08 (2.942)			0.42	1.99	-4
ANANTAPUR	709.86 (14.3)	0.4 (2.9)	0.38 (2.042)		0.35	2.02	-4.08
CHITTOOR	408.49 (27)	0.16 (5.526)			0.6	2.07	-4.51
NIZAMABAD	279.24 (44.356)	0.02 (3.981)	0.02 (1.167)		0.45	2.09	-4.24
MAHABUBNAGAR	769.96 (8.338)	0.21 (3.514)	0.21 (1.57)		0.35	1.3	-2.45
KARIMNAGARR	431.59 (15.5)	0.07 (3.067)	0.11 (1.577)	-972.15 (-2.464)	0.47	1.98	-4.69
WARANGAL	354.19 (5.009)	113 (7.102)		-3,814.72 (-3.614)	0.65	1.25	-2.91
ADILABAD	596.88 (28.894)		0.19 (3.426)	-1,011.06 (-1.314)	0.63	1.48	-3.1

Note: Sample period is 1965-66 to 1984-85; RSW is rainfall from South West Monsoon, RNE is rainfall from North East Monsoon, CNL is canal irrigation, DW is *Durbin-Watson statistic, DFT is Dickey-Fuller Test Statistic (t-value without trend)* for the error where the critical value at 95% confidence level is -3.04. Figures in brackets below the coefficients are t-statistics.

4. LAND UTILISATION: INTENSITY OF CULTIVATION

4.1 INTRODUCTION

In Chapter 3 we dealt mostly with the extent of cultivation or net sown area, and partly with the pattern of land use. In the latter context we also touched on the seasonal aspects of cultivation, which have serious implications on land utilisation, as most crops take only a few months from sowing to harvesting. Use of land in multiple seasons for raising two or three crops (or a single perennial crop) signifies a high cropping intensity and thus, fuller utilisation of land. In view of the limited scope of extending the net sown area, the cropping intensity is a powerful instrument for augmenting food supplies. *This chapter is also on the utilisation of valuable and scarce land resource and deals with the intensity* of *cropping.*

In the determination of agricultural output, the total 'cropped' acreage or the gross cropped area is of greater relevance than the 'land acreage' measured by the net sown area (NSA). This is because any piece of land may be cropped a number of time in a year and utilised as if the land area were so many times more. The gross cropped area (GCA) then depends on the net sown area as well as the number of crops grown in a unit area of land in a year. The cropping intensity (CI) measures the average number of crops raised on a unit of land area. Thus,

$$GCA = NSA \ X \ CI$$

For example, if each unit of NSA is cropped twice both in the kharif and rabi seasons, GCA is exactly twice the NSA. If part of NSA is double cropped and the rest is left fallow in one of the two main seasons, on the average, CI will lie between 1 and 2. In the land use statistics collected, the Department of Agriculture report data on NSA and GCA (as the sum of gross acreages under all crops) and derive CI as the ratio of GCA to NSA. In our analysis we have also accounted for land going to the perennial crop sugarcane in calculating CI by counting the same sugarcane acreage twice in GCA.

Now, as pointed out in Chapter 3, NSA is largely an endowment to the farmer. It depends essentially on the availability of cultivable land in the different parts of the country and in the long run, the area sown is influenced by factors beyond the control of the farmer. In India there is little scope of extending NSA any further owing to the paucity of land relative to population pressure and the risks of environmental degradation. Even the cultivation of whatever land is available for agriculture in any area depends largely on rainfall, which is again beyond control. On the contrary, there may be immense possibility of increasing GCA by improving CI. In India, the climate in most parts permits crop growth practically throughout the year, provided moisture is available. Roughly, this amounts to two or three crops a year in a sequence, depending on the duration of the crop growth, of course. The cropping intensity can theoretically be as high as 3. In actuality, however, CI is only around 1.3 at the all India level and varies from 1.1 in Gujarat to 1.8 in Punjab and 1.9 in Himachal Pradesh. Given the seasonal nature of crop cultivation and the possibility of raising a majority of crops in both kharif and rabi seasons, the meagre value of CI underscores an opportunity to step up production by multiple cropping and minimising wastage of valuable land resources.

This chapter is devoted to studying the behaviour of CI in Andhra Pradesh. Section 4.2 gives an overview of land utilisation behaviour. In section 4.3 the objectives of the econometric analysis to be undertaken are provided, followed by a trend analysis looking for possible long term movement of CI in the districts in 4.4. Section 4.5 gives a brief theoretical discussion on the determination of CI and in ensuing sections 4.6 and 4.7 the econometric analysis of CI is provided. The relation between CI and irrigation infrastructure is examined in 4.6 and that between CI and the crop level input intensities is discussed in 4.7. Section 4.8 gives some concluding remarks on the study.

4.2 LAND UTILISATION IN ANDHRA PRADESH

At the outset we mark that CI is quite low in this state (1.17 in 1984-85, 1.21 in 1992-93) even compared to the all India level (1.26 and 1.30) which itself is not high. Table 4.1 presents the cropping intensity for 1965-66, 1984-85 and 1992-93 at the district level. Although the value is quite impressive in the Coastal region, (reaching 1.5 in 1984-85 and 1.59 in 1992-93 in East Godavari), it is extremely low in many of the districts of Rayalaseema and Telangana.

Table 4.1: Cropping Intensity in Andhra Pradesh Districts

District	1965-66	1984-85	1992-93	District	1965-66	1984-95	1992-93
1	2	3	4	5	6	7	8
SRIKAKULAM	1.22	1.21	1.39	RANGAREDDY	1.04	1.07	1.07
EGODAVARI	1.41	1.50	1.59	NIZAMABAD	1.09	1.23	1.27
WGODAVARI	1.29	1.49	1.50	MEDAK	1.04	1.06	1.13
KRISHNA	1.30	1.50	1.56	MAHABUBNAGAR	1.02	1.08	1.09
GUNTUR	1.22	1.17	1.23	NALGONDA	1.11	1.18	1.28
KURNOOL	1.05	1.09	1.11	WARANGAL	1.11	1.27	1.21
ANANTAPUR	1.02	1.02	1.03	KHAMMAM	1.01	1.09	1.05
CUDDAPAH	1.07	1.04	1.14	KARIMNAGAR	1.04	1.15	1.30
CHITTOOR	1.09	1.12	1.10	ADILABAD	1.00	1.03	1.02

Source: Season and Crop Report, Andhra Pradesh.

As noted in Chapter 3, NSA showed no increase over the years 1965-66 through 1984-85 to 1992-93 (10994, 104846, 10466 in thousand hectares) and came down in a number of districts. Happily, the scene is somewhat better for GCA which rose marginally at the state level (12091, 12212, 12754 in thousand hectares). Table 4.2 gives the percentage increase in land use indices NSA, GCA and CI between 1965-66 and 1992-93. At the district level, GCA increased in the Coastal districts and in 2 of Rayalaseema districts but declined uniformly in the Telangana districts with the exception of Khammam and Adilabad. The improvements registered by Rayalaseema districts are also rather poor. The rise in total cropped acreage at the state level despite little contribution from NSA, is naturally accounted for by the improvement of CI. The cropping intensity has gone up during the period not only at the state level but for all districts.

Though CI increased, it is a very slow progress, with Rayalaseema showing very little improvement. However, in many cases it served in balancing the fall in NSA, even producing a marginal increases in GCA, indicating that in many districts less land is cultivated but with greater intensity. Only in six districts (Chittoor, Anantapur, West Godavari, East Godavari, Srikakulam, Khammam and Adilabad) both NSA and CI contributed positively to the improvement of GCA. The dissimilar behaviour of the net sown area and the cropping intensity over time makes it difficult to make a judgement about the overall performance of land utilisation and deciding whether one makes up for the other. [1]

In any case, it appears from the land utilisation behaviour in Andhra Pradesh agriculture, that greater emphasis and reliance has to be placed on cropping intensity than on net sown area. A high CI indicates prevalence of the practice of multiplecropping. In view of the excessive demand made on limited available land, multiplecropping seems to hold the key to a higher GCA, a higher level of land utilisation and greater food production. We have marked that CI went up in most of the districts of AP, albeit slowly, between the two years 1965-66 and 1984-85. We would now like to know more about this growth process and the factors behind the determination of CI.

Table 4.2 Increase (%) in Net Sown Area, Gross Cropped Area and Cropping Intensity **(1965-66 to 1992-93)**

District	NSA	GCA	CI	District	NSA	GCA	CI
1	2	3	4	5	6	7	8
SRIKAKULAM	23.1	40.8	13.9	RANGAREDDY	-9.1	-5.5	2.9
E.GODAVARI	17.4	34.5	12.8	NIZAMABAD	-16.9	-3.1	16.5
W.GODAVARI	7.4	26.8	16.3	MEDAK	-17.2	-9.7	8.7
KRISHNA	-1.4	19.9	20	MAHABUBNAGAR	-25.1	-20.2	6.8
GUNTUR	-2	9.1	0.8	NALGONDA	-26.9	-15.8	15.3
KURNOOL	-17.3	-12.4	5.7	WARANGAL	-21.5	-13.8	9
ANANTAPUR	11.8	13.7	0.98	KHAMMAM	13.1	16.9	4
CUDDAPAH	-10	-3.84	6.5	KARIMNAGAR	-20.7	-0.95	25
CHITTOOR	6.3	7.6	0.92	ADILABAD	6.7	8.65	2

Note: Cropping intensity (CI) is estimated by counting the perennial crop sugarcane's acreage twice in the gross cropped area (GCA) and dividing the same by net sown area. Possibly, this accounts for the minor discrepancy in the growth rate in CI, GCA and NSA. *Source:* Season and Crop Report, Andhra Pradesh.

4.3 OBJECTIVES

In this chapter we will try to answer he following questions:

(i) Has there been a steady change in cropping practices leading to a positive growth of CI over time?

(ii) What are the cause and effect relations behind the determination of CI and what are the factors accounting for its variation between years?

With increased access to new technology, and to institutional facilities like credit, transport and other support and with the dissemination of knowledge, it is possible that CI has grown over time i.e., it has had a deterministic positive time trend. Whether such improvement of cropping practices has steadily pulled up CI over time can be examined by studying the time trend of CI, taking into account all points of time in the sample period 1965-66 to 1984-85 rather than comparing two distinct points (as done in Table 4.1). Details of data used are provided in Appendix (B) of the thesis.

4.4 TREND ANALYSIS

As in the case of NSA, two time trends are fitted to CI, one in a simple linear trend and other a quadratic one, allowing for the trend to change direction (see section 3.4).

$$CI\,t = a + b\,t + u \qquad \text{...4.4.1.}$$

$$CIt = a + b\,t + b'\,t^2 + ut \qquad \text{...4.4.2.}$$

where CI= Cropping Intensity, t = time, and u is the disturbance term.

Although the linear or quadratic equations estimated (reported in Table 4.1(A4) in Appendix A4) show positive trend in most cases, 5 of the 14 regression equations reported could not explain even 40% of the variations of cropping intensity (CI). Also, the possibility of a unit root process could not be ruled out in some cases (namely Rangareddy, Anantapur, Nizamabad, Karimnagar, Khammam and Nalgonda).[2] In the Coastal region only district group Guntur has not shown any trend. All the other districts show positive trends, although East Godavari has a declining CI until 1970-71, which marked a turning point. In Rayalaseema, Kurnool and Chittoor do not show any trend in CI and the other two districts produce turning points in the trend curves (while for Cuddapah, cropping intensity fell in the initial years, reached a minimum and then recovered, the story is reverse for Anantapur where it had a falling trend in the last few years of the sample period). In Telangana, all districts recorded growth but reversals in the direction of growth took place in Rangareddy and Nalgonda.

Behaviour of Land Utilisation:.

We are not so satisfied with the above analysis owing to the poor explanatory power of most of the trend equations and the possibility of spurious trends. Also, in many of the cases there have been reversals in direction of trend. The explanation of such changes in trend is not clear. We cannot conclude that cropping practices in the state improved to pull up CI steadily over the years (although this may be true in some areas). We would like to examine the factors or constraints that possibly explain the farmers' multiplecropping behaviour and thereby determine the CI in a year and the role of foodgrain crops in multiple cropping decisions.

4.5 FACTORS BEHIND CROPPING INTENSITY

At the outset, we recall that the agro-climatic conditions, infrastructure and economic conditions vary across districts of AP. As a result of such differences and those relating to the historical evolution of agricultural practices, dissimilarities arise in activities such as soil preparation, manuring, drainage, choice of crops, rotations and seasonal patterns of cropping and attitude towards modern technology. Due to these differences, the very response of CI to the same explanatory variable may be quite different. In fact the same set of variables may produce an effect on CI, which can be quite unlike in any two districts .

Availability of moisture is an important prerequisite for cropping, and since natural rainfall may not be enough and is seasonal, irrigation becomes important and even a basic necessity for multiplecropping and attainment of a high CI. Irrigation has therefore been the focus of most studies on CI and has even become a contentious point. The overriding role of irrigation in enhancing the cropping intensity in India has been doubted and questioned by many, beginning with V.K.R.V. Rao's Panse Memorial Lecture in 1974 and recently to some extent by Rao, Ray and Subbarao (1988) and Alagh (1987). The importance of other factors like the availability of labour and mechanisation has also been explored. The role of labour was implicitly pointed out by the debate over farm size and productivity in India (Sen, 1964, Saini, 1979) in the 1960s where farm size could serve as a proxy for labour availability (in an inverse sense) and productivity per net sown area incorporated the intensity of cropping. Mechanisation expedites farm operations and enables timely sowing of a second crop. It is credited to be a factor behind intensive use of land, although not much evidence has emerged from empirical studies to support this point (see Agarwal, 1982, Binswanger, 1978).

4.6 IRRIGATION INFRASTRUCTURE AND CROPPING INTENSITY

Since the importance of water in aiding multiple cropping cannot be denied, and rainfall may not be adequate for the purpose, the infrastructure provided for irrigation water may have an important influence on the cropping intensity of a region. In view of the controversy over the role of irrigation[3] we will investigate for AP the beneficial contribution of irrigation towards a high crropping intensity. To capture the effect of irrigation input we will use as explanatory variables (i) the basic irrigation infrastructure available to the farmer i.e., the proportion of net sown area that can be irrigated and then (ii) infrastructure in the form of two broad categories of irrigation, namely surface and ground water irrigation and (ii) further disaggregated sources of irrigation.

4.6.1.*Method of Estimation*

In our ensuing investigation of the role of irrigation and other variables in explaining CI, multiple regression analysis will be made after defining the variables appropriately. With time series data to be used, the disturbance term is possibly serially correlated and AR(1) model will be used to correct autocorrelation using Hildreth-Lu (HILU) method. Multicollinearity among variables is also severe in many cases and resulted in poor regressions. In some cases certain variables produced good regressions *when used as single variables with high* $\bar{R}^2$ *and significant* parameters, but used conjointly, the equations become worthless. In such cases we are forced to estimate the equation separately using different variable combinations to get over multicollinearity among variables and yet identify those that matter in determining CI. A choice is made from alternative specifications though some information is lost in the process. In a few cases where all specifications give reasonably good results we have refrained from making a judgement and reported more than one equation to bring out the effect of different variables. In selecting the equations to be reported we judged on the basis of (a) significance of parameters and (b) fit of the model as measured by $\bar{R}^2$. We have not reported equations with variables whose t-values of parameters fall short of unity (COV Estimator, Maddala, 1989, pp 243). The Durbin-Watson statistics for serial correlation are reported as also Dickey-Fuller test statistics for the presence of unit root in residuals.

In cases where no meaningful regression could be obtained for reporting with the linear specification we have also tried logarithmic transformation of the variable and have reported the result if meaningful. But in general, we have stuck to estimating linear equations since some of the variables are inessential inputs for multiplecropping and occasionally happen to be zero (loglinear specification might require omission of observations in such cases).

4.6.2. *Irrigation Intensity*

To examine if extension of irrigation facility has contributed favourably to CI in AP, we have estimated the following equation.

$CIt = a + b\ II\ t + ut$ .... **4.6.1.**

where t is time, CI is Cropping Intensity, II = Net Irrigated Area \ Net Sown Area is the overall irrigation intensity of land and u is the disturbance term. The result is however very disappointing, with only ***two districts Nizamabad and Karimnagar***, both in Telangana providing any equation worth reporting (Table 4.2(A4)) and both showing ***positive impact of irrigation***. Both districts witnessed improvement in irrigation intensity over the sample period accompanied by a near doubling of share of ground water (GW) in their net irrigated area (NIA)

The poor performance of irrigation intensity as a variable to explain CI may be possibly due to the way it is measured. Net irrigated area in our statistics constitutes only that area which gets at least one irrigation in the course of a year. It says nothing about the quantity of water delivered, the number of irrigations in the growing periods of crops, the seasonal orientation, timeliness and dependability of the irrigation system. The quality of irrigation in this context has repeatedly been emphasized in studies of CI , although this variable is difficult to capture with our available statistics.

4.6.3 Surface water and Ground water irrigation intensities

Since multiple cropping in India usually involves growing a crop in the dry season in addition to the main monsoon season, it is the access to water in the rabi season that is considered of relevance for determining cropping intensity. The perenniality of irrigation is often held more meaningful in this matter than the mere existence of the system (Dharm Narain, 1980, Dhawan, 1988, 1993). In particularly, Dhawan (1988) pointed out that the impact of irrigation on CI depends on the degree to which it is oriented towards the dry season rather than its extent and intensity. In a sceptical analysis of the benefical role of irrigation, he wrote of misconceptions and the failure to recognise the fact that most of the irrigation development in India is actually directed towards the kharif crop for insulating it against rainfall failures and improving yield rates in this season. Such an irrigation system can be of limited use to increasing CI.

Let us now try to modify our irrigation variable to incorporate 'quality' or 'dry season' orientedness of irrigation. Statistics on irrigated acreages are reported both as net acreages under different sources of surface and ground water irrigation and as gross acreages under different crops. Since the different sources of irrigation differ in their perenniality, their level of dependence on rainfall and the mode of control over water supply, source wise irrigation intensity can be used as a proxy for the quality of irrigation. We will make use of the data on net irrigated area and examine how infrastructure created in the form of the two broad categories - surface water (SW) and ground water (GW) irrigation helps the farmers to cultivate more intensively.

Surface water irrigation in this analysis comprises canal and tank irrigation while tube wells and other wells constitute ground water irrigation. The differential character of the two broad categories of irrigation (as elaborated in 1.5.1) lead to disparate impacts on cropping practices. In the following section we will examine how cropping intensity is influenced by the two categories of irrigation.

Before going into the analysis, it is essential to appreciate that irrigation, though important, is not always a necessary or sufficient factor for intensive cropping of land. In the first place many of the sources are themselves dependent on rainfall. Although multiplecropping entails farming in both seasons it must also be pointed out that in AP, rainfall is more evenly distributed across the year than in many other parts of India and about 40% of the annual rainfall is received in the north east monsoon season. Rainfed cultivation can therefore be possible in both kharif and rabi seasons. Rainfall in both seasons may therefore themselves be important sources of moisture in determining CI. On the whole, there is need for a certain adequate amount of water for growing a second or a third crop on the same land, and this water can come from irrigation as well as from natural rainfall with one source supplementing the other. Too much water or uncontrolled watering can also be deleterious for plant growth. Thus we have the following four simple possibilities.

(i) Two irrigated crops in two seasons.
(ii) A rainfed kharif crop succeeded by an irrigated rabi crop.
(iii) A rainfed or irrigated kharif crop followed by an unirrigated crop fed by north east monsoon and drawing from moisture retained in the soil from previous season.
(iv) Two rainfed crops.

Usually, one expects case ii) to be of significance and argues in favour of a dry season directed irrigation as the usual course to a high CI. However, one cannot rule out the other possibilities as the distribution of rainfall, the type of irrigation, drainage and moisture conserving properties of soil and the choice of crops decide the outcome. In this state (AP) with a bi-modal rainfall pattern and prevalence of dry crops, the argument for a dry season directed or even a perennial source of irrigation may not be as strong and deserves consideration. It is therefore interesting to study the effects of different forms of irrigation on CI in AP.

While the impact of irrigation is normally expected to be favourable, negative effects are possible: (a) when drainage is poor and irrigation leads to excess watering or water logging of land, cropping may be difficult; (b) the assurance of irrigation in some tracts can lead to concentration of limited resources and time on them for growing certain lucrative crops with higher yield rates and less risk, letting some dry land go fallow in the process in any season. In this case a farmer enjoys higher returns from a single irrigated crop (in the year) in place of two/ three dry ones. For similar reasons, rainfall can also become unfavourable for CI. Also, where there is assured water from irrigation, cropping pattern and practices may be so planned (e.g., HYV cultivation in rabi season) that heavy rainfall proves to be a disturbance and deters cropping.

We now estimate the following equation.

$$CI_t = a + b\,SW_t + c\,GW_t + m\,RSW_t + n\,RNE_t + u_t \quad \text{....}\mathbf{4.6.2}$$

where CI= cropping intensity, SW= net area under surface water irrigation divided by net sown area, GW= net area under ground water irrigation divided by net sown area, RSW= total rainfall in south west monsoon season (June to September), RNE= total rainfall in north east monsoon season (October to December), t = time and u = disturbance. While parameter *a* is expected to be positive, *b, c, m* and *n* can be positive or negative according as the corresponding variable plays a favourable or unfavourable role as discussed earlier in this section.

Results with two categories of irrigation SW and GW

We can report results of only 12 out of 18 districts of AP (the estimated equations are presented in Table 4.3(A4) in Appendix A4). The fit of the model in the equations reported has been fairly satisfactory with $\bar{R}^2$ exceeding 0.4 in all cases but one (Khammam). In the Coastal districts RNE has produced negative effects on CI, possibly pointing to the value of controlled water in promoting multiplecropping in the dry season. The variable RSW has not appeared as a variable in this region. The role of rainfall is more apparent in the Rayalseema region where parameters are found significant for RSW in Anantapur and Cuddapah and for RNE in Cuddapah and Chittoor. RNE is also important in Telangana districts. Thus, rainfall in both kharif and rabi seasons can be important for CI. Remarkably, the coefficient of RSW is always positive (though not always significant).

Table :4.3 Districts Reported

REGION 1	DISTRICTS REPORTED 2
Coastal	East Godavari, West Godavari, Krishna
Rayalaseema	Anantapur, Cuddapah, Chittoor
Telangana	Rangareddy, Medak, Mahabubnagar, Nizamabad, Karimnagar, Khammam

Ground water irrigation (GW) has a significant positive coefficient for the Godavari districts in Coastal region, is found deleterious in in Rayalaseema (Ananatpur, Cuddapah and Chittor) and in Telangana the effect is mixed, the coefficient being significantly positive for Nizamabad, Mahabubnagar and Khammam but significantly negative for Medak..

In the Coastal districts variable SW for surface water irrigation appears only for Krishna with a negative coefficient. The variable also bears a negative parameter for two districts (Anantapur and Cudappah) in Rayalaseema (these districts show negative impact of both categories of irrigation) but a positive significant one for one (Chittoor). In Telangana SW has a significant and positive impact in three districts of Telangana (Rangareddy, Mahabubnagar and Karimnagar) and negative nowhere.

Our observations from the results are as follows.

(1) In *Coastal region* GW is the only variable for water input that promotes CI. In fact, SW and the rainfall variables, where they appear bear negative coefficients. The results possibly point to the abundance of moisture and a drainage problem in the region and highlights the importance of controlled and well managed irrigation in improving CI.

(2) The *Rayalseema* districts go for multiplecropping when rainfall is more. In fact Cuddapah gains from both rainfalls. But irrigation, both ground and surface water is deterrent for intensive cropping (except Chittoor). Both GW and SW have adverse effects in two of the districts. This perverse effect may be an unpleasant sign of insufficient resources and their concentration in irrigated tracts at the cost of dry/ rainfed cultivation in another season.

(3) The *Telangana* districts appear to benefit from greater moisture in terms of rainfall and irrigation (except for Medak where GW brings down CI). RNE and SW are more important in their influence.

Table 4.4: Impacts of variables on Cropping Intensity (Irrigation Categories and Rainfall)

VARIABLE	IMPACT	DISTRICTS	IMPACT	DISTRICTS
1	2	3	4	5
SW	+	CHITTOOR, RANGAREDDY, MAHABUBNAGAR, KARIMNAGAR, NIZAMABAD	-	KRISHNA, ANANTAPUR, CUDDAPAH
GW	+	E.GODAVARI, W.GODAVARI, NIZAMABAD, KHAMMAM, MAHABUBNAGAR	-	ANANTAPUR, CUDDAPAH, CHITTOOR, MEDAK
RSW	+	ANANTAPUR, CUDDAPAH, MEDAK	-	(None)
RNE	+	CUDDAPAH, CHITTOOR, MAHABUBNAGAR, KARIMNAGAR, KHAMMAM, NIZAMABAD	-	E.GODAVARI, W.GODVARI
SW AND GW	+	MAHABUBNAGAR, NIZAMABAD	-	ANANTAPUR, CUDDAPAH
RSW AND RNE	+	CUDDAPAH	-	(None)

Notes: + denotes positive impact, - denotes negative impact.

As discussed in Chapter 1 section 1.5.1, the categorisation of irrigation infrastructure as ground water and surface water has implications on the extent of irrigation and its controllability and distribution but it says little about the assurance and perenniality of the sources embodied. The constituent sources under any category vary in their dependence on rainfall and can have significant and conflicting effects on CI and our results only show the net impact of these constituents.

4.6.4 *Source wise irrigation intensities*

We therefore now analyse the determination of CI with more disaggregated variables for irrigation intensity - Tank irrigation (TNK), Canal irrigation (CNL), Tube well irrigation (TW), 'other' well irrigation (OW) and other sources of irrigation (OS). CNL represents assured and perennial sources of water in Andhra Pradesh independent of rainfall in the current period but it can have undesirable effects like water logging and drainage problems. Tanks, on the other hand, are traditional sources, unreliable and dependent on rainfall. TW is a modern and reliable source but is not so common in the state. OW are a traditional ground water source in the state, often energised but are not so assured as canals when rainfall is scanty. In addition, all other sources like lift irrigation comprise OS. The rainfall variables are as usual RSW and RNE measuring the total rainfall in the two main seasons. We now have

$$CI_t = a + b_1\ CNL_t + b_2\ TNK_t + c_1\ TW_t + c_2\ OW_t + d\ OS_t + k_1\ RSW_t + k_2\ RNE_t + u_t \quad ..\mathbf{4.6.3}$$

While estimating equation 4.6.3, multicollinearity problem proved severe. Inclusion of all the explanatory variables led to doubtful results with poor parameters though the fit was good. To overcome the difficulty, we were forced to drop some variables and try alternative specifications. The best specification in terms of fit and t-statistics (COV criterion) is reported although there may be some bias in the estimates. In certain cases we have reported multiple specifications of the equations in the results to get at the effects of different variables.

Results with source wise irrigation variables

We have now got 14 results to report (equations in Table 4.4(A4)). We now have some additional findings on the Coastal region with district group Srikakulam being reported. Earlier we did not find any favourable role of rainfall in this region, but for Srikakulam both rainfalls appear with positive coefficients, though this is the only case in Coastal region (RNE appears with a negative significant parameter in cases of E.Godavari, W.Godavari, Krishna and Guntur and in Krishna, both RSW and RNE appear with negative coefficients). CNL is also found to have a significant positive effect on CI in the same district group Srikakulam. TW has a positive effect in Srikakulam and the Godavari districts, but OW has negative one in two districts (Krishna and Guntur) and positive nowhere. The variable OS comes only in one case (Guntur) with a positive parameter where in fact, it is the only positive factor identified. Tank irrigation does not appear anywhere (although it may have a negative impact for Krishna where SW and CNL seem to have opposite effects). In the *Coastal region,* the districts vary with respect to the sources that help cropping intensity. Canals and tube wells, both relatively assured sources, are beneficial while other wells have adverse effect. Tanks and rainfall have little impact.

Table 4.5: Districts Reported

REGION 1	DISTRICTS REPORTED 2
Coastal	Srikakulam, East Goadavari, West Godavari, Krishna, Guntur
Rayalaseema	Anantapur, Cuddapah, Chittoor
Telangana	Rangareddy, Medak, Mahabubnagar
	Nizamabad, Karimnagar, Khammam.

In the Rayalaseema districts, rainfall is found beneficial. Variable TNK benefits cropping intensity only in Chittoor, a predominantly tank irrigated district, but the other surface water source CNL has differing effects within the region (it has a positive effect in Chittoor but a negative one in Anantapur and Cuddapah, which are relatively drier districts). In *Rayalaseema districts* cropping intensity is not helped by other wells and canals (except Chittoor), while tanks and other sources can help in a few districts. But by far, rainfall is the most important source of moisture for intensive cropping.

In Telangana, rainfall RNE is favourable in four cases, and adverse in none. Rainfall RSW is found favourable in two cases and in only one case (Rangareddy) rainfall (RSW) is found to have a negative effect. Each of the two surface water sources has positive effects in three cases and negative in none but the ground water sources as well as other sources (OS) have both positive and negative effects within the region. Nizamabad is a remarkable district in the region where all the sources of water, namely, RSW, RNE, CNL, TNK, OW, TW and OS have positive roles in determining cropping intensity (due to multicollinearity, several equations are estimated to identify these variables). *Telangana region* shows some heterogeneity with respect to the impacts of wells but canals, tanks and rainfall are mostly beneficial for intensive cropping.

Among the irrigation sources, canal is found beneficial in 6 cases out of the 14 reported for the state. Canals have a positive role in two districts (Srikakulam and Krishna) in Coastal region, where surface water irrigation as a whole did not show a positive impact. In Rayalaseema canals have negative effect in two cases (Cuddapah and Anantapur) and positive effect in only one (Chittoor). This may be sign of diversion of limited resources to tracts with assured irrigation in dry districts. Canals are favourable for cropping intensity in Telangana region. Tank irrigation has no significant role in Coastal region, but in Chittoor in Rayalaseema, it joins canal irrigation in raising the CI. In Telangana, tanks are found favourable in as many as four cases. Tube wells, as we know are not prominent as a source of irrigation in the state but their impact is observed in Coastal region accounting for the positive role of GW noted earlier and also in Telangana. Except for one case (Rangareddy), the impact is always positive. Other wells also have a role in determining CI but the impact is unfavourable in general. (with only two districts Nizamabad and Mahabubnagar in Telangana showing a positive effect). Rainfall, mostly has a negative effect in Coastal region. Rainfall is favourable in Rayalaseema and Telangana but while it plays the main role in improving CI in the former, in Telangana irrigation also has a very important role. The rainfall in the rabi season is more often a determining variable for CI (11 out of the 14 cases reported), although the effect is not always favourable (possibly depending on the kind of crops grown and the drainage quality of soil).

Table 4.6: Impact of variables on Cropping Intensity (Source-wise Irrigation and Rainfall)

VARIABLE	IMPACT	DISTRICTS	IMPACT	DISTRICTS
1	2	3	4	5
CNL	+	SRIKAKULAM, KRISHNA, CHITTOOR, RANGAREDDY, MAHABUBNAGAR, NIZAMABAD	-	CUDDAPAH, ANANTAPUR
TANK	+	CHITTOOR, MAHABUBNAGAR, NIZAMABAD, KARIMNAGAR, RANGAREDDY	-	(None)
TW	+	SRIKAKULAM, E.GODAVARI, W.GODAVARI, MAHABUBNAGAR, NIZAMABAD, KHAMMAM	-	RANGAREDDY
OW	+	NIZAMABAD, MAHABUBNAGAR	-	KRISHNA, GUNTUR, CUDDAPAH, MEDAK
OS	+	GUNTUR, ANANTAPUR, NIZAMABAD	-	CUDDAPAH, KARIMNAGAR
RSW	+	SRIKAKULAM, ANANTAPUR, CUDDAPAH, MEDAK, NIZAMABAD	-	KRISHNA, RANGAREDDY
RNE	+	SRIKAKULAM, CHITTOOR, CUDDAPAH MAHABUBNAGAR, NIZAMABAD, KARIMNAGAR, KHAMMAM,	-	E.GODAVARI, W.GODAVARI, KRISHNA, GUNTUR

Notes: + denotes positive impact, - denotes negative impact.

In this study on Andhra Pradesh we do find that *cropping intensity is influenced greatly by rainfall and irrigation.* The availability of irrigation, by itself, did not improve CI (the poor results obtained with irrigation intensity as the variable), but a lot depended on the quality if irrigation and other conditions of the district. Also, due to the rainfall distribution and the nature of crops grown in the state, both seasonal rainfall and various sources of irrigation (and not just perennial or dry season directed ones) influence cropping intensity and the impact can be favourable or adverse.

4.7 INPUT INTENSITIES AND CROPPING INTENSITY

We have so far examined how infrastructural facility for irrigation influences the intensity with which the land can be cultivated. The planting decisions of the farmers are hardly an integrated set of decisions. In fact, farmers take a number of decisions relating to the *various crops* they want to plant in the different tracts of land in their holding and in different seasons of the year. Such disjoint actions taken at various points of time not only make up the net sown area but also add up to the gross cropped area and thereby determine the cropping intensity. In this section, we will view the evolution of CI as a result of such planting decisions and examine how variables *relating to foodgrain crops (under consideration)* influence and shape the CI of land.

This is an approach to the farmers' multiple cropping decision different from the earlier one. We took no account of the types of crops farmers raised in the different seasons, their nature and technology of production. We noted that in Andhra Pradesh rainfall is more evenly distributed than most part of the country. Many of the crops raised here have modest demand for water. Existence of irrigation therefore may not always be binding for cultivation of crops in any season. However, irrigation becomes neceassary for certain crops and technology such as high yielding rice especially in the rabi season. In some cases increased irrigation given to a crop merely turns some dry crop acreage to irrigated acreage with higher yield rate but has little effect on cropping intensity. Yet, in other cases it encourages cultivation of a higher yielding crop on fallow land where dry cultivation was considered uneconomic. In such cases the impact on cropping intensity is likely to be favourable. In some cases seasonal rainfall may not be adequate for the crop and only irrigation makes the second crop possible. Irrigation facility extended to a crop can be beneficial for cropping intensity if the crop benefits significantly from irrigation, given the rainfall, and provided some land suitable for the crop is lying fallow in the season when it can be cultivated. The impact can also be negative if the increased yield of the crop due to its irrigated status, discourages dry cultivation in the other season. That is, when the farmer chooses to raise one irrigated crop instead of two dry ones in a sequence.

Let us consider the case of the cereals more explicitly. Now, the possibility of multiplecropping arises because of the seasonal nature of agriculture. Most of the cereal crops, take two to four months from sowing to harvesting and they account for not less than 60% of GCA in AP. We are aware that nearly all of the crops, particularly rice, jowar and maize can be grown as both kharif and rabi and sometimes even as a third summer crop. Whether the farmer decides to plant the same crop as a second crop on the plot or or chooses a different one is of little relevance in the context of CI. (In fact, for the sake of exposition we can visualise a case where the farmer follows a kharif rice rop by rabi jowar on a piece of land and kharif bajra by rabi rice in another one). What matters is that he/she does not let the land lie fallow in any of the two seasons. Thus the cereal crops are the (a)most important of all crops and are usually raised on qualitatively superior land and (b) they are fairly short duration crops and can be grown in more than one season. These crops therefore are expected to contribute significantly to multiple cropping practice and a higher croping intensity(CI). Monocropping, which essentially involves land wastage in the case of a cereal, can possibly be the result of input constraints. Can we not ask the question: Do these crops need any input support so that they can be raised as a second or a third crop in multiple seasons?

In this section we will try to answer the above question by examining how input intensities of cereal crops influence overall CI. We make use of data available for gross irrigated area under the cereal crops and try to study the contributions of the five cereal crops to cropping intensity .

As we observed already, irrigation is neither a necessary nor a sufficient condition for planting. Raising a second crop definitely calls for other inputs as well. In fact, if irrigation becomes possible, it is often tempting to grow HYV in the comparatively predictable weather of the rabi season. But availability of fertiliser becomes a requisite for multiplecropping to make use of the irrigation facility. The withdrawal of nutrients from the soil needs to be replenished if a second crop is to follow immediately. This is an instance where irrigation is necessary but not a sufficient condition for multiplecropping.

But we have noted, that even without a dry season oriented irrigation or with no irrigation at all, it may be possible to raise multiple crops if (i) the seasonal rainfall or the moisture retained in the soil are adequate and (ii) when the crop is not too demanding of moisture. Thus a rainfed rabi or even a rainfed kharif crop may be grown as an additional crop if other conditions permit. But here too the soil has been drained of nutrients by the preceding crop and fertility must be restored for the coming one.

Thus fertiliser can be of importance for CI with or without the association of irrigation. The complementarity between irrigation and fertiliser noted in some cases (mostly where high yielding technology is available) and the observation that irrigated acreage appropriates the major share of fertiliser input used in India may lead us to place too much emphasis on irrigation. Such a perception is rather misplaced. For one thing it ignores the necessity of fertilising the soil for multiplecropping when sufficient moisture is present from irrigation, rainfall or past watering to support it. In addition, this view minimises the role of dry/ rainfed agriculture which is quite sizable in AP, constituting more than 50% of GCA under foodgrains (more so in the rabi season at 58%, see Table 3.4.) A large part of the fertiliser input (nearly 50%) also goes for rabi crops. Also the presumption that fertiliser use is only guided by the availability of irrigation (the so called complementarity hypothesis), assumes an elastic supply of fertiliser, a more or less perfect market and adequate purchasing power of the farmers. We know that none of the above is necessarily true in India. Fertiliser supply is constrained by production capacity, the foreign exchange position, and the efficiency of distributional agencies. The ability of the farmers to buy fertiliser depends on their resource position, their access to credit and physical availability of fertiliser and all at the correct time too. In addition are the complexities imposed by subsidies, pricing mechanism as well as the tenurial arrangements and interlock rural markets all of which make market far from perfect. Thus fertiliser can be a constraining input variable for a high CI. In short, the importance of fertiliser cannot be ignored (i) when there are traditional and inferior crops raised with or without irrigation in multiple seasons provided fertiliser can be applied and (ii) when, in the presence of irrigation, the farmer consider it economically feasible to raise a lucrative crop as an additional one provided fertiliser can be applied.

The input variables we will consider in this analysis are irrigation, fertiliser and rainfall. Crop wise irrigation intensities are the variables for irrigation. The two seasonal rainfall are considered as before. Since data on fertiliser intensity for individual crops or for cereal crops as a whole are not available we have used data on overall fertiliser intensity as our variable (we assume that the proportion of fertiliser going to cereal crops did not significantly vary over time).

$$FRT = TF/TA \ldots\ldots\ldots\ldots 4.7.1$$

where FRT is the proxy fertiliser variable, TF is total fertiliser over all crops and TA is acreage under the five cereals (this is further elaborated in Chapter 6).

$$CI_t = a + b_1 IRR_t + b_2 IRJ_t + b_3 IRG_t + b_4 IRM_t + b_5 IRB_t + m FRT_t + d_1 RSW_t + d_2 RNE_t + u_t.. \qquad \ldots\ldots 4.7.2$$

$$\text{or} \quad CI_t = a + b\ AGIT_t + c\ FRT_t \quad d_1\ RSW_t + d_2 RFNE_t + u_t \ldots.4.7.3$$

where

CI= Cropping Intensity

AGIT = Gross irrigated area under 5 cereals/ Gross cropped area under 5 cereals

IRR = Gross irrigated area under rice/ Gross cropped area under rice

IRJ = Gross irrigated area under jowar/ Gross cropped area under jowar

IRG = Gross irrigated area under ragi/ Gross cropped area under ragi

IRM = Gross irrigated area under maize/ Gross cropped area under maize

IRB = Gross irrigated area under bajra/ Gross cropped area under bajra

FRT = Total fertilser used/ Gross cropped area under 5 cereals

RSW = Total rainfall from south west monsoon (June to Septenber)

RNE = Total rainfall from north east monsoon (October to December)

u is disturbance and t is time.

Results of regressions with input intensities

We have 14 results to report (Table 4.5(A4) in Appendix A4). The fit is usually found good. The model explains CI in all districts of Coastal region. The aggregate cereal crop irrigation intensity (AGIT) has a positive effect in the Godavari districts. In other words, increasing the irrigation intensity of cereal crops would be accompanied by an improved cropping intensity. But the effect is negative for the district group Srikakulam, where we had found a favourable effect of irrigation as an infrastructure. We could not identify the cereal crop responsible for the adverse effect. Possibly some non cereal crop (like sugarcane, which is a dominant crop in this district group) promoted higher CI. Rice appears to promote intensive cropping when irrigated in the Godavari districts but in the district group Guntur, cereals jowar and ragi, which are not prominent crops, contributed positively (we noted in 2.4, however, that Guntur is a high value district relative to the state level in irrigation intensities of both jowar and ragi). Fertiliser variable (FRT) appears in two cases of Coastal region and both with positive impact. We mark that the two cases are quite different. District group Srikakulam has a mixed cropping pattern and relatively dry crops like bajra enjoy prominence. Irrigation given to cereal crops is found to favour monocropping but intensive use of fertiliser encourages multiple cropping. In contrast, West Godavari is totally rice dominated and being extremely fertile and endowed, probably tend towards an input intensive technology. More of irrigation and fertiliser both encourage a second crop with high yield.

Table 4.8: Results Reported

REGION	DISTRICTS
1	2
Coastal	Srikakulam, East Godavari, West Godavari, Krishna, Guntur
Rayalaseema	Kurnool, Anantapur, Chittoor
Telangana	Rangareddy, Nizamabad, Medak, Karimnagar, Mahabubnagar, Warangal

Rainfall once again is found mostly harmful for CI (except for Guntur where we find a beneficial variable in RSW; Earlier we already noted a negative effet of RNE but due to multicollinearity the impact of RSW was not captured.)

In the three results reported for Rayalaseema, variable AGIT appears only for Chittoor . For Kurnnol and Ananatapur, we identified individual crops which count. Rice is significant (variable IRR) for promoting cropping intensity in both districts. For Anantapur, we also find ragi and bajra but ragi (IRG) has a negative effect (yet, Anantapur has high irrigation intensity of ragi as noted in 2.4). Variable FRT is favourable for CI only for Kurnool in Rayalaseema.. Rainfall has a favourable impact.

In Telangana, AGIT appears for four cases (Rangareddy, Nizamabad, Medak and Karimnagar), always with a positive parameter. Taking individual crops, the result is less uniform. Rice (IRR) has a positive influence for Nizamabad but jowar (IRJ) has a negative impact on CI in Nizamabad and Warangal. (Nizamabad and Warangal are both low value districts in irrigation intensity of jowar relative to state level). IRB (bajra) has a positive parameter for Warangal where no impact of rice is noted. For Mahabubnagar, fertiliser alone comes as a variable explaining 75% of variations of CI.

We can make the following observations.

(1) The overall cereal crop irrigation intensity AGIT explains cropping intensity in 9 out of 12 cases reported, and except for one case (Srikakulam), in all others (i.e., E.Godavari, W.Godavari, Guntur, Chittoor, Rangareddy, Nizamabad, Medak and Karimnagar), the effect is positive.

(2) The irrigation intensity of rice explains cropping intensity in 6 cases encompassing all 3 regions (EGodavari, W.GodavariI, Krishna, Kurnool, Anantapur and Nizamabad) and in each case the effect is positive and significant. Rice is the foremost crop where intensive irrigation helps to achieve more intensive use of land.

(3) The impact of no other cereal is powerful and the effect is also not always positive. Irrigation given to jowar pulls up CI in one case (Guntur) but brings it down in two (Nizamabad and Warangal). Similarly, irrigation given to ragi helps multiplecropping in one case (Guntur) but deters it in another (Anantapur). Irrigation given to bajra helps CI in two cases (Warangal and Anantapur) only.

(4) Fertiliser FRT explains CI in 4 cases (Srikakulam, W.Godavari, Kurnool, Mahabubnagar) and the effect is always favourable. In fact FRT alone explains 75% of variations in CI in one district.

4.8 CONCLUDING REMARKS

Cropping intensity provides the key to land utilisation in a land scarce country like India. In our study of Andhra Pradesh, CI is found to have improved (though slightly) over the years since 1965-66. Irrigation is often credited to be the main force behind such improvement though there has been scepticism about the matter. Although no cause-effect relation could be discerned between CI and the irrigation intensity in AP, further investigation revealed that *CI was certainly sensitive to irrigation infrastructure and rainfall.* Except for Kurnool, Warangal and Nalgonda we have found sugnificant effects of both irrigation and rainfall on CI. The relation is not necessarily a positive one and depends on the type of irrigation and general conditions of the district. The same source, whether perennial or not, may promote multiplecropping in one district and discourage it in another.

Surface and ground water sources have varied impact and only in Nizamabad and Mahabubnagar both categories have positive impacts. Canals and tube wells, both assured sources of irrigation, are mostly beneficial except in some dry districts. Other wells appear to discourage intensive land use. Tank, a traditional source (which is non-perennial in supply) also helps CI in some cases, but its effect is limited to a few districts mostly in Telangana. We find that irrigation, even assured sources, sometimes bring down CI possibly by concentrating resources in the irrigated areas. Rainfall too does not always help intensive farming, especially where opportunity of high yielding technology exists. But in some cases, mostly in Rayalaseema, rainfall is more important than irrigation.

The major foodgrain crops of the state, namely the cereal crops rice, jowar, ragi, maize and bajra, together contribute significantly to multiplecropping practice. This is understandable in view of their importance in the state's cropping pattern and their (short) duration of growth. Increased irrigation intensity of these crops is associated with a higher cropping intensity. However, rice is the most important positive contributor to multiplecropping practice while increased irrigation given to coarse cereals can at times lead to lower cropping intensity. Increased fertiliser input given to cereals is associated with a higher CI.

The actual level of land utilisation which depends on the behaviour of both the extent and intensity of cultivation is therefore influenced not only by natural rainfall but also the quality of irrigation available and the crops that benefit from inputs. Thus, fuller utilsation of land resources calls for irrigation infrastructure and crop technologies appropriate for the region concerned.

Notes:

[1] Between 1965-66 and 1984-85 (our sample period for the regression analysis) we find from Tables 3.1 and 4.1 that in 11 of the 18 cases, NSA and CI moved in opposite directions and both NSA and CI increased only in 6 cases (Chittoor, Rangareddy, Nizamabad, Nalgonda, Khammam and Adilabad) implying clear betterment of land utilisation in agriculture. Cuddapah showed fall in both indicators. Although the decline in CI is arrested in the following period, the same is not true of NSA, so that GCA increased only marginally.

[2] A Dickey-Fuller test (with trend) is conducted on the cropping intensity (CI) variable at 95% confidence level. A stochastic trend (possibly, a random walk with drift) may be present in the cases of Rangareddy and Nalgonda . The equations are as follows.

RANGAREDDY

$$\Delta CI = \underset{(2.292)}{0.5014} + \underset{(.992)}{0.000899T} - \underset{(-2.268)}{.4807CI_{T-1}}$$

RSS = .005896

NALGONDA

$$\Delta CI = \underset{(2.96)}{.772} - \underset{(-.086)}{.0002\ T} - \underset{(-2.905)}{.642\ CI_{T-1}}$$

RSS = .083256

Figures in brackets are t-statistics.

[3] Vaidyanathan (1994) makes a disscssion on the controversy related to the irrigation's role in determining the cropping intensity in any area. No consistent and significant relation between the extent of rainfall and irrigation on the one hand and intensity of land use on the other was noted in studies conducted on U.P. and Karnataka by Ray (1980), Nadkarni and Deshpande (1979). Ray (1985) even failed to find any significant and primary role of irrigation, its intensity as well as its quality, in determining cropping intensity. They considered factors like mechanisation and availability of labour as more relevant. On the other hand, studies by Dev(1989), Dharm Narain and Roy did find a dominating role of irrigation. The present study examines the role of irrigation and rainfall in determining cropping intensity in Andhra Pradesh and does find significant impact of rainfall and the type of irrigation although the intensity of overall irrigation does not show much influence. However, the impact of rainfall and the different kinds of irrigation vary widely even within the state and is not always favourable (also, Ghosh, 1990).

Appendix A4: ESTIMATED REGRESSION EQUATION

Table 4.1 (A4) Trend Equations for Cropping Intensity

	CONSTANT	T	T^2	$\bar{R}^2$	DW	DFT	T^*
1	2	3	4	5	6	7	8
SRIKAKULAM	1.180 (-108.269)	0. 002 (-2.696)		0.25	1.870	-5.16	
E. GODAVARI	1.399 (-37.372)	-0.013 (-1.616)	0.0096 (-2.5350)	0.47	2.200	-4.28	1971
W.GODAVARI	1.264 (46.976)	0.009 (4.117)		0.46	2.370	-5.85	
KRISHNA	1.312 (59.010)	0.008 (4.778)		0.53	1.440	-3.83	
CUDDAPAH	1.086 (89.466)	-0.006 (-2.590)	0.0002 (1.2500)	0.39	1.630	-4.20	1982
ANANTAPUR	1.005 (132.400)	0.006 (3.294)	-0.0002 (-2.6801)	0.42	1.300	-3.13	1978
RANGAREDDY	1.012 (72.273)	0.009 (3.017)	-0.0003 (-2.3550)	0.41	1.290	-2.97	1979
NIZAMABAD	1.007 (66.099)	0.009 (6.980)		0.72	1.650	-3.39	
NALGONDA	1.091 (23.550)	0.028 (2.761)	-0.0013 (-2.7922)	0.24	1.890	-3.03	1975
MEDAK	1.027 (66..367)	0.004 (2.912)		0.28	1.780	-3.84	
MAHABUBNAG	1.020 (273.860)	0.002 (7.071)		0.72	1.700	-3.62	
WARANGAL	1.130 (44.740)	0.007 (3.265)		0.34	1.300	-3.69	
KARIMNAGAR	1.050 (104.070)	0.007 (8.890)		0.80	1.600	-3.11	
KHAMMAM	1.050 (135.380)	0.003 (3.971)		0.44	1.720	-3.30	

A4: Table 4.2 (A4): Regression Results for Cropping Intensity using Irrigation Intensity as variable

DISTRICT	CONSTANT	IRRIGATION	$\bar{R}^2$	DW	DFT
1	2	3	4	5	6
KARIMNAGAR	0.055 (28.06)	0.305 (2.57)	0.75	1.66	-5.19
NIZAMABAD	0.95 (11.25)	0.51 (0.26)	0.65	2.07	-4.28

A4: Table 4.3 (A4) :Regression Results for Cropping Intensity using two categories of irrigation as variables

	CONSTANT	GW	SW	RSW	RNE	$\bar{R}^2$	DW	DFT
1	2	3	4	5	6	7	8	9
E. GODAVARI	1.346 (37.11)	2.936 (4.472)			-0.0002 (-2.92)	0.49	2.08	-4.33
W. GODAVARI	1.287 (35.796)	3.594 (5.22)			-0.0003 (-2.89)	0.52	1.92	-3.9
KRISHNA	2.046 (7.812)		-0.93 (2.209)		-0.0001 (-1.52)	0.48	2	-4.01
ANANTAPUR	1.051 (45.323)	-0.225 (-1.083)	-0.31 (-1.88)	0.00006 (2.56)		0.61	1.88	-4.03
CUDDAPAH	1.134 (18.54)	-0.569 (-1.949)	-0.37 (-1.23)	0.00007 (2.06)	0.00005 (1.627)	0.48	1.8	-6.64
CHITTOOR(1)	1.253 (29.26)	-0.913 (-3.935)			0.00007 (3.146)	0.5	1.66	-3.45
CHITTOOR(2)	1.027 (45.39)		0.585 (3.503)		0.00007 (2.459)	0.49	1.88	-3.84
RANGAREDDY	0.126 (3.444)		0.019 (1.822)			0.46	2.16	-4.37
MEDAK	1.119 (0.409)	-1.095 (-2.639)		0.00005 (1.909)		0.42	1.86	-3.69
MAHBOOB NAGAR(1)	1.006 (224)	0.916 (8.403)				0.78	1.8	-4.26
MAHBOOB NAGAR(2)	1.015 (1.54)		0.206 (2)		0.00004 (1.9)	0.59	1.96	-4.26
NIZAMABAD	0.874 (17.98)	1.789 (6.09)	0.459 (3.26)		0.0003 (3.10)	0.77	1.9	-4.79
KARIMNAGAR	1.11 (40.13)		0.25 (2.347)		0.00007 (1.22)	0.76	1.82	-3.44
KHAMMAM	1.046 (100.7)	0.721 (2.48)			0.00009 (2.568)	0.34	2.2	-4.77

A4 :Table 4.4(A4): Regression Results for cropping Intensity with source wise irrigation intensities as variables

	CONS TANT	CNL	TNK	OW	TW	OS	RSW	RNE	$\bar{R}^2$	DW	DFT
1	2	3	4	5	6	7	8	9	10	11	12
SRIKAK ULAM(1)	1.09 (24.3)				10.18 (3.34)		0.0001 (1.78)	0.0001 (2.42)	0.42	1.99	-4.01
SRIKAK ULAM(2)	1.02 (36.46)	1.12 (6.65)						0.00013 (3.49)	0.59	2.49	-5.24
E.GODA VARI	1.36 (39.2)				2.89 (4.48)			-0.00024 (-3.06)	0.48	2.07	-4.3
W.GODA VARI	1.28 (38.85)				1.4 (6.02)			-0.0003 (-3.53)	0.55	2.03	-4.08
KRISH NA	0.86 (3.73)	1.54 (3.81)		-9.32 (-1.72)			-0.00009 (-1.65)	-0.00024 (-2.34)	0.59	1.46	-3.59
GUNTU R	1.28 (28.31)			-2.71 (-3.1)		6.97 (4.14)		0.0001 (-3.89)	0.65	1.89	-3.79
ANANT APUR(1)	1.05 (68.14)	-0.87 (-2.67)					0.00006 (3.36)		0.69	2.07	-3.44
ANANT APUR(2)	1 (117.7)					1.49 (2.21)	0.00006 (2.54)		0.57	2.03	-4.18
CUDDA PAH	1.41 (22.29)	-1.97 (-4.49)		-1.47 (-7.6)		-2.81 (-4.47)	0.00009 (2.75)	0.00005 (1.12)	0.58	1.99	-4.25
CHITT OOR	1.01 (42.8)	2.86 (3.1)	0.61 (3.59)					0.00006 (1.87)	0.6	1.61	-3.46
RANGA REDDY	1.10 (22.51)	3.61 (1.76)	0.78 (1..98)		-50 (-2.17)		0 (-2.17)		0.59	1.72	-3.46
MEDAK	1.12 (20.4)			-1.1 (-2.64)			0.00005 (1.9)		0.42	1.86	-3.69
MAHABU BNAGAR	1 (114.8)	0.63 (1.65)	0.23 (2.44)	0.34 (2.68)	58.1 (6.32)			0.00003 (1.4)	0.82	2.1	-5.02
NIZAMA BAD(1)	0.91 (24.87)	0.67 (3.16)		1.48 (3.77)				0.00027 (3.2)	0.74	2.02	-4.44
NIZAMA BAD(2)	0.93 (16.3)		0.52 (1.71)	2.44 (5.44)				0.0002 (2.02)	0.65	1.78	-4.52
NIZAMAB AD(3)	1.06 (38.24)				22.97 (6.24)		0.00006 (1.86)		0.71	2.05	-4.26
NIZAMA BAD(4)	1.03 (55.7)					7.59 (7.68)		0.0002 (2.67)	0.76	2.09	-4.52
KARIM NAGAR	1.15 (34.9)		0.46 (3.19)			-2.58 (-1.95)		0.00009 (1.61)	0.79	1.85	-3.69
KHAMMA AM	1.06 (177.2)				1.31 (3.76)			0.00009 (2.84)	0.49	2.43	-4.77

A4: Table 4.5(A4) : Regression Results for Cropping Intensity using crop level input use as variables

district	CONSTANT	AGIT	IRR	IRJ	IRG	IRM	IRB	FRT	RSW	RNE	R^2	DW	DFT
1	2	3	4	5	6	7	8	9	10	11	12	13	14
SRIKAKULAM	1.67 (11.75)	-0.76 (-3.47)						0.77 (3.25)			0.56	2.2	-4.44
E.GODAVARI(1)[1]	0.51 (13.18)	1.19 (4.74)									0.56	2.07	-4.22
E.GODAVARI(2)[1]	0.61 (5.89)		2.58 (3.85)							-0.02 -1.37	0.5	2.1	-4.17
W.GODAVARI(1)[1]	0.57 (5.89)	1.66 (4.68)								-0.03 -1.77	0.43	2.1	4.21
W.GODAVARI(2)[1]	0.67 (8.66)		1.98 (2.17)					0.05 (2.09)		-0.03 -2.55	0.61	0.23	-4.74
KRISHNA[1]	0.63 (10.15)		10.5 (4.91)							-0.03 -3.46	0.75	1.7	-3.53
GUNTUR(1)	0.15 (0.38)	1.09 (5.26)							0 (2.28)		0.48	1.7	-4.16
GUNTUR(2)	0.77 (4.5)			0.8 (7.29)	0.38 (2.13)						0.68	1.67	-3.72
KURNOOL	0.54 (4.37)		0.58 (4.26)					0.25 (2.21)			0.58	1.9	-3.99
ANANTAPUR	1.05 (28.1)		0.02 (2.03)		-0.09 (-2.14)		0.56 (6.48)		0 (1.21)	0 2.86	0.78	2.3	-4.8
CHITTOOR	0.89 (11)	0.28 (2.26)							0 (2.02)	0 3/7	0.52	1.81	-3.9
RANGA REDDY	0.97 (35.45)	0.56 (3.59)							0 (-2.6)	0 2.92	0.7	2.2	-4.69
NIZAMAABAD(1)	0.97 (11.83)	0.41 (3.11)									0.72	2.14	-4.61
NIZAMABAD(2)	0.82 (5.32)		0.46 (3.85)	-5.34 (-1.78)							0.77	1.96	-4.05
MEDAK	0.95 (21.73)	0.41 (2.69)									0.36	0.82	-4.18
MAHBOOBNAGAR	1.02 (469)							0.73 (9.97)			0.75	1.77	-3.62
KARIMNAGAR	1.01 (20.46)	0.27 (3.01)									0.81	1.74	-3.41
WARANGAL	1.22 (34.57)			-37.37 (-4.72)			2.54 (2.12)				0.67	2.56	-6.02

A4 Table 4.6(A4): Summary Results for Regressions of Cropping Intensity: Effect of Irrigation and Rainfall

District	II	SW	GW	CNL	OW	TW	TNK	OS	RSW	RNE
1	2	3	4	5	6	7	8	9	10	11
SRIKAKULAM				+		+			+	+
E.GODAVARI			+			+				-
W.GODAVARI			+			+				-
KRISHNA		-		+	-				-	-
GUNTUR					-			+	+	-
KURNOOL										
ANANATAPUR		-	-	-				+	+	+
CUDDAPAH		-	-	-	-			-	+	+
CHITTOOR		+	-	+			+		+	+
RANGAREDDY		+		+		-	+		-	+
NIZAMABAD	+	+	+	+	+	+	+	+	+	+
MEDAK			-		-				+	
MAHABUBNAGAR		+	+	+	+	+	+			+
NALGONDA										
WARANGAL										
KHMMAM .			+			+				+
KARIMNAGAR	+	+			-		+	-		+
ADILABAD										

Notes on Tables: .

(1) Figures in brackets below the coefficients are corresponding t-statistics.

(2) Variables are as follows: CI= Cropping Intensity; T= time, II = Irrigation intensity (net irrigated area divided by net sown area),GW= ground water irrigated (net) area divided by net sown area, SW= surface water (net)irrigated area divided by net sown area, CNL= canal irrigated area (net) divided by net sown area, TNK= tank irrigated area divided by net sown area, TW= tube well irrigated area divided by net sown area, OW= area irrigated by other wells divided by net sown area, OS= area irrigated by other sources divided by net sown area, IRR= proportion of rice(gross) area under irrigation, IRJ=proportion of jowar area under irrigation, IRG= proportion of ragi area under irrigation, IRM= proportion of maize area under irrigation, IRB= proportion of bajra area under irrigation, AGIT= proprtion of irrigated area under the 5 cereals, FRT= fertiliser (N+P+K) per Hectare of cereal area, RSW= rainfall from South West Monsoon, RNE= rainfall from North East Monsoon.

(3)DW= Durbin-Watson statistic,

(4)DFT= Dickey-Fuller Test Statistic. Dickey-Fuller test is conducted on the variable CI (with trend) for the trend analyses (Table 4.1(A4))and on the estimated residuals (without trend) for the other regression equations (Tables 4.2(A4), 4.3(A4), 4.4(A4), 4.5(A4)). Critical values for DFT at 95% confidence level are -3.57 for Table 4.1(A4) and -3.04 for the other.

(5)In Table 4.1(A4), T* stands for turning point year where CI has a maxima(MAX) or a minima (MIN)

(6)+:positive impact and -: negative impact in Table 4.6(A4).

(7)Superscript 1 indicates that equation is estimated in log-linear form.

(8)Results on effect of rainfall in Table 4.6(A4)are based on equations reported in Tables 4.3(A4), 4.4(A4) and 4.5(A4).

(9) Sample period is 1965-66 to 1984-85.

5. ACREAGE RESPONSES OF FOODGRAIN CROPS : A NERLOVIAN APPROACH

5.1 INTRODUCTION

In the last two chapters we discussed how farmers decide about utilisation of land. The outputs of individual crops then depend on how farmers allocate the total acreage among crops and the crop yield rates. In this chapter we will study the acreage responses of the cereal crops in Andhra Pradesh. Section 5.2 gives a review of the movement of acreage and output of cereal crops. Section 5.3 spells out the objectives of the econometric analysis to be done followed by a theoretical discussion of acreage response models and related concepts in 5.4. The Adaptive expectations and Partial adjustment model and its application to the case of cereal crop cases in Andhra Pradesh is presented in 5.5. Section 5.6 dwells on the data used in the analysis and the results are provided in section 5.7.

5.2 CEREAL CROP ACREAGES IN ANDHRA PRADESH

Table 5.1 provides data on acreages under the 5 major foodgrain (cereal) crops at the state level for Andhra Pradesh for the years 1965-66, 1984-85 and 1992-93. Although the observed values are related to discrete time ponts, these show a tendency of rice and maize to increase their acreages and the inferior cereals jowar, ragi and bajra to lose them over time since the launch of the new technology. We recall that the coarse cereals, especially jowar, have been important crops in the state and still constitute significant proportion of the state foodgrains output. Also, we noted the concern expressed in some quarters regarding the decline of cultivation of these crops (see 1.4). They are said to be ecologically suited for the dry regions of in the country (and this state in particular) and are the main sources of nutrition for poorer people (especially in the context of the diminishing role that the PDS may play in future). On the whole, the downfall of these important crops brought down the overall acreage under the cereal crops (section3.6). The improvement of rice and especially maize acreages may be due to the increased profitability from high high yielding technology although jowar and bajra too have high yielding varieties. The growing demand for land for raising cash crops and for other purposes may have led to the contraction of acreages while increasing yield rates compensated for the loss. In other words, with technical progress, yield rates become more important for growth while the role of acreage becomes less important in determining production level. In Table 5.2 we present the direction of movement (increase or decrease) of both acreage and production in each case. The changes in yield rates are not reported as they moved upward in almost all cases. (The only exception is bajra, the yield rate of which fell in all of Telangana barring only Nalgonda. Ragi yield also declined in Medak in Telangana.) The picture at the district level is more varied in the case of rice. Although output in all cases registered positive movements, acreage moved in the same direction only in Coastal region and in 3 districts of Telangana. In all of Rayalaseema and major part of Telangana, improvement in yield was the only impetus to production growth which offset the decline in acreage. Maize is another crop where output increased throughout the state but here acreage contributed to the process in all cases except 3 (Cuddapah, Rangareddy and Nalgonda). On the contrary, the other coarse cereals mostly showed decline in output, more specifically ragi and bajra. The Coastal districts showed large decreases in acreage and output. Jowar did show increase in output in 2 cases in Rayalaseema and 4 in Telangana but acreage came down in all but one case. In Rangareddy acreage and production both increased but in Anantapur, Kurnool, Medak, Mahabubnagar and Adilabad yield rate was pivotal for the output growth as acreage fell. Ragi acreage decreased throughout and output also declined with the exception of one case in Coastal region (Srikakulam) and one in Telangana (Rangareddy) where yield increase was the only contributor. Bajra output too declined, Nizamabad being the only exception but Rangareddy witnessed an improvement in acreage along with a decline in output. *Thus acreage has in most cases contributed to the movement of output, though this is less so for* rice.

Table 5.1 Acreages ('000 Hectares) of Cereal crops in Andhra Pradesh : State level

	RICE	JOWAR	RAGI	MAIZE	BAJRA	CEREALS
1	2	3	4	5	6	7
1965-66	3,139.5	2,453.2	321.5	215.9	530.4	6,660.5
1984-85	3,497.5	1,862.3	226.1	312.9	394.6	6,293.4
1992-93	3,604.1	1,051.9	144.7	321.9	170.8	5,293.4

Note: Col.7 gives total of 5 cereal crop acreages. *Source:* Season and Crop Report, Andhra Pradesh.

Table 5.2 Movement of Cereal Crop Acreage and Output between 1965-66 and 1992-93

CROP	RICE		JOWAR		RAGI		MAIZE		BAJRA	
1	2	3	4	5	6	7	8	9	10	11
DISTRICT	A	O	A	O	A	O	A	O	A	O
SRIKAKULAM	+	+	-	-	-	+	+	+	-	-
E.GODAVARI	+	+	-	-	-	-	+	+	-	-
W.GODAVARI	+	+	-	-	-	-	+	+	-	-
KRISHNA	+	+	-	-	-	-	+	+	-	-
GUNTUR	+	+	-	-	-	-	+	+	-	-
KURNOOL	-	+	-	+	-	-	+	+	-	-
ANANTAPUR	-	+	-	+	-	-	+	+	-	-
CUDDAPAH	-	+	-	-	-	-	-	+	-	-
CHITTOOR	-	+	-	-	-	-	+	+	-	-
RANGAREDDY	-	+	+	+	-	+	-	+	+	-
NIZAMABAD	-	+	-	-	-	-	+	+	-	+
MEDAK	-	+	-	+	-	-	+	+	-	-
MAHABUBNAGAR	-	+	-	+	-	-	+	+	-	-
NALGONDA	+	+	-	-	-	-	-	+	-	-
WARANGAL	-	+	-	-	-	-	+	+	-	-
KHAMMAM	+	+	-	-	-	-	+	+	-	-
KARIMNAGAR	+	+	-	-	-	-	+	+	-	-
ADILABAD	-	+	-	+	-	-	+	+	-	-

Note: A= Acreage, O=Output, '+ '=increase, '-'= decrease.
Source: Based on Season and Crop Report, Andhra Pradesh.

5.3 OBJECTIVE OF STUDY

In this chapter we shall study the district-wise acreage responses of the foodgrain crops rice, jowar, ragi, maize and bajra in Andhra Pradesh. The Nerlovian formulation of Adaptive Expectations and Partial Adjustment (AEPA) model is chosen to model supply response. The analysis would attempt to answer the following questions:

(a) Are the acreages of foodgrain crops responsive to economic incentive, and if so, what are the incentives to which they respond? Do yield rates also constitute economic incentive? Do coarse cereals also respond to economic incentives or do their acreages simply vary with rainfall?

(b) Since the complete response of acreage to change in an economic incentive is expected to take time (in the presence of restraints on acreage adjustments), what are the extents of responses in the short run and in the long run ?

(d) How is expectation of prices /economic returns formed on the basis of past experience?

(e) Judging by the short run and long run responses of acreage to an incentive change, what is the speed of acreage adjustment? Are there restraints which make the adjustment slow?

(f) What other factors are significant in guiding the farmer in acreage decision and how strong are their impacts? Is availability of irrigation also a constraint on acreage decision?

Before presenting the model, we shall discuss some theoretical issues involved.

5.4 PRODUCTION DECISIONS AND ACREAGE

It was once common to consider the acreage response as a proxy for supply (or production) response of a crop (most notably the seminal work of Nerlove (1958) and others like those of Krishna (1963),Narain (1965) and Madhavan (1972))[1]. However, with technological development, inputs other than land became important as a source of output growth. We have by definition,

$$\text{Production} = \text{Acreage X Yield Rate} \qquad \text{...5.4 1}$$

Farmers seek to influence crop yield rate through a change in technology. It is in fact possible that a farmer plans to enhance production of a crop by allotting less area to it but aiming at a higher yield level (in section 5.2 we found that output, in a number of cases in Andhra Pradesh, increased despite acreages coming down). In studying the supply responses of foodgrain crops we shall first consider acreage responses in this chapter and then take up yield responses in Chapter 6. Before modelling acreage decisions of farmers some issues need to be resolved such as the nature of farmers' responses to economic incentive and the role of expectations in acreage decisions.

5.4.1 FARMER'S REPONSE TO MARKET INCENTIVE

The issue of farmers' responses to economic incentives is of great significance for policy making and in the 1960s raised debates in the context of developing economies. The assumption that farmers' behaviours are based on rationality have been doubted by scholars like Rudra

(1992), Ghosh and Chattopadhyay (1995)). It is also said that activities in a semi-commercial households and aversion to risk can stand in the way of maximising behaviour of the farmers. There has even been some controversy over a possible perverse response of marketed surplus to price as advocated by Neumark (1959), Mathur and Ezekiel(1961) and Enke (1963). They argued that farmers in a less developed subsistence economy have fixed monetary needs and obligations (rents, interests on debts and purchase of some inescapable nonagricultural items). With an increase in their product price they thus need to sell less and, when subsistence needs are also fixed, this would naturally imply a perversely responsive overall supply behaviour. (However, it was also pointed out that food supply in the subsistence sector is ususally inadequate, and therefore, such a perverse relation need not really follow). An alternative formulation suggested a dominant role of the income effect on consumption (accruing from a rise in crop price) over the price effect thus explaining a possible inverse relation between price and marketed surplus. Such contentions were emphatically contradicted by Schultz (1964). He charged the doctrine which held farmers in poorer countries indifferent or perverse in response to price changes as patently false and harmful. Several economists like Dantwala (1963), Falcon (1963), Mellor et al (1966) agreed with Schultz that underdeveloped agriculture also responds normally and significantly to price changes, with due allowances for risks and uncertainties.

While arguing for a normal price response, Schultz however concedes the presence of institutional and cultural restraints' on agricultural production in less developed countries. That such restraints can make price response insignificant has been of concern in literature and policy discussion related to underdeveloped economies. Behrman(1968) includes among such constraints ' limitations of knowledge of the possible, limited tastes, limited inquisitiveness, natural conservativeness and peculiar social values', all of which he describes as human inelasticity. Moreover, the attitude of 'resigned contentment' held by the farmer in a less developed economy in general may inhibit their natural and rational tendency to respond to economic incentives.

Another set of restraints faced by the farmers relate to imperfections in the market. Inadequacy of infrastructure, difficulties in getting inputs like fertiliser at the required time, insufficiency of credit, all stand in the way of the farmer in making quick changes in acreage decisions. Tenurial arrangements of the region and interlocked market system minimise the role of the monetary exchange mechanism. Oligopolistic behaviour of the middlemen also restrains efficient allocation of resurces including land. The overwhelming necessity of producing enough of the staple diet for survival in the face of uncertainty regarding access to food in the market may also prevent quick changes even if demanded by economic rationality. Thus, the actual or observed acreage at any point of time may not be the long run desired acreage of the rational farmer as adjustments may take several years to be complete [2].

5.4.2 DESIRED ACREAGE

A rational farmer is assumed to have a notion of an optimum acreage under a crop based on the expectations of economic returns and other relevant considerations. But the actual planted acreage often diverges from this notional or desired acreage due to the limitations or restraints discussed (5.4.1). A knowledge of the desired acreage would help in reading a farmer's mind and in understanding his true responses to policy actions in the absence of extraneous restraints. A comparison with the actual acreage would also help to guage how far a farmer is able to act in accordance with the rationality rules. The concept of the desired acreage frees the farmer's actions of the shackles of past practices and exposes his purely rational course of action or intended behaviour. However, the desired acreage is not observable. Collection of information on the same by interviewing the farmers or otherwise, can be too cumbersome and anyway, unreliable. Scientists have thereby gone in a roundabout way to look at the desired acreage (and thereby the farmers' true responses) via the actual acreage.

Among the factors that possibly guide the farmers in acreage decisions, economic incentive is of most interest to the policy maker. The response would depend on the farmer's attitudes and the institutional and infrastructural factors determining the market orientedness of agriculture as well as agro-climatic conditions. When farmers cultivate mostly for self consumption, their own consumption pattern and preferences may become more important than market demand in deciding acreages and the response to profitability factor will be less. Their attitude towards risk will also influence the crop mix chosen and limit the role of prices.

As in the cases of land utilisation and yield levels (chapters 3 , 4 and 6), in decisions about acreage too, the availability of water is important and binding. Water requirements of crops vary. It may not be rewarding to raise a crop which thrives in abundant water, in a tract where access to water is poor or uncertain. Neither is it judicious to allot an irrigated plot of land to a crop with a small water requirement. Thus, when a farmer is inclined to grow (on grounds of profitability or self consumption) a crop which demands copious water, an increased availabilty of irrigation facility is likely to have a favourable impact on its acreage (but a negative one on crops which compete for acreage). [3] Poor rainfall (as anticipated at the time of sowing) can deter cultivation of water intensive crops and encourage planting of dry crops. Soil quality and other agro-climatic conditions of a region decide the range of substitutability and limit the choice of crops.[4] The more the number of substitute crops, greater is the flexibility in production pattern. The nature and the intensity of response of acreage to incentives are therefore expected to vary among regions.

5.4.3 ROLE OF EXPECTATIONS

Agricultural production involves a lag between sowing of land and harvesting of crop and the ultimate realisation of revenue. The planting decision therefore is based only on the farmers' expectations of the future price/ revenue. A theory of expectation formation is therefore crucial for underatanding agricultural supply decisions. Since expectation is usually based on past experience, most formulations of expected prices assume past price or prices to be the determining factor. In its simplest form, expected price is taken to be the previous year's price (Cobweb model) but a more general formula is the Adaptive Expectations Hypothesis or the Nerlovian scheme. [5] The crop acreages are also taken to adjust to the desired levels slowly over a period of time, depending on the 'restraints' faced ('Partial Adjustment Hypothesis'). The ARIMA model is an alternative description of the expectation.[6] The Cobweb model, the Nerlovian model and the ARIMA model are all essentially extrapolative formulations where expected future price depends on past prices[7]. Another approach to expectation formation is the Rational Expectations Hypothesis (REH) where farmers are said to base their expectations on all information available and on their knowledge of how the economy works. In India, where the foodgrain market is subject to active government intervention and where market information may be accessible to farmers, REH may be a superior formulation to capture supply responses. The estimates are likely to be more efficient than extrapolative estimates because the REH model can use structural information on all relevant aspects of the market rather than just the supply side in isolation. Such a model has been explored at the national level and presented in the Appendix C (as Chapter 8) at the end of the thesis.[8]

5.4.4 PRICES AND REVENUES AS ECONOMIC INCENTIVES

Given the cost structure, relative price or profitability of a crop is usually considered to be the index of economic incentive.[9] When modelling the supply response of a crop, it is is necessary to identify the substitute crop (or crops) which compete for land and other resources in the region under study. The crop price deflated by the substitute crop price or the average price of the competing crops may be used as the relative price considered for estimating the supply response.

When yield levels change, a profit maximising farmer may not be content with only the relative price as the basis of his decision. The benefit anticipated from a rise in expected price and the resultant acreage allocation can be completely negated by a fall in yield level. On the other hand, in the face of technological progress, farmers have to increasingly move towards crops with fast growing yield rates. It is found that farmers take advantage of new inputs whenever they are available and accessible and the governments of less developed countries come in a big way to help farmers adopt new technology through institutional measures, public investment and subsidisitation of large part of the expenditure. Thus expected yield rates can also influence acreage decisions of farmers.

A more compact scheme would be to consider expected relative revenue which is the product of expected relative price and yield rate rather than to consider the two separately. And, since in years of good harvest, price levels usually fall and vice versa, use of this product as a variable is quite appropriate (see Narayana and Parikh, (1981)).

5.5 THE ADAPTIVE EXPECTATIONS AND PARTIAL ADJUSTMENT (AEPA) MODEL

The Nerlove model (Nerlove, 1957) rests on the following premises : (i) Current price changes affect acreage to the extent that they alter expected future price; (ii) Farmers keep adjusting their acreages overtime towards a desired (or equilibrium) level in the long run, based on expected future price and other relevant factors; (iii) Short term adjustments are made keeping in mind the long term desired acreage.

5.5.1 THE MODEL

The Adaptive Expectations Hypothesis says that price expectations are revised by a proportion of the last period's error i.e.,

$$(P^e_t - P^e_{t-1}) = \beta\,(P_{t-1} - P^e_{t-1}) \text{....... } \mathbf{5.5.1}$$

where P is price, P^e is expected normal price, t is time and β is the coefficient of expectation. expected to be less than one.

The Partial Adjustment Hypothesis states that

$$A_t - A_{t-1} = \gamma\,(A^*_t - A_{t-1}) \text{ ....} \mathbf{5.5.2}$$

where A is actual planted acreage, A^* is desired acreage, γ is acreage adjustment coefficient, expected to be less than one and t is time. The desired acreage is a function of the expected price

$$A^*_t = a_0 + a_1\, P^e_t + u_t \text{ .....5.5.3}$$

(where a_0 and a_1 are the constant and the price response parameters and u is the disturbance), so that, by substituting **5.5.3** in **5.5.2** and rearranging, we get the following equation:

$$A_t = \gamma a_0 + (1-\gamma)A_{t-1} + \gamma a_1 P^e_t + \gamma u_t \text{...5.5.4}$$

where the unobservable desired acreage A^* is removed in favour of the actual acreage. However, another unobservable variable, namely expected price still appears. To arrive at the reduced form equation in terms of observed and exogenous variables, the following procedure is usually followed (Narayana and Parikh, 1981,). Equation **5.5.1** is rearranged as

$$P^e_t - (1-\beta)P^e_{t-1} = P_{t-1} \text{....5.5.5}$$

equation **5.5.4** is lagged by one year as

$$A_{t-1} = a_0\gamma + (1\text{-}\gamma)A_{t-2} + \gamma a_1 P^e_{t-1} + \gamma u_{t-1} \text{...5.5.6}$$

Multiplying **5.5.6** by (1-β) and subtracting the same from **5.5.4** gives

$$A_t - (1-\beta)A_{t-1} = a_0\gamma\beta + (1-\gamma)(A_{t-1} - (1-\beta)A_{t-2})$$

$$a_1\gamma(P^e_t - (1-\beta)P^e_{t-1}) + \gamma(u_t - (1-\beta)u_{t-1}) \text{......5.5.7}$$

Equation 5.5.5 can be substituted in 5.5.7 to get our reduced form equation

$$A_t-(1-\beta)A_{t-1}=a_0\beta\gamma+(1-\gamma)(A_{t-1}-(1-\beta)A_{t-2})$$
$$+a_1\beta\gamma P_{t-1}+\gamma(u_t-(1-\beta)u_{t-1})..5.5.8$$

Problems of Identification

The estimation of equation **5.5.8** poses some difficulties. Expanding it, we get the acreage function as $A_t=a_0\gamma\beta+(1-\gamma+1-\beta)A_{t-1}(1-\gamma)(1-\beta)A_{t-2}+a_1\beta\gamma P_{t-1}$

$$+\gamma(u_t-(1-\beta)u_{t-1})...5.5.9$$

This is a second order stochastic linear difference equation with four regression parameters, (including those corresponding to A_{t-1}, , A_{t-2}, and P_{t-1}))and the four structural parameters (a_0, a_1, β and γ) but the symmetrical presence of β and γ makes identification impossible. If an exogenous variable z_t is entered in **5.5.3** the reduced form looks like

$$A_t=a_0\gamma\beta+(1-\gamma+1-\beta)A_{t-1}-(1-\gamma)(1-\beta)A_{t-2}+a_1\gamma\beta P_{t-1}$$
$$+a_2\gamma Z_t-a_{2\gamma}(1-\beta)Z_{t-1}+\gamma(u_t-(1-\beta)u_{t-1})....5.5.10$$

In equation **5.5.10** though β and γ do not enter symmetrically, there are now six regression coefficients and five parameters and γ is now overidentified. One way out of the difficulty is to write equation **5.510** as

$$A_t-(1-\beta)A_{t-1}=a_0\gamma\beta+(1-\gamma)(A_{t-1}-(1-\beta)A_{t-2})+a_1\gamma\beta P_{t-1}+a_2\gamma(Z_t-(1-\beta)Z_{t-1})+\gamma(u_t-(1-\beta)u_{t-1})$$
$$+\gamma(u_t-(1-\beta)u_{t-1})....\mathbf{5.5.11}$$

which can be identified and estimated if β is known. Two methods are suggested to get an estimate of β, viz., (i) A two step procedure in which β is estimated first from **5.5.10** and then **5.5.11** is estimated using the estimated value of β(ii) Estimating equation **5.5.11** by searching for β over an acceptable range.

The problem of autocorrelation

The response function in **5.5.11** is linear in parameters which are identified but estimation of **5.5.11** still gives rise to the problem of serial correlation. The error term is often superimposed on eqution **5.5.11** (eg, Nerlove 1958, Behrman, 1968) but it may be important to specify it carefully. We may assume that the adjustment functions given by **5.5.1** and **5.5.2** are deterministic but the desired acreage function **5.5.3** is stochastic so that the disturbance term in **5.5.11** is given by

$$v_t = \gamma(u_t - (1-\beta)u_{t-1}) \; ..... \qquad ....\mathbf{5.5.12}$$

There is no reason to suppose u_t to be serially uncorrelated, but even if it is i.e,

$$u_t = p\, u_{t-1} + \epsilon_t \; ... \qquad .....\mathbf{5.5.13}$$

with $p = 0$, v_t is still serially correlated (see Sawant, 1978).

5.5.2 A MODEL FOR CEREAL CROP ACREAGE RESPONSE

In the following subsections we present a model for the supply responses of foodgrain using the Nerlovian AEPA formulation and will specify variables and the econometric method applied.

Specifications: Variables

We will first specify the variables employed , with special consideration to the incentive variable.

Economic incentives

Because the present study covers the period of green revolution, we specify crop yield also as an incentive for planting. We will consider (a) yield rate, (b) relative price and (c) relative revenue as possible variables for economic incentive.

(a) We assume that previous period's yield rate determines the current expectation of yield and specify expected yield as

$$Y_t^e = \psi Y_{t-1} + u_t \; ... \qquad .... \qquad ......\mathbf{5.5.14}$$

(b) Relative price is taken to be expected adaptively (as given in equation **5.5.1**). The relative price (RP) is considered with respect to one or more competing/ substitute crops as follows

$$RP_i = WP_i / WP_j \; . \qquad . \qquad .....\mathbf{5.5.15}$$

where WP is the nominal price (discussed later) and i and j are substitute crops. In cases where crop i has a number of substitutes, WP_j is the average of the prices of the substitute crops.

(c) The relative revenue, also expected adaptively, includes yield rate and price as a single variable and is specified in two alternative ways, viz., (i)Relative Revenue (RR1) is measured as the crop revenue deflated by the (average) revenue of substitute crop(s), i.e.,

$RR1 = R_i/R_j$. …. **5.5.16**

where $R_i = (WP_i)(Y_i)$ ……**5.5.17**

giving the revenue from a hectare of acreage devoted to crop i and R_j is the same from a substitute crop,

(ii) In this formulation, the relative price is used while computing the crop revenue (RR2) ie, RR2 is revenue valued at the relative price

$RR2 = (WP_i / WP_j) \times Y_i$ …..**5.5.18**

or, $RR2 = RP_i \times Y_i$ ……**5.5.19**

RR2 incorporates the yield rate of crop i but the same for crop j is not considered. It gives the purchasing power of crop i obtained from a hectare of acreage devoted to it in terms of crop j (*using* ***5.5.18*** *and* **5.5.17**) as

$RR2 = R_i / WP_j$. … ***5.5.20.***

This formulation for relative revenue may be suitable for representing profitability of a crop when either *(i) yield level of j is largely stable over time or (ii) crop i is grown for sale,* in which case crop j will be purchased from market.

In order to capture relative profitability, costs of production of crops need to be taken into account. However, lack of time series data on cost of production has been a problem.. Besides, institutional support to facilitate access to credit and necessary inputs also influences the real cost of crop production..Thus, real cost of production relevant to the armer is difficult to quantify. In the absence of reliable cost data we consider *relative price or revenue as the index of relative profitability.* Since irrigation charges have been nominal and largely stationary, changes in fertiliser price could possibly be a source of change in the profitabilty ratio. But all the cereal crops considered in this study call for same chemical nutrients (Nitrogen+Phosphorus+Potassium), so that input price changes would affect crops in the same way (for similar reasons, movements in wage rates would *not make a difference to relative* profitabilty) and thus relative price or revenue may in fact approximate the relative profitability of crops.[10]

Choice of Deflator

The construction of relative price variables involves a choice of the deflator. This requires identification of substitute crop(s) in the different regions. In Table 5.6(A5) we have laid down an array of crops for each district in the order of their importance in acreage allocation. This may be a guidance to understanding the substitution pattern among crops in a region but can can be misleading at times[11]. In specifying the relative profitability variable, for each crop we therefore considered the following as the possible substitute(s) (a) all crops together, (b) each of the other cereal crops individually[12]. However, this is an attempt to identify the cereal (s) that might be the closest substitute among the cereals and it is admitted that the other cereals may also be competing to certain extent. Also, crops other than the five cereal crops considered may also be substitues. However, we have not kept them within the scope of the present work as the shares of such crops in GCA are small with the exception of groundnuts (groundnuts: 17%, sugarcane: 1.6%, cotton: 5%, tobacco: 1.2%). In any case, consideration of substitution merely within the five cereal crops is a limitation of the work.

When there are more than one substitute, the price/ revenue must be averaged for use as a deflator in the relative index. Both arithmetic mean (AM) and geometric mean (GM) were tried alternatively in averaging. The deflators WP_j and R_j used to derive RP, RR1 and RR2 in equations **5.5.15**, **5.5.17** and **5.5.18** are as follows.

$$WP_j = \text{Mean}(WP_r) \qquad \mathbf{...5.5.21}$$

$$R_j = \text{Mean}(R_j) \qquad \mathbf{......5.5.22}$$

with crop r being a substitute of i and Mean is either (a) arithmetic mean or (b) geometric mean.

Construction of price index (WP)

The construction of the crop price index (WP) involves a choice between Farm Harvest Price (FHP) and the Wholesale Price Index (WSPI). The FHP seems preferable as it is directly observable to the farmers. But continuous time series data on the same is not available and approximation or interpolation is necessary to build the same, which is certainly undesirable. In comparison, the database of WSPI might make its choice preferable[13]. But then, WSPI are not available at the district level or even at the state level. But the data on the Value of agricultural products for the state are reported both at constant and current prices. These have been used to construct the necessary price index by the following formula.

$$WP_{it} = V_{it\,(at\ current\ price)} / V_{it\,(at\ 1970\text{-}71\ price)} \qquad \text{......5.5.23}$$

where i refers to the crop, t to the time. Now, V is the value of the crop so that

$$WP_{it} = Q_{it} \text{ X } P_{it} / Q_{it} \text{ X } P_{i0} \qquad \text{...5.5.24}$$

where Q_{it} is the quantity of *i*th good produced at period *t* while P_{it} and P_{i0} are weights which are the Current period (t) and base period (0) prices of crop i. WP_{it} then gives the index of price of crop i at time t with base 0.

Supply shifter variables

The supply shifter variables (Sawant,1978) are variables which cause a shift of the supply curve are specified in the following way.

Irrigation

Depending on their genetic properties, crops differ in their water requirement. Crops which call for abundant water usually require additional irrigation support, especially if they demand controlled watering. Rice, and in particular HYV rice can be categorised as such a water intensive cereal. In Andhra Pradesh rice is mostly grown entirely as an irrigated crop. The proportion of rice area under irrigation is nearly unity in many of the districts (example, Anantapur) and this creates difficulty in specifying the irrigation variable. The data shows an overwhelming importance of rice and its priority in the allocation of irrigated acreage.[14] The availability of irrigation (or possibly of some assured forms of irrigation) possibly has a remarkable impact on rice acreage.

The farmer sets aside for rice a part of the available irrigated acreage. The decision may be based on considerations like remunerativeness of irrigated (possibly also high yielding) rice, own consumption needs and market imperfections, the quality and dependability of the irrigation facility and the type of soil in the irrigated tracts in relation to the crop's requirements, all of which are beyond the purview of the present model. *In other words, the share of rice in irrigated* *acreage is taken as exogenous and determined outside our system.* The allocation of irrigated acreage to rice however sets a limit to the total acreage available for other cereals (as also unirrigated rice) since irrigated acreage is but a part of overall acreage. The proportion of total cereal acreage set aside for rice due to its access to irrigation is non-stochastic to the model. The higher is this proportion, the less is the area available for other cereals and dry /rainfed rice. The acreage allocated to any other cereal is likely to be inversely related to the proportion of available area allotted to irrigated rice. Similarly, the acreage given to rice, is expected to be inversely related to the proportion of total acreage taken away by irrigated non rice cereals (note that unirrigated rice acreage would behave similarly to other cereal acreages but irrigated rice generally dominates in rice acreage).

The irrigation variable istherefore specified differently for rice and the other cereals.

IRR = IRR(R) when cereal crop is rice ...and

IRR = IRR(O) when cereal crop is not rice .....

where IRR(R) = Irrigated acreage under non rice cereals /Total cereal crop acreage .. 5.5.25

IRR(O) = Irrigated acreage under rice/Total cereal crop acreage. ... 5.5.26

The relation between acreage of a crop and the irrigation variable is normally expected to be negative *but it can be positive if farmers try to protect the production level by planting more of unirrigated acreage to make up for the loss.*

Rainfall

Rainfall is another source of water input which can guide acreage decision. The response depends on the variety of crops grown and the type of irrigation practised. For a dry crop light rainfall may be beneficial, while high rainfall may encourage a more water intensive crop. Rainfall can deter cultivation of high yielding crops which count on controlled watering. Since cereal crops are grown in multiple seasons, the rainfalls for the two main agricultural seasons kharif and rabi are used as variables RSW (south west monsoon) and RNE (north east monsoon) .

The variables for rainfall are

RSW= total rainfall from June to September

RNE= total rainfall from Octobe to December

Functional form and Error specification

The structural model for acreage decision is given by

$$A_t^* = a_0 + a_1 P_t^e + a_{11} Y_t^e + a_2 IRR_t + a_3 RSW_t + a_4 RNE_t + u_t ..5.5.27$$

$$P_t^e = P_{t-1} + (1-\beta) P_{t-1}^e ......5.5.28$$

$$A_t = A_t^* + (1-\gamma) A_{t-1} ....5.5.29$$

where A = Acreage under crop,
A* = desired acreage under crop,
P = Incentive variable =(Price/Revenue) of crop
IRR = Irrigation variable
Y = Incentive variable- yield of crop,
RSW = rainfall from south west monsoon
IRR = Irrigation variable,
RNE = rainfall from north east monsoon.

Superscript e denotes expected value and subscript t the time. The reduced form equation will have the following transformed variables.

$$DEP = (A_t - (1-\beta) A_{t-1})..$$

$$PRL = P_{t-1}, YLL = (Y_{t-1} - (1-\beta) Y_{t-2})...$$

$$IRL = (IRR_t - (1-\beta) IRR_{t-1}).$$

$$RSWL = (RFSW_t - (1-\beta) RFSW_{t-1}).$$

$$RNEL = (RNEL_t - (1-\beta) RFNE_{t-1})..$$

$$ACRL = (A_{t-1} - (1-\beta) A_{t-2})....$$

$$v_t = (u_t - (1-\beta) u).....5.5.30$$

Four variants of the model that have been used are the following.

1. $$DEP = A_0 + A_1(PRL) + A_2(ACRL) + A_3(IRL) + A_4(RSWL) + A_5(RNEL) + v ...5.5.31$$

where **PRL = RP$_{t-1}$** .

2. $$DEP = A_0 + A_{11}(PRL) + A_{12}(YLL) + A_2(ACRL) + A_3(IRL) + A_4(RSWL) + A_5(RNEL) + v \ldots 5.5.32$$

where **PRL = $\mathbf{RP_{t-1}}$ (see 5.5.15)**

3. $$DEP = A_0 + A_1(PRL) + A_2(ACRL) + A_3(IRL) + A_4(RSWL) + A_5(RNEL) + v \ldots 5.5.33$$

where **PRL= $\mathbf{RR1_{t-1}}$ (see 5.5.16)**

4. $$DEPA = A_0 + A_1(PRL) + A_2(ACRL) + A_3(IRL) + A_4(RSWL) + A_5(RNEL) + v \ldots 5.5.34$$

where **PRL= $\mathbf{RR2_{t-1}}$ (see 5.5.18)**.

Estimation

Equations 5.5.27 to 5.5.29 are generally considered in log-linear form so that the coefficients are elasticities of corresponding variables and the constant term is the scale parameter[15]. Only in few cases, the linear form is reported where it gives a distinctly better fit and t-values and the elasticities are computed at mean values of variables in such cases. The Reduced form equations **5.5.31** through **5.5.34** are estimated using the Hildreth and Lu (HILU) method for correcting serial correlation. In each case, different values of β ranging between 0 and 2 (explained later in this section) and at an interval of 0.1 are used in a search procedure. The equation with the minimum standard error of estimate (SEE) and the corresponding value of β is chosen [16] for reporting and analysis. Multicollinearity problem is not likely to arise as variables are transformed. The DW staistics is checked for the reported equation. A value of DW close to 2 would minimise the chances of serial correlation as well as of a spurious regression (when $\bar{R}^2$ and t-values are satisfactory). However, stationarity of residuals is also checked through inspection of graphs of residuals against time (not presented) and a Dickey-Fuller test is conducted for stationarity of error (Enders, 1995).

From the alternative formulations (model variants and specifications) we selected the equation for reporting and analysis on the basis of the following:

(i) consistency of parameters signs with theoretical justification,

(ii) a high R^2 (not less than 0.35).

(iii) satisfactory t- statistics. We have not reported any equation where any t-value falls short of unity (see COV criterion, Maddalla, 1989 pp 243). In the cases where no equation was adjudged satisfactory on above counts, we could not report any estimated equation.

From the estimated (equations **5.5.31** through **5.5.34**) reduced form parameters A_0, A_1 or A_{11} and A_{12}, A_2, A_3, A_4 and A_5 and also β we obtain the structural form parameters by the following relations (as explained in **5.5.1**).

$$A_0 = a_0\beta\gamma \ldots\ldots 5.5.35.$$

$$A_1 = a_1\beta\gamma \ldots\ldots 5.5.36$$

$$A_2 = (1-\gamma) \ldots 5.5.37$$

$$A_3 = a_2\gamma\beta \ldots\ldots 5.5.38$$

$$A_4 = a_3\beta\gamma \ldots\ldots 5.5.39$$

$$A_5 = a_4\beta\gamma \ldots\ldots 5.5.40$$

The adjustment parameters and elastcities

The adjustment parameters β and γ must lie between 0 and 2 for an estimated model to be meaningful [17]. The economic interpretations for β and γ taking different ranges of value in our acreage response model are as follows:

(a) *When* $\beta < 1$, we have the case of pure 'Adaptive Expectations'. The farmer makes an initial expectation and goes on adjusting it over the years according to the experience acquired. Basically, the farmer depends on his own predictions though he takes some corrective action on his errors.

(b) *When* $\beta = 1$, expectations do not really play any part and the farmer chooses to go by the past price (even if such a prediction does not always prove correct). This is the case of *naive or static expectations.*

(c) *When* $\beta > 1$, the weightage of past expectations is negative! The farmer takes the past realised price as the point of reference and adjusts it on the basis of his error. Taking $\beta = 1+b$

$$\begin{aligned} P_t^e &= P_{t-1}^e + \beta(P_{t-1} - P_{t-1}^e) = P_{t-1}^e + (1+b)(P_{t-1} - P_{t-1}^e) \\ &= P_{t-1} + b(P_{t-1} - P_{t-1}^e) \quad \cdots \quad 5.5.41 \end{aligned}$$

where b lies between 0 and 1. The past expectation seems to matter to the farmer only to guard him against his own error. Every time he finds that his expectation has led him to underestimate price, he makes an upward revision and vice versa. But the revision or adjustment is made on his experience of the *past actual price* and not on his *past expected price* which in any case failed to materialise. A *partial adjustment* is made on the past price to arrive at current expected price. We will describe such cases as of 'Partially Adjusted Expectations'.

(d) *When* $\gamma<1$, we have the pure case of Partial Adjustment of acreage. When estimated parameter $(1-\gamma)$ is statistically significant and positive, we infer that γ is significantly less than one and the weightage of the past acreage on acreage decision is significant. The farmer is restrained by his past practice but adjusts towards the desired acreage by a fraction of the discrepancy in the short run.

(e) *When* $\gamma>1$, there is no restraint on farmers' actions and the actual acreage even overshoots the desired acreage in the short run to make the most of any opportunity of gain. This is Overadjustment of acreage and over time, the farmer approaches the desired acreage by fluctuating around the desired acreage. In this case we expect parameter $(1-\gamma)$ to be significant and negative. The farmer does have a long term goal but goes for short term gains and the agro-climatic conditions permit the adjustment.

(f) *When* $\gamma=1$, the desired acreage has a weight of one in acreage decision and the actual acreage is close to the desired acreage. This is the case of Perfect Adjustment of acreage and the farmer is free of restraints.

If $(1-\gamma)$ is insignificant, we infer that γ is not significantly different from 1. The response of acreage to a variable is measured by its elasticity. Since farmers may adjust acreage to its desired level over a period of time, we distinguish between the short run and the long run elasticities. The short run price elasticity is the response of acreage to a price change during an agricultural year and the long run elasticity measures the response when the farmer is allowed enough time to adjust fully to the desired acreage. (Note, that the notion of desired acreage pertains to the time of decision making and may itself change when profitability changes). The price responses or elasticities (for log-linear model) are the following:

The *short run price* response is given by $A_1 = a_1\beta\gamma$ .....

The *long run price response* is given by A_1/γ

Note that

(a) If $\gamma>1$, long run response is less than the short run response, and if $\gamma<1$, the short response is less, a typical case of partial adjustment of acreage.

(b) The response (elasticity) to supply shifting variables in the long run are given by the following.

Irrigation: A_2/γ,
South West monsoon rainfall: A_3/γ,
North East monsoon rainfall: A_4/γ.

5.6 DATA AND SAMPLE

The acreage response functions of the five cereal crops rice, jowar, ragi maize and bajra is estimated for the 18 districts or district groups (see Appendix B) . The sample period of 20 years covers 1965-66 to 1984-85. Time series data on crop acreages, value of products at both current and constant prices, crop-wise irrigated acreages and monthly rainfall are used (sources mentioned in Chapter 2).

5.7 RESULTS

The estimated acreage response equations are reported in Appendix (A5). Districts for which estimates are poor could not be reported. However, the model explains crop acreages for districts accounting for major part of the state output in each case. Table 5.3 gives the number of districts reported and their total share in state output for each crop.

Table 5.3 Districts reported and Coverage of crop output

CROP	DISTRICTS FOR WHICH RESULTS ARE REPORTED (TOTAL=18)	(%)SHARE OF STATE OUTPUT (1984-85)
1	2	3
RICE	14	96
JOWAR	12	78
RAGI	5	80
MAIZE	9	96
BAJRA	9	90

Notes: Regression equations presented in Appendix A5.

For rice the model performed well for all but 4 districts and accounted for 96% of the state's rice output. The number of districts that can be reported are less for the other crops. Maize acreage was explained for just 9 districts but these districts contributed nearly all of the state output. Except for jowar where the model worked for 12 districts accounting for 78% of state output, the results cover more than 80% of state production for all crops.

The irrigation variable (IRL in the reported equations) did not turn out to be significant in many cases and in 3 of the cases (Krishna and Guntur for rice and Karimnagar for maize) it had a positive impact (see *Irrigation in section 5.5.2)*. Rainfall emerged as a variable in all cases though the impact was not always favourable. Kharif rainfall (RSWL) was mostly favourable but the effect of the rabi rainfall (RNEL) was mixed, especially for the coarse cereals. The incentive variable was relative revenue in majority of the cases, with RR1 being the dominant incentive variable while RR2 worked for 9 cases. Relative price RP was found to guide acreage in at least 1 case for each cereal and 6 cases for bajra. The incentive variable had a significant positive impact in all except 4 cases (the parameter was positive insignificant for rice in Krishna, jowar in Anantapur, ragi in Guntur and maize in Srikakulam). The substitute for any crop varies across districts.

We shall first analyse the result for the case of rice in East Godavari in some detail. This will be followed by summary results for each of the cereals over the different districts, analysed in a similar way.

5.7.1 *Acreage response of Rice in East Godavari*

East Godavari (EG henceforth) in Coastal Andhra Pradesh is one of the most fertile districts. As classified in Chapter 3, EG is a high value district (HVD) with respect to rainfall in both seasons and irrigation intensity. Moisture, therefore, is little constraint to farming in this district. It is basically a surface water irrigated district, with canals as the dominant source. However, tube wells which form a negligible part of the state's irrigated area are mostly concentrated in the Godavari area, catering to 12% of EG's net irrigated area. Both canals and tube wells are assured sources of water, and this advantage reflects on the quality of irrigation in the district. The cropping intensity is also above state level. Rice occupies a very high share of cereal acreage, claiming 92.5% of the area under the 5 cereals (Table 5. 6(A5)). The other crops have very small shares viz., jowar 1.9%, ragi 1.1%, maize 0.4% and bajra 4%. Rice is also highly irrigated with an intensity 95% compared to that of 14% and 4% for maize and jowar, respectively. The district has higher than state level yield rates of rice, ragi, maize and bajra. EG accounts for 12.5% of

AP's rice output, but the rice acreage is already large and it is the only cereal to register a positive growth rate in the district during the sample period.

The estimated acreage response equation is

$$A = 8.2036 + 0.2285\ RR2(A) - 0.5992\ ACRL - 0.0654\ IRL + 0.1658\ RSWL - 0.1056\ RNEL,$$
$$(8.3668)^{*} \quad (4.4055)^{*} \quad (-3.4642)^{*} \quad (-1.3898) \quad (2.9597)^{*} \quad (-4.0129)^{*}$$
$$\beta = 0.5 \qquad RBAR^2 = 0.77; \quad DW = 2.2; \quad p = -.469; \quad SEE = .0504 \qquad \textbf{...5.7.1}$$

All the explanatory variables appear (t-values greater than one) and the fit is satisfactory. Except for IRL, parameters of variables are statistically significant (* denotes significance at 1%level). The SEE of .0504 is the minimum over all values of β between 0 and 2 with β turning out to be 0.5. The serial correlation is statistically significant and is corrected for and the DW statistic is 2.2.

The positive and highly significant constant term implies a scale parameter greater than one. A negative sign of parameter for IRL would mean that an increase in irrigated area given to any non rice cereal as a proportion of total acreage brings down rice acreage. This suggests withdrawal of irrigated acreage from rice in favour of other cereals. However, the parameter in this case is nonsignificant and irrigated acreage given to other crops possibly makes little impact on rice. This is understandable as other than rice, no crop is important in this district, the other four cereals making up only 5% of cereal crop area.

The two rainfall variables have opposite effects on acreage. Kharif rainfall has a positive impact inspite of the canal dominated irrigation system. A high rabi rainfall tends to move acreage away from rice.

The economic incentive is found to be RR2 with no single crop turning out be a substitute of rice in this overwhelmingly rice dominated district. The incentive measures the amount of other crops that the rice raised from a hectare of acreage can buy (other crops are hardly raised here).

From the reduced form equation we derive the following structural equations:

$A^*_t = 40.9349 + .2858\, P^e_t - .1034\, IRR + .1037\, RSW - .066\, RNE$ **5.7.2**

$P^e_t = P^e_{t-1} + .5\,(P_{t-1} - P^e_{t-1})$ 5.7.3

$A_t = A_{t-1} + 1.5992\,(A^*_t - A_{t-1})$ ...**5.7.4**

An adaptive expectation model (equation **5.7.3**) emerges as the price expectation coefficient (0.5) is less than one. The price of a crop at the state level is determined by demand and supply conditions prevailing all over the state as well as external factors. The farmer is possibly not completely informed of the overall market conditions and gives weightage to his past expectations and also equally to his past experience. For example, consider a case when a farmer enjoyed a good harvest which he anticipated, while drought conditions in Rayalaseema and neighbouring districts led to soaring prices. While the judicious farmer might not ignore possibility of such occurrences, there can be no ground to suppose that the high price would prevail in future. Consequently, he depends more on his own expectations which he adjusts according to his experience.

The negative coefficient for past acreage (γ=-.5992) suggests that the farmer not only reaches but overshoots his desired goal. When acreage planted is less than the desired level the farmer overadjusts acreage and subsequently he cuts down acreage to something below the desired level. In this manner, over time, the farmer moves towards the desired acreage in an oscillatory path, with the acreage being alternately above and below the desires acreage. The oscillations however become damped (γ<1) and the acreage converges towards the desired level. The sharp adjustments in acreages in response to changes in profitability, irrigation or rainfall conditions are made possible by the favourable conditions enjoyed by the district. The farmers, through tradition have a preference shown to rice and exploits any opportunity of quick returns from rice.

The estimated elasiticicities are as follows:

PRICE ELASTICITY		IRRIGATION	RAINFALL	
short run	long run		South West monsoon	North East monsoon
0.2285	0.1429	-0.01034	0.10365	0.06602

The price elasticities are below 1 and in fact quite low. The elasticity is less in the long run than in the short run and suggests overadjustment of acreage. The low elasticities are not surprising as the district has anyway allocated nearly all of its cereal acreage to rice alone and any change in acreage due to a price change can be but a small fraction of the large rice acreage. The elasticities to irrigation and rainfall are also small due to the enormity of rice acreage. The variables can have little influence as the availability of acreage and the scope of substitution are themselves limited owing to the preference for rice shown in the district.

Summary Results of Acreage Responses of Foodgrains

5.7.2 District-wise Acreage Responses of Rice

AP is the second largest rice producer in India and rice is AP's principal crop. The model work for 14 districts and generally gave high R^2. The scale parameter is positive in all cases. The other features are discussed below.

Response to Price

The district-wise estimated acreage responses to incentive variables are presented in Table 5.4 (not all parameters are however statistically significant). We find a positive role of relative crop revenue in guiding acreage in general. Krishna is the only aberration but here the coefficient is not significant (we shall see that past acreage has a significant and strong effect on acreage with $1-\gamma > .7$). In other cases the impact is significant (at 10% level in Medak and 1% in others). Krishna and Guntur are the only districts where relative price RP is the incentive, with yield rate playing no role. For the others, relative revenue (RR1 or RR2) emerge. The relative revenue as an incentive follows the RR2 scheme in East Godavari, West Godavari, Chittoor and Medak but RR1 in other cases. As noted earlier, RR2 measures purchasing power of rice where the substitute crop(s) are possibly more often procured from the market. The farmers in the Godavari districts produce little else than rice anyway, but in Chittoor and Medak they also grow ragi and jowar in sizable proportions respectively (see Table 5.6(A5)).

In Krishna and Guntur, the substitute for rice is bajra and its price/revenue is the opportunity foregone when planting rice. Guntur is the second largest producer of bajra (21%) in the state and devotes 9% of cereal area to this crop. But in Krishna bajra is neither important nor an irrigated crop. Perhaps, as the third most important crop bajra is grown on quality land suited for rice and the second largest crop, jowar, does not qualify as the substitute. In Nizamabad the substitute is maize, the second most important cereal in the district (the district also ranks second in the state in maize production). The RR1 scheme for incentive suggests that the yield rates of both crops make a difference to the profitability of rice and possibly both crops are raised commercially. Ragi is the substitute crop in Chittoor, Rangareddy and Mahabubnagar, which are all major producers of ragi. However, in the latter two, jowar is the most important cereal. We note that although jowar is an important crop in many districts, ranking even first or second in the cropping patterns, it does not emerge as a distinct substitute of rice in any case. In the remaining districts all the cereals together seem to vie for acreage with rice.

Table 5.4 Acreage Response to Incentive Variable: Rice

DISTRICT	REGION	VARIABLE	SUBSTITUE(S)	EXPECTATION COEFFICIENT β	SHORT RUN ELASTICITY	LONGRUN ELASTICITY
1	2	3	4	5	6	7
SRIKAKULAM	Coastal	RR1	ALL	1.2	0.080	0.060
EAST GODAVARI	Coastal	RR2	ALL	0.5	0.229	0.140
WEST GODAVARI	Coastal	RR2	ALL	0.3	0.206	0.119
KRISHNA	Coastal	RP	BAJRA	1.4	0.163	1.020
GUNTUR	Coastal	RP	BAJRA	1.3	0.284	0.610
ANANTAPUR	Rayalaseema	RR1	ALL	1.3	0.551	2.000
CUDDAPAH	Rayalaseema	RR1	ALL	1.1	0.555	0.660
CHITTOOR	Rayalaseema	RR2	RAGI	1.6	0.171	0.220
RANGAREDDY	Telangana	RR1	RAGI	1	0.107	0.151
NIZAMABAD	Telangana	RR1	MAIZE	1.4	0.092	0.096
MEDAK	Telangana	RR2	ALL	0.8	0.102	0.094
MAHABUBNAGAR	Telangana	RR1	RAGI	1.1	0.195	0.330
NALGONDA	Telangana	RR1	ALL	0.5	0.293	0.500
KARIMNAGAR	Telangana	RR1	ALL	1.1	0.101	0.176

Note: ALL=all 5 cereal crops, RP=Relative Price, RR1= Relative Revenue, RR2= Revenue valued at relative Price.

Expectation formation

Table 5.5 classifies the districts according to the nature of expectation formation process identified by the model in terms of the β values There are only 4 districts (East Godavari, WestGodavari, Medak and Nalgoda) as cases of adaptive expectations and one of naive expectations, although β is never much greater than one (it is 1.1 in 3 of the districts). It seems that price expectation, following a partially adjusted scheme, is mostly formed by making a small adjustment to the previous year's realised price.

Table 5.5 Expectation formulations for Districts of Andhra Pradesh:Rice

ADAPTIVE EXPECTATIONS $\beta<1$	NAIVE EXPECTATIONS $\beta=1$	PARTALLY ADJUSTED EXPECTATIONS $\beta>1$
1	2	3
East Godavari, West Godavari, Nalgonda, Medak	Rangareddy	Srikakulam, Krishna, Guntur, Cuddapah, Anantapur, Chittoor, Rangareddy, Nizamabad, Mahabubnagar, Karimnagar

The price elasticity of acreage (Table 5.4)in the short run is very low in the Coastal and Telangana districts. But it is above 0.5 in the two Rayalaseema districts Cuddapah and Anantapur. The latter are not principally rice growing, the diversified pattern possibly allowing some room for acreage adjustments. The long run price elasticity is also rather low in general but exceeds unity in Krishna and Anantapur. The elasticity also exceeds 0.5 in 5 districts. The short run elasticity is greater than long run elasticity in 4 cases, 3 of them in the Coastal region.

Response to Irrigation

The variable does not appear in the equation for 3 districts of Rayalaseema (Anantapur, Cuddapah and Chittoor) and one in Telangana (Mahaboobnagar). All of them are characterised by low irrigation intensities, dominance of rainfall dependent sources of irrigation and low share of canals and mixed cropping patterns. There is a lack of substitution between rice and other crops on irrigated acreage owing to seasonality of cultivation, soil types and the type of irrigation allotted to rice. For example, when coarse cereals are tank irrigated (or raised as kharif crops) and rice is grown with energised well water (possibly HYV in rabi season), irrigation allotted to the former crop has little significance to decisions about rice acreage. At the other extreme, Krishna and Guntur represent two curious cases where IRL actually has a positive effect on rice acreage, though the effect is insignificant for Guntur and significant only at 15% for Krishna. However, the parameter for IRL is insignificant in cost cases.

On the whole we mark that rice enjoys a priority, with respect to irrigated acreage and its acreage is largely protected (or constituted of its own irrigated acreage) so that variable IRR has little effect on its acreage. The irrigation elasticity is low in all cases and the highest value is recorded for Karimnagar where other crops may be competing for irrigated acreage.

Response to Rainfall

The variable RSWL appears in most cases with a positive parameter. It appears that although many of the districts enjoy canal irrigation facility, kharif crop is also grown rainfed or with traditional irrigation supported by rainfall. In West Godavari the dominance of tube wells and canals (and HYV cultivation) may be responsible for the absence of the variable (we shall find its adverse impact on rice yield in Chapter 6). But in Anantapur, a poorly irrigated district served mostly by traditional sources, perhaps rabi rice acreage responds to variations in rainfall and kharif acreage is unaffected. (see Chapter 6 also).

Table 5.6 Acreage Elasticities with respect to variables: Rice

		ELASTICITIES			
1	2	3	4	5	6
DISTRICT	REGION	IRRIGATION A_3/γ	RAINFALL-SWM A_4/γ	RAINFALL-NEM A_5/γ	PAST ACREAGE $A_2=1-\gamma$
SRIKAKULAM	COASTAL	-0.0384	0.4138	-	-0.1645
EAST GODAVRI	COASTAL	-0.0103	0.1037	-0.0660	-0.5992
WEST GODAVARI	COASTAL	-0.0258	-	-0.0550	-0.7270
KRISHNA	COASTAL	0.1729	0.3391	-0.1803	0.7044
GUNTUR	COASTAL	0.2179	0.4770	0.2507	0.5404
ANANTAPUR	RAYALASEEMA	-	-	1.4127	0.7240
CUDDAPAH	RAYALASEEMA	-	0.5689	0.2954	0.1600
CHITTOOR	RAYALASEEMA	-	0.7110	0.4050	0.2250
RANGAREDDY	TELANGANA	-0.1554	0.6705	-	0.2884
NIZAMABAD	TELANGANA	-0.1290	0.5192	-	0.0459
MEDAK	TELANGANA	-0.2079	0.2893	0.0114	-0.0944
MAHABUBNAGAR	TELANGANA	-	1.3262	0.1189	0.4208
NALGONDA	TELANGANA	-0.0503	0.0640	0.2081	0.4166
KARIMNAGAR	TELANGANA	-0.5760	1.5920	0.2697	0.4257

Note: SWM stands for South West Monsoon, NEM for North East Monsoon ; Elasticities with respect to irrigation and rainfall are for long run.

The variable RNEL appears in all cases barring 3, but adverse effect is observed in the three fertile and canal irrigated coastal districts East Godavari, West Godavari and Krishna. The Godavari districts have high rabi rainfall and all three districts have cropping patterns heavily in favour of rice. Possibly, these districts devote most of their canal irrigated acreage to raise high yielding rice in the rabi season and rainfall in this season is a deterrent to controlled input intensive agricultural practice. In as many as 7 districts both rainfalls bear positive impact on rice acreage. Elasticities with respect to rainfall are not so poor, the Godavari districts being exceptions. Karimnagar and Mahabubnagar record values greater than unity for RSWL and Anantapur for RNEL. But, on the whole, acreages are more responsive to kharif rainfall.

Acreage adjustment

The acreage variable ACRL brings out the positive influence of the past on current acreage decisions (equation 5.5.2). The impact is positive in 10 cases but is not significant in 2 of them. Thus, although farmers are rational and do plan acreage on the basis of profitability and other relevant factors, there are restraints which slow down their adjustment towards a desired acreage in some cases. In the short run, the past is a dominant influence in 8 cases and only a part of the adjustment is achieved. These are the cases of partial adjustment of acreage. In 4 districts (Srikakulam, Cuddapah, Nizamabad and Medak) the effect of past is insignificant and acreage adjusts perfectly to the desired level. At the other extreme we find the impact significantly negative for the two Godavari districts where acreage overadjusts.

None of the four districts showing perfect adjustment are principal producers of rice also, with some other cereal enjoying prominence. These districts are fairly rich in moisture (rainfall or irrigation, though not canal irrigated). The favourable conditions with respect to moisture and the modest target for rice acreage seem to make perfect adjustment of acreage not a difficult task.

Overadjustment of acreage is observed in East Godavari and West Godavari, the two most fertile and moisture rich principal producers of rice. Here the farmer makes the most out of any opportunity presented by a possible increase in profitability of rice by taking advantage of the privileges enjoyed by the districts. In the cases where partial adjustment is observed, on the contrary, the farmer acts with caution and restraint and the conditions of the districts do not permit quick changes.

Table 5.7 Acreage Adjustment: Rice

DISTRICT	REGION	COEFFICIENT γ	ADJUSTMENT	DISTRICT	REGION	COEFFICIENT γ	ADJUSTMENT
1	2	3	4	5	6	7	8
SRIKAKULAM	COASTAL	1.169*	PERFECT-ADJUSTMENT	CHITTOOR	RAYALASEEMA	0.775	PARTIAL ADJUSTMENT
E. GODAVARI	COASTAL	1.599	OVER-ADJUSTMENT	RANGA REDDY	TEANGANA	0.712	PARTIAL ADJUSTMENT
W. GODAVARI	COASTAL	1.727	OVER-ADJUSTMENT	NIZAMABAD	TELANGANA	0.954*	PERFECT-ADJUSTMENT
KRISHNA	COASTAL	0.157	PARTIAL ADJUSTMENT	MEDAK	TELANGANA	1.094*	PERFECT-ADJUSTMENT
GUNTUR	COASTAL	0.459	PARTIAL ADJUSTMENT	MAHABUBNAGAR	TELANGANA	0.579	PARTIAL ADJUSTMENT
ANANTAPUR	RAYALASEEMA	0.276	PARTIAL ADJUSTMENT	NALGONDA	TELANGANA	0.583	PARTIAL ADJUSTMENT
CUDDAPAH	RAYALASEEMA	0.840*	PERFECT-ADJUSTMENT	KARIMNAGAR	TELANGANA	0.574	PARTIAL ADJUSTMENT

Note: * insignificant parameter $(1-\gamma)$

5.7.3 District-wise Acreage Response to Jowar

The model has explained the acreage of jowar, the second most important cereal, in only 12 districts which contribute 78% of state output. The results include all of Rayalaseema, the main jowar producing region of the state, and explain 78% of state output. The fit of the model is usually good, and (with the exception of Chittoor) the scaling parameter exceeds unity.

Table 5.8 Acreage Response to Incentive Variable: Jowar

DISTRICT	REGION	VARIABLE	SUBSTI-TUE(S)	EXPECTATION COEFFICIENT β	SHORT RUN ELASTICITY	LONGRUN ELASTICITY
1	2	3	4	5	6	7
E. GODAVARI	COASTAL	RR1	ALL	1.7	0.720	0.140
W. GODAVARI	COASTAL	RR1	ALL	0.1	1.310	0.119
GUNTUR	COASTAL	RR1	ALL	0.1	0.174	0.610
KURNOOL	RAYALASEEMA	RP	RAGI	1.3	0.212	0.000
ANANTAPUR	RAYALASEEMA	RP	BAJRA	1.6	0.263	2.000
CUDDAPAH	RAYALASEEMA	RP	RAGI	1.7	0.175	0.660
CHITTOOR	RAYALASEEMA	RR2	MAIZE	0.4	0.119	0.220
RANGA REDDY	TELANGANA	RR1	RAGI	1	0.102	0.151
MEDAK	TELANGANA	RR1	ALL	0.9	0.182	0.094
MAHABUBNAGAR	TELANGANA	RR1	RAGI	1.3	0.145	0.330
WARANGAL	TELANGANA	RR1	RICE	0.9	0.263	0.500
KHAMMAM	TELANGANA	RR1	ALL	1	0.268	0.176

Note: ALL=all 5 cereal crops, RP=Relative Price, RR1= Relative Revenue, RR2= Revenue valued at relative Price.

Response to Price

The incentive variable is relative revenue in 9 out of the 12 cases reported following the RR1 scheme in 8 of them. In Rayalaseema districts Kurnool, Anantapur and Cuddapah, the major jowar producers, relative price (RP) guides acreage allotment to jowar. Jowar is apparently not grown for its yield here. The price coefficients are also not significant at 1% level. Food habits as also the limited availability of moisture and poor soil quality may be more important factors in planting decision than profitability (the coefficient of either the irrigation or the rainfall variable is significant). But Chittoor, which does not specialise in jowar may be growing it for commercial reasons including its high yield rather than self consumption (RR2 is the incentive). Jowar is raised here with a far higher irrigation intensity (14%) than any other district of AP and the highest yield level (7.2 quintal per Ha.) is recorded here (Table2.13(A2)).

While there is no distinct substitute crop in the Coastal districts, ragi dominates as a substitute for jowar in Telangana and Rayalaseema. The latter also share the common feature of having jowar as the leading cereal, rice as the second and ragi as relatively unimportant in their cropping patterns. Similarly, Chittoor, in Rayalaseema also has a relatively insignificant crop maize as the substitute and bajra ranks third in Anantapur. Thus, the substitute crop for jowar turns out to be one of the less important cereals in each of these districts. Warangal is the only district where rice is the substitute for jowar and rice is also an important cereal crop. (Warangal however has poor yield rates of all the cereals compared to other districts.)The price elasticity ranges from 0.1 to 1.3 in the short run and from 0.16 to 1.15 in the rong run. The price elasticity in the short run and the long run are high in the two Godavari districts, where jowar claims little acreage but it is fairly low (0.18 to 0.3) in Rayalaseema and other districts. The short run and the long run elasticities are usually not much different i.e., the adjustment rates are fairly high owing probably to moderate demands made on soil-water-climatic conditions by jowar.

Expectation Formations

The value of β is close to one in a number of cases like Mahabubnagar, Medak and Warangal but the naive expectation emerges only for Khammam and Rangareddy, two very important jowar producers. Both adaptive and partially adjusted expectation are found to occur but in the major jowar growing Rayalaseema expectation is formed by adjusting past price.

Table 5.9 Expectation formulations for Districts of Andhra Pradesh: Jowar

ADAPTIVE EXPECTATIONS $\beta<1$	NAIVE EXPECTATIONS $\beta=1$	PARTALLY ADJUSTED EXPECTATIONS $\beta>1$
1	2	3
West Godavari, Guntur Warangal, Chittoor, Medak,	Rangareddy, Khammam	East Godavari , Krishna,, Kurnool, Cuddapah, Anantapur, Mahabubnagar,

Response to Irrigation

At the outset we recall that jowar is extremely lowly irrigated in AP. Jowar, an inferior crop, calls for little privilege with respect soil and water. But irrigation (IRL) is found to be an important variable explaining jowar acreage[18].The higher productivity of of irrigated rice may be a discouragement to jowar cultivation. Anantapur and Guntur are exceptions. The former grows jowar with some irrigation. Jowar is its main cereal and its acreage is possibly protected.

Guntur shares a similar feature, but here the irrigation avariable (IRL) any way matters little except for bajra.

The elasticity with respect to irrigation is very high in the Godavari districts and is in most other cases quite high. Thus although it is raised as a dry crop in the state, jowar acreage is found to respond to any fall in the share of irrigated rice acreage.

Table 5.10 Acreage Elasticities with respect to variables: Jowar

		ELASTICITIES			
DISTRICT	REGION	IRRIGATION A_3/γ	RAINFALL-SWM A_4/γ	RAINFALL-NEM A_5/γ	PAST ACREAGE $A_2=1-\gamma$
1	2	3	4	5	6
E.GODAVRI	COASTAL	-8.4260	-0.8094	-0.1514	0.2309
W. GODAVARI	COASTAL	-14.1800	-0.5740	-	-0.1442
GUNTUR	COASTAL	-0.3020	0.1060	-	-0.1220
KURNOOL	RAYALASEEMA	-0.8720	-	0.1270	0.0428
ANANTAPUR	RAYALASEEMA	-	-	0.6160	0.1564
CUDDAPAH	RAYALASEEMA	-0.9274	-	0.1884	0.2102
CHITTOOR	RAYALASEEMA	-3.6184	0.8492	0.4038	0.4695
RANGAREDDY	TELANGANA	-0.8391	0.2837	-	0.3872
MEDAK	TELANGANA	-0.3307	-	-	0.5451
MAHABUBNAGAR	TELANGANA	-0.4127	0.2335	0.0446	0.2326
WARANGAL	TELANGANA	-0.5298	-	-	0.1599
KHAMMAM	TELANGANA	-0.7478	0.3736	-0.0242	0..0376

Note: SWM stands for South West Monsoon, NEM for North East Monsoon ; Elasticities with respect to irrigation and rainfall are for long run.

Response to Rainfall

We normally expect rainfall to promote planting of jowar, an unirrigated crop, although there is likely to be competition among different rainfed (or tank fed) crops if rainfall happens to be good. RSWL is largely found to be beneficial, except for the two Godavari districts of coastal AP where moisture in this season seems to be excessive.Curiously, no impact of the kharif season rainfall is observable at all for 3 jowar growing Rayalaseema districts. A moderate irrigation intensity (HVD status, see Chapter2) of the crop and the moderate kharif rainfall in these districts make up an ideal condition for jowar cultivation and small changes in rainfall are of no significance to its planting decision. However, all the Rayalaseema districts benefit from a rabi rainfall. In Khammam and East Godavri rabi rainfall deters jowar planting. The elasticity with respect to kharif rainfall (RSWL) is highest in Chittoor (0.85) followed by East Godavari but is low, never exceeding 0.62 (Anantapur) with respect to rabi rainfall (RNEL).

Acreage adjustment

Past acreage appears as a variable in all cases reported and perfect adjustment of acreage is indicated for 7 districts including Kurnool and Cuddapah in Rayalaseema. Overadjustment is noted in the case of West Godavari. The modest demands of the crop possibly makes adjustment easy in many cases but partial adjustment is observed in 4 cases.

Table 5.11 Acreage Adjustment:Jowar

DISTRICT	REGION	COEFFICIENT γ	ADJUSTMENT	DISTRICT	REGION	COEFFICIENT γ	ADJUSTMENT
1	2	3	4	5	6	7	8
E. GODAVARI	COASTAL	.769**	PERFECT-ADJUSTMENT	CHITTOOR	RAYALASEEMA	0.530	PARTIAL ADJUSTMEN
W. GODAVARI	COASTAL	1.144	OVER-ADJUSTMENT	RANGA REDDY	TELANGANA	0.613	PARTIAL-ADJUSTMEN
GUNTUR	COASTAL	1.122*	PERFECT ADJUSTMENT	MEDAK	TELANGANA	0.455	PARTIAL-ADJUSTMEN
KURNOOL	RAYALAEEMA	.957*	PERFECT-ADJUSTMENT	MAHABUBNAGAR	TELANGANA	0.767*	PERFECT-ADJUSTMEN
ANANTAPUR	RAYALASEEMA	0.844	PARTIAL ADJUSTMENT	WARANGAL	TELANGANA	0.84*	PERFECT-ADJUSTMR
CUDDAPAH	RAYALAEEMA	0.790*	PERFECT-ADJUSTMENT	KHAMMAM	TELANGANA	0.962*	PERFECT-ADJUSTMEN

Note: * insignificant parameter ($1-\gamma$). ** significant only at 10%.

fairly high owing probably to the low risk involved and moderate demands made on soil-water-climatic conditions by jowar.

5.7.4 *District-wise Acreage Response of Ragi*

For ragi, another coarse and inferior cereal, although cases reported cover only 5 districts, these produce over 80% of AP's ragi output. The scale parameter is sometimes less than one(Table 5.3(A5)).

Response to Price

The incentive variable turns out to be relative revenue RR1 in all cases reported. The parameter is significant. The substitute crop varies among districts but apart from Srikakulam, one other distinct crop is found to be a substitute of ragi. The short run price elasticity is small in all cases (about .15 in 3 cases. The long run elasticity is however higher, above 0.5 for Mahabubnagar and as high as 6.02 for Cuddapah where adjustment is extremely slow. These are not rice dominated districts, with diversified cropping patterns and irrigated by different sources. The flexibilities implied by these conditions make adjustments of ragi acreage possible in response to price changes.

Table 5.12 Acreage Response to Incentive Variable: Ragi

DISTRICT	REGION	VARI-ABLE	SUBSTI-TUE(S)	EXPECTATION COEFFICIENT β	SHORT RUN ELASTICITY	LONGRUN ELASTICITY
1	2	3	4	5	6	7
SRIKAKULAM	COASTAL	RR1	ALL	0.4	0.145	0.153
GUNTUR	COASTAL	RR1	BAJRA	1.3	0.146	0.409
CUDDAPAH	RAYALASEEMA	RR1	BAJRA	1.2	0.306	6.024
CHITTOOR	RAYALASEEMA	RR1	JOWAR	1.7	0.151	0.276
MAHABUBNAGAR	TELANGANA	RR1	JOWAR	0.4	0.497	0.556

Note: ALL=all 5 cereal crops, RP=Relative Price, RR1= Relative Revenue, RR2= Revenue valued at relative Price.

Expectation formation

There are cases of both adaptive expectations and partially adjusted expectations but never any case of naive expectations. Chittoor records a high β of 1.7. The table below presents the results.

Table 5.13 Expectation formulations for Districts of Andhra Pradesh: Jowar

ADAPTIVE EXPECTATIONS $\beta<1$	NAIVE EXPECTATIONS $\beta=1$	PARTIALLY ADJUSTED EXPECTATIONS $\beta>1$
1	2	3
Srikakulam, Mahabubnagar, Khammam	None	Guntur, Cuddapah, Chittoor,

Response to Irrigation

Ragi, unlike jowar is irrigated quite extensively and the proportion of ragi acreage that gets the benefit is very high for Guntur (98%) and Cuddapah (99%) and reasonably so for Srikakulam (14%) and Chittoor (29%). However, the irrigation variable appears only except for Srikakulam, Guntur and Cuddapah and has a significant effect only in Cuddapah. All these three districts are irrigated by diverse sources and rice is therefore likely to benefit from sources other than canals. The irrigation elasticity is high (negative) for CU again at 13.04.

Response to Rainfall

The districts Guntur and Cuddapah, where ragi enjoys extremely high irrigation intensity, appear to be unaffected by rainfall. An increase in the rainfall possibly has a contractionary effect on ragi acreage releasing the area for a more desirable crop to benefit from the rainfall. The others benefit from rainfall. But the elasticities with respect to rainfall are generally low.

Table 5.14 Acreage Elasticities with respect to variables: Ragi

		ELASTICITIES			
DISTRICT	REGION	IRRIGATION	RAINFALL-SWM	RAINFALL-NEM	PAST ACREAGE
		A_3/γ	A_4/γ	A_5/γ	$A_2=1-\gamma$
1	2	3	4	5	6
SRIKAKULAM	COASTAL	-0.8059	0.4627	0.0626	0.0505
GUNTUR	COASTAL	-0.1642	-0.1170	-	0.9384
CUDDAPAH	RAYALASEEMA	-13.0400	-	-	0.9490
CHITTOOR	RAYALASEEMA	-	0.4110	0.1826	0.4546
MAHABUBNAGAR	TELANGANA	-	0.8090	0.1160	0.1060

Note: SWM stands for South West Monsoon, NEM for North East Monsoon ; Elasticities with respect to irrigation and rainfall are for long run.

Acreage adjustment

Perfect adjustment of acreage is noted in one case in Coastal region and two in Telangana and partial adjustment in the two Rayalaseema districts reported and in Guntur.

The value of γ is nearly one for Srikakulam, (0.95) and Mahabubnagar (0.89) but the adjustment is very slow for Cuddapah (.05), Guntur (.06). The coefficient exceeds unity only in Khammam where ragi is a very unimportant crop.

Table 5.15 Acreage Adjustment:Ragi

DISTRICT	REGION	COEFFICIENT γ	ADJUSTMENT	DISTRICT		COEFFICIENT γ	ADJUSTMENT
SRIKAKULAM	COASTAL	0.949*	PERFECT-ADJUSTMENT	CHITTOOR	RAYALASEEMA	0.545	PARTIAL-ADJUSTME
GUNTUR	COASTAL	0.060	PARTIAL ADJUSTMENT	MAHABUBNAGAR	TELANGANA	0.894*	PERFECT-ADJUSTME
CUDDAPAH	RAYALASEEMA	0..051	PARTIAL ADJUSTMENT	KHAMMAM	TELANGANA	1.023*	PERFECT-ADJUSTME

Note: * insignificant parameter ($1-\gamma$).

5.7.5 *District-wise Acreage Response of Maize*

Maize is also a coarse cereal with modest water requirement, but it has gained from the new technology. Maize is also an important material for the food preocessing industry, and in this respect has significant potential as agriculture becomes more market oriented. In Andhra Pradesh maize cultivation is mostly concentrated in the Telangana region, principally in Karimnagar and Nizamabad in the north and also in some surrounding districts like Adilabad, Warangal, Medak and Rangareddy. The model worked extremely well for maize, covering 9 districts which account for 96% of AP's maize output and the R^2 is mostly above 90%.

Response to Price

Relative revenue is the dominant incentive, but in 3 cases (Ranga Reddy, Warangal and Karimnagar) RR2 emerges as the variable. It appears that the yield rate of the substitute crop does not matter or maize may be grown for commercial reasons. Chittoor and Guntur, two insignificant producers, are the only two cases where relative price is the incentive variable and yield rates do not matter. These districts have low maize yield. These districts are also similar in having ragi as the substitute to maize, ragi being an insignificant cereal in the districts. In the two major maize producing districts as also in Adilabad, rice is the substitute for maize. Jowar is the substitute crop in Rangareddy and in Srikakulam and Warangal where the cropping pattern is mixed, no distinct substitute crop is identified. Maize is not very elastic to price changes in the short run possibly reflecting the restraints imposed by consumption pattern and market orientation.

Table 5.16 Acreage Response to Incentive Variable: Maize

DISTRICT	REGION	VARIABLE	SUBSTITUE(S)	EXPECTATION COEFFICIENT β	SHORT RUN ELASTICITY	LONGRUN ELASTICITY
1	2	3	4	5	6	7
SRIKAKULAM	COASTAL	RR1	ALL	1.5	0.311	1.560
GUNTUR	COASTAL	RP	RAGI	1.2	0.387	0.514
CHITTOOR	RAALASEEMA	RP	RAGI	1.1	0.993	1.507
RANGAREDDY	TELANGANA	RR2	JOWARI	1.7	0.172	0.332
NIZAMABAD	TELANGANA	RR1	RICE	1.1	0.035	0.034
WARANGAL	TELANGANA	RR2	ALL	1.4	0.527	0.396
KARIMNAGAR	TELANGANA	RR2	RICE	1.3	0.097	0.067
ADILABAD	TELANGANA	RR1	RICE	0.4	0.072	0.071

Note: ALL=all 5 cereal crops, RP=Relative Price, RR1= Relative Revenue, RR2= Revenue valued at relative Price.

The long run elasticity is large in some cases. For example, Srikakulam, a moisture rich district with a varied cropping pattern has a small elasticity in the short run but in the long run the elasticity is large at 1.6. Responses are often more in the short run I.e., farmers make use of any advantages by quick adjustment in the short run though the acreages are largely stable in the long run.

Table 5.17 Expectation formulations for Districts of Andhra Pradesh: Jowar

ADAPTIVE EXPECTATIONS $\beta<1$	NAIVE EXPECTATIONS $\beta=1$	PARTALLY ADJUSTED EXPECTATIONS $\beta>1$
1	2	3
Adilabad	None	Srikakulam,Guntur, Chittoor, Rangareddy, Nizamabad, Warangal, Karimnagar.

Response to Irrigation

Although in Chittoor, Warangal, Guntur, Nizamabad and Adilabad some amount of irrigated maize is raised, irrigation variable (IRL) fails to show a significant effect. Possibly, rice has its own sources of irrigation and there is no competition with maize for acreage. But IRL does have an adverse effect on maize acreage in Srikakulam and Rangareddy which grow dry maize. The leading maize producers Karimnagar and Nizamabad both show an adverse impact of IRL (but insignificant in the latter) on maize acreage.

Table 5.18 Acreage Elasticities with respect to variables: Maize

		ELASTICITIES			
DISTRICT	REGION	IRRIGATION	RAINFALL-SWM	RAINFALL-NEM	PAST ACREAGE
		A_3/γ	A_4/γ	A_5/γ	$A_2=1-\gamma$
1	2	3	4	5	6
SRIKAKULAM	COASTAL	-16.6100	4.4030	0.9910	0.8010
GUNTUR	COASTAL	-	0.3000	-	0.2460
CHITTOOR	RAYALASEEMA	-	-1.5590	-0.6310	0.3412
RANGAREDDY	TELANGANA	-0.0934	0.6500	0.0250	0.4838
NIZAMABAD	TELANGANA	-0.0659	0.0382	0.0133	-0.0245
WARANGAL	TELANGANA	-	-0.1850		-0.3286
KARIMNAGAR	TELANGAN	-0.0566	-	-	-0.4399
ADILABAD	TELANGANA	-	-	0.0070	-0.0089

Note: SWM stands for South West Monsoon, NEM for North East Monsoon ; Elasticities with respect to irrigation and rainfall are for long run.

Srikakulam, a poorly irrigated district (group) with a varied irrigation pattern, shows a significant impact of the irrigation variable and a very high elasticity to this variable. For the other cases, the elasticity is fairly low.

Response to Rainfall

Kharif rainfall has little impact on maize acreage in Nizamabad and Karimnagar, the two leading districts. The variable has a negative effect in Chittoor and Warangal, possibly diverting acreage away from the unimportant cereal in the districts. Srikakulam, Guntur and Rangareddy show a favourable effect. These districts grow mostly unirrigated maize. Rabi rainfall has a significant positive coefficient in Srikakulam and Nizamabad and a negative one in Chittoor. The latter shows an adverse impact of rainfall in oth seasons.

Elasticities with respect to rainfall are high for Srikakulam (as in the case of irrigation). Chittoor shows a high elasticity with respect to kharif rainfall indicating a reallocation of acreage against maize when rainfall is high.

Acreage adjustment

The acreage adjustment coefficientγ is greater than unity in 4 districts, all in Telangana but it is ssignificantly so only in Warangal and Karimnagar (indicating oveadjustment). Perfect adjustment is observed in Nizamabad, Guntur and Adilabad. Partial adjustment occurs in three minor maize producing districts Srikakulam, Chittoor and Rangareddy, the rate of adjustment being very low (20%) in Srikakulam.

Table 5.19 Acreage Adjustment::Maize

DISTRICT	REGION	COEFFICIENT γ	ADJUSTMENT	DISTRICT	REGION	COEFFICIENT γ	ADJUSTMENT
1	2	3	4	5	6	7	8
SRIKAKULAM	COASTAL	0.199	PARTIAL-ADJUSTMENT	**NIZAMABAD**	TELANGANA	1.025*	PERFECT-ADJUSTMENT
GUNTUR	COASTAL	.754*	PERFECT-ADJUSTMENT	**WARANGAL**	TELANGANA	1.329	OVER-ADJUSTMENT
CHITTOOR	RAYALASEEMA	0.659	PARTIAL-ADJUSTMENT	**KARIMNAGAR**	TELANGANA	1.440	OVER-ADJUSTMENT
RANGA REDDY	TELANGANA	0.516	PARTIAL ADJUSTMENT	**ADILABAD**	TELANGANA	1.009*	PERFECT-ADJUSTMENT

Note: * insignificant parameter (1-γ)

5.7.6 *District-wise Acreage Response of Bajra*

Bajra is grown mostly unirrigated and in only a few districts in Andhra Pradesh, with Srikakulam alone accounting for as much as 32% of the state's output. The model worked for 9 districts contributing more than 90% of state production, including three major bajra producers, namely Srikakulam, Guntur and Cuddapah (together producing 60%).

Response to Price

For Srikakulam, the leading producer of bajra, the price response is significant only at 12 %. Apart from Srikakulam and Guntur, the price coefficient is significant everywhere. Relative price (RP) dominates as the incentive variable and yield rates do not count except for Guntur, Cuddapah and Warangal. Rice is the distinct substitute crop in most cases, but in Guntur and Nalgonda two insignificant crops, namely jowar and maize compete for acreage.

The short run price elasticity takes a wide range of values from .086 in Srikakulam to 1.69 in Krishna, but apart from Krishna, the elasticity is less than unity in other cases. The long run price elasticity also varies widely, but is generally close to the short run one as the adjustment coefficient γ is around unity. Except for Srikakulam the short run response is more than the long run one. In Warangal, price is the only guiding factor for acreage, with past acreage too having no significant effect.

Table 5.20 Acreage Response to Incentive Variable: Bajra

DISTRICT	REGION	VARIABLE	SUBST-ITUE(S)	EXPECTATION COEFFICIENT β	SHORT RUN ELASTICITY	LONGRUN ELASTICITY
1	2	3	4	5	6	7
SRIKAKULAM	COASTAL	RP	RICE	1.2	0.086	0..146
KRISHNA	COASTAL	RP	RICE	0.4	1.690	1.335
GUNTUR	COASTAL	RR1	RAGI	0.8	0.169	0.144
ANANTAPUR	RAYALASEEMA	RP	RICE	0.3	0.882	0.645
CUDDAPAH	RAYALASEEMA	RR1	ALL	0.4	0.387	0.341
CHITTOOR	RAYALASEEMA	RP	RICE	0.1	0.756	0.609
MAHABUBNAGAR	TELANGANA	RP	RICE	1.1	0.442	4.218
NALGONDA	TELANGANA	RP	MAIZE	0.5	0.582	0.472
WARANGAL	TELANGANA	RR1	RICE	1	0..086	0.075

Note: ALL=all 5 cereal crops, RP=Relative Price, RR1= Relative Revenue, RR2= Revenue valued at relative Price.

Expectation formation

The value of β is on the whole low i.e., farmers do not adjust their expectation sharply. For Srikakulam as also Mahabubnagar expectation is found to be formed by adjusting past realised prices and there is one case (Warangal) of naive expectation. Other districts show adaptive expectation of prices.

Table 5.21 Expectation formulations for Districts of Andhra Pradesh: Bajra

ADAPTIVE EXPECTATIONS $\beta<1$	NAIVE EXPECTATIONS $\beta=1$	PARTALLY ADJUSTED EXPECTATIONS $\beta>1$
1	2	3
Krishna, Guntur, Anantapur, Cuddapah, Chittoor, Nalgonda,	Warangal	Srikakulam, Mahabubnagar,

Response to Irrigation

Bajra is mostly an unirrigated crop in the state (irrigation intensity is only12%) with only a few districts Guntur (50%), Cuddapah (57%), Chittoor (23%), Nizamabad (99%) and Karimnagar (13%) growing some amount of irrigated bajra.

In Srikakulam, bajra is raised as a dry crop. Yet, the impact of irrigation variable is negative and highly significant. Possibly, farmers switch their resources and effort toward irrigated rice when conditions are favourable and cut down on bajra cultivation. Mahabubnagar and Nalgonda too show similar behaviour. Irrigation variable (IRL) is not important (it is either absent in the equation or bears an insignificant parameter) in as many as five cases.The elasticity is highest in Srikakulam.

Table 5.22 Acreage Elasticities with respect to variables: Bajra

		ELASTICITIES			
DISTRICT	REGION	IRRIGATION	RAINFALL-SWM	RAINFALL-NEM	PAST ACREAGE
		A_3/γ	A_4/γ	A_5/γ	$A_2=1-\gamma$
1		2	3	4	5
SRIKAKULAM	COASTAL	-3.5490	0.7283	0.9910	0.4109
KRISHNA	COASTAL	-	0.4324	-	-0.2662
GUNTUR	COASTAL	-1.1037	0.2379	-	-0.1704
ANANTAPUR	RAYALASEEMA	-	0.3549	-	-0.1693
CUDDAPAH	RAYALASEEMA	-	0.4245	0.2600	-0.1365
CHITTOOR	RAYALASEEMA	-0.4640	0.2917	-	-0.2422
MAHABUBNAGAR	TELANGANA	-1.4381	-	-	0.8900
NALGONDA	TELANAGANA	-0.5759	0.2227	-0.2166	-0.2334
WARANGAL	TELANGANA	-	-	-	-0.1569

Note: SWM stands for South West Monsoon, NEM for North East Monsoon ; Elasticities with respect to irrigation and rainfall are for long run.

Response to Rainfall

Kharif rainfall (RSWL) is important and has a beneficial effect in all cases except Warangal and Mahabubnagar where it does not appear. Bajra acreage is not much affected by rabi rainfall. Only Cuddapah shows a positive impact where both rainfalls promote planting. Nalgonda shows a negative but insignificant parameter.Srikakulam has a fairly high elasticity to rainfall and in general the elaticities are low and do not exceed unity in any case.

Acreage adjustment

The parameter for lagged acreage is positive only for 2 cases and negative in all other cases but the latter are nonsignificant. Partial adjustment is implied only for Srikakulam and Mahabubnagar, where past acreage has a significant influence on the current one, the elasticity being low(0.4) in Srikakulam. Although γ exceeds unity in most cases, overadjustment of acreage is not confirmed.

Bajra acreage is thus adjusted easily to its desired level without much restraint in the short run. The process reflects the undemanding nature of bajra and the suitability of soil to this crop

Table 5.23 Acreage Adjustment:Bajra

DISTRICT	REGION	COEFFI-CIENT γ	ADJUSTMENT	DISTRICT	REGION	COEFFI-CIENT γ	ADJUSTMENT
1	2	3	4	5	6	7	8
SRIKAKULAM	COASTAL	0.589	PARTIAL-ADJUSTMENT	CUDDAPAH	TELNAGAN	1.1365*	PERFECT-ADJUSTMENT
KRISHNA	COASTAL	1.2662*	PERFECT-ADJUSTMENT	CHITTOOR	TELANGANA	1.2422*	OVER-ADJUSTMENT
GUNTUR	COASTAL	1.1704*	PARTIAL-ADJUSTMENT	MAHABUBNAGAR	TELANGANA	0.105	OVER-ADJUSTMENT
ANANTAPUR	RAYALASEEMA	1.1693*	PARTIAL ADJUSTMENT	NALGONDA	TELANGANA	1.2334*	PERFECT-ADJUSTMENT
WARANGAL	TELANGANA	1.1569*			TELNAGANA		

Note: * insignificant parameter (1-γ)

5.8 CONCLUDING REMARKS

Acreage and yield together decide the growth of cereal output. Though yield is said to have been the main source of growth since agrarian technology improved in India, a positive price response of crop acreage is a sign of progressive agriculture. It also helps the government to bring about desirable cropping patterns in the country through a suitable agricultural price policy . We have studied the behaviour and the responses of cereal crop acreages in the districts of Andhra Pradesh and noted the following results:

(i) During the period 1965-66 to 1992-93, changes in output levels were usually associated with changes in acreages in the same direction. The only exception is rice in which case yield rate was the chief impetus to output change. In fact, rice acreage declined in several districts of Rayalaseema and Telangana (but increased in Coastal region) while output increased in all the districts. For maize, both acreage and output went up in most cases, but for the other coarse cereals jowar, ragi and bajra, both acreage and output came down in general. Thus, in Andhra Pradesh, movements in acreages usually accompanied and contributed to those in output for the all cereal crops barring rice.

(ii) The Nerlovian model tried in this study could, on the whole, explain cereal crop acreage decisions satisfactorily in Andhra Pradesh. For each of the five cereal crops, the model explained acreage in districts accounting for bulk of the state's production of that cereal.

(iii) The response of acreage to economic incentive (relative price or revenue) is found to be positive and significant in general and this applies to rice, maize as well as to the inferior grains.

(iv) In most cases the economic incentive is relative revenue, i.e., changes in crop yield is taken into account as also the price. The yield rate of the competing crop(s) is usually not considered in assessing a crop's profitability except in some cases like those of rice in the Godavari districts and maize in Karimnagar. Relative price as the incentive is obtained in a number of cases for bajra and in majority of the Rayalaseema districts for jowar. For the other crops it is the relative revenue that dominates as the incentive.

(v) The substitute crop for any cereal varies from place to place and in some cases such as some of the Coastal districts, all crops together vie for acreage with rice, jowar, ragi and maize. But in general, some distinct crop is identified as the main substitute crop. For rice, the substitute is usuallly some important cereal in the district. However, jowar is nowhere found to be the substitute for rice. The substitute for jowar is often a crop which is not so significant in the district while rice is found to be a substitute for maize and bajra in several cases. Bajra, jowar and also maize are found to be substitutes for ragi in different districts.

(vi) Expectation is found to be adaptive or partially adjusted and even naive expectation is noted in some cases such as rice and jowar in Rangareddy and bajra in Warangal. The adjustment coefficient for expectations is usually large, and is mostly greater than unity for rice and maize.

(v) Although rice is a highly irrigated crop, the irrigation variable measuring the allotment of irrigated acreage to other cereals has little significance for rice acreage. Rice acreage seems to be protected and constituted of its own irrigated acreage. On the contrary, though jowar is a dry crop in the state, the irrigation variable appears to be significant in determining its acreage. That is, greater incidence of irrigated rice discourages jowar cultivation. Similarly, irrigation variable is unimportant for ragi which is often raised irrigated but not so for bajra which is mostly grown dry.

(vi) Rainfall is ususlly beneficial except in the Coastal districts. The importance of kharif rainfall comes out more clearly, but rabi rainfall does have an important role in guiding acreage of rice and jowar.

(vii) There are restraints on acreage adjustment accounting for a large number of cases where we found partial adjustment. However perfect adjustment is possible as we find in majority of the cases for jowar and in many other cases for the other crops. Even overadjustment of acreage is marked in a few cases where there is overwhelming preference for the crop, most notably rice in the Godavari districts.

On the whole the positive response shown by cereal crop acreages to economic incentives and the possibility of quick adjustment to desired acreage in Andhra Pradesh are encouraging signs for future agriculture growth and planning. The large number of cereal crops grown in the state and the adjustment possibilties offer a flexibility which can help planners work towards food security or commercialisation or export orientation as the policy obective may be.

Notes:

[1] The optimising farmer has a planned output level in mind and allocates acreage accordingly among crops. The actual production that results, however may not match the planned one and is highly uncertain. On the contrary, the acreage planned is in the farmer's control and may be a better index of the farmers' supply response than the production itself. In short, owing to the discrepancies between planned and realised output, most economists approximated planned output not by the actual output but by the area planted (Behrman, 1968).

[2] Acreage decisions are made in the general envioronment of the cropping pattern historically prevalent in the area. Such patterns evolve from the food habits and customs of the region, the soil-clamatic conditions and irrigation infrastructure suited for certain crops, crop rotations and substitutions. Thus, it is unrealistic to expect drastic and sudden changes in cropping pattern in response to price changes.

[3] This feature is often noted in rice growing regions. Here the availability of irrigation is found to be the most important determinant of rice acreage (and thereby of other crop acreages too) and rice turns out to be very highly irrigated. It is not unusual to come across some districts specialising in inferior grains while neighbouring districts having otherwise similar conditions, but which happen to enjoy developed irrigation system, go for rice. There is little doubt, that given the irrigation facility, the farmers in the less irrigated districts will emulate their more fortunate neighbours and switch to rice.

[4] For example, rice faces close competition from jute in some regions of India, bajra in some and jowar in others. Where water and cropping practices allow a rabi rice, it is not unusual even to find wheat competing with rice for land. If the soil climatic conditions of a region is suited only for a certain crop, say bajra, little can be done if bajra price crashes, except perhaps for cutting down bajra acreage in favour of fallow land. However, a farmer facing land shortage may not prefer this course if the cost of growing bajra is not too high. In this case the acreage response to price changes would be found poor.

[5] Nelove used the concept of an expected 'normal' price or the average of all future prices.

[6] The Nerlovian formulation can also be expanded to a distributive lag formulation with past prices appearing as variables Narayana and Parikh (1981) estimated acreage responses of major Indian crops with the ARIMA model when they found unsatisfactory results with the Nerlove model.

[7] The expectation process assigns the weightage that the farmer attaches to the past in making future expectations. It is basically a subjective process but it may also be influenced by the history of the place concerned.

[8]In this chapter, we have prefered the Nerlovian scheme to to REH on the following grounds. (a) At a micro level such as the present sudy is, where we consider not the entire production decision, but only that of acreage allocation at district levels of the state Andhra Pradesh, Nerlovian approach may be more appropriate than REH which can help in examining the effect macro policies which in India are taken at the national level. (b) Besides, REH is the property of a system of equations as a whole, like the foodgrain market including demand, supply and imports, unlike in the present case where we consider acreage allocation only in isolation. (c) Under certain conditions, REH also reduces to distributive lags form (although estimation in this form without bringing in structural information available may be less efficient). (d) Lack of required data at the state level and of interstate grain movement makes estimation of a REH model undesirable.

However, we have explored the REH approach to expectation formation in Indian agriculture. As is clear from (a) to (c) above the formulation is more suitable for national level modelling of supply response.We have considered the two main cereals of the country rice and wheat and interrelations among them and estimated a complete model of their supply determination at the all India level. The model is presented as Appendix C of the thesis for the reader's referral.

[9]It is important to distinguish between aggregate crop acreage and acreages under individual crops. For the former, the relative price would capture agricultural (or foodgrain price) relative to general price level or the price of agricultural inputs. The supply response of a single crop, on the other hand can be better explained by its price relative to a competing crop or crops. A change in such a price index need not lead to any significant alteration of total cropped (food grain) acreage but can very well change the composition of the crops grown.

[10]We may consider relative profitability in the following way.

$R_i/R_j = (P_i/P_j)/ (C_i/C_j)$ where R is profitability, P is price and C is cost per unit of product.

The cost ratio is
$C_i/C_j= P_f F_i/P_f F_j$
where P_f is the price of input (fertiliser) and F is the input dose for unit of *production* which gives $C_i/C_j= F_i/F_j$. Now,the agronomic doses of different crops and expected optimum yield rates vary across crops and also across different varieties of crops but the ratio F_i/F, is unlikely to change significantly over time.

[11]In a district where jowar follows rice in importance, we may (erroneously) reason out that jowar is the closest competitor of rice for acreage. But in reality, the crops may not vie for the same kind of land. In fact, when rice cultivation is cut down, rice land may be diverted to bajra as the first alternative on the ground that (a) the soil is suited more for rice and bajra than for jowar or (b) bajra is more prominent (than jowar) in the dietary habits of the above rice growers or (c) jowar being less remunerative and demanding less soil fertility is, by custom, assigned inferior grade land while rice usually claims the best quality land.

[12] We have actually tried using all possible combinations of crops as substitutes such that a crop can have one, two, three and four substitute crops while modelling supply. However results showed in each case that either a single distinct crop compted for acreage or all five crops competed among themselves. It is possible however that other crops also substitue for a given crop in varying degrees, but the substitute crop(s) obtained in the analysis is (are) the crop(s) whose price/revenue matters significantly as foregone returns while assessing the profitability of any crop.

[13]Since farmers sell part of the output to government agencies some averaging of the administered and market prices may be suggested for constructing the price variable. But this involves assigning of weights to the two prices. The choice of weight may impose some arbitrariness and such adjustments are therefore avoided.

[14]Two possible reasons for the priority give to rice can be offered.

(a) Rice becomes attractive because of the opportunity of growing high yielding varieties. . (b) Rice enjoys a place of prominence in the farmers' consumption basket.

[15]In the log-linear case, the structural model is given by the following equations:

$$A_t^* = a_0' P_t^{ea_1} Z_{it}^{a_i} u_t \text{....} 5.1(n)$$

$$P_t^e = P_{t-1}^{\beta} P_{t-1}^{e(1-\beta)} \text{......} 5.2(n)$$

$$A_t = A_t^{*\gamma} A_{t-1}^{(1-\gamma)} \text{.........} 5.3(n)$$

where u_t is the multiplicative disturbance term, variables are as defined for section 5.5.1 of text, Z being an exogenous variable. Logarithmic transformation of the equations give a linear structural model in terms of the logarithms of the original variables. The constant term in reduced form model, $a_0 = 0$ implies a unit scale parameter (a_0'); $a_0>0$ implies that scale exceeds unity; and $a_0<0$ implies that scale is less than one.

[16]The criterion of mininmum SEE rather than maximum R^2 is preferred because the latter consideration is mostly found to lead to corner solution, with $RBAR^2$ increasing monotonically in the interval (see also Narayana and Parikh, 1981). In our present exercises SEE is found to decrease, reach a minimum and then rise again within the range of β considered.

[17]The condition that both β and γ should lie between 0 and 2 (i.e., (1β) and ($1-\gamma$) lies between -1 and +1 is clear from the following forms of the acreage adjustment and the price expectation equations.(obtained by successive substitution of P^e_{t-1} and A_{t-1} in 5.5.1 and 5.5.2).

$$P_t^e = \sum (1-\beta)^i P_{t-i-1} \ldots$$

$$A_t = \sum (1-\gamma)^i A_{t-i}^* \ldots\ldots$$

The above equations express expected price and acreage as infinite weighted sums of all past values. In either case, if the value of bracketed expression is greater than one, the weight will go on increasing as we go further back in time and the variable will explode. Convergence is oscillatory when the value lies between 0 and -1 (as the weights alternate in sign) and is monotonic when it is between 0 and 1.

[18]This effect may not always mean direct transfer of land from jowar to rice. The exchange may involve a third crop which releases superior grade land to rice but in turn take away some acreage from jowar.

Appendix A5: Estimated Regression Equations

A5: Table 5.1(A5): Estimated Acreage Response Equations : Rice

	SHARE	β	CONST	PRL	ACRL	IRL	RSWL	RNEL	R^2	SEE	DW	DFT
SRIKAKULAM	7.4	1.2	14.1 (6.961)	0.081 (1.92)	-0.165 (-1.326)	-0.045 (-1.072)	0.482 (7.34)	———	0.75	0.04	1.7	-3.38
E.GODaAVARI	12.7	0.5	8.203 (8.337)	.229 (4.405)	-.599 (-3.464)	-.017 (-1.39)	.166 (2.96)	-.106 (-4.013)	0.77	0.05	2.3	-4.67
W.GODAVARI	17.3	0.3	5.199 (7.03)	.206 (3.373)	-.727 (-3.441)	-.045 (-1.51)	———	-.095 (-3.162)	0.54	0.07	2.02	-4.3
KRISHNA	12.3	1.4	5.302 (1.545)	.163 (1.121)	.704 (3.246)	.051 (1.609)	.100 (1.125)	-.053 (–1.62)	0.41	0.08	2.1	-4.24
GUNTUR	16.3	1.3	5.71 (2.71)	.284 (1.848)	.54 (3.577)	.1 (1.173)	.219 (5.184)	.115 (6.6)	0.72	0.06	2.1	-4.31
CUDDAPAH	14.1	1.1	5.45 (3.11)	.55 (4.272)	.16 (1.396)	—	.478 (9.156)	.248 (5.076)	0.85	0.06	2	-4.87
ANANTAPUR	1.22	1.3	1.181 (.604)	.552 (1.908)	.724 (5.068)	—	——	.390 (3.227)	0.71	1.67	2.06	-4.12
CHITTOOR	3.2	1.6	4.9 (1.728)	.171 (2.307)	.225 (1.733)	——	.551 (6.745)	.314 (6.057)	0.86	0.08	2.1	-4.27
RANGAREDDY	5.2	1	3.863 (3.996)	.107 (2.03)	.288 (3.46)	-.111 (-2.346)	.477 (9.121)	—	0.86	0.07	2.2	-4.73
NALGONDA	6.7	0.5	1.796 (2.386)	.293 (2.526)	.417 (3.271)	-.029 (-1.089)	.373 (3.962)	.121 (3.585)	0.66	0.1	1.5	-3.55
MEDAK	2.2	0.8	6.61 (4.891)	.102 (1.23)	-.094 (-.745)	-.228 (-2.628)	.317 (1.854)	.0125 (1.145)	0.77	0.12	1.7	-3.49
MAHABUBNAGAR	1.8	1.1	1.675 (1.353)	0.196 (1.803)	0.421 (3.916)	———	0.768 (7.281)	0.069 (2.313)	0.83	0.11	1.7	-3.79
KARIMNAGAR	5.2	1.1	-.904 (-.40)	.101 (2.296)	.426 (2.941)	-.33 (-1.701)	.914 (4.875)	.155 (2.504)	0.65	0.2	2.1	-4.24
NIZAMABAD	4.1	1.4	10.51 (4.339)	.092 (1.72)	.0459 (.332)	-.123 (-1.281)	.495 (5.257)	———	0.8	0.12	1.9	-3.84

A5: Table 5.2(A5): Estimated Acreage Response Equations : Jowar

	SHARE	β	CONST	PRL	ACRL	IRL	RSWL	RNEL	R^2	SEE	DW	DFT
E.GODAVARI	0.2	1.7	18.679 (7.507)	.72 (3.141)	.231 (1.67)	-6.48 (-3.958)	-.622 (-3.696)	-.116 (-1.353)	0.92	0.18	2	-4
W.GODAVARI	0.2	0.01	2.41 (9.605)	1.311 (5.389)	-.144 (-2.065)	16.233 (5.98)	-.657 (-7.644)	——	0.94	0.11	1.83	-3.67
GUNTUR	6.6	0.1	1.394 (5)	.174 (2.496)	-.122 (-.558)	-.339 (-1.061)	.119 (3.908)	——	0.57	0.05	1.9	-3.81
KURNOOL	20	1.3	13.12 (5.38)	.21 (2.37)	.043 (.30)	-.84 (-4.43)	——	.122 (4.41)	0.81	0.07	1.7	-3.47
CUDDAPAH	6	1.7	11.9 (4.51)	.176 (1.69)	.21 (1.58)	-.927 (-7.29)	——	.188 (3.15)	0.82	0.09	2.4	-5.09
ANANTAPUR	6.3	1.6	12.9 (.3.87)	.26 (1.09)	.156 (2.17)	——	——	.52 (5.18)	0.84	0.15	2.9	-4.07
CHITTOOR	0.9	0.4	-.74 (-.778)	.119 (1.72)	.469 (3.30)	-1.92 (-5.34)	.451 (4.07)	.214 (3.23)	0.66	0.09	1.8	-3.76
RANGAREDDY	7.2	1	5.236 (4.16)	.103 (2.298)	.387 (3.08)	-.54 (-3.59)	.174 (2.11)	——	0.65	0.05	1.9	-4.5
WARANGAL	4.3	0.9	8.87 (4.11)	.26 (2.72)	.16 (.81)	-.45 (-3.22)	——	——	0.42	0.13	1.9	-4.03
MEDAK	6.6	0.9	4.75 (2.84)	.182 (3.043)	.55 (3.56))	-.15 (-1.894)	——	——	0.55	0.06	1.8	-3.63
MAHABUBNAGAR	8.3	1.3	10.38 (2.518)	0.142 (2.16)	0.23 .976)	-.32 (-2.25)-	0.179 (1.71)	0.034 (1.60)	0.6	7	1.4	-2.71
KHAMMAM	4.3	0.9	8.87 (4.11)	.26 (2.72)	.16 (.81)	-.45 (-3.22)	——	——	0.42	0.12	1.9	-4.38

Table 5.3(A5): Estimated Acreage Response Equations: Ragi

DISTRICT	SHARE	β	CONST	PRL	ACRL	IRL	RSWL	RNEL	R^2	SEE	DW	DFT
1	2	3	4	5	6	7	8	9	10	11	12	13
SRIKAKULAM	29.5	0.4	2.859 (3.6)	.145 (2.07)	.051 (.29)	-.765 (-1.41)	.439 (4.0)	0.59 (2.31)	0.56	0.06	2.3	-4.69
GUNTUR	18.8	1.3	1.56 (.741)	.146 (6.59)	-.949 (-1.23)	-.117 (-1.23)			0.55	0.12	2.3	-4.7
CUDDAPAH	6.3	1.2	-.558 (-.612)	.306 (3.04)	.95 (11.66)	-.662 (-2.976)			0.85	0.14	2.1	-4.33
CHITTOOR	14.7	1.7	6.53 (2.1)	.151 (2.6.8)	.455 (2.759)	—	.224 (2.89)	.099 (1.95)	0.89	0.07	1.6	-3.43
MAHABUBNAGAR	11.1	0.4	1.66 (2.09)	0.497 (2.965)	0.106 (.639)	—	0.723 (4.68)	0.10 (2.356)	0.55	0.17	2	-4.02

A1: Table 5.4(A5): Estimated Acreage Response Equations : Maize

DISTRICT	SHARE	β	CONST	PRL	ACRL	IRL	RSWL	RNEL	R^2	SEE	DW	DFT
SRIKAKULAM	1.7	1.5	-10.1 (-3.94)	.31 (2.0)	.80 (12.4)	-3.30 (-4.69)	.88 (3.31)	.197 (3.16)	0.96	0.14	2.1	-3.47
GUNTUR	0.44	1.2	5.09 (3.32)	.387 (2.0)	.246 (1.48)	—	.226 (2.63)	—	0.71	0.12	1.7	-3.41
CHITTOOR	0.05	1.1	13.2 (5.13)	.99 (1.93)	.34 (2.97)	—	-1.03 (-4.04)	-.42 (-1.76)	0.55	0.25	2.6	-5.49
RANGAREDDY	2	1.7	1.63 (1.97)	.172 (3.86)	.484 (7.75)	-.05 (-5.29)	.34 (4.727)	.013 (1.66)	0.92	0.05	2.1	-4.42
WARANGAL	9.5	1.4	18.3 (9.57)	.527 (7.07)	-.33 (-2.33)	—	-.246 (-5.56)	—	0.92	0.04	1.6	-3.19
KARIMNAGAR	43.9	1.3	20.7 (8.72)	.097 (2.40)	-.44 (-2.64)	.08 (1.83)	—	—	0.9	0.04	1.75	-3.44
NIZAMABAD	24.2	1.1	12.33 (5.67)	.035 (2.09)	-.025 (-.14)	-.068 (-1.02)	.039 (1.36)	.014 (2.50)	0.98	0.03	2.7	-6.38
ADILABAD	4.3	0.4	4.04 (4.74)	.072 (2.87)	-.009 (-.042)	—	—	.007 (1.22)	0.62	0.02	2.4	-5.34

A1: Table 5.5(A5): Estimated Acreage Response Equations : Bajra

DISTRICT	SHARE	β	CONST	PRL	ACRL	IRL	RSWL	RNEL	R^2	SEE	DW	DFT
1	2	3	4	5	6	7	8	9	10	11	12	13
SRIKAKULAM	32	1.2	4.52 (4.52)	.086 (1.66)	.411 (5.99)	-1.87 (-10.57)	.299 (5.70)	—	0.92	0.03	2.2	-4.94
KRISHNA	0.13	0.4	2.15 (2.68)	1.69 (1.17)	-.266 (-1.46)	—	.547 (2.68)	—	0.4	0.45	1.7	-3.47
GUNTUR	21	0.8	8.93 (5.60)	.17 (2.18)	-.17 (-.99)	-1.29 (-4.6)	.278 (4.39)	—	0.67	0.09	1.9	-3.76
CUDDAPAH	9.6	0.4	2.91 (3.48)	.389 (2.256)	-.136 (-.78)	-.48 (-4.93)	.296 (3.56)	—	0.61	0.15	2.4	-6.07
ANANTAPUR	7.8	0.3	3.02 (4.55)	.882 (3.98)	-.169 (-.91)	—	.415 (2.79)	—	0.57	0.15	1.9	-3.88
CHITTOOR	5.9	0.1	.91 (4.08)	.76 (4.24)	-.242 (-1.33)	-.578 (-1.55)	.36 (3.48)	—	0.69	0.11	2	-4.12
NALGONDA	8.6	0.5	6.19 (5.33)	.58 (2.68)	-.23 (-1.24)	-.71 (-3.17)	.275 (4.71)	-.27 (-1.27)	0.54	0.08	1.8	-3.57
WARANGAL	2	1	11.56 (5.5)	.087 (2.56)	-.16 (-.74)	—	—	—	0.51	0.09	1.9	-4.93
MAHABUBNAGAR	3.2	1.1	.938 (.65)	.44 (2.88)	.89 (7.33)	-.15 (-1.78)	—	—	0.65	0.11	2.2	-5.04

A5: Cropping Pattern in Andhra Pradesh Districts

Table 5.6 (A5): Average percentage share in 5 cereal acreage (1975-76 to 1984-85)

DISTRICT	RICE	JOWAR	RAGI	MAIZE	BAJRA
1	2	3	4	5	6
SRIKAKULAM	69.6	3.1	13.2	1	13.1
E.GODAVARI	92.5	1.9	1.1	0.4	4
W.GODAVARI	97.6	1.8	0.2	0.3	0.1
KRISHNA	88	11	0.1	0.4	0.6
GUNTUR	66.5	20.5	3.6	0.2	9.2
KURNOOL	24.9	66.8	0.1	0.1	8.1
ANANTAPUR	27	40.4	12	0.4	20.3
CUDDAPAH	33.4	48	5.8	0.1	12.8
CHITTOOR	61.2	7.5	20.1	0.1	11.2
RANGAREDDY	24.7	59.7	6.9	4.5	4.2
NIZAMABAD	56	20	0.8	22.9	0.4
MEDAK	31.4	45.7	2.3	18.9	1.6
MAHABUBNAGAR	25.6	56.9	8.7	0.1	8.9
NALGONDA	48.3	28.9	0.1	0.3	22.5
WARANGAL	38.4	42.1	0	13.2	6.2
KHAMMAM	36.3	59.5	0	1.2	2.7
KARIMNAGAR	47.8	25.4	0	26.8	0
ADILABAD	20.5	72.4	0	7.1	0.1

Notes to Appendix A5: Figures below the coefficients are t-statistics. DW= Durbin-Watson statistics, DFT= Dickey-Fuller Test Statistics on error (without trend), The critical value at 95% confidence level is -3.04.

6. YIELD RESPONSES OF FOODGRAIN CROPS: A SEARCH FOR INTERACTIONS AMONG INPUTS

6.1 INTRODUCTION

In this chapter yield functions of cereal crops will be studied as technical relations between inputs and yield levels. We shall examine the interactions among inputs and look for desired technologies that will make fuller use of limited inputs and natural resources of the regions.

Before going to the analysis at district level we will follow the movements of cereal crop yields over time for the state Andhra Pradesh.

Table 6.1 gives the state level yield rates of the cereal crops along with those at the all India level for 1992-93. The state records an increase in average yield for cereal crops but this is on account of the high yield rate of superior cereals rice as well as maize both of which gained from the high yielding technology. But yield rates of coarse cereals which are important crops in Andhra Pradesh in terms of their share in acreage (Table 5.6(A5)), jowar, ragi and bajra are poor even relative to state level. However, yield rates of the cereal crops have improved over time for all the crops. Between 1965-66 and 1992-93, the most impressive record was shown by maize (219% increase) and rice and jowar also doubled their yield levels. But improvements in the cases of ragi and bajra were modest. We noted in Chapter 5 that rice and maize also gained acreages while the others lost.

Table 6.1 Yield Rates (in Kg/Ha.) of Cereal Crops in State: Andhra Pradesh

	RICE	JOWAR	RAGI	MAIZE	BAJRA	CEREALS
1965-66	1,241.8	407.6	712.5	833.1	447.6	832.5
1984-85	1,975.4	652.9	956.5	1,383.2	521.6	1,495.6
1992-93 (India)	2,495. (1744.)	864 (989.)	1,103 (2059.)	2,660 (1694.)	760 (824.)	2,087 (1650.)

Source: Season and Crop Report, Andhra Pradesh

In the ensuing analysis we shall try to understand the yield responses of foodgrain crops as part of our overall project of understanding their supply responses in the light of policy options. The approach should help us in answering the following questions:

(1) How is yield rate determined? Do yield rates of the foodgrain crops respond to technology inputs- irrigation and fertiliser? Or, are yield rates of some crops, especially the coarse grains, unresponsive to technical progress? Are they determined simply by weather ?

(3) How important are the two main seasonal rainfalls in influencing yield levels of different crops? How important is technology by itself in determining yield rates? How do technology and rainfall interact in determining yield levels? Should the technology chosen take into account the pattern of rainfall?

(4) To what extent is irrigation support required to make gainful use of natural rain water, especially in the drier areas? To what extent is the effectiveness of chemical fertiliser use determined by the rainfall performance? Can rainfall promote fertiliser use even in the absence of irrigation? Are irrigation and fertiliser always complementary in nature? Can irrigation and fertiliser inputs be substitutable?

(5) What are the implications, if any, on input use when the effect of each input, irrigation and fertiliser, interacts with rainfall? What if the effect of each input depends also on the level of use of the other input? Do these interactions provide any guidance to the choice of technology in the light of the natural conditions and input scarcity that is encountered in a region? Is it desirable that farmers use more or less of irrigation/ fertiliser than they do currently?

(6) Are the responses of yield rates to technology and rainfall and the interactions among inputs similar or different among the regions of Andhra Pradesh? Do they call for differences in input use?

In sections 6.2 and 6.3 we shall clarify some basic concepts and possible approaches and difficulties involved in estimating yield functions in agriculture. The model is presented in 6.4. This is followed by some clarifications on the Data used and their limitations in 6.5. The results are discussed in 6.6 followed by some concluding remarks in 6.7.

6.2 INPUTS AND PRODUCTION CONDITIONS

Agricultural inputs can be broadly categorised into two kinds. Firstly there are the *technology inputs* like irrigation, fertilser, labour, machinery etc. The levels of these inputs are largely decided by the farmers themselves. However, these decisions are also influenced by infrastructural and institutional facilities mostly determined by government actions. On the other hand, there are also some inputs which are beyond the control of the farmers and even the government. Soil quality, rainfall, sunshine, humidity are such natural conditions that also determine yield levels of crops.

Some inputs are *essential* like some minimum water, labour, seeds etc. There are also nonessential inputs such as chemical fertilisers, tractors, (some) pesticides and irrigation for certain crops when rainfall is not too poor. When some of the latter category inputs are absent, yield rates may suffer but they may still be positive. Two inputs may be *substitutable* in the sense that one input makes up for the shortfall of another. Alternatively, inputs can be *complementary* and help improve one another's productivity (more later).

Apart from technology and weather, there are many factors shaping the crop yield rates. They constitute the entire production environment and constrain or aid technology in drawing the best results. Natural conditions such as soil fertility, geography and the general climatic conditions of the place may suit some crops but not others. The economic conditions of the people, their adaptability to changes, their customs and practices relating to cropping patterns, rotations, soil preparation, manuring, drainage and other agricultural activities are expected to have some influence on yield rates of crops. Infrastructure and institutions provided by the government affect the adoption as also the effectiveness of technology. Roads, transport, storage, marketing, credit and other facilities all influence the quality as well as quantity of inputs applied.[1] The infrastructure for irrigation in terms of reservoirs, canals and field channelling system or the types of wells supplying irrigation water and the availability of power for energising pumps determine the quality of irrigation. There are, in fact, innumerable factors, not all of them quantifiable, which determine the responses of yield rates to the technology inputs and weather. *Any study conducted at a certain level of aggregation can not be adequately taking account of dissimilarities in these conditions. The assumption of a uniform yield response function irrespective of the* *diverse agro-climatic conditions is unrealistic and of little use in planning. A* disaggregrate or a regional level of study of yield responses is therefore desirable.

6.2.1.Substitution and Complementarity among inputs

A principal aim of the present study is to examine the interactions - substitution /complementarity among the various inputs in determining yield levels. In view of the exhaustible nature of some resources, limitation of investible resources and undesirable impacts of too much input use, the knowledge of these relations becomes meaningful for policy purposes. For example, it is pertinent to ask questions like (a) whether construction of wells can make up for some withdrawal of subsidies on fertiliser (b) or whether such construction calls for further stepping up of fertiliser use for its effective use, (c) whether investment on irrigation is inessential in view of the rainfall performance and the crop pattern (d) or whether the investment will actually be beneficial by preventing wastage of natural water through storage and effective distribution and help to make better utilisation of rain water and (e) given the rainfall, is it a wastage of resources to apply the fertiliser at the rate currently being used (f) or if such wastage can be prevented by a suitable irrigation system.

The complementarity between irrigation and fertiliser is a widely observed phenomenon. A soil when well nourished and well cultivated, having improved porosity and texture is good for the proper utilisation of irrigation. Similarly, water is the medium that transports fertiliser from soil to the plant. For high yielding varieties of seeds, this complementarity is more conspicuous, as it involves a package consisting of a certain number of controlled irrigation and recommended doses of chemical fertiliser among other requirements, all of which may or may not be met in reality. It is also suggested (Ishikawa, 1967, Chopra, 1985) that this complementarity is only a sufficiency relation in the sense that a certain minimum supply of water is necessary for the use of chemical fertiliser but beyond this threshold level, substitution is a possibility. It may also be pointed out that factors such as the moisture retained in the soil from past rainfall and irrigation and manuring and rotation practices of the farmers are seldom explicitly be taken into account in most studies (as in the present one). In fact it is possible that a minimum and sufficient mix of inputs (for a given crop) is already attained through these sources so that irrigation water and chemical fertiliser over and above these levels act like substitutes. Some agronomic explanations are also offered for the substitutability of inputs. Much of the nitrogen absorbed by the rice plant are fixed from the atmosphere when land is submerged. This is the action of bacteria and green plants in algae film at the soil surface. Also the mineral content of the water reacts with the soil to enrich the the organic fertiliser content.When the crop's requirement of water is modest, irrigation and fertiliser can be considered substitute in the following sense. The yield rate of the crop can be raised by light irrigation of drier parts of tracts under the crop and alternatively, by fertilising rainfed tracts growing the crop. For effective use of fertiliser, correct volumes of water are necessary at certain times. But the irrigation variable reported (data) relates to the proportion of crop acreage having at least one irrigation. Increasing irrigation intensity of a crop may not mean better quality of irrigation unless the source of water is totally reliable. In fact, with scanty rainfall and traditional means of irrigation, the effect may be reverse, with the greater spatial spread of irrigated area (increased number of beneficiaries) coming at the cost of lower volumes of water per unit irrigated area and greater uncertainty. Even in canal dominated areas, an increased irrigation intensity can sometimes imply poorer quality irrigation if water management is poor.

The relation between irrigation and rainfall is relatively simple. In places where rainfall is scanty and irrigation is not assured, it is reasonable to expect that the two supplement each other in helping plant growth. In areas dominated by tanks, wells and other traditional non-perennial sources of irrigation, dependent on rainfall for recharging, an increase in irrigation intensity will be effective only if rainfall is adequate. This shows complementarity between irrigation and rainfall. When irrigation is assured, as from a canal backed by a reservoir or a deep well, substitution relation is more likely to dominate, with more rainfall tending to bring down the productivity of irrigation. At any point of time irrigation from such assured sources and rainfall can be substitutes (provided past rainfall or that in the catchment outside the region) have been enough to keep the sources charged.

The relation between fertiliser and rainfall is not much different from that between fertliser and irrigation. In low rainfall and less irrigated areas the relation is likely to be complementary, the inputs possibly supporting the cultivation of inferior cereals or traditional varieties. In the presence of perennial irrigation, which often encourages cultivation of high yielding crops, rainfall and fertiliser as well as rainfall and irrigation will possibly be in the nature of substitutes (we expect a complementarity between fertiliser and the controlled water input). In other words high rainfall can be undesirable for the technology practised. Where the drainage is poor, rainfall (or ill managed irrigation) can result in fertiliser getting washed away. Although this may suggest a substitution relation, it is possible that a high dosage of fertiliser is necessary to compensate for this loss.

6.3 APPROACHES TO ESTIMATION

In estimating agricultural yield functions one encounters a choice among different possible approaches.

(1) An yield function can be estimated as a technical relation between inputs and output. Alternatively, the equation can be expressed as a reduced form characterisation of the underlying model of farmers' supply responses (see Narayana and Parikh, 1987). There are two possible ways. A price based yield function may be derived from a profit maximisation exercise, give the price. Alternatively, an optimisation exercise may be made, subject to overall input constraints.

(2) Estimation of yield function may be based on time series data on inputs and yield level. This runs into difficulties arising from insufficient data on inputs (see 6.5). Even when the data are available, agricultural inputs show high degree of correlation among themselves leading to multicollinearity problem. While one can overcome this problem by resorting to cross section data analysis, heteroscedasticity is another pitfall. Also, yield levels depend not only on inputs like water and fertiliser but also other agro-climatic factors. There is a chance of misspecification of yield function. Data from different areas can be pooled, but only after accounting for these other factors carefully. Experimental data can also be used (eg., Narayana and Parikh (1987)). While this approach offers a way out of the problems associated with real life data, approximating this to the actual relationships that would result when farmers take decisions in different environments and with variables out of the experimenter's control is not an easy task . (Vaidyanathan, 1994).

(3) Different functional form for the yield response, such as the linear and the Cob-Douglas form offer a choice. Each form has its own rigidities or flexibilities regarding production possibilities and the choice depends on economic reality and the purpose of study. It is *desirable that the functional form* is flexible and at the same time dictated by economic theory and *a priory* information. Although, if situation demands, non-linear or complex estimation techniques have to be employed, but where the option is available for tackling the problem at hand, the simplest one is the choice (Deasi, 1979). On the whole, the functional form must serve as an efficient instrument for satisfying the objective at hand.

6.4 MODEL: THIS STUDY

The present study seeks to estimate and study the yield response functions of major foodgrains of the state Andhra Pradesh at the district level. The crops are rice, jowar, ragi, maize and bajra. The study is conducted for 18 districts/district groups of Andhra Pradesh (see Appendix B) using time series data for 1965-66 to 1984-85.

As already mentioned, we chose among the following procedures in modelling yield functions (i) profit maximisation approach, (ii) joint revenue maximisation (over competing crops) approach subject to input constraints and (iii) technical input output relation.

(i) A profit maximisation exercise (with respect to input intensities) first solves the following problem for each crop i= 1, 2,....n

$$\textbf{Max} \;\; PF_i = P_i Y_i - P_1 X_{1i} - P_2 X_{2i}$$

$$Y_i = f(X_{1i}, X_{2i})$$

where PF is per hectare profit, Y_i is yield rate, X_{ji} are input intensities and i is crop. This would give optimal input use functions (for X_{1i}, X_{2i}) that can be substituted back in the yield equation to get the following indirect yield function

$$Y_i = Y_i^*(P_i, P_1, P_2)$$

This indirect yield function in terms of exogenously given prices can be estimated.

(ii) Inputs are assumed to be limited in supply and are optimally allocated among competing crops. The optimising exercise over total returns is

$$\text{Max} \qquad L = \sum_n P_i Y_i A_i$$

$$where\, Y_i = f(X_{1i}, X_{2i})$$

subject to constraints $\sum_n X_{1i} A_i = X_1$ and $\sum_n X_{2i} A_i = X_2$

where A is acreage and X_j is total availability of j input. This exercise leads to optimal input intensities and the consequent crop yield rate in terms of the crop price, the crop acreage, the parameters of the above structural model and the shadow prices of the inputs. The shadow prices can be further solved in terms of the parameters, the yield rates of all competing crops, the acreages and the input constraints. Thus, we get a simultaneaous equations model which may be estimated using appropriate methods. A typical model of above type (worked out and estimated by the present author jointly with Majumdar et al (1988) as part of a Project Report submitted to the Planning Commission, Government of India) is presented in the appendix A6 of this chapter.

Estimation of the indirect yield function is made difficult by the complexity of the way crop and input prices in Indian agriculture are determined.[2] The method of simultaneous optimisation over competing crops in the presence of input constraints may be suitable in the all India context but the severe endogeneity problem makes the estimation process complex (see Appendix A6). Besides endogenising the acreage variable (just as other input variables) proved difficult and having acreage as an exogenous variable in the model is not appealing. Moreover, parameters in any structural form relation are likely to be more stable than those of a reduced form one in the presence of food policies which change the production environment (see Narayana and Parikh, 1987). The yield response function in this study is therefore considered as a technical relation between inputs and output in preference to a reduced form or indirect relation.

6.4.1. MODEL SPECIFICATION AND ESTIMATION

The relation between inputs and output is characterised in terms of a production functions of the following general form.

$$y = f(x_1, x_2, \ldots x_n, z_1, z_2, \ldots z_n) \quad \ldots.. \quad \textbf{6.4.1}$$

where y is yield rate and x_i and z_i are control and exogenous variables respectively.The variables are flows per unit of time i.e., an agricultural year.

Some of the common functional forms are Linear, Log-linear or Cobb-Douglas, CES, Translog and Quadratic forms. Each has its own advantages and disadvantages (see Halter et al, 1957 and Desai, 1979). The linear form is a simple generalisation, imposing restrictions like constant marginal productivities of inputs and perfect substitutability. The Cobb-Douglas is a more flexible form, but assumes that inputs are substitutes. Also, *it does not allow for inessential inputs* as the equation becomes meaingless when an input variable takes zero value. The CES form, of which the Cob-Douglas is a special case, is relatively more flexible and allows for inessential inputs, but the nonlinearity can cause complication of estimation and under certain conditions this equation becomes meaningless. The Translog form, which also reduces to the Cob-Douglas form under some restrictions, has the advantage of allowing for complementarity among inputs. But like the Cob-Douglas form, it considers essential inputs only. The Quadratic function has the advantages of the Translog form, imposing little imposing little restriction on the marginal productivities, input substitution and returns to scale. But at the same time, it allows for inessential input variables to take up zero values.

Although the Cob-Douglas and more recently the Translog functions are popularly used to characterise agricultural production, we have selected the Quadratic form (Equation 6.4.2) with interaction terms. (The quadratic form has been used in agricultural studies in Inida by Dhawan (1988), Narayana and Parikh (1987) Bliss and Stern (1982).)

The yield function is

$$y = A + a_1 x_1 + a_2 x_2 + a_{11} x_1^2 + a_{22} x_2^2 + a_{12} x_1 x_2 \quad \ldots\ldots 6.4.2$$

where y is output and x_i an x_2 are input variables.

The following justification may be given for the choice in the present case.

(i) The variables in real life agriculture are in a continuous flux, unlike in a controlled experiment. It is logical to presume that the effect of a change in any variable on yield level is not independent of the levels of other.associated variables.

(ii) Relations among explanatory variables need not be of a substitutable nature. With the adoption of modern methods, complementarity between irrigation and fertiliser may be a reality. Similarly, rainfall may be a substitute or a complement to irrigation and fertiliser (see section 6.2.1). In this work, our emphasis is on the interactions among the inputs in determining yield levels and the quadratic function allows flexibility in this matter.

(iii) Other rigidities like constant marginal products, constant returns to scale, constant elasticity of yield to inputs and constant elasticity of substitution are avoided. .

(iv) Agricultural inputs, irrigation and fertiliser are not indispensable. Crops can often be grown unirrigated or without fertiliser. In the presence of assured irrigation, even rainfall may be inessential (though of course, rainfall at *some* point of time or some place is essential for the availability of the same irrigation). In the present case, we sometimes encounter zero values of inputs particularly irrigation, for inferior crops. The Translog specification is rejected on this consideration.

(v) The quadratic form, being linear in parameters is easily estimable.

(vi) Another consideration in the choice is the problem of multicollinearity which is severe in the data. This problem often makes most of the parameters statistically nonsignificant and the equations estimated quite useless. Dropping some variables to get over multicollinearity would mean that the parameters become biased and anyway, the purpose of the study is lost. The interaction terms offer the possibility of using more number of variables all of which may not be collinear (more later in this section). Even if one input variable has to be dropped, its effect is still captured in the other variables which measure the interactions between this variable and others.

A suitable agrarian technology would be expected to bring out the most from the limited land and other natural resources. The marginal productivity of an input can be a source of guidance[3] in choosing the input mix. For a quadratic yield function, the marginal product of any input depends on the levels of associated inputs and possibly, on the level of use of the same input.

For example in equation 6.4.2,

$$\partial y/\partial x_1 = a_1 + 2a_{11} x_1 + a_{12} x_2 \ldots\ldots \qquad 6.4.3$$

is the marginal product of input variable x_1.

The standard (Hicksian) definition of substitutes/ complements runs in terms of cross partial derivatives with respect to the prices of other inputs. As we are here concerned with production technology rather than market behaviour, we will look at the relations differently. Bliss and Stern's (1982) definition in terms of cross partial derivative of production function with respect to the other input quantity is more appealing in this case.

Inputs x_1 and x_2 are

substitutes if $\partial y/ \partial x_1 \partial x_2 < 0$

and complement if $\partial y/ \partial x_1 \partial x_2 > 0$

Input x_2 is a substitute of x_1 if more of its application brings down the marginal productivity of x_1 .

and is a complement in the reverse case.

For the yield fuction of any crop i, the variables used are as follows.

YLD= yield rate per unit area

IRR= irrigation intensity
FRT= fertiliser intensity
RSW= rainfall from south west monsoon
RNE= rainfall from north east monsoon
IRFR= IRR X FRT
IRSW= IRR X RSW
IRNE= IRR X RNE
FRSW= FRT X RSW
FRNE= FRT X RNE
IRSQ= IRR X IRR
FRSQ= FRT X FRT
U= stochastic error term

$$YLD = \begin{aligned} & a_0 + a_1 IRR + a_2 FRT + a_3 RSW + a_4 RNE \\ & + a_{12} IRFR + a_{13} IRSW + a_{14} IRNE + a_{23} FRSW \\ & + a_{24} FRNE + a_{11} IRSQ + a_{22} FRSQ + u \ldots 64.4 \end{aligned}$$

The stochastic error term u is assumed to be distributed around a mean value zero with a constant variance. But autocorrelation is a likely due to the time series nature of the data.[4] The error process in this study is specified to follow a first order autoregressive pattern.

The parameters a_1 , a_2 ,a_3 ,a_4, the coefficients of the input variables in isolation, each captures the (pure) effects of the corresponding variables on yield in the absence of associated inputs (ignoring the effect of the squared terms). This effect can be negative. For example, too much rainfall may be harmful, causing water logging or erosion of soil nutrients unless there is a good drainage system (involving land shaping, a good network of canals and field channels or tanks to store and distribute water over time and over tracts). A high rainfall can also bring about a reallocation of resources to favour a different crop and hence a fall in yield level can follow. Irrigation too can lead to waterlogging, salinisation and loss of soil nutrients if water management is inadequate. Where the irrigation system is dependent on rainfall, in the absence of sufficient rainfall, greater irrigation intensity may imply less number of irrigation during the growing season and lower yield level. Too much use of chemical fertiliser can lead to 'lodging' of plants, though the levels at which this will occur depend on the type of soil, seeds and irrigation and on the application of organic manures (see Chapter 1, Chapter 2). Thus the signs of the coefficients of irrigation, fertiliser and rainfall inputs can be positive or negative depending on the soil-climatic conditions. The marginal product of an input, say fertiliser in equation 6.4.4, can be known only when the other input levels are known. If say, the parameters a_{24} and a_{22} are zero, we find that the MP (marginal product) of fertiliser depends on irrigation and south west monsoon rainfall. If a_2 is negative and a_{12} is positive, there is a certain minimum level of irrigation intensity that can ensure a positive MP of fertiliser and this minimum depends on the level of rainfall[5] RSW! If a_{23} is positive, it essentially means that there is a certain prerequisite water input for effective fertiliser use and when rainfall RSW is high, a low IRR can suffice to make fertiliser MP positive. Thus the parameters a_{12}, a_{13}, a_{14}, a_{23}, a_{24} give the interactions among the inputs, *where a positve interaction implies complementarity and a negative one shows substitution according to our definitions.* Parameters a_{22} and a_{11} are the coefficients of the quadratic or squared terms. The former may be expected to be negative while a_{11} may be positive or negative, given the way that irrigation variable is specified. (Variable IRR says nothing about the volume of water given at the plant root. A negative coefficient would probably mean that irrigation is first extended to more fertile tracts and then to the lesser ones.)

Multiple regression method is used for estimating ethe quations. Autocorrelation is corrected by using HILU method. Durbin-Watson (DW) statistics are computed for serial correlation. The stationarity of the errors is checked in each case by visual inspection of the graph of residuals against time and the Dickey-Fuller Test statistics (DFT) for the presence of a unit root process in the residuals is also computed.

A serious difficulty faced is multicollinearity among variables (such as between irrigation and fertiliser where high yielding package is used or rainfall and irrigation when irrigation is rainfall dependent). This usually leads to equations the parameters of which are not precise and the equations are of little value (see Maddala,1977). The usual sign of multicollinearity is high R^2 but nonsignificant t-values of coefficients. Another symptom is the instability of parameters over samples. That is, the parameters are highly sensitive to the sample at hand and droppimg a few observations would effect drastic differences in estimated coefficient values. In the present case the transformation of equations to correct for autocorrelation reduces the chance of multicollinearity also. There is also no a priori reason for the inteaction terms to be correlated. In estimating our equations we checked that (i) the t-statistics are at least unity and R^2 at least 0.3, and (ii) the parameters (and their significance) are fairly stable even if the sample size is changed to ensure that the equaions do not suffer from multicollinearity. Condition (ii) is checked by reestimating the equations after dropping observations. A specification where the parameter is affected significantly by the change in sample probably suffers from multicollinearity and is not accepted for reporting. To illustrate, we present the following example corresponding to rice yield in Chittoor. When the entire sample period 1965-66 to 1984-85 is considered, we get an equation where the *R^2 and the significance of parameters are satisfactory.*

RICE: CHITTOOR

YLD = 9132.6 - 8333.4 IR R + 45253.7 FRT - 53407.2 IRFR + 1.27 IRSW + 57.4 IRNE + 23.9 FRNE - 54.8 RNE

(2.20) (- 1.91) (2.58) (-2.68) (5.08) (4.57) (3.67) (-4.53)

R^2 = ..86 DW = 2.43 .... 1965-66 - 1984-85 .....**6.4.5(a)**

Now, when we drop the first three and the last three observations and estimate the same equation for the subsample period 1968-69 to 1981-82 we have equation

YLD= 28691..9 - 28849..IRR - 31595.5 FRT + 28272.2 IRFR + 1.04 IRSW + 83.7 IRNE + 25.2 FRNE -80.1 RNE

(2.93) (-2.79) (-..95) (.80) (4.16) (4.76) (4.18) (4.76)

R^2 = .87 DW= 2.6 ....1968-69 - 1981-82 ....**6.4.5(b)**

We find that not only have the parameter values changed two to three folds for some variables, in the case of FRT and IRFR the signs (and significance) have also changed. The above case shows how useless an estimated equation can be. The equations presented in this chapter are checked and do not suffer from this kind of shortcoming arising from multicollinearity. In choosing the specifications we have sought to include as many variables as possible, to reduce bias and capture the effects of the inputs while avoiding the problems associated with muticollinearity.

To sum up, our estimation procedure goes through the following steps:

From all such specifications which satisfy (i) and (ii) above, we selected the best on the basis of (i) high R^2, (ii) high t-values, (iii) inclusion of as many input variables (as pure or interaction variables) as is possible.

The estimated yield response equations are analysed in the light of the conditions of the districts concerned, especially the type of irrigation infrastructure available (discussed in Chapter 2). Special attention is given to identifying the interactions among variables while examining the beneficial/ adverse effects of inputs and some policy options are inferred from the results. *In most cases we emphasised the possibilty of utilising the natural and costless input from rainfall through proper use of technology.*

6.5 DATA

The sample period covers 20 years in the green revolution era from 1965-66 to 1984-85 for which continuous data were available at the time of estimation. The data required for the analysis includes yield rate, irrigation intensity and fertiliser intensity of the five cereal crops and seasonal rainfall (Appendix B).

Use of data on fertiliser has however not been simple. *Fertiliser data according to crops is not available* except for some survey data on specific years (see Notes, Chapter 1). We adopted the following procedure to get round this inadequacy. We have used a proxy variable FRT_i for the crop level fertiliser intensity variable (F_i / A_i).

$$FRT_i = TF/A_i = (F_i/A_i)/\,(F_i/TF) \quad \ldots\ldots\ldots\ldots\mathbf{6.5.1}$$

where TF is total fertiliser over all crops, A_i is the acreage under crop i and F_i is the actual but unknown quantity of fertiliser given to crop i (this measure of fertiliser dose 'over cereal crops' has been used by Ganesh Kumar (1992) with i standing for the cereal crops together and a similar approach was also resorted to by Narayana and Parikh (1988) to overcome the dearth of data). We have employed the same formula for rice and maize (which have high yielding varieties and have gained in acreage and yield rates over the sample period) but some modification is made in the cases of the coarse cereals jowar, bajra and ragi as the sahres of these cereals in input use have been poor. For each of these crops, A_i in (equation 6.5.1) is the total area under the three crops together, whereas for rice and maize, it is the acreage under the specific crop concerned. We are in effect assuming that the fertiliser intensity is approximately the same for all the millet crops jowar, ragi and bajra. FRT_i is the total fertiliser (over all crops) per unit of crop (or crop group) acreage from which the fertiliser intensity of the crop can be derived once we know the crop's share in total fertiliser consumption (F_i/TF in equation 6.5.1). For rice, the proportion may be close to one in many districts of AP, in which case FRT_i and F_i/A_i may be quite close (rice claiming the lion share in inputs), but for other crops with low shares FRT_i is several times F_i/A_i. If the crop share in fertiliser consumption F_i/TF is constant over time the result will not be much different whether we use FRT_i or F_i/A_i as the variable (the proportion being absorbed in the constant term). The crop wise shares in total feritiliser consumption has been found to be rather stable (see Vaidyanathan,1993). For Andhra Pradesh, shares reportd by NSSO, 1971 (Sarvekshana, 1978) were as follows: Rice 60.5%, Jowar 1.9%, Ragi 0.76%, Maize 3.37%, Bajra 0.73%[6]. Thus, to arrive at our proxy variable for fertiliser intensity, we used data on total fertiliser (tonnes) and the crop wise acreage (Hectares).

As explained earlier, rainfall variables are RSW and RNE for rainfall (millimeters) during south west monsoon and north east monsoon. These are total rainfall received between June and September and between October and December respectively and represent the khraif and rabi rainfalls.

There are some limitations regarding this data availability.

(ii) the available crop-wise irrigation data was quite inadequate. The variable IRR as used, measures the proportion of crop area that gets at least one irrigation during the crop period. It says nothing about the volume of water delivered and the quality and timeliness of irrigation. Irrigation is treated as a homogeneous input, no distinction being made among the sources. The interaction of fertiliser and rainfall may be quite different with canal irrigation and tank irrigation. Moreover, the external effects of irrigation such as water logging by canal or seepage from tanks leading to some interactions among the sources are not explicitly taken into account. But to some extent,all these profound implications of irrigation on yield rates will be borne out by the study if we compare the district level results.

(iii) HYV acreage cannot be incorporated in the model as *district level time series data are not available*. Its prevalence is bound to influence the parameters and the interactions such as that between irrigation and fertiliser.

(iv) Several other input variables could not be included partly because of their unavailability at the district level though also for simplicity. They include labour, farm animals, farmyard manures, pesticides and seeds. These inputs have been subsumed in the inputs considered and we are specifically interested in the effects of technology inputs irrigation and fertiliser.

However, these variables draw on farmers' limited resources and influence yield levels and their omission is bound to affect the parameters.

(v) Another limitation of the data that limits our scope is the lack of distinction among different crop seasons. The yield rate estimated is the composite yield level over kharif and rabi crops. Also, if irrigation is directed towards the kharif monsoon season its effect may not be as strong as when it is directed towards the rabi season. But our annual level variable IRR cannot help us distinguish these impacts. The variables RSW and RNE and their interaction differentials, it is hoped, will help us in making some judgement about the seasonality of crops and technology.

6.6 RESULTS

Estimated yield response functions are reported in Appendix A6 of this chapter. We could not report results for all (crop-district)cases either because the multicollinearity problem proved too severe or the model gave a very poor fit ($R^2 < 0.3$). Fortunately, for most crops the districts reported in this study contribute a major part of the state's output of that crop and barring a few cases, the relevance of the omitted districts is limited. Table . 9 (B) gives the importance of the districts in the production of the five cereal crops. The reported equations mostly have satisfactory fit and are tested to be free from multicollinearity as discussed in section 6.4. The DW and the Dickey-Fuller test statistics are in general satisfactory ruling out problems of serial correlation and unit root process in the residuals. (The possibility of unit root however could not be ruled out in the cases of Guntur, Kurnool and Mahabubnagar for rice and in Srikakulam for ragi. For these cases, the DW statistics are also low.)

Let us examine the empirical results with special reference to the interactions among inputs, i.e., substitution (negative interaction) or complementarity (positive interaction) relations and their implications on the choice of technology. It may be mentioned at the outset that our study will mostly be concerned with the qualitative aspects of the results rather than the details of parameter estimates (the parameters are not always statistically significant, the criteria for model selection having been discussed in section 6.4). The impacts of the input variables and their interactions (whether favourable or adverse) on crop yield rates will be the focus of the analysis. Estimated parameter values will be employed in limited extent along with sample means of variables in working out marginal products of variables. Thus an input would be identified as marginally productive only at the sample average values of variables. In actuality, the values may be different from the means in any year and the implication on the marginal product can possibly be different. For each crop we report a table (a) giving the impact as favourable, adverse or none, of the variables on yield and another (b) presenting the sample means of variables and the marginal products computed at the given sample means of the variables.

Number of districts for which results could be reported and the corresponding contribution to the state output are given in Table 6.2.

Table 6.2 Districts Reported and Coverage of crop output

CROPS	DISTRICTS FOR WHICH RESULTS ARE REPORTED (TOTAL = 18)	(%)SHARE OF STATE OUTPUT (1984-85)
1	2	3
Rice	18	100
Jowar	8	54.8
Ragi	4	59.4
Maize	10	69.3
Bajra	5	51.9

Note: Equations are presented in Table 6.1(A) in Appendix.

The model worked quite well for rice and we report the results of all 18 cases, ie, for 100% of state output. The performance is relatively modest for the other crops. To illustrate the nature of analysis made with the estimated equation, we will first elaborate the case of rice in one case in section 6.7.1. The summary results obtained by similar analysis for all crop district cases follow.

6.6.1 YIELD RESPONSE OF RICE IN GUNTUR

The district group Guntur+ Prakasam + Nellore or Guntur (henceforth) situated in Coastal region, is fairly endowed with moisture availability (high R 'NE). It is highly irrigated as nearly half of its net sown area is under irrigation. Guntur is mainly canal irrigated (67% of NIA), but tanks (14.3%) and other wells (10.8%) and even tube wells (6.4%) also serve substantial part of the district's net irrigated area. So far as cropping pattern is concerned, Guntur has more than 66% of acreage under rice, which accounts for 87% of its total output of the five major cereals. The district also contributes about 16% of the state's output of rice. Rice is grown mostly as an irrigated crop with 97% irrigation intensity. Ragi and bajra are other important cereals . The yield response function for rice estimated for the sample period 1965-66 to 1984-85 is as follows:

$$\mathrm{YLD} = 1.65 + .0017\,\mathrm{RNE} \quad -.092\,\mathrm{FRNE} + 34.6\,\mathrm{IRFR} + .0005\,\mathrm{IRSW} \qquad R^2 = .85$$

$$(1.9476) \quad (2.6582) \quad (-2.93320) \quad (2.4072) \quad (2.001) \qquad \mathrm{DW} = 1.5 \qquad ...6.6.1$$

SAMPLE SIZE= 20 DF= 13

The parameters are all significant at 1% level and the fit of the model is good. The equation seems to be free from multicollinearity. The stability of the parameters may be judged by comparing the folowing parameters with those reported: For subsample 1967-68 to 1981-82 the parameters for **RNE, FRNE, IRFR and IRSW** are respectively **.0017, -.097, 33.8 and 0.0005**. They are all significant at 1% level. The equation thus appears free from multicollinearity.)

The marginal product (MP henceforth) of the kharif rainfall RSW depends on the level of irrigation and increases with irrigation intensity and that of the rabi rainfall RNE declines as fertiliser dose goes up. But it can be positive when FRT is low enough. The estimates suggest following types of interrelationships between inputs.

Irrigation and fertiliser	**Complements**
Irrigation and south west monsoon rainfall	**Complements**
Irrigation and north east monsoon rainfall	**none found**
Feriliser and south west monsoon rainfall	**none found**
Fertiliser and north east monsoon rainfall	**Substitutes**

The interactions show that the MP of an input varies as the levels of inputs change. We shall use the sample period averages of input levels to study the marginal products.

$$\partial Y/d(\mathrm{IRR}) = 34.6\,\mathrm{FRT} + 0.0005\,\mathrm{RSW} \quad ....6.6.2$$

$$\partial Y/d(\mathrm{FRT}) = -0.092\,\mathrm{RNE} + 34.6\,\mathrm{IRR} \quad ....6.6.3$$

$$\partial Y/d(\mathrm{RFSW}) = 0.0005\,\mathrm{IRR} \quad ....6.6.4$$

$$\partial Y/d(\mathrm{RFNE}) = 0.0017 - .00912\ \mathrm{FRT} \quad ....6.6.5$$

Equation 6.6.2 depicts the positive interactions that irrigation has with fertiliser and south west monsoon rainfall. Since these variables (FRT and RSW) are likely to be positive, (RSW will in any case be positive, FRT may be zero), there is some gain in extending irrigation. We recall (from 2.4) that Guntur has a low kharif rainfall (low value relative to state level). A good rainfall presents the potential of improving rice yields in this season through better performance of rainfall dependent sources of irrigation such as tanks. The presence of the fertiliser variable (FRT) in equation 6.6.2 however suggests that modern technology, involving irrigation and fertiliser, is used for rice cultivation and that the use of each technology input enhances the marginal product (MP) of the other. Given any level of RSW, the MP of irrigation increases with fertiliser input. Even in the absence of rainfall, expansion of irrigation, if possible, will bring additional yield, provided the soil is treated with fertiliser. As we noted in Chapter 1, even if rainfall is very low (say, nearly nil) in a year, irrigation can be possible if there are perennial sources such as reservoir backed canals or deep tube wells (provided of course that there is adequate storage in the reservoirs or under ground). The interaction between IRR and FRT suggests that canal (or tube well) irrigation can possibly be used for raising HYV rice based on controlled watering and chemical nutrients for higher yields. Thus, it appears from the positive interactions (IRFR and IRSW) that while rice benefits from traditional irrigation (with or without fertiliser) modern techonolgy involving assured irrigation and fertiliser can also help rice cultivation.

The interactions of fertiliser (6.6.3) reveal a different character. While water from irrigation has a positive effect on the marginal product of fertiliser, that from rainfall has an adverse one. The rainfall which matters in this case is north east monsoon (RNE). At very low intensity of irrigation, a greater use of fertiliser may not help rice yield. This once again suggests the potential of high yielding technology. The ideal condition for encouraging higher fertiliser use is minimal rainfall and a high irrigation intensity. The adverse interaction of RNE and FRT reflects the potential of modern technology for raising rice in the rabi season. If IRR is at the sample average level of 96%, additional *fertiliser can be beneficial to yield rate if RNE is less than sample average level of 407 mm*. This can be derived by setting the marginal product of FRT to zero in equation 6.6.3 and solving for RNE[7]

That is, at the sample average of RNE, the MP of FRT is negative. Further fertiliser use can only be waste of resources and the district can gain and also save resources by cutting down fertilser intensity. Although the choice of technique depends on the pattern and distribution of rainfall, the performance of rabi rainfall in the district group (high relative to state level) sounds a caution to the use of a fertiliser intensive technology. The latter calls for more of regulated water supply than natural rainfall. The district however can gain from a good kharif rainfall if it steps up irrigation intensity. The drainage and soil quality of the district probably gains support from the traditional irrigation system to store and distribute the rain water over a large area and over time such that a higher level of rainfall shows up in a higher rice yield rate.

Remarkably, in 6.6.5 we find that in the absence of any other input, RNE can help rice yield suggesting the possibility of the rainfed technology in rabi season. But the use of fertiliser (probably indicative of HYV cultivation), has a negative effect on the marginal product of rainfall. Fertiliser acts like a substitute to RNE. In particular, if farmers were to optimise with respect to RNE alone they would not use fertiliser at all, but since they also irrigate land (recall the dominance of canals) they surely take into account the positive interaction with IRR (note that in the absence of irrigation, fertilisation of soil would be undesirable). In any case, there is a limit to fertiliser use in order to derive some gain out of rabi rainfall and this limit is estimated (setting equation 6.6.5 equal to zero and solving for FRT) to be 18 kg/Ha. The sample mean of 32 kg /Ha. exceeding this level may be a sign of excessive use of fertiliser. (Note that absence of seasonal data of input use is a limitation for the analysis. Also, the fertiliser dose may not be excessive in many years when RNE is moderate)

Since rain water is costless among all inputs and rainfall is beyond control, a desirable technology should primarily aim at making the most of this natural input. This district offers an option of increasing rice yield by promoting a costly modern technology including chemical fertiliser and another, through a less input intensive traditional path involving better utilisation of rainfall along with an irrigation system which utilises rain water. When natural rainfall in rabi season is plentiful, resources may be better used for other deserving crops or districts. An irrigated kharif crop and a rainfed rabi crop with little use of chemical fertiliser may be the answer in such a year. As noted in Chapter 2, the three regions show distinct agro-climatic features. The Coastal region consistes mostly of fertile, moisture rich, irrigated and predominantly rice growing districts while Rayalaseema districts are dry and poorly irrigated and raise mostly jowar and other coarse cereals. Telangana is also dry and lowly irrigated except for a few districts like Nizamabad and grow coarse cereals and especially maize. The impacts of variables are characterised as (a) pure effects and (b) interaction effects with other variables or itself (when there is a quadratic term) and provided as such, . Pure effects are identified when the variables IRR, FRT, RSW and RNE appear in the yield response equation by themselves whereas interaction effects are indicated by the presence of the interaction terms IRSW, IRNE, FRSW, FRNE and IRFR. For example, the coefficient of IRR shows the pure effect of irrigation and IRFR shows the interaction effect of irrigation and fertiliser.

Summary Results of Yield responses of foodgrain crops:

6.6.2 DISTRICT-WISE YIELD RESPONSES: RICE

In Table 6.3 the impacts of variables are presented district-wise in order of the three regions Coastal, Rayalaseema and Telangana to bring out any possible regional pattern in yield responses. In Coastal region, pure effects of variables could not be discerned except for RNE in East Godavari and Guntur. Irrigation (IRR) and fertiliser (FRT) variables do not appear by themselves and their impacts depend entirely on the rainfall. But in Rayalaseema districts pure effects of input variables are noted and the influence is often favourable irrespective of rainfall (which is low on the average). The pure effects of rainfall variables are also observed and they are found to be mostly adverse in the kharif season and favourable in the rabi season. In Telangana too, the variables IRR and FRT appear by themselves and in three out of the four cases the effect is favourable. For the rest, rainfall decides their effectiveness. As in Rayalaseema, pure effect of rainfall is found mostly positive in rabi season and negative in kharif season. Let us now examine the nature of the interaction effects in the three regions.

Interactions: Irrigation and Rainfall

Irrigation and rainfall interact in all Coastal districts except West Godavari. In three of them (Srikakulam, East Godavari and Krishna) rice yield is explained only by irrigation and a seasonal rainfall (RNE in East Godavari and RSW in others). The complementarity observed between irrigation and rainfall underscores the positive role that traditional rainfall dependent irrigation can play in promoting rice yield although perennial systems dominate in Coastal region. Rainfall by itself is not always found beneficial. In Rayalaseema districts, the interaction between irrigation and rainfall is mostly positive (Anantapur being the only exception) although the pure effects of irrigation and rainfall variables by themselves are sometimes negative. In particular, Cuddapah presents a case where irrigation interacts as a complement with both seasonal rainfalls although individually all three variables IRR, RSW and RNE have negative impacts. By itself, rabi rainfall (RNE) has a favourable effect in 3 cases (Kurnool, Anantaput and Chittoor) but kharif rainfall (RSW) is deleterious in 3 cases (Kurnool, Cuddapah and Chittoor) and is nowhere favourable. The importance of irrigation for making positive use of rainfall, particularly kharif rainfall, is clear in Rayalaseema.

Table 6.3 Impacts of variables of Rice yield : Pure and Interaction effects

DISTRICT	REGION	IRR	FRT	RSW	RNE	IRR IRR	FRT FRT	IRR RSW	IRR RNE	FRT RSW	FRT RNE	IRR FRT
1	2	3	4	5	6	7	8	9	10	11	12	13
SRIKAKULAM	COASTAL	n	n	n	n	n	n	+	n	n	n	n
E GODAVARI	COASTAL	n	n	n	-	n	n	n	+	n	n	n
WGODAVARI	COASTAL	n	n	n	n	n	n	n	n	-	-	+
KRISHNA	COASTAL	n	n	n	n	n	n	+	n	n	n	n
GUNTUR	COASTAL	n	n	n	+	n	n	+	n	n	-	+
KURNOOL	RAYALASEEMA	n	+	-	+	n	n	+	n	+	n	-
ANANTAPUR	RAYALASEEMA	+	+	n	+	n	n	n	-	n	n	-
CUDDAPAH	RAYALASEEMA	-	n	-	-	n	n	+	+	n	+	n
CHITTOOR	RAYALASEEMA	n	+	-	+	n	n	+	n	+	n	-
RANGAREDDY	TELANGANA	+	n	n	n	n	n	n	n	-	n	+
NIZAMABAD	TELANGANA	n	n	-	n	n	n	+	n	+	n	+
MEDAK	TELANGANA	n	n	n	+	n	n	+	n	n	-	+
MAHABUBNAGAR	TELANGANA	n	-	n	n	n	n	n	n	n	n	+
NALGONDA	TELANGANA	+	n	n	+	n	n	-	-	+	+	-
WARANGAL	TELANGANA	n	n	n	n	n	n	+	n	+	n	n
KHAMMAM	TELANGANA	n	n	-	+	n	+	+	-	n	n	n
KARIMNAGAR	TELANGANA	n	+	n	n	n	-	n	+	n	n	n
ADILABAD	TELANGANA	n	n	-	n	n	n	+	n	n	n	+

Note: +: favourable impact, -: adverse impact, n: no impact.

In Telangana, *rainfall* and irrigation do not always interact. Where interaction is present it is mostly positive. IRR and RSW are complements in 5 cases and Nalgonda is the only case where they are substitutes (in fact, both rainfalls have adverse interactions with IRR in Nalgonda). RNE and IRR are substitutes in Nalgonda and Khammam and complements only in Karimnagar. By itself, RNE is beneficial in 3 cases (Medak, Nalgonda and Khammam) while RSW is harmful in 2 cases. Thus, irrigation is once again useful for proper utilisation of rain water, mostly in kharif season.

To summarise, we find that (i) kharif rainfall and irrigation interact favourably, even though the rainfall by itself is of little help. (ii) Rabi rainfall is often favourable by itself but its interaction with irrigation is favourable in three cases and adverse in three cases. (iii) Nalgonda is the only district where both RSW and RNE interact as substitutes with IRR.

Interactions: Fertiliser and Rainfall

Unlike with irrigation, the interaction of kharif rainfall with fertiliser is not so prominent. FRSW appears as a variable only in 6 of the 18 cases, with a positive coefficient in 4 cases. FRNE has a positive effect in 2 out of the 6 cases where it appears. Among the Coastal districts, West Godavari is the only one where FRSW appears, but the interaction is adverse. This district also shows negative effect of FRNE. Guntur also shows adverse impact of FRNE. Thus, in the irrigated and high rainfall Coastal region, the interaction of fertiliser with rainfall is not found favourable. In contrast, Rayalaseema districts show greater interaction between fertiliser and rainfall (Kurnool, Cuddapah and Chittoor), and nowhere is it unfavourable for rice yield. In this relatively dry and lowly irrigated region, the moderate rainfall seems suitable for fertiliser absorption. Out of the 9 cases of Telangana districts reported, variables FRSW and FRNE appear in 5 cases. In Nalgonda both seasonal rainfalls interact favourably with fertiliser (but adversely with irrigation). Warangal is the only other district where a positive interaction (FRSW) is noted. To summarise :

(i) In the Coastal region, rice yields do not benefit from the interaction effect between fertiliser and rainfall. (ii) The Rayalaseema districts (excepting Anantapur), show complementarity between the two. (iii) Not much interaction is observed for Telangana, the interaction being negative in 2 cases and positive in 2.

Interactions: Irrigation and Fertiliser

An interaction effect between the technology inputs emerged in 11 out of the 18 cases. Consistent with the prevalent view, a complementary relation is found to dominate, with the interaction turning out to be favourable in 7 cases. But the *possible substitution between the two inputs cannot be ruled out*, as the interaction is negative in certain agro-climatic conditions relating to 4 of our districts. In the Coastal region (West Godavari and Guntur), the interaction between the two inputs is positive, indicating the importance of the modern technology in helping rice yield. Rayalaseema districts (Kurnool, Anantapur and Chittoor) display substitution relation between IRR and FRT. We recall that the region mostly showed positive interaction between irrigation and rainfall (indicating the importance of rainfall dependent irrigation) and also between fertiliser and rainfall (indicating possibility of rainfed rice cultivation). The interactions, along with the information that the districts are relatively dry suggest that possibility of HYV rice cultivation is limited. In Telangana, a number of districts show interaction between the technology inputs. Districts lying along the western edge of the region (Nizamabad, Rangareddy, Medak, Mahabubnagar and Adilabad) show positive interaction. These districts enjoy fair amount of rainfall, although the mode of irrigation varies. Nalgonda is the only district in the region which shows a negative interaction between irrigation and fertiliser (but a positive one between rainfall and fertiliser). To summarise we observe that:

Table 6.4: Sample Means and Marginal Products of Variables: Rice

		SAMPLE MEANS				MARGINAL PRODUCTS			
DISTRICT	REGION	IRR	FRT	RSW	RNE	IRR	FRT	RSW	RNE
1	2	3	4	5	6	7	8	9	10
SRIKAKULAM	COASTAL	0.89	0.05	648	249	+	n	+	n
EAST GODAVARI	COASTAL	0.94	0.09	662	295	+	n	n	-
WEST GODAVARI	COASTAL	0.97	0.11	691	235	+	+	-	-
KRISHNA	COASTAL	0.99	0.11	627	229	+	n	+	n
GUNTUR	COASTAL	0.96	0.03	393	407	+	-	+	+
KURNOOL	RAYALASEEMA	0.9	0.29	438	139	+	-	+	+
ANANTAPUR	RAYALASEEMA	0.95	0.14	313	152	+	+	n	+
CUDDAPAH	RAYALASEEMA	0.99	0.19	389	244	+	+	+	+
CHITTOOR	RAYALASEEMA	0.92	0.1	388	366	+	+	+	+
RANGAREDDY	TELANGANA	0.88	0.17	688	118	+	+	-	n
NIZAMABAD	TELANGANA	0.93	0.23	877	92	+	+	-	n
MEDAK	TELANGANA	0.91	0.08	750	98	+	+	+	+
MAHABUBNAGAR	TELANGANA	0.93	0.12	533	99	+	+	n	n
NALGONDA	TELANGANA	0.99	0.07	528	144	+	+	-	+
WARANGAL	TELANGANA	0.95	0.16	777	129	+	+	+	n
KHAMMAM	TELANGANA	0.74	0.13	829	144	+	n	+	+
KARIMNAGAR	TELANGANA	0.98	0.13	781	103	+	-	n	+
ADILABAD	TELANGANA	0.63	0.01	857	81	+	+	+	n

Note: FRT in Tonnes/Hectare; RSW and RNE in millimeters.
Marginal products are computed at sample mean values of variables.

(i) Irrigation and fertiliser interact to improve yield rate in certain districts of Coastal and Telangana regions. (ii) The two technology inputs have negative interaction, i.e., they act as substitutes, in some districts, especially the drier ones, mostly in Rayalaseema region, with traditional irrigation systems. In these districts we mark that rainfall often interacts favourably with one of the inputs to help yield.

Response Behaviour and Technology Options: Rice

Table 6.4 gives the sample mean values of variables and the signs of the marginal products (MP) computed at these mean values. A negative MP would suggest excessive use of the input and wastage of resources. With respect to irrigation we note that the MPs are always positive so that prevailing technologies do not make over-use of irrigation. *Excessive use of fertiliser, given the other input levels, is noted in 3 cases.* Rainfall, treated as an input, is beyond control and is also a costless source of water. A negative (positive) MP of rainfall (given the technology) may be of benefit if rainfall tends to be low (high). Otherwise, the input mix of IRR and FRT can be readjusted to gain from a higher/lower rainfall. Kharif rainfall is found excessive and harmful in relation to the technology practised in 4 cases and rabi rainfall only in 2 cases. But, even if the MPs do not imply excess input use, the district may nevertheless gain from a change in technology and a reallocation among inputs taking into account the rainfall distributions and input scarcities. Some inferences of this nature is attempted in the following passage based on the yield responses observed.

Srikakulam: The marginal product (MP) of each of the two variables IRR and RSW depends on the availability of the other. Irrigation (tanks and wells contribute to 60% of NIA) in the absence of rainfall, would be ineffective. Thus, irrigation is important in making use of rainfall.

Krishna: Even in this canal dominated district, a good south west monsoon can be made use of by providing as much irrigation as possible with an emphasis on the kharif season. We note that irrigation intensity of rice in this district is below the state average (at sample mean).

East Godavari: Here too the MP of irrigation depends on rainfall but during the rabi season. But this rainfall itself can be harmful, unless supported and supplemented by an adequate irrigation system. It appears that at least 98% of rice area must be irrigated to derive gains from a good monsoon (the sample average is only 94%). The interesting implications are as follows: (i) Though RNE contributes about 30% of the total annual rainfall, the variations in this rainfall are important for changing yield rates of rice; (ii) Although rainfall is higher than state average, it can help yield only through an effective irrigation system (possibly through draining, storing and distributing the water; (iii) Though canals are most important sources of irrigation, rain water dependent sources can yet help in improving the yield.

West Godavari: Both fertiliser and irrigation can help in increasing yield and each input enhances the MP of the other. The benefit from increasing irrigation depends essentially on the use of fertiliser, rainfall having no interaction with irrigation. But the two rainfalls are detrimental to the FRTs' impact and can be compensated by sufficiently high IRR. (With the rainfall at sample average (RSW=691 mm and RNE=235 mm), IRR must be at least 80% (sample average is well above at 97%) for additional fertiliser use to be of any help). Given any irrigation intensity, less rainfall is desirable when fertiliser is applied. The results point to a technology driven yield function, where fertiliser and controlled irrigation lead to yield increases. Rainfall discourages fertiliser use (proper drainage of rain water may be a problem). Rainfall seems to be excessive and redundant and the success of modern technology depends partly on investment in agricultural inputs and also partly on the rainfall being moderate in any year.

Guntur: . Fertiliser and rainfall are both complements to irrigation. But while MP of FRT increases with IRR it declines as RNE increases. At the sample averages, there is sign of over-fertilisation of soil (Table 6.3). On the whole, fertiliser's role in improving rice yield is not so crucial as it can be substituted by rainfall particularly RNE which constitutes more than half of the annual average rainfall for the sample period (higher than state level RFNE). The district offers a choice between modern technology with the use of chemical fertiliser and a traditional one relying on better use of rainfall and rain dependent sources of irrigation. In years of good rainfall, fertiliser can be spared for other crops, but modern technology is more valuable when rabi rainfall is low.

Coastal Region:

Although moisture rich and progressive, it appears that (i) most Coastal districts stand to gain from rainfall and traditional irrigation for growing rice even though the importance of modern technology is also borne out. (ii) Only in West Godavari modern technology is all important with the abundant rainfall being an impediment.

Kurnool: Irrigation acts as a complement to rainfall RSW but as a substitute to fertiliser. However, fertiliser, by itself is quite beneficial and the ideal condition for fertiliser use is a rainfed agriculture with good kharif rainfall. RSW is found to complement both IRR and FRT which are not so compatible themselves. At sample averages, IRR and FRT have positive MPs as seen in

Table 6.4. (At RSW equal to sample mean of 438 mm, there is an upper limit for each input to ensure non-negative MP of the other, the limits being 0.36 for FRT and 0.92 of IRR. The sample means of FRT and IRR at 0.29 and 0.9 are found to obey these requirements.) Rabi rainfall (RNE) has a positive MP in any case but a good kharif rainfall can help yield level only when irrigation and/ or fertiliser use are adequate. At the sample average of IRR and FRT, the MP of RSW is also found positive. The interactions in this district suggest two alternatives for improving yield rate - (a) Supplement rainfall with more irrigation (at the cost of competing crops as the district is poorly irrigated) or (b) apply more fertiliser which can even be useful by itself. Possibly, the variety of grain in each case differs in its water requirements. Although both irrigation and fertilser are used and within limits too, it is worthwhile to keep the substitutability in mind when planning technology to allocate and utilise scarce resources. It is reasonable to choose an irrigation intensive technology and make use of rain water in a year of very good rainfall and utilise the potential of fertiliser in others.

Anantapur: Irrigation and fertiliser, individually, both have positive effects but their mutual interaction is negative. Irrigation can be marginally productive only at very low levels of RNE and FRT (at the sample average RNE (152 mm) irrigation expansion can be helpful so long as FRT does not exceed 0.22 (sample average being 0.14)). Similarly, there is an upper limit for IRR if MP of FRT is to be positive but this limit is not affected by the rainfall level. In fact the limit (99%) is close to 100% - so that essentially there is no real limit to irrigation and increased fertiliser use is always helpful. Rabi rainfall itself is beneficial and additional rainfall can help so long as IRR is within 96%. About 95% of the rice area (close to the state average) is irrigated and since potential for further irrigation is limited and can mean depriving other crops, fertiliser use may be a more useful instrument for improving yields. Irrigation can be advised when rabi rainfall is poor.

Cuddapah: Cuddapah demonstrates remarkable complementarity among variables and shows how meaningless irrigation and rainfall are, one without the other. Rainfall (RSW or RNE) must be sufficiently high to make IRR marginally productive, suggesting that in both seasons irrigation depends on the rainfall and irrigation is not assured. But, IRR, RSW and RNE are each by itself harmful at the margin! More of fertiliser intensity is of help so long as there is rain in the rabi season. RSW can be harmful, but a 99% irrigation intensity of rice in this generally poorly irrigated district helps in utilising a high kharif rainfall. RNE is also harmful on its own but can be favourable with adequate use of irrigation or fertiliser (at 99% irrigation intensity, MP of RNE will be positive with or without fertiliser use). Though both IRR and FRT have positive MPs at the average (Table 6.3), considering that Cuddapah has high RNE, and the high irrigation intensity already attained, perhaps, fertiliser can serve in utilising rain water for higher yield.

Chittoor: Fertiliser, by itself is beneficial and irrigation and fertiliser are substitutes. A high RSW can be damaging unless associated with inputs IRR and/ or FRT. RNE is anyway favourable. Much of the decision about input use is guided by the level of south west monsoon rainfall. The prevalent technology involving both inputs, is not inefficient, the MP of each input being nonnegative. (For the sample average RSW (388 mm), the upper limits for IRR within 99% and FRT less than 0.19 ensure positive MP of each) . But between two strategies involving rainfall and irrigation and rainfall and fertiliser there is a choice provided by the substitution relation between the two inputs. In a year of poor RSW, fertiliser (possibly with some remnant moisture in the soil and with whatever rainfall that comes) can still offer some way of helping yield while irrigation cannot.

Rayalaseema

In the Rayalaseema region (i) both inputs can be helpful and rainfall in the two seasons play a decisive role in the choice of technolgy. (ii) Fertiliser is more often the crucial input which can help rice yield even in years of poor rainfall. It can substitute for irrigation, which happens to be a scarce input in the region and is required by other crops too.

Rangareddy : Irrigation and fertiliser are complements though irrigation, by itself, is helpful. RSW is harmful for fertiliser use. The sample mean of IRR (88%) is just high enough to turn MP of FRT positive but at the sample average of RSW, the district will gain from further irrigation.

Nizamabad: This is a moisture rich district. The MP of irrigation gains both from high FRT and RSW, this dual character suggesting the importance of both traditional rainfall dependent sources and assured sources for irrigating rice (the district is well endowed in both kinds of irrigation systems). For greater fertiliser use, irrigation is essential, while rainfall does not matter. This importance of *controlled* water for fertiliser use possibly hints at HYV cultivation with canal irrigation. Nizamabad presents ample scope of achieving high rice yield rate both by means of modern technology involving assured irriagtion and chemical fertiliser and by traditional rainfall dependent irrigation along with natural rainfall and at the same time. On the whole, irrigation seems to be the more important and perhaps essential (RSW is harmful unless IRR is adequate) input and tanks and wells deserve maintenance in order to make full utilsation of the kharif rainfall.

Medak: The positive interaction enjoyed by IRR with both RSW and FRT once again reflect the importance of both perennial and rainfall dependent irrigation at the same time for aiding rice cultivation. Fertiliser intensive technology with controlled irrigation is more relevant for the rabi season, rainfall being a disturbance. A high RSW leads to higher yield if rice is irrigated. Rice yield can gain from rabi rainfall too, provided FRT is kept low. The importance of irrigation is clear. The traditional sources that abound in the district need to be utilised for harnessing the water from kharif rainfall (higher than state level RSW). Fertiliser may be used with assured irriagtion (canals) in the rabi season if RNE is low. But in a year of high RNE, a rainfed rabi crop may be advisable, sparing the inputs to other crops.

***Mahabubnagar*:** The technology inputs are of little help by themselves, but together they can be meaningful. The inadequacy of rainfall and the use of perennial irrigation for rice cultivation may be resposible for minimising the role of rainfall. Fertiliser use can help yield only when irriagtion intensity is quite high at 91% (Mean= 93%). The results leave very little option other than diverting resources for modern technology to rice . Irrigation is the more important of the two inputs, since the efficacy of fertiliser (note the negative pure effect of FRT) use depends on a high irrigation intensity.

***Nalgonda*:** IRR, by itself is favourable for yield (showing the importance of assured sources), but since the other variables FRT, RSW and RNE bring down its MP, irrigation increase is justified at very low levels of the other input variables (sample averages of all three are very low). The irrigation intensity is however already very high and nearly all rice is raised irrigated. The MP of FRT increases with rainfall, but with a high IRR(Mean= .99), there is an excess of fertiliser application (Table 6.3). A good rainfall in any season can improve yield provided irriagtion intensity is low and fertiliser intensity is high though RNE can be beneficial even if no fertilser is used. There are two courses open - make use of irrigation (canal) only, or alternatively use fertiliser and grow rice as rainfed crop, rainfall being the deciding factor. In a year of high rainfall it may be economical to spare irrigation for other crops and spend more on fertiliser, especially if rabi rainfall is good. And, in a year of poor rainfall make use of canal irrigation.

Karimnagar: We have a quadratic term FRSQ, and fertiliser shows diminishing returns. FRT is beneficial provided it is applied in a moderate dose (76 kg/Ha.). A highly irrigated district but served mostly by tanks and wells, it shows complementarity between irrigation and rainfall RNE. Decisions about irrigating rice depends essentially on the performance of the rabi rainfall and fertiliser must be used optimally and excessive fertilisation (Mean= 125 kg/Ha.) avoided.

***Khammam*:**, The performance of both rainfalls decide the desirable irrigtaion intensity. When RSW is high, greater irrigation intensity is essential (note the adverse effect of RSW, by itself) and a high RNE can be best utilised by lowering irrigation intensity. No role of fertiliser comes out.

***Warangal*:** RSW is the main determinant. Kharif rainfall determines the MP of both inputs but itself is of little use without association of the inputs. Not much can be done when the most valuable input RSW is poor, except by cutting down on input use.

***Adilabad*:** The importance of both traditional and modern irrigation for rice cultvation is brought out by the complementarity of irrigation with fertiliser as well as rainfall. Fertiliser can help only in the presence of irrigation (perennial). RSW is harmful unless irrigation is practised (intensity not less than 44%). Irrigation is thus a very important input, and since the district has high RSW, traditional irrigation plays a bigger role in making use of natural water.

Telangana Region

(i) Irrigation seems to be the more valuable of the inputs helping to utilise rain water. (ii) Fertiliser interacts favourably with irrigation in as many as 5 districts. (iii) the efficacy of fertiliser use is dependent on the performance of rainfall and irrigation.

6.6.3 DISTRICT-WISE YIELD RESPONSES: JOWAR

Jowar, an inferior cereal, is an important one in the country and AP contributes more than 10% of national output. It is the second most important cereal in AP and the leading one in many of the district. The model's coverage is 54.8% (Table 6.2) of state output.

Interactions: Jowar

Out of the 9 cases reported, we observe pure effects of variables IRR and FRT in 2 and 6 cases respectively (Table 6.5). The effect of irrigation depends mostly on rainfall performance. Also, the pure effects of inputs are often adverse, making rainfall even more important for the use of technology.

The two inputs irrigation and fertiliser interact with rainfall more often in the kharif season (irrigation as a substitute in 3 cases and a complement in 2 but fertiliser as a complement in 3 cases and a substitute in 2). In fact, irrigation and rabi rainfall interact only in two cases (as substitutes in one and complements in the other). Similarly, fertiliser and rainfall interact both favourably and adversely, and there is no regional pattern in the interaction. Irrigation and fertiliser are found to interact only in Karimnagar and as substitutes. Table 6.6 gives the sample average values of variables and the marginal products (signs) at mean values.

Table 6.5 Impacts of variables on Jowar yield: Pure and Interaction effects

DISTRICT	REGION	PURE EFFECTS				INTERACTION EFFECTS						
1	2	3	4	5	6	7	8	9	10	11	12	13
		IRR	FRT	RSW	RNE	IRR IRR	FRT FRT	IRR RSW	IRR RNE	FRT RSW	FRT RNE	IRR FRT
WGODAVRI	COASTAL	+	n	-	n	n	n	-	n	+	-	n
GUNTUR	COASTAL	n	-	+	-	n	n	-	+	n	+	n
KURNOOL	RAYALASEEMA	-	n	+	-	n	n	+	n	-	+	n
ANANTAPUR	RAYALASEEMA	n	+	n	+	n	n	n	n	n	n	n
CHITTOOR	RAYALASEEMA	n	-	n	n	n	n	-	n	+	n	n
RANGAREDDY	TELANGANA	n	-	-	+	n	n	n	-	+	n	n
MEDAK	TELANGANA	n	+	n	n	n	-	n	n	n	n	n
KARIMNAG	TELANGANA	n	+	n	+	n	n	+	n	-	n	-
KHAMMAM	TELANGANA	n	n	-	+	n	n	n	n	+	-	n

Note: +: favourable impact, -: adverse impact, n: no impact found.

Irrigation has appeared as a variable in 6 cases and its MP is negative in 3 of them. Fertiliser is a more important input and has a positve MP in 7 of the 9 cases. The rainfalls are sometimes excessive for jowar cultivation.

Response Behaviour and Technology options: Jowar

***West Godavari*:** Jowar is an insignificant crop here. At given RSW an incerease in irrigated area can help (Mean RSW less than the limit 922 mm implied by the model). Fertiliser use, on the other hand, can be advisable if kharif rainfall is high but in the rabi season rainfall deters its use. Rainfall is a crucial variable and is rather abundant for the use of technology except for the good interaction between RSW and FRT. A relatively high rainfall in the kharif season asks for sufficient use of fertiliser (at least FRT=11.3, Mean= 5.8), but fertiliser use may be avoided in the rabi season.

Guntur: The MP of both irrigation and fertiliser variables gain from rabi rainfall but IRR interacts adversely with RSW. At the sample average of RNE and RSW, IRR can be further reduced, though the irrigation intensity is already very low, but a minimum RNE at 406 mm (Mean= 407 mm) would advise greater fertiliser use. A good rabi rainfall has a negative effect but is helpful when irrigation or fertilser is applied. A good rabi rainfall therefore calls for input use especially fertiliser while irrigation can not help much.

Table 6.6: Sample Means and Marginal Products of Variables: Jowar

		SAMPLE MEANS				MARGINAL PRODUCTS			
DISTRICT 1	REGION 2	RSW 3	RNE 4	IRR 5	FRT 6	IRR 7	FRT 8	RSW 9	RNE 10
WGODAVRI	COASTAL	691	235	0.020	5.840	+	-	-	-
GUNTUR	COASTAL	393	407	0.039	0.058	-	+	-	+
KURNOOL	RAYALASEEMA	438	139	0.007	0.092	+	-	+	+
ANANTAPUR	RAYALASEEMA	313	152	0.047	0.046	n	+	n	+
CHITTOOR	RAYALASEEMA	388	366	0.132	0.155	-	+	+	n
RANGAREDDY	TELANGANA	688	118	0.004	0.056	-	+	+	+
MEDAK	TELANGANA	750	98	0.000	0.051	n	+	n	n
KARIMNAGAR	TELANGANA	782	102	0..002	0.220	+	+	-	+
KHAMMAM	TELANGANA	829	144	0.000	0.068	n	+	+	-

Note: Sample period 1965-66 to 1984-85;
FRT in Tonnes per Hecatre, RSW and RNE in millimeters.

Coastal region

The Coastal districts are moisture rich where kharif rainfall and irrigation together become harmful for jowar and irrigation is advisable only if this rainfall is inadequate. Rainfed jowar with fertiliser use in kharif season is advisable for West Godavari but Guntur calls for input intensive technology in rabi season if rainfall is good.

Kurnool: This is the most important jowar producing district. Rainfall is vital for making use of technology. Aditional irrigation will be of little help if kharif rainfall (RSW) is short of 349 mm (sample mean 438 mm) reflecting the importance of rainfall dependent irrigation for jowar. Fertiliser acts as substitute to RSW but as a complement to RNE. At the sample means of RSW and RNE, the district may be using more fertiliser (negative MP) than desirable. More of RSW can be beneficial by itself, i.e., without input use and better with irrigation but with low fertiliser use. On the contrary, gain from rabi rainfall comes from fertiliser use. A high kharif rainfall should encourage irrigation of soil (although not essential) and discourage fertilsation of soil. A high rabi rainfall calls for adequate fertilser dose but no irrigation.

Anantapur: FRT and RNE are crucial variables but there is no interaction. Both variables have positive marginal products irrespective of other conditions.

Chittoor: Though RNE is high, rabi rainfall has no significant part in explaining jowar yield. Kharif rainfall is important for fertiliser use and a minimum RSW of 298 mm(Mean=388 mm) is necessary to make FRT marginally productive. The same rainfall, however makes irrigation undesirable. It appears that jowar gains if grown dry (Mean=0.13) and irrigation is directed to other crops. A higher kharif rainfall would help yield at sample average of FRT.

Rayalaseema

Results for Rayalaseema are not uniform. Rabi rainfall is of importance in Kurnool and Anantapur but has no role for Chittoor. Fertiliser use would help particularly if rainfall (RFNE in Kurnool and RSW in Chittoor) is high but irrigation is not important.

Rangareddy: Irrigation interacts adversely with RNE which can be helpful by itself. FRT, on the other hand, complements RSW which itself is harmful. A minimum FRT of 0.099 (Mean=0.06) can make MP of RSW positive. Irrigation seems unnecessary (the intensity is already very low) and rabi rainfall is just enough to grow jowar. If the kharif rainfall is good, some fertiliser can serve well (by itself fertiliser use is unfavourable).

Medak: FRT turns out to be the only variable explaining the variation in the yield rate without interaction with other variables. An optimal dose of 76 kg/Ha. is indicated. The district can gain by allocating more fertiliser to its chief cereal.

Karimnagar: Fertiliser is beneficial by itself but interacts adversely with irrigation and rainfall in the kharif season. Possibly, fertiliser is used in the kharif season if rainfall is relatively low (RSW and overall irrigation intensity are high here). IRR and RSW are however complements. An increase in RSW can help yield best in the absence of FRT and with plenty of irrigation. RSW decides input application while RNE is favourable anyway.

Khammam: This is an important producer of jowar with a high jowar yield, but irrigation has little to contribute to a yield increase. Fertiliser use is supported by kharif rainfall but is deterred by rabi rainfall. (For a positive MP of FRT, RSW must be almost 3 times RNE. The district enjoying high RSW and low RNE satisfies this condition). In fact, an increase in RSW will harm yield unless jowar is cultivated with fertiliser (a high FRT at .150). But a good RNE will by itself be helpful and fertiliser use is undesirable (a ceiling of .060). Thus, choice of technology depends on rainfall distribution.

Telangana Region

In Telangana, the role of technology is not so significant and rabi rainfall itself is helpful in 3 out of 4 cases. Choice of technology depends on rainfall distribution as interactions differ but fertiliser is more often of greater importance than irrigation for this dry crop.

6.6.4 DISTRICT-WISE YIELD RESPONSES: RAGI

Ragi is a less important cereal of AP and though an inferior cereal, is 33% irrigated. In some districts such as Anantapur and Cuddapah it is raised fully irrigated. The model explains ragi yield in only 4 districts accounting for hardly 60% of the state output.

Interactions: Ragi

Kharif rainfall has a pure effect on yield in 3 of the 4 cases reported and favourably in 2 of them. Complementarity between fertiliser and rainfall is mostly observed but irrigation and rainfall are found to act as substitutes as well as complements . There is little relation between the two technology inputs (note that ragi has no HYV). In Srikakulam, the most important ragi producer, irrigation and fertiliser are substitutes though each complements rainfall. The technologies are such that fertiliser has positive MPs in all cases but Mahabubnagar can gain by reducing the irrigation intensity.

Table 6.7 : Impacts of variables on Ragi yield: Pure and Interaction effects

		PURE EFFECTS				INTERACTION EFFECTS						
DISTRICT	REGION	IRR	FRT	RSW	RNE	IRR IRR	FRT FRT	IRR RSW	IRR RNE	FRT RSW	FRT RNE	IRR FRT
1	2	3	4	5	6	7	8	9	10	11	12	13
SRIKAKULAM	COASTAL	n	n	-	-	n	n	+	n	+	+	-
KRISHNA	COASTAL	+	n	n	n	n	n	n	-	+	n	n
GUNTUR	COASTAL	n	n	+	n	n	n	n	n	n	+	n
MAHABUBNA GARABOO BNAGAR	TELANGANA	n	+	+	n	n	n	-	+	-	n	n

Note: +: favourable impact, -: adverse impact, n: no impact found.

Table 6.8: Sample Means and Marginal Products: Ragi

		SAMPLE MEANS				MARGINAL PRODUCTS			
DISTRICT	REGION	IRR	FRT	RSW	RNE	IRR	FRT	RSW	RNE
1	2	3	4	5	6	7	8	9	10
SRIKAKULAM	COASTAL	0.188	0.111	648.000	-249.000	+	+	+	-
KRISHNA	COASTAL	0.044	0.835	628.000	229.000	+	+	+	-
GUNTUR	COASTAL	0.960	0.058	393.000	407.000	n	+	n	+
MAHABUBNAGAR	TTELANGANA	0.021	0.036	533.000	99.000	-	+	+	+

Note: Sample period 1965-66 to 1984-85;
FRT in Tonnes per Hectare; RSW and RNE in millimeters.

Response Behaviour and Technology Options: Ragi

***Srikakulam*:** Irrigation and fertiliser act as substitutes but both interact as complements to RSW. In fact, FRT interacts with rainfall in both seasons. There is a choice between an irrigation intensive and a fertiliser intensive technology (a positive MP of IRR and FRT at a given rainfall levels would set a limit to FRT within .17 and to IRR at 0.2). Rainfall in either season is harmful unless adequate use of inputs is made. A high RNE must be accompanied by fertilser use (at least 0.18,), but a high RSW leaves an option of using more of irrigation or fertiliser. A more fertiliser intensive technology with less of irrigation may help in using the high RNE here.

Guntur: Irrigation seems unimportant (ragi is already a 96% irrigated crop). RSW is itself important but the crop is preferably grown with fertiliser in the rabi season..

Krishna: Irrigation is quite important here and beneficial too provided RNE is moderate (below 410 mm, sample mean is 229), emphasising the role of irrigated ragi in the rabi season. Ragi is mostly raised as an irrigated crop in Krishna. A high RSW helps when FRT is high. The district is characterised by a low RNE and a high RSW and thus offers a chance of growing more irrigated ragi in the rabi season and utilising kharif rainfall through a fertiliser intensive technology.

***Mahabubnagar*:** This is also an important ragi producer but grows ragi mostly without irrigation. IRR is a substitute for RSW but complements RNE and shows negative MP at the average. In fact RSW, which is itself helpful, acts as a substitute of both IRR and FRT. A good kharif rainfall can be utilised through a low input technolgy but a good rabi rainfall calls for some irrigation. However, fertiliser use can usually help unless RSW is excessive (800mm, Mean=533mm).

Rainfall is the crucial variable and a good rainfall must be supported by appropriate input use. Fertiliser is more important of the technology inputs but in Krishna and Mahabubnagar, where ragi is raised dry, irrigation can help in the rabi season.

6.6.5 DISTRICT-WISE YIELD RESPONSES: MAIZE

Maize is the third most important cereal in Andhra Pradesh in terms of output. Production of the crop is concentrated mostly in a few Telangana districts. The model worked for as many as 11 districts. Although they account for nearly 70% of the state output, we unfortunately could not report for Nizamabad, a very important maize growing district. Maize is only 20 % irrigated in AP, but the irrigation intensity is high in some Coastal and Rayalaseema districts but in very few Telangana districts.

Interactions: Maize

The variables do not always have an interaction and in 2 cases in Coastal region there is quadratic term for fertiliser with no interaction among different inputs. IRR appears as a pure variable in 7 cases but FRT only in 2 (see Table 6.9).

Irrigation and kharif rainfall are complements in 4 cases, 2 in Coastal and 2 in Telangana and all of them enjoying high RSW. In Anantapur in Rayalaseema and Warangal in Telangana they are substitutes. Irrigation and rabi rainfall interact only in 4 cases, and negatively in 3 of them. Fertiliser interacts with rainfall in 3 cases in the kharif season and in 5 cases in the rabi season. Irrigation and fertiliser interact both as substitutes and complements for maize. There is no regional pattern in the the interaction behaviour. Some districts show incidences of excess input use (Table 6.10).

Response Behaviour and Technology Options:Maize

Srikakulam: The MP of IRR is found positive without any interaction, maize being an irrigated crop here. Yield shows diminishing returns to FRT, an optimum dose of 6.3 (Mean= 4.7) being suggested. The district can gain by using more irrigation and fertiliser and rainfall has no role.

East Godavari: Here also no interaction among inputs and rainfall are observed, and the yield displays diminishing returns to fertiliser use. The optimum FRT derived is 10.2 (Mean=20) and maize will gain by using less fertiliser. Kharif rainfall is helpful any way but irrigation can be of little help.

Table 6.9 : Impacts of variables of Maize yield : Pure and Interaction effects

		PURE EFFECTS				INTERACTION EFFECTS						
DISTRIcT	REGION	IRR	FRT	RSW	RNE	IRR IRR	FRT FRT	IRR RSW	IRR RNE	FRT RSW	FRT RNE	IRR FRT
1	2	3	4	5	6	7	8	9	10	11	12	12
SRIKAKULAM	COASTAL	+	+	n	n	n	-	n	n	n	n	n
EGODAVARI	COASTAL	n	+	+	n	n	-	n	n	n	n	n
WGODAVARI	COASTAL	-	n	n	n	n	n	+	n	n	n	n
KRISHNA	COASTAL	+	n	-	n	n	n	n	n	+	n	-
GUNTUR	COASTAL	n	n	n	+	n	n	n	-	n	-	+
ANANATAPUR	RAYALASEEMA	+	n	+	-	n	n	-	n	-	+	n
CHITTOOR	RAYALASEEMA	n	n	+	n	n	n	n	n	n	n	-
MEDAK	TELANGANA	-	n	+	-	n	n	+	+	-	+	n
WARANGAL	TELANGANA	n	n	+	+	n	n	-	-	n	-	+
KARIMNAGAR	TELANGANA	+	n	n	+	n	n	n	-	n	+	-
KHAMMAM	TELANGANA	-	n	-	n	n	n	+	n	n	n	n

Note: +: favourable impact, -: adverse impact, n: no impact found..

***West Godavari*:** Though this is a canal dominated district, maize can be grown with traditional irrigation like tanks or wells as implied by the positive interaction between IRR and RSW. But irrigation can help only if RSW is as high as 789 mm (Mean=691mm), and so expansion of irrigation is not desired.

***Krishna*:** Both irrigation and fertiliser interact favourably with kharif rainfall but adversely between themselves. Since kharif rainfall can harm yield unless inputs are applied, an ideal technology would be either a rainfed crop with fertiliser use or an irrigated (rainfall dependent) crop with no fertiliser use.(For a positive MP of each variable IRR and FRT, upper limits of IRR at .28(Mean=.28) and of FRT at 21.3 (Mean= 25.7) respectively are implied). Since FRT has a positive MP at the sample average, it may be advisable to opt for an unirrigated technology with fertiliser being the significant input.

***Guntur* :** Both irrigation and fertiliser interact unfavourably with rabi rainfall but favourably between themselves, indicating the importance of high yielding technology. But there is an option between a technology intensive agriculture and a rainfall dependent one shown by the positive effect of RNE itself. The district group being rich in rabi rainfall can have the option of utilising this source of water in good years and spare inputs for other crops if required

Table 6.10: Sample Means and Marginal Products of Variables: Maize

		SAMPLE MEANS				MARGINAL PRODUCTS			
DISTRICT	REGION	*IRR*	*FRT*	*RSW*	*RNE*	*IRR*	*FRT*	*RSW*	*RNE*
1	2	3	4	5	6	7	8	9	
SRIKAKULAM	COASTAL	0.000	4.670	648	249	+	+	n	n
EGODAVARI	COASTAL	0.129	19.970	663	295	n	-	+	n
WGODAVARI	COASTAL	0.430	4.460	691	236	-	n	+	n
KRISHNA	COASTAL	0.279	25.700	628	229	-	+	+	n
GUNTUR	COASTAL	0.180	10.600	393	407	+	+	n	-
ANANTAPUR	RAYALASEEMA	0.708	12.800	313	152	+	-	-	-
CHITTOOR	RAYALASEEMA	0.830	64.900	388	366	-	-	+	n
MEDAK	TELANGANA	0.030	0.142	750	98	+	-	+	+
WARANGAL	TELANGANA	0.950	0.160	777	129	-	+	-	+
KHAMMAM	TELANGANA	0.740	0.130	829	144	+	n	-	n
KARIMNAGAR	TELANGANA	0.346	0.210	781	103	-	-	-	+

Note:Note: Sample period 1965-66 to 1984-85; C=Coastal, R=Rayalaseema, T= Telangana.
FRT in Tonnes per Hectare, RSW and RNE in millimeters.

***Anantapur*:** Both IRR and RSW as sources of water input can help in this dry district, but the two have a negative interaction between themselves. The MP of IRR is positive so long as RSW is less than 434 mm.(Mean=313mm). Fertilser use is best with a high RNE and a low RSW but given the rainfall distribution, has a negative MP. Irrigation will be beneficial only when kharif rainfall is low but otherwise unirrigated cultivation is best.

***Chittoor*:** Kharif rainfall is the only beneficial input identified and input intensification technology is undesirable.

***Medak*:** IRR cannot help unless rainfall is good, the interaction being positive in both seasons. Fertiliser use is encouraged by rabi rainfall but deterred by kharif rainfall. RSW itself is favourable and its effect is further strengthened by irrigation but RNE is unfavourable unless IRR and FRT are adequate. Irrigation is the important input capable of utilising rainfall in either season.

Karimnagar: RSW does not appear for this largest producer of maize. The two variable of water input, IRR and RNE are both beneficial for yield but themselves have an adverse interaction. The two technology inputs also interact adversely. Since they are substitutes, a rainfed crop can be chosen when rabi rainfall is high (positive impact of RNE) but fertiliser may be applied for higher yield. Since IRR and FRT interact adversely, irrigation is better not used when RNE is high (at the sample averages both inputs are used excessively).

Khammam: Here RNE and FRT do not occur. Irrigation by itself is harmful but a high kharif rainfall (792mm, Mean 829mm) can make it beneficial. Similarly, an adequate irrigation intensity of 0.17 (Mean= .14) is necessary for RSW to be beneficial. Irrigation is therefore very important for utilising rain water in this case.

Warangal: The technology inputs interact adversely with rainfall but as complements between themselves. The significance of assured irrigation and high yielding technology is indicated but the rainfalls in both seasons are also beneficial themselves. There is a choice between high yielding and rainfed technologies and the choice depends on rainfall. When rainfall is high there is no point going for an irrigationt intensive technology.

The interactions differ but often there is a choice between high yielding technology and a rainfed technology. In Coastal region input intensive technology is not always necessary especially when rainfall is high. In the 2 Rayalaseema districts reported yield can gain from less of inputs. In Telangana too input use can be low but irrigation is helpful in Medak and Khammam.

6.6.6 DISTRICT-WISE YIELD RESPONSES: BAJRA

Bajra enjoys 7.4% of area under the five cereals. It is an inferior cereal and is irrigated in only a few districts, the state level irrigation intensity being only 12%. The model explains bajra yield in five districts contributing 52% of the state output.

Interactions: Bajra

Fertiliser is found to have a negative pure effect in most cases but the effect of irrigation depends wholly on rainfall. Irrigation and kharif rainfall are usually complements (except for Srikakulam, the leading producer of bajra which finds them substitutes), the districts reported being mostly tank irrigated. But the same districts where irrigation and rainfall are complements in the kharif season find them substitutes in the rabi season. Fertiliser is found to interact positively with rainfall mostly in the rabi season. Its interaction with irrigation is also favourable but only in 2 cases including Srikakulam. The prevailing technologies yield positive MPs for IRR, FRT and also RSW in all cases except for IRR in Adilabad.

Table 6.11 Impacts of variables on Bajra yield: Pure and Interaction effects

DISTRICT	PURE EFFECTS				INTERACTION EFFECTS						
	IRR	FRT	RSW	RNE	IRR IRR	FRT FRT	IRR RSW	IRR RNE	FRT RSW	FRT RNE	IRR FRT
1	3	4	5	6	7	8	9	10	11	11	12
SRIKAKULAM	n	n	+	-	n	n	-	n	n	+	+
KURNOOL	n	-	n	n	n	n	+	-	+	n	n
CUDDAPAH	n	+	n	n	n	-	n	n	n	n	n
CHITTOOR	n	-	n	n	n	n	+	-	n	+	+
ADILABAD	n	-	+	-	n	n	+	-	n	+	n

Note: +: favourable impact, -: adverse impact, n: no impact found.

Response Behaviour and Technology Options

Srikakulam**:** In this district group (contributing 32% of the state output) bajra is grown mostly dry. But possibility of high yielding technology in kharif season is implied by the positive interaction between IRR and FRT and the negative one between IRR and RSW. On the other hand, there is also gain from a good kharif rainfall. The choice of high yielding technology depends on RSW being low. In the rabi season a rainfed crop with fertiliser would be advisable (Srikakulam has high RNE).

Kurnool: The technology chosen would depend mostly on the performance of the kharif rainfall in this Rayalaseema district. Both irrigation and fertiliser depend on RSW for their effectiveness. Additional FRT can be of help normally (if RSW exceeds 238mm, Mean=438mm) . Although irrigation and fertiliser can both be used when kharif rainfall is good, the negative interaction with rabi rainfall tilts the choice in favour of a fertiliser intensity technology.

Cuddapah: Fertiliser is the only input whose role is noted in changing yield level, with the yield function showing diminishing returns to FRT. An optimum FRT of .24 (Mean=.089) is derived suggesting the potential of fertiliser technology.

Table 6.12 ***Sample Means and Marginal Products of Variables: Bajra***

DISTRICT	SAMPLE MEANS				MARGINAL PRODUCTS			
	IRR	FRT	RSW	RNE	IRR	FRT	RSW	RNE
1	3	4	5	6	7	8	9	10
SRIKAKULAM	0.001	0.111	648.000	249.000	+	+	+	-
KURNOOL	0.033	0.976	438.000	139.000	+	+	+	-
CUDDAPAH	0.437	0.089	389.000	244.000	n	+	n	n
CHITTOOR	0.207	0.154	588.000	365.000	+	+	+	+
ADILABAD	0.026	0.060	857.000	81.200	-	+	+	-

Note: Sample period 1965-66 to 1984-85;
FRT in Tonnes per Hectare, RSW and RNE in millimeters.

Chittoor: Irrigation is found to substitute for rainfall in the rabi season but complements kharif rainfall. The positive interaction of irrigation and fertiliser reflects the use of modern technology involving assured irrigation for bajra. Thus, both assured and rainfall dependent sources are used to irrigate bajra. The negative interaction of IRR with RNE suggests that high yielding technology is used in the rabi season and rainfall is a disturbance. However rainfed cultivation with fertiliser use also has potential (positive FRNE). An input intensive technology is possible when rabi rainfall is poor and when the rainfall is high fertiliser intensive rainfed cultivation may be feasible. Traditional irrigation can be gainfully used in the kharif season.

Adilabad: Bajra is not an important crop here and enjoys only 2.6% irrigation intensity. IRR and RSW and FRT and RNE are complements and rainfall interferes with irrigated agriculture in rabi season. RSW is not so high (relative to RNE) to call for an expansion of irrigation. At RNE higher than 53 mm (Mean=81mm) fertiliser use can be stepped up to increase yield.

Fertiliser is the crucial input and its use is more effective in the rabi season. Irrigation (traditional) is encouraged by a high kharif rainfall in most cases. In Srikakulam, the largest producer, however, input intensive technology is desirable when kharif rainfall is low.

6.7 CONCLUSIONS

The studies conducted show that yield rates of cereal crops improved over time significantly for rice and maize but moderately for other cereals. The model incorporating interaction effects among inputs has succeded in explaining yield rates for all of rice production in Andhra Pradesh and some substantial proportion of the production of other cereals jowar, ragi, maize and bajra. Technology and weather input variables and the interactions among the variables determine the yield levels of the crops including the coarse cereals in most cases. *Irrigation also emerges as a more significant impact for rice and maize. But for the inferior cereals jowar, ragi and bajra fertilser is relatively more important.*

Rainfall in both season influence yield rates implying that the cereals have prospects in both seasons. However its impact, in the absence of other inputs, is not always favourable. Kharif rainfall seems to be more crucial for rice and maize whether in isolation or in interaction with other inputs (14 out of 18 cases for rice and 7 out of 11 cases for maize). Rabi rainfall is relatively less important for these superior cereals (11 and 5 cases repectively), but for the other cereals both rainfalls are equally important. We have encountered very few cases (three in the entire analysis) where any contribution of rainfall to yield level is not noted at all and only technology inputs and their interactions are important.

While technology turns out to be important in yield determination, its interactions with rainfall deserve attention.The interactions often offer a choice among a purely rainfed technology, a rainfed one with fertiliser use (but with no irrigation), an irrigated technology supported by the rainfall and an input intensive technology with assured irrigation and fertiliser use. These interactions are more notable for rice and maize but are also present for the inferior cereals.

For rice, bajra and maize, irrigation interacts more with kharif rainfall than rabi rainfall and the relation is mostly complementary. In rabi season rainfall and irrigation are mostly substitutes. But for ragi and jowar the interactions are less significant and rainfall is found to complement and substitute for irrigation in either season. Interaction between rainfall and fertiliser is relatively less marked and they are found to act both as complements and substitutes. Complementarity dominates in the cases of ragi and bajra (no substitution observed) especially in the rabi season but substitution between rabi rainfall and fertiliser is more common for rice..

Interaction between the two technology inputs is more marked for rice and maize where the high yielding technology is dominant. Irrigation and fertiliser are mostly found to be complementary to each other for rice but substitution is possible as seen in the case of Rayalaseema districts. For maize, both relations are found to hold and notably, for Karimnagar, a major maize producer, irrigation and fertiliser are substitutes. Bajra benefits from technology and shows positive interaction between the inputs in Srikakulam, the largest producer. Ragi shows only one instance, that of substitution in the same district group which is also the largest ragi producer. Jowar shows no interaction between irrigation and fertiliser except an adverse one in Karimnagar. On the whole, the technology, judged in the light of sample averages has in some cases implied excessive use of inputs. In most cases, however, the yield rates would at the mean levels gain from greater use of inputs. But the marginal products of rainfall variables, which are not always positve, need to be heeded and the technology must be adjusted in accordance with rainfall performance (to the extent that it can be anticipated).

The responses to the inputs and the interactions appear to vary with the agro-climatic and other conditions of the region concerned and a technology which is appropriate for a region may not suit another. Rainfall is found to substitute the technology inputs in some districts and complement them in others possibly depending primarily on the type of irrigation prevalent as also the variety of seeds sown, soil quality, moisture requirement of the crop etc. Rainfall is the natural and costless input to agriculture and a technology chosen must aim to make full use of it. The interactions that technology inputs irrigation and fertiliser have with the seasonal rainfalls can provide some guidance towards this choice. Where sources such as tanks and well can serve in cultivating a crop, rainfall and irrigation are found complements and irrigation becomes necessary for greater use of rainfall. On the other hand, rainfall is a hindrance where modern technology is employed using assured sources like canals. In such cases, the input intensive technology may be avoided in years of high rainfall. In many such cases we also mark that the rainfall by itself is beneficial for yield so that rainfed technology is an alternative.

We also noted in some cases that an irrigation intensive technology may be substituted by a fertiliser intensive one (although they need not have negative interaction in all such cases) and since both irrigation and fertiliser have costs, social and private, it may be possible to economise on one input. Essentially, the choice depends not only on the nature of interactions, but also on the resource constraints (such as poor irrigation facility in Rayalaseema districts) and rainfall patterns (such as abundant rainfall of the Godavari districts). In the process, the technology would seek to bring out the maximum from the inputs, the soil and the natural rain water resource of the region. The objectives may be enumerated as follows:

(i) Make full use of natural and costless rain water;

(ii) Minimise the ill effects of a high rainfall;

(iii) Allocate limited irrigation facility and fertiliser available among crops and districts which will best benefit from them ;

(iv) Avoid ill effects of irrigation, such as water logging due to drainage difficulties;

(v) Lessen subsidy burden and environmental problems imposed by fertiliser use; and finally;

(vi) Optimise use of scarce resources.

Notes:

[1]The access to different standards of inputs and timeliness of such procurement are mostly determined by infrastructural and institutional factors.

[2] The production decisions taken by a rational farmer are expected to be outcomes of profit maximisation exercises. Yield rates are functions of inputs, some of which have costs which the farmer would take into account. To the extent the use of inputs is determined by prices of inputs and output,the yield rate in a reduced form equation will be a function of these prices. But, for more than two decades since the launch of the agrarian technology, the government palyed an active role in encouraging input use and also intervened in the grain market. Partly, a policy of complex subsidised pricing was used which makes estimation of a price based function difficult. For, example irrigation rates have not changed for years in some cases. The government also helped farmers through investment in irrigation and power projects, concessional finance and institutional measures such as better input distribution, price support (at times this also became a levy) and marketing facilities. It is said that non-price factors have been more important in deciding input use than market price. The technological, institutional and infrastructural development have a profound infuence on the real cost of inputs and, unless the true prices of the inputs are known, it is difficult to describe farmers' economic actions. Output prices are also multiple, farm harvest prices, procurement prices, wholesale and retail prices. Farmers cultivate for the market or for subsistence and often operate in diverse markets depending on their objectives (such as selling of surplus to market or government agencies, distress selling, stocking and trading). Their selling behaviour is also influenced by the procurement policies of the state. All this complicates specification of price variables and estimation of price based yield functions.

[3]It is the objective of the state to encourage a technology which which brings out the maximum from the limited resources of the nation in a sustainable manner. In other words, we are concerned more with an agronomic optimum as a goal for which necessary policy need to be taken. Farmers, however, are expected to take economic decisions based on the environment created by the government. As long as the agricultural market is away from perfection, farmers' actions on the basis of their subsitence/ market needs and the crop/input prices can hardly be assumed to conform with social optimisation.

[4]Tthe slowness of response to a given change in variable or the durability of variables such as residual moisture/ fertiliser in soil from previous year will bring out the influence of the past values of independent or dependent variables(Desai, 1979)

[5]Differentiation 6.5.4

$$\partial(YLD)/\partial(FRT) = a_2 + a_{12}\ IRR + a_{23}\ RFSW > 0$$

if $$IRR > -(a_2 + a_{23} RFSW)/a_{12}$$

[6] We illustrate with the help of data at the state level for the beginning and end years of the sample. Consider rice and maize.

At the state level for Andhra Pradesh we have:
Rice:
1965-66 -- TF= 93582 tonnes and A_i = 3139505 hectares such that FRT= .0298 tonnes/Ha.

1984-85 -- TF= 980293 tonnes and A_i= 3497542 hectares such that FRT= .28 tonnes/Ha.
Maize:
1965-66 -- TF= 93582 tonnes and A_i= 215876 hectares such that FRT= .433 tonnes/Ha.
1984-85 -- TF= 980293 tonnes and A_i= 312950 tonnes such that FRT= 3.13 tonnes/Ha

where $FRT_i = TF/A_i$ with variables defined in 6.6.1 in text.
Equation 6.6.1 gives

$$(F_i/A_i) = FRT_i \text{ X } (F_i/TF)$$

Using the proportions of fertiliser given to rice and maize (F_i/TF) for the state given by survey data (.605 and .0337 respectively, see text) we get fertiliser intensities F_i/A_i as follows.
Rice:
1965-66 -- 18.0 kg/Ha.
1984-85 -- 169 kg/Ha.
Maize:
1965-66 -- 14.6 kg/Ha.
1984-85 -- 105 kg/Ha.

[7]The marginal product of fertiliser is given by $(-.092 \text{ RNE} + 34.6 \text{ IRR})>0$ if RNE<362.7 when IRR=.096. Sample mean of FRT is 407 (see Note 5).

Appendix To Chapter 6 : A6

A6: An Alternative Model for Yield Function

The model is based on the assumption that farmers always try to maximise the total revenue REV given that total input supplies are fixed. The total revenue is given by

$$\boxed{REV = \Sigma P_i Y_i A_i} \quad .....1.A6$$

where Pi= expected price of crop i,

Yi= yield rate of crop i, Ai=acreage under crop i,

YiAi= production of crop i and n = total number of crops.

The yield function considered is of Cobb-Douglas type with inputs fertiliser and irrigation along with rainfall as explanatory variables.

$$Y_i = a_i R_i^{\theta_i} (G_i/A_i)^{\alpha_i} (F_i/A_i)^{\beta_i} \quad ....2.A6$$

where, Gi = gross irrigated area under crop i,

Fi = fertiliser input applied to crop i,

Ai = gross area under crop i,

Ri = crop period specific rainfall and

a_i, α_i β_i θ_i are the parameters, the last three representing the elasticities of yield rate with respect to irrigation intensity (G_i/A_i), fertiliser intensity (F_i/A_i) and rainfall respectively. Area allocation to crop i is taken to be exogenouly determined by separate considerations like price expectations, past practices, subsistence needs, etc. and rainfall is exogenous too. The other variables G_i, F_i and Y_i are endogenous representing total irrigation and fertiliser given to crop i and the resultant yield rate. The total irrigated area and total fertiliser amount applied over all n crops are given exogenously while their distribution among crops is endogenously determined.

Revenue is maximised under two resource constraints, namely,

G=Gi = total gross irrigated area allocated to n crops together,

and

F=Fi = total amount of fertiliser allocated to n crops together,

G and F being exogenously given to the system. Substituting equation 2A6 in equation 1.A6 and introducing Lagrangian multipliers L is maximised where

$$L = \Sigma P_i A_i a_i R_i^{\theta_i} (G_i/A)^{\alpha_i} (F_i/A_i)^{\beta_i} - \gamma_g(\Sigma G_i - G) - \gamma_f(\Sigma F_i - F) \text{ .....3.A6}$$

Maximising L with respect to G_i and F_i leads to the following first order conditions

$$\alpha_i P_i Y_i A_i / G_i = \gamma_g \text{..............4.A6}$$

$$\beta_i P_i Y_i A_i / F = \gamma_f \text{ .... 5.A6}$$

The shadow prices of irrigation and fertiliser are respectively determined by multiplying both sides of equations 4.A6 by G_i and of 5.A6 by F_i and then summing up so that

$$\gamma_g = (\Sigma \alpha_i P_i Y_i A_i)/G \text{ ....6.A6}$$

$$\gamma_f = (\Sigma \beta_i P_i Y_i A_i)/F \text{ ....7.A6}$$

Rearranging equations 4A6 and 5.A6 we have the following expressions for input intensities

$$G_i/A_i = \alpha_i (P_i/\gamma_g) Y_i \text{............8.A6}$$

$$F_i/A_i = \beta_i (P_i/\gamma_f) Y_i \text{.............9.A6}$$

The optimal input intensities are positively related to the ratios of the crop price to corresponding input shadow prices and they are higher for crops with higher input elasticies than with lower ones. Putting back the expressions for input intensities (equations 8.A6 and 9.A6) in yield function (2.A6) we have

$$Y_i = a_i' R_i^{\theta_i'} (P_i/\gamma_g)^{\alpha_i'} (P_i/\gamma_f)^{\beta_i'} \text{ ....10.A6}$$

$$a_i' = (a_i \alpha_i^{\alpha_i} \beta_i^{\beta_i})/(1 - \alpha_i - \beta_i) \text{................11.A6}$$

$$\theta_i' = \theta_i/(1 - \alpha_i - \beta_i) \text{..........................12.A6}$$

$$\alpha_i' = \alpha_i/(1 - \alpha_i - \beta_i) \text{........................13.A6}$$

$$\beta_i' = \beta_i/(1 - \alpha_i - \beta_i) \text{..........................14.A6}$$

Thus yield rate is obtained as a function of rainfall and the input price relatives (relative to shadow prices) in the same Cobb-Douglas form. However, the estimation process is rather complex as the the shadow prices which appear on the right hand side are functions of the endogenous variables and parameters to be estimated.

Appendix A6: Estimated Regression Equations

A6: Table 6.1 (A6): Estimated Yield response Equations: Rice

DISTRICT	CONST	IRR	FRT	FSQ	RSW	RNE	IRSW	IRNE	FRSW	FRNE	IRFR	$\bar{R}^2$	DW	DFT
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SRIKAKULAM	.07 (.204)						.0018 (3.21)					0.5	2.05	-4.44
E.GODAVARI	2.72 (2.0)					-.02 (-3.56)		.02 (3.55)				0.87	2.06	-4.13
W.GODAVARI	2.16 (6.7)								-.002 (-1.7)	-.009 (-2.48)	4.36 (2.27)	0.69	2.52	-5.4
KRISHNA	1.63 (5.4)						.0003 (1.75)					0.5	2.12	-5.05
GUNTUR	1.65 (1.948)					.0017 (2.65[illegible])	.0005 (2)			-.092 (-2.93)	34.6 (2.41)	0.85	1.4	-2.97
KURNOOL	1.63 (3.22)		47.6 (2.78)		-.042 (-3.42)	.0008 (1.92)	.045 (3.46)		.006 (1.81)		-54.5 (-2.76)	0.7	1.4	-2.95
ANANTAPUR	-98.1 (-2.65)	100.1 (2.68)	273.7 (2.065)			.26 (2.79)		-.26 (-2.76)			-274 (-2.05)	0.55	1.88	-3.76
CUDDAPAH	107.5 (2.08)	-107.8 (-1.99)			-.16 (-1.77)	-.25 (-1.68)	.17 (1.79)	.25 (1.67)		0 (6.68)		0.61	2.1	-4.37
CHITTOOR	1.7 (7.02)		33.4 (1.76)		-.021 (-2.41)	.001 (6.9)	.02 (2.34)		.02 (4.02)		-42.8 (-1.95)	0.83	1.51	-3.09
RANGAREDDY	-3.45 (-4.27)	6.05 (7.38)							-.002 (-3.17)		1.45 (1.91)	0.83	1.74	-3.84
NIZAMABAD	1.5 (6.21)				-.012 (-5.56)		.012 (5.81)		12.28 (5.81)		1.44 (2.09)	0.71	1.6	-4.04
NALGONDA	.00 (.00)	298.7 (3.43)				1.56 (3.54)	-.002 (-2.55)	-1.57 (-3.55)	.014 (2.048)	.043 (3.84)	-12.6 (-3.44)	0.9	1.5	-3.31
WARANGAL	.838 (6.99)						.0007 (4.82)		.001 (2.059)			0.8	2.4	-5.73
MEDAK	-.131 (-.42)					.004 (2.34)	.0013 (4.58)			-.05 (-2.14)	9.75 (3.24)	0.63	1.98	-4.04
MAHABUBNAGAR	1.26 (6.85)		-85.9 (-3.83)								93.8 (3.79)	0.76	1.23	-2.67
KHAMMAM	.43 (1.75)				-.006 (-2.76)	.017 (1.45)	.01 (3.21)	-.022 (-1.39)				0.6	1.99	-3.98
KARIMNAGAR	779.5 (2.21)		4.2 (1.668)	-27.8 (-2.66)				1.18 (2.94)				0.86	2.05	-4.31
ADILAAD	.67 (5.15)				-.001 (-1.688)		.002 (2.68)				6.19 (1.86)	0.65	1.72	-3.54

A6: Table 6.2(A6): Estimated Yield Response equations: Jowar

DISTRICT	CONST	IRR	FRT	FSQ	RSW	RNE	IRSW	IRNE	FRSW	FRNE	IRFR	$\bar{R}^2$	DW	DFT
W.GODAVARI	0.553 (4.627)	18.76 (2.428)	—		-.0002 (-1.335)		-.02 (-2.13)		-.00201 (3.814)	-.0002 (-3.61)		0.46	1.9	-3.94
GUNTUR	.977 (5.567)	—	-8.512 (-3.47)		.001 (4.29)	-.002 (-3.828)	-.03 (-3.48)	.022 (3.223)		.021 (3.46)		0.49	2.3	-4.65
KURNOOL	2.97 (3.158)	-57.4 (-2.688)	-		.0009 (2.038)	-.002 (-4.42)	.165 (2.99)	—	-.014 (3.84)	.027 (4.217)		0.76	1.7	-4
ANANTAPUR	.16 (1.12)		5.77 (3.595)			.0009 (2.10)	—					0.65	1.6	-3.22
CHITTOOR	.809 (18.99)		-1.66 (-2.87)				-.004 (-3.22)		.006 (3.98)			0.61	2.7	-6.36
RANGAREDDY	1.2 (5.11)		-4.9 (-2.67)		-.0005 (-3.237)	.0003 (1.21)		-.19 (-2.135)	.004 (2.57)			0.63	2.2	-3.54
MEDAK	.38 (8.13)		7.03 (4.28)	-45.9 (-4.07)								0.41	2.49	-5.29
KHAMMAM	.99 (7.512)				-.0007 (-4.476)	.0008 (1.89)			.0047 (3.89)	-.014 (-3.27)		0.53	1.4	-3.11
KARIMNAGAR	.23 (4.905)		2.388 (6.1)			.0008 (4.19)	.085 (4.09)	1.18 (2.94)	-.001 (-5.08)		-247.8 (-5.79)	0.68	1.98	-3.99

A6: Table 6.3(A6): Estimated Yield Response equations: Ragi

DISTRICT	CONST	IRR	FRT	FSQ	RSW	RNE	IRSW	IRNE	FRSW	FRNE	IRFR	$\bar{R}^2$	DW	DFT
SRIKAKULAM	1.66 (4.331))		—		-.002 (-2.88)	-.001 (-3.23)	.009 (3.36)		.009 (2.75)	.007 (2.728)	-37.2 (-2.91)	0.57	1.15	-2.49
GUNTUR	.76 (5.39)	—			.0005 (1.239)					.012 (6.28)		0.78	2.1	-3.24
KRISHNA	1.02 (9.87)	4.13 (2.74)	-					-.01 (-2.6)	.00 (.28)			0.5	2.59	-5.53
MAHABUBNAGAR	.017 (.112)		4.8 (2.01)		0.0009 (3.644)		-.012 (-2.78)	.052 (3.81)	-.006 (-1.26)			0.64	1.7	-3.42

A6: Table 6.74(A6): Estimated Yield response Equations: Maize

DISTRICT	CONST	IRR	FRT	FSQ	RSW	RNE	IRSW	IRNE	FRSW	FRNE	IRFR	R^2	DW	DFT
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SRIKAKULAM	-.69 (-.49)	25.9 (2.06)	.64 (1.538)	-0.5 (-1.595)								0.43	1.66	-3.34
E.GODAVARI	1.67 (1.77)		.061 (1.466)	-.003 (-2.90)	.001 (2725)							0.76	1.93	-3.96
W.GODAVARI	2.37 (3.18)	-1.67 (-2.66)					.002 (3.066)					0.74	1.6	3.42
KRISHNA	1.32 (1.17)	6.03 (3.3)			-.002 (-2.05)				.0001 (2.84)		-0.29 (-3.229)	0.63	1.6	-3.3
GUNTUR	-.69 (-1.06)					.01 (4.63)		-.029 (-4.49)		-.0007 (-5.52)	1.8 (5.72)	0.79	1.5	-3.07
ANANTAPUR	.79 (.38)	4.79 (2.28)			.014 (2.78)	-.012 (-2.468))	-.011 (-1.73		-.0008 (-3.63)	0.0008 (2.75)		0.69	2.07	-4.24
CHITTOOR	1.54 (2.23)				.0017 (1.6)						-.007 (-1.84)	0.46	1.86	-4.64
WARANGAL	.055 (.123)				.002 (1.63)	.022 (2.318)	-.007 (-2.15)	-.03 (-1.27)		-.017 (-7.41)	8.38 (9.08)	49	2.54	-6
MEDAK	2.63 (3.54)	-36.5 (-2.74)			.002 (2.729)	-.007 (-2.868))	.043 (1.59)	.12 (1.93)	-.17 (-5.93)	-.045 (-2.72)		0.58	1.84	-3.86
KHAMMAM	2.3 (4.74)	-6.4 (-2.2)			-.001 (-2.62)		.008 (2.136)			.05 (4.76)	-30.7 (-5.29)	0.71	2.15	-3.44
KARIMNAGAR	230.6 (3.15)	.79 (4.3)				.019 (3.53)		-.079 (-4.13)				0.45	2.17	-4.56

A6: Table 6.5 (A6): Estimated Yield response Equations: Bajra

DISTRICT	CONST	IRR	FRT	FSQ	RSW	RNE	IRSW	IRNE	FRSW	FRNE	IRFR	$\bar{R}^2$	DW	DFT
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SRIKAKULAM	.426 (2.64)				.0006 (2.88)	-.0007 (-3.46)	-.098 (-1.731)			.005 (5.0)	802.7 (1.52)	0.69	1.6	-3.22
KURNOOL	.23 3.44)		-1.38 (-1.03)				.016 (2.968)	-.021 (-1.35)	.006 (2.31)			0.64	2.25	-4.62
CUDDAPAH	.355 1.96)		7.67 (2.35)	-16.2 (-1.36)								0.46	2.01	-4.04
CHITTOOR	.69 (2.88)		-10.1 (-2.62))				.0032 (2.10)	-.007 (-2.197)		.019 (3.939)	28.6 (2.48	0.73	1.94	-4.09
ADILABAD	.27 (3.23)		-10.6 (-3.13)		0002 (2.16)	-.002 (-3.12)	.005 (5.48)	-.073 (-5.02)		.188 (3.69)		0.7	1.89	-3.83

Notes: Figures in brackets are t-statistics; DW= Durbin-Watson statistic; DFT= Dickey-Fuller Test statistics of errors (without trend), critical value at 95% confidence level being -3.04.

7. CONCLUSION

This chapter summarises the findings of the previous chapters and discusses some limitations of the analysis conducted. India, a less developed country, faces some crucial contradictions with respect to development strategies to be pursued in coming years. With a commitment towards food security, especially for the poor, and in the post W.T.O. scenario of globalisation, India feels the overwhelming need to strengthen her foodgrain economy. At the same time, the experience of the green revolution era and the limitation of resources, especially budgetary resources, establish the perils of excessive use of technological inputs and the importance of sustainable development in the long run. The potential of Indian agriculture lies mostly in the regions of the country, particularly the low and medium rainfall areas and the unirrigated tracts which constitute the bulk of the country's cultivable area. While the superior cereals rice and wheat benefitted from the agrarian technology in the last three decades the potentials of the coarse but nutritious cereals need to be realised in the interest of the poor and for the utilisation of the rainfed regions. There is a critical need for efficient and economic use of inputs in keeping with the conditions of the regions, the requirements of the crops and the costs imposed. Above all, the potentials of the natural and costless input, water from rainfall, need to be harnessed by appropriate use of technology and cropping pattern, especially in the drier regions. All this necessitates an understanding of the supply responses of foodgrain crops in the different agro-climatic conditions of the country.

In Chapter 1 we discussed the potentials in Indian agriculture and decomposed the supply decisions into different stages of decision making, each with its own considerations. The level of land utilisation, a primary source of growth in foodgrain supply, depends on the decisions about the extent and intensity of land use. The acreage decisions of farmers with respect to the different crops and the latters' yield responses to the inputs result in the ultimate supply and composition of foodgrains in the country. In Chapters 3 to 6 we have econometrically estimated and analysed the responses of foodgrain supply taking account of each stage in the supply decision. The study is conducted for the southern state of Andhra Pradesh at the district level to capture the differences in agro-climatic conditions. The major cereal crops including the coarse cereals of the state are considered.

In Chapter 2, as a prelude to the district level analyis, a comparative discussion is made of the districts with respect to rainfall, soil, irrigation and crop performances. The Coastal districts are identified as more fertile and moisture rich than the other regions and most of them have cropping patterns dominated by rice. The Rayalaseema districts are the driest and have jowar and other millet crops as important cereals. The Telangana districts themselves show some diversity, a few them having gained from irrigation projects and also enjoying copious rainfall while many of them are dry. Coarse grains, maize in particular, are important in this region.

In Chapter 3, we studied the behaviour and the determination of the extent of land use or the net sown area. The net sown area failed to increase in the period following 1965-66 and in fact, it declined in many districts. The extent of land use is almost entirely dependent on rainfall, mostly from the south west monsoon and the impact is invariably favourable. There is little effect of technology. In fact, wherever any impact of assured irrigation input is discerned, it is an adverse one signifying pooling of resources on irrigated land. The improvement of irrigation facility is found to be accompanied by a decline in (i) unirrigated/ rainfed farming and (ii) in the cultivation of coarse grains which call for little moisture. In fact, although irrigation is usually expected to promote cultivation in the dry season, it is rabi cropping that suffered in this state. Thus Andhra Pradesh, which enjoys a fairly balanced distribution of rainfall in the two main seasons and which traditionally raised coarse cereals like jowar in both seasons to a significant extent, has witnessed remarkable changes in its cropping pattern and its seasonal orientation. The cropping pattern has been moving against coarse cereals in particular and foodgrains in general. Although part of this decline is a result of diversification in agriculture and of increased non-agricultural activities, part of it is found to be a sign of land wastage too. The implications of these developments on the welfare and food security of the poor may be of concern.

Cropping intensity is the key to greater land utilisation and in Andhra Pradesh, it is seen to have improved, though slightly, over the years. The importance of irrigation, especially perennial irrigation, in promoting cropping intensity has been of interest to policy makers. Investigation involving quality of irrigation as captured by the sources, revealed the immense importance of irrigation in determining the cropping intensity of a region, although the overall irrigation intensity showed little impact. However, the effect is not necessarily favourable and the districts vary widely in respect of the types of irrigation that determine the cropping intensity and their impacts. Surface water and ground water irrigation have varying effects and only in two districts both are beneficial. Canals and tube wells, which are perennial and assured sources, are on the whole favourable for cropping intensity except in some dry districts. In the latter cases, there may be a chance of resource pooling for superior productivity leading to some land underutilisation. But tanks, which are non- perennial in nature and essentially utilise and depend on the rainfall are also favourable, mostly in the dry districts. They offer an important opportunity of improving land utilisation even in dry districts where potential for irrigation is limited. However, wells other than tube wells, which are also non-perennial sources mostly discourage intensive cropping. Rainfall does not always help intensive farming, especially where opportunity of high yielding technolgy exists, but in some cases, especially in Rayalaseema, rainfall is more important than irrigation for a higher cropping intensity. Cereal crops, rice in particular, are found to lend themselves to multiple-cropping and higher cropping intensity when higher input doses are conferred on them.

A positive acreage response to price would signify a progressive, market oriented agriculture and the scope of policy in promoting a desirable cropping pattern. Although yield rates have been a more potent factor for foodgrain supply in India in the last decades, acreages are still an important contributor to changes in foodgrain output, specifically the coarse grains, in Andhra Pradesh. For jowar, ragi and bajra, acreages and output levels mostly moved in the same direction and this is also true for rice in the Coastal region. The Nerlovian model tried in this study could explain the acreage responses of the cereals crops in a number of districts accounting for bulk of the production. The responses of crop acreage, including those of coarse cereals, to economic incentive is found to be positive. But the incentive varies among crops and regions. The substitute crop or crops relevant in the acreage decision about a given cereal crop differ among districts (possibly according to prevalent cropping patterns, soil conditions, consumption preferences and the requirements of the crop). For rice, the substitute is mostly another important crop (excepting jowar) in the district. In some cases all crops vie for acreage and no distinct crop stands out as a substitute. The relative revenue which takes account of the yield rate of the crop (as also the substitute crop in most cases) is most often the economic incentive for planting, but in some cases as for bajra in many districts, relative price is the incentive and yield rate does not count. The expectation process for price is not uniform among the districts and we observe occurrence of adaptive expectations as well as partially adjusted (over past realised price) expectations and even naive expectations. On the whole, the expectation coefficient, however, is large and is mostly above one for rice and maize. Apart from economic incentives, irrigated acreage sets a limit to acreage allocation among crops. Greater incidence of irrigated rice cultivation is found to discourage jowar cultivation although, by itself, jowar is a dry crop. Similarly, irrigated rice cultivation has a negative impact on acreage of bajra, another dry crop, but the impact is less significant for ragi acreage where ragi is fairly irrigated in many districts. Remarkable, the allocation of irrigated acreage given to coarse cereals has little impact on rice acreage though rice is a highly irrigated crop in the state. Probably, rice acreage is constituted of its own irrigated (assured) acreage and has little competition with others for irrigated acreage. Rainfall, especially kharif rainfall has a beneficial effect on crop acreages except in the Coastal region which probably experiences excessive rainfall relative to crop requirement. Although acreages respond positively to incentive and are also influenced by other relevant variables, there are restraints on their adjustment in the short run in many cases where partial adjustment of acreage is indicated. But there are cases of perfect adjustments (as in most cases of jowar) and even over-adjustments where there is an overwhelming preference towards any crop, and in any case the adjustment coefficient is usually large implying favourable conditions and greater flexibility.

Since the launch of the agrarian technology yield rates have been a major source of growth in agriculture and yield rates have been responsive to inputs irrigation and fertiliser, though rainfall still has a say in their determination. In Andhra Pradesh, we note that yield rates of rice and maize increased impressively while those of the other cereals jowar, ragi and bajra improved moderately. The yield rates are found to respond to technology inputs irrigation and fertiliser as also to natural rainfall but the impacts vary among districts which differ in their agro-climatic characterestics, especially in the nature and quality of the irrigation sources they enjoy. In fact, the interactions among the inputs i.e., between the two technology inputs and between the technology inputs and rainfall, differ and are important in determining the yield rates of crop. On the whole irrigation is found to be the more crucial input for rice and maize but fertiliser may be the key to improved yield in respect of the coarse cereals jowar, ragi and bajra. Rainfall is extremely important and there are few cases where technology is the only factor for improvement of yield rate. Kharif rainfall is more relevant than rabi rainfall for rice and maize yield but for the other cereals both seasons are important. The interactions effects offer a choice among a purely rainfed technology, a rainfed technology with fertiliser use, an irrigated technology supported by rainfall and an input intensive technology with assured irrigation and fertiliser use in the various districts of the state. For rice, bajra and maize irrigation interacts with rainfall more in the kharif season than in the rabi season and the relation is mostly complementary. In the rabi season irrigation and rainfall are more often substitutes. For ragi and jowar, interactions are less prominent and both complementarity and substitution relations are equally important. Interaction between rainfall and fertiliser is less marked and while substitution relation is common for rice, for ragi and bajra, complementarity dominates. The interaction is observed mostly in the rabi season. Consistent with prevailing notions, irrigation and fertiliser are mostly complements for rice, but substitution is also a possibility as in the Rayalaseema districts. The interaction is less marked for other crops and both relations occur. Notably, in Srikakulam, a major producer of ragi and bajra, the relation is of complementarity for bajra and of substitution for ragi and the inputs are substitutes for maize in Karimnagar, a leading producer. The interactions among the variables depend on the nature of the irrigation, its assurance or dependence on rainfall and the variety of grain grown and the relation has great significance for the choice of a suitable technology. A technology which takes account of the interactions can go a long way in achieving satisfactory yield levels while making full use of the natural and costless rain water, avoiding the ill effects associated with rainfall and irrigation and in making economic use of resources which are costly to the budget and to the ecology. In the our study of Andhra Pradesh districts, there have been some instances of excessive use of inputs.

The studies attempt to take a detailed look at the supply responses by considering the elementary components of supply decision and by concentrating at the district level. However, there are several limitations that they suffer from. An important lacunae is the failure to incorporate infrastructural and institutional factors directly in the study. There is little doubt that transport and credit facilities, distribution and tenancy systems of land and the economic conditions of farmers are extremely important factors associated with input use and supply decisions, especially in the context of land utilisation. There have been some assumptions in this study regarding input variables which confer some bias in the estimates. The lack of data on crop-wise fertiliser use is a usual hindrance to research in this field and our recource to a proxy is only a way out. Lack of continuous data on seasonal input use and output of crops prompted the aggregation of responses at the annual level and may be a serious limitation. However, we made some attempt to view the seasonal aspects of input use and their implications through the use of data on seasonal rainfall. Separate studies on supply responses in the different seasons might be interesting and useful for planning greater land utilisation. Multicollinearity in data has restricted the coverage of study although we tried to get around the problem but some bias in estimates is inevitable.

Thus, from Chapters 3 to 6, we find that production of foodgrain crops do respond to both technology and weather, although the responses differ with the varied agro-climatic conditions of the country. While the understanding of supply responses at the regional level can be of importance for policy planning, implementation at the grass root level may be difficult. India is a planned economy but while industry was regulated by reserving a part of it directly in the public sector and controlling the rest through various instruments like licensing, agricultural production was largely left to be decided by the farmers. Millions of farmers all over the country operate from various agro-climatic and economic conditions and each has his or her own expectations regarding the future prospects of crops. Many of them are also constrained by limited information, small sizes of holdings, imperfections in market and exploitation in a semi-feudal climate. There are cultural and institutional restraints. All this complicates the process of planning. Efficient use of resources in coming years on the basis of regional conditions and needs would need more of farmers' active participation. This in turn depends on effective institutional arrangements to regulate the use of land, water and other resources in the interest of sustaining a high level of productivity (Vaidyanathan, 1995). Both government and farmers' organisations can contribute to the process. Even in the era of economic liberalisation, the government can still play an enlightened role in planning for national food security. In the process, local bodies of farmers with thorough understanding of local conditions can work for efficient and ecologically prudent use of local resources. A good information system can help in providing farmers with 'location specific information on meteorological, marketing and management factors' .. and enable them to 'adopt precision farming techniques involving the correct application of inputs at the correct time and in correct doses' (Swaminathan, 1997(a)). Thus, formation of a sound data base and use of information technology and development of appropriate institutional systems to motivate, organise and utilise local community endeavour are important areas of investigation for agricultural planning at the regional level.

The way to future development in agriculture and foodgrain production in the light of the changing needs and outlook of the country, incorporates (i)fuller utilisation of our scarce land resources through less wastage of land and greater intensity of cultivation, (ii) suitable cropping pattern in keeping with the conditions of the regions as also the needs of the people, particularly the poor and (iii) suitable technology leading to high crop yield rates such that efficient use is made of costly input and scarce natural resources. This study on supply responses of major foodgrains in diverse agro-climatic conditions of the country will, it is hoped, be a useful submission for policy making and, more important, in encouraging further research.

Appendix B:

Variables and Data used, Some Agricultural Statistics and a Map for Andhra Pradesh:

VARIABLES AND DATA

For our district level discussion in Chapter 2 and the analyses in Chapters 3 to 6, let us first clarify the sources and the procedures adopted in the study in regard to data and variables used. Data sources include various issues of **Season and Crop Report (Andhra Pradesh), Indian Agriculture in Brief, Economic Survey** and **India Data Base**. Data reported cover the post green revolution years upto 1992-93 as available. **Time series data** considered for econometric analyses in ensuing chapters are mostly taken from the Season and Crop Report, Andhra Pradesh and cover the period 1965-66 to 1984-85 yielding a sample period of 20 years following the launch of the technology. Non-availability of consistent and continuous data at the district level for subsequent years and the possibility of structural changes since late eighties limited our choice of sample period.

There are 23 districts in AP but the use of continued time series data at the ditsrict level has been rendered difficult by the reorganisation of districts which took place twice during the sample period. In 1967 Guntur and Nellore districts were reorganised to form three districts Guntur, Prakasam and Nellore. Again in 1979 Srikakulam and Visakhapatnam were reorganised to form three districts Srikakulam, Visakhapatnam and Vizianagaramand also the old district of Hyderabad (state capital and surrounding area) was split up into two districts Hyderabad and Rangareddy. To overcome the problem imposed, we have clubbed the above districts as follows:

(i)Srikakulam, Vizianagaram and Visakhapatnam are considered as a single group which we refer to as Srikakulam.

(ii) Hyderabad and Rangareddy are one single district group Hyderabad.

(iii)Guntur, Nellore and Prakasam are together referred to as Guntur.

These district groups in subsequent work are treated as any other district without making any distinction between districts and district groups. Thus, a total of 18 districts are used for the entire analysis with three actually constituting district groups.

The following abbreviations are often used in the study:

CI: cropping intensity, **II**: irrigation intensity (net), **GCA**: gross cropped area, **GIA**: gross irrigated area, **NSA**: net sown area, **NIA**: net irrigated area, **SW:** surface water irrigation intensity, **GW:** ground water irrigation intensity, **CNL**: canal water irrigation intensity, **TNK**: tank irrigation intensity, **TW**: tube well irrigation intensity, **OW**: other well irrigation intensity, **OS**: other sources irrigation intensity, **RSW**: rainfall in south west monsoon season, **RNE**: rainfall in north east monsoon season, **IRR**: irrigation intensity of rice, **IJ**: irrigation intensity of jowar, **IRG:** irrigation intensity of ragi, **IMZ**: irrigation intensity of maize, **IBJ**: irrigation intensity of bajra, **FRT**: fertiliser intensity, **YR**: rice yield, **YJ**: jowar yield, **YRG**: ragi yield, **YMZ**: maize yield, **YBJ**: bajra yield, **HVD**: high value district, **LVD**: low value district, **CV**: coefficient of variation

The following district level variables are used for the empirical analyses:

Gross cropped area; Net sown area; Cropping intensit; Rainfall in south west monsoon season (June to September); Rainfall in north east monsoon rainfall (October to December); Fertiliser (nutrients) consumption over all crop; Net irrigated area; Source-wise Net irrigated area under canal, tank, tube wells, other wells and other sources; Cropwise Gross acreages; Gross irrigated acreages and yield rates of rice, jowar, ragi, maize and bajra and also crop-wise value of product at constant and current prices.

To obtain the variables required for our analysis, the data have been handled in the following ways:

(1) The variables for acreage and production posed no problem. In the case of district groups the district level data are summed up to obtain the aggregate acreages and production level.

(2) Yield rates is production per unit cropped area (in kilograms or tonnes per hectare). For a district group the total production level of the group is divided by the total acreage of the group to get the yield for the district group.

(3) Intensity variables are treated likewise. Gross or (net) irrigated areas are divided by gross (or net) cropped area to arrive at irrigation intensities. In the case of a district group, both the variables are aggregate totals and the ratio between them is taken as the intensity. The same applies to fertiliser intensity (in kilogram per hectare of gross acreage) and to cropping intensity (gross cropped area divided by net sown area). Surface water irrigation is irrigation by tanks and canals only while tube wells and other wells comprise ground water irrigation. The intensities are the ratios of these source-wise net irrigated areas to the net sown area.

(5) In the absence of crop-wise data on fertiliser intensity overall fertiliser consumption of the district (for all crops together) per unit of cereal cropped area is taken as a proxy for the fertiliser intensity of cereal crops (described in more detail in chapter 6).

(6) Rainfall used in the studies relate to the two main seasons. South west monsoon rainfall RSW covers the period June to September and North east monsoon rainfall RNE covers October to December. The rainfall variables have been computed by summing up the amounts of rainfall for the relevant months to get the seasonal rainfall. For the district group the sum is also over all the districts comprising the group and the total is divided by the number of districts to get an idea of the average.

(7) For prices of crops (used in chapter 5), in the absence of continuous data on wholesale prices even at the state level, data on value of output at current and constant prices at the state level are employed. District level data on farm harvest prices are reported but the data were not available for all years continuously in the sample period.

B: Agricultural Statistics on Andhra Pradesh: Districts

Table 1 (B):Land Utilisation District-wise for Andhra Pradesh

DISTRICT	NSA	GCA	CI	NSA	GCA	CI	NSA	GCA	CI
	1965-66			1975-76			1992-93		
1	2	3	4	5	6	7	8	9	10
SRIKAKULAM	824392	998498	1.10	931279	1134157	1.23	1014620	1406027	1.39
E.GODAVARI	379409	528549	1.41	413603	563187	1.38	445410	710651	1.59
W.GODAVARI	409835	523775	1.29	413337	560722	1.38	440137	664101	1.50
KRISHNA	484393	624310.3	1.30	501657	696052	1.40	477650	748853	1.56
GUNTUR	1518609	1677173	1.22	1606531	1838153	1.23	895149	1829763	1.23
KURNOOL	1088853	1146660	1.05	957560	1029283	1.08	901011	1004550	1.11
CUDDAPAH	872815	885520.6	1.02	944232	987461	1.05	365912	416948	1.14
ANANTAPUR	406707	433579	1.07	401300	425635	1.06	976043	1006948	1.03
CHITTOOR	435044	472787	1.09	502523	577457	1.15	462438	508849	1.10
RANGAREDDY	323024	334788.6	1.04	318992	347780	1.09	293544	316216	1.07
NIZAMABAD	289186	314033	1.09	310043	369070	1.21	240445	304373	1.27
MEDAK	477992	495697.1	1.04	428651	494721	1.16	395704	447591	1.13
MAHABUBNAG	905357	925291	1.02	960982	1004020	1.05	678316	738024	1.09
NALGONDA	647783	718848.6	1.11	577106	793855	1.38	473494	605466	1.28
WARANGAL	501067	553885	1.11	436460	539856	1.24	393430	477193	1.21
KHAMMAM	404101	409225	1.01	405715	446828	1.10	457262	478549	1.05
KARIMNAGAR	487877	507344	1.04	482093	550270	1.14	387145	502515	1.30
ADILABAD	538048	540743	1.01	580149	599468	1.03	574277	587528	1.02

Table 2(B): Intensities of Irrigation and Fertiliser Use District-wise for Andhra Pradesh

	NET IRRIGATION INTENSITY			GROSS IRRIGATION INTENSITY			FERTILISER INTENSITY		
1	2	3	4	5	6	7	8	9	10
DISTRICT	1965-66	1975-7	1992-93	1965-66	1975-76	1992-93	1965-66	1975-76	1992-93
SRIKAKULAM	0.4809	0.43	0.47	0.4198	0.4006	0.38	7.0	10.0	65.0
E. GODAVARI	0.6122	0.6431	0.63	0.5945	0.6474	0.55	21.0	51.2	152.0
W. GODAVARI	0.7234	0.7677	0.81	0.7674	0.81	0.84	22.5	52.1	218.0
KRISHNA	0.6331	0.6645	0.71	0.5602	0.5680	0.62	17..50	30.0	195.0
GUNTUR	0.3092	0.4222	0.57	0.3202	0.4228	0.52	9.5	42.7	159.0
KURNOOL	0.0871	0.0984	0.17	0.11	0.1394	0.19	3.4	10.0	84.4
CUDDAPAH	0.1222	0.14	0.29	0.1331	0.1849	0.33	0.5	6.3	43.5
ANANTAPUR	0.2530	0.29	0.15	0.2979	0.3341	0.17	4.8	10.0	109.8
CHITTOOR	0.3197	0.2955	0.32	0.3676	0.3831	0.37	4.9	18.3	74.6
RANGAREDDY	0.1454	0.1349	0.58	0.1698	0.1964	0.60	0.0	18.1	181.0
NIZAMABAD	0.4067	0.45	0.54	0.42	0.50	0.60	26.7	67.2	195.0
MEDAK	0.1949	0.16	0.28	0.2149	0.2566	0.32	5.5	12.2	84.0
MAHABUBNAGAR	0.1157	0.1265	0.14	0.1290	0.1581	0.18	1.8	10.5	69.0
NALGONDA	0.1651	0.3087	0.37	0.1965	0.4091	0.47	0.0	22.8	124.0
WARANGAL	0.2496	0.2644	0.51	0.25	0.32	0.47	0.0	21.8	168.0
KHAMMAM	0.1740	0.2088	0.38	0.1771	0.2257	0.38	4.9	17.8	129.0
KARIMNAGAR	0.2801	0.2872	0.64	0.3070	0.35	0.64	4.4	27.2	156.0
ADILABAD	0.0569	0.06	0.12	0.0615	0.0846	0.12	1.9	5.4	32.0

Table 3(B): Net Irrigated Area District-wise in Andhra Pradesh

DISTRICT	TOTAL			SURFACE WATER			GROUND WATER		
	1965-66	1975-76	1992-93	1965-66	1975-76	1992-93	1965-66	1975-76	1992-93
1	2	3	4	5	6	7	8	9	10
SRIKAKULAM	396464	408530	473216	354249	380326	422702	354249	8273	35514
E.GODAVARI	232276	266019	282334	223339	248378	247643	223339	16060	34691
W.GODAVARI	296490	317330	356090	261610	258356	257913	261610	50978	981772
KRISHNA	306695	333391	337945	283235	303606	306185	283235	19276	31760
GUNTUR	469653	678274	774234	400777	567048	617149	400777	98123	157085
KURNOOL	94857	94274	152371	84259	82266	103703	84259	8905	48668
CUDDAPAH	106739	140200	105535	46360	75249	29451	46360	51162	76084
ANANTAPUR	102915	118010	148364	55446	51794	50486	55446	52990	97878
CHITTOOR	139091	148494	147999	62411	74281	32070	62411	66280	115929
RANGAREDDY	46984	43059	52125	22747	19996	8248	22747	20172	43876
NIZAMABAD	117624	140922	129617	108574	120745	60183	108574	15256	69434
MEDAK	93186	71349	110384	69325	53097	37331	69325	17135	73053
MAHBOOBNA	104751	121625	95225	74925	83067	17054	74925	32953	78171
NALGONDA	106985	178186	1726187	78215	145485	90756	78215	26634	81861
WARANGAL	125104	115401	202362	102238	91271	65117	102238	22536	137245
KHAMMAM	70320	84729	172551	58750	73700	132334	58750	8532	40217
KARIMNAGA	136664	138496	248374	100478	64625	98406	100478	64611	149968
ADILABAD	30642	38499	67533	28098	33003	40907	28098	4404	26626

Table 4(B): Source-wise Irrigation intensities District-wise for Andhra Pradesh

	CANAL		TANK		TUBE WELL		OTHER WELLS		OTHER SOURCES	
DISTRICT	**1965-66**	**1984-85**	**1965-66**	**1984-85**	**1965-66**	**1984-85**	**1965-66**	**1984-85**	**1965-66**	**1984-85**
1	2	4	5	7	8	10	11	13	14	16
SRIKAKULAM	0.290	0.429	0.604	0.362	0.000	0.031	0.060	0.009	0.046	0.160
E.GODAVARI	0.801	0.764	0.161	0.123	0.029	0.082	0.000	0.013	0.009	0.018
W.GODAVARI	0.758	0.630	0.124	0.050	0.054	0.268	0.020	0.019	0.036	0.026
KRISHNA	0.800	0.860	0.121	0.037	0.014	0.050	0.019	0.013	0.044	0.033
GUNTUR	0.428	0.576	0.425	0.199	0.000	0.081	0.116	0.100	0.024	0.035
KURNOOL	0.546	0.589	0.340	0.125	0.000	0.006	0.077	0.200	0.035	0.072
CUDDAPAH	0.170	0.316	0.260	0.098	0.000	0.030	0.528	0.520	0.038	0.033
ANANTAPUR	0.337	0.229	0.200	0.129	0.000	0.154	0.450	0.464	0.008	0.020
CHITTOOR	0.000	0.014	0.449	0.293	0.000	0.010	0.460	0.670	0.087	0.006
RANGAREDDY	0.070	0.050	0.411	0.170	0.000	0.017	0.420	0.690	0.087	0.050
NIZAMABAD	0.464	0.460	0.459	0.191	0.000	0.049	0.063	0.234	0.017	0.066
MEDAK	0.070	0.074	0.674	0.447	0.000	0.003	0.222	0.460	0.034	0.010
MAHABUBNAGA	0.100	0.220	0.611	0.150	0.000	0.008	0.250	0.596	0.030	0.020
NALGONDA	0.255	0.480	0.476	0.108	0.000	0.000	0.263	0.360	0.006	0.042
WARANGAL	0.060	0.009	0.752	0.500	0.000	0.008	0.155	0.454	0.028	0.020
KHAMMAM	0.136	0.375	0.700	0.345	0.000	0.044	0.026	0.161	0.138	0.075
KARIMNAGAR	0.140	0.284	0.595	0.223	0.000	0.000	0.229	0.462	0.035	0.030
ADILABAD	0.270	0.415	0.640	0.387	0.000	0.008	0.056	0.172	0.027	0.010

Table 5(B): Crop-wise Irrigation Intensity District-wise for Andhra Pradesh

	1965-66					1975-76				
DISTRICT	RICE	JOWAR	RAGI	MAIZE	BAJRA	RICE	JOWAR	RAGI	MAIZE	BAJRA
1	2	3	4	5	6	7	8	9	10	11
SRIKAKULAM	0.976	0.000	0.206	0.008	0.000	0.879	0.000	0.228	0.053	0.003
E.GODAVARI	0.919	0.020	0.007	0.037	0.002	0.930	0.043	0.002	0.050	0.000
W.GODAVARI	0.943	0.000	0.054	0.076	0.001	0.969	0.052	0.043	0.411	0.046
KRISHNA	0.985	0.002	0.019	0.090	0.041	0.988	0.002	0.058	0.420	0.011
GUNTUR	0.916	0.016	0.930	0.038	0.302	0.962	0.027	0.970	0.124	0.390
KURNOOL	0.872	0.010	0.853	0.997	0.109	0.912	0.004	0.267	0.740	0.025
CUDDAPAH	0.970	0.064	0.801	0.271	0.001	1.000	0.036	0.855	0.900	0.041
ANANTAPUR	0.970	0.019	0.991	0.990	0.377	0.992	0.014	0.987	0.460	0.486
CHITTOOR	0.878	0.175	0.357	0.737	0.160	0.944	0.083	0.387	0.930	0.206
RANGAREDDY	0.868	0.002	0.000	0.005	0.000	0.934	0.002	0.002	0.035	0.020
NIZAMABAD	0.940	0.000	0.930	0.060	0.302	0.961	0.006	0.970	0.029	0.396
MEDAK	0.937	0.002	0.001	0.009	0.000	0.935	0.00	0.001	0.011	0.001
MAHABUBNAG	0.924	0.001	0.008	0.000	0.000	0.950	0.001	0.016	0.520	0.00
NALGONDA	0.998	0.002	0.590	0.049	0.000	0.998	0.00	0.216	0.045	0.00
WARANGAL	0.962	0.000	0.173	0.287	0.000	0.966	0.00	0.202	0.348	0.016
KHAMMAM	0.680	0.000	0.000	0.058	0.000	0.770	0.00	0.012	0.12	0.017
KARIMNAGAR	0.952	0.001	0.016	0.276	0.000	0.986	0.00	0.00	0.342	0.750
ADILABAD	0.567	0.000	0.000	0.057	0.000	0.688	0.00	0.00	0.097	0.00

Table 6(B): Acreages under Crops District-wise in Andhra Pradesh

	1965-66					1992-93				
DISTRICT	RICE	JOWAR	RAGI	MAIZE	BAJRA	RICE	JOWAR	RAGI	MAIZE	BAJRA
1	2	3	4	5	6	7	8	9	10	11
SRIKAKULAM	416660	20217	80903	2497	61882	467560	7063	73604	6628	45662
E.GODAVARI	309788	13824	7478	828	16156	358607	1737	648	3717	9813
W.GODAVARI	366087	12623	1710	433	1757	443856	2488	7	4023	1
KRISHNA	325741	64278	670	1561	2907	402201	1273	1	2129	3
GUNTUR	466680	348147	35035	3556	110898	623025	39995	13020	16567	34161
KURNOOL	94158	293804	7238	138	32707	74858	161352	61	707	17713
CUDDAPAH	56601	119852	38038	89	59119	48863	17958	2280	1263	4704
ANANTAPUR	62937	90838	19650	421	28687	46693	43120	11323	250	4070
CHITTOOR	116794	18348	59457	31	35295	80286	6802	16079	314	4070
RANGAREDDY	50253	100030	12336	6249	7046	43730	100918	8499	3760	1734
NIZAMABAD	107555	56860	1963	30094	1	106064	34310	117	57840	4412
MEDAK	102496	158091	11368	52325	4857	93969	112973	614	65890	2390
MAHBOOBNA	114806	293532	44271	495	38181	77346	216357	18378	2543	13323
NALGONDA	137000	182214	346	2114	107270	238255	40580	23	1387	25908
WARANGAL	125152	211398	416	31394	18763	109837	31157	20	31765	832
KHAMMAM	98066	171313	467	6895	3822	148896	39397	36	12032	580
KARIMNAGA	133781	117036	62	58286	349	176920	7779	1	83611	224
ADILABAD	212126	212126	87	18471	199	63164	186601	1	24747	155

Table 7(B): Yield Rates (Kg/Hectare) of Crops District-wise for Andhra Pradesh

	RICE		JOWAR		RAGI		MAIZE		BAJRA	
DISTRICT	1965 -66	1992 -93	1965 -66	1992 -93	1965 -66	1992 -93	1965 -66	1992 -93	1965 -66	1992 -93
1	2	3	4	5	6	7	8	9	10	11
SRIKAKULAM	605.90	2,091	401.90	634	833.60	1,073	832.90	1,982	699.80	825
E.GODAVARI	1592.01	2682	403.86	678	799.80	1073.00	833.30	2872	428.01	694
W.GODAVARI	1614.15	2994	408.80	725	799.90	1286	832.90	3038	500.83	1
KRISHNA	1496.10	2849	319.70	849	799.80	1	832.90	2566	500.95	938
GUNTUR	1243.20	2599	413.40	733	919.20	1649	832.70	2928	587.10	1189
KURNOOL	1063.00	2455	376.20	1299	777.70	1279	835.80	2382	536.10	749
CUDDAPAH	1483.00	2736	244.10	884	776.60	1489	835.20	2348	226.10	1662
ANANTAPUR	1182.10	1991	470.60	1346	1187.00	1609	833.90	2443	397.10	637
CHITTOOR	1125.40	1788	388.40	789	560.40	805	833.30	2471	388.30	1181
RANGAREDDY	1026.30	2153	499.70	732	359.60	976	832.80	1946	365.10	304
NIZAMABAD	1816.00	2027	524.60	754	417.20	809	923.30	3129	351.30	304
MEDAK	1448.00	1758	607.00	757	500.80	473	853.80	2203	351.90	304
MAHABUBNAR	1119.30	1768	454.10	717	411.50	800	833.20	2670	484.30	271
NALGONDA	1091.90	2798	264.30	426	415.70	1620	832.70	2593	252.60	317
WARANGAL	1111.10	1949	323.30	684	416.30	809	879.20	2231	647.60	428
KHAMMAM	870.30	1977	344.20	673	417.90	1111	809.70	3389	351.90	304
KARIMNAGAR	1226.50	2373	374.70	624	422.80	1	828.50	3066	352.60	304
ADILABAD	778	1633	554	854	418	1	573	1801	351.60	304

Table 8(B): Normal Rainfall (millimeters) District-wise for Andhra Pradesh

District 1	South West Monsoon 2	North East Monsoon 3	Total 4
SRIKAKULAM	685	281	1,111
E.GODAVARI	742	326	1,160
W.GODAVARI	740	260	1,076
KRISHNA	672	277	1,029
GUNTUR	406	385	874
KURNOOL	449	112	630
CUDDAPAH	388	140	521
ANANTAPUR	297	231	695
CHITTOOR	380	410	908
RANGAREDDY	652	100	828
NIZAMABAD	949	79	1,082
MEDAK	810	89	959
MAHABUBNAGAR	611	92	754
NALGONDA	554	120	742
WARANGAL	866	109	1,049
KHAMMAM	837	119	1,045
KARIMNAGAR	794	93	953
ADILABAD	917	76	1,045

Notes to Tables 1(B) to 9(B): Acreages in hectares, Net irrigation intensity= net irrigated area divided by net sown area, Gross irrigation intensity= gross irrigated area divided by gross cropped area, Fertiliser intensity= total fertiliser consumption (kg) divided by gross cropped area.
Source: Season and Crop Report, Andhra Pradesh.

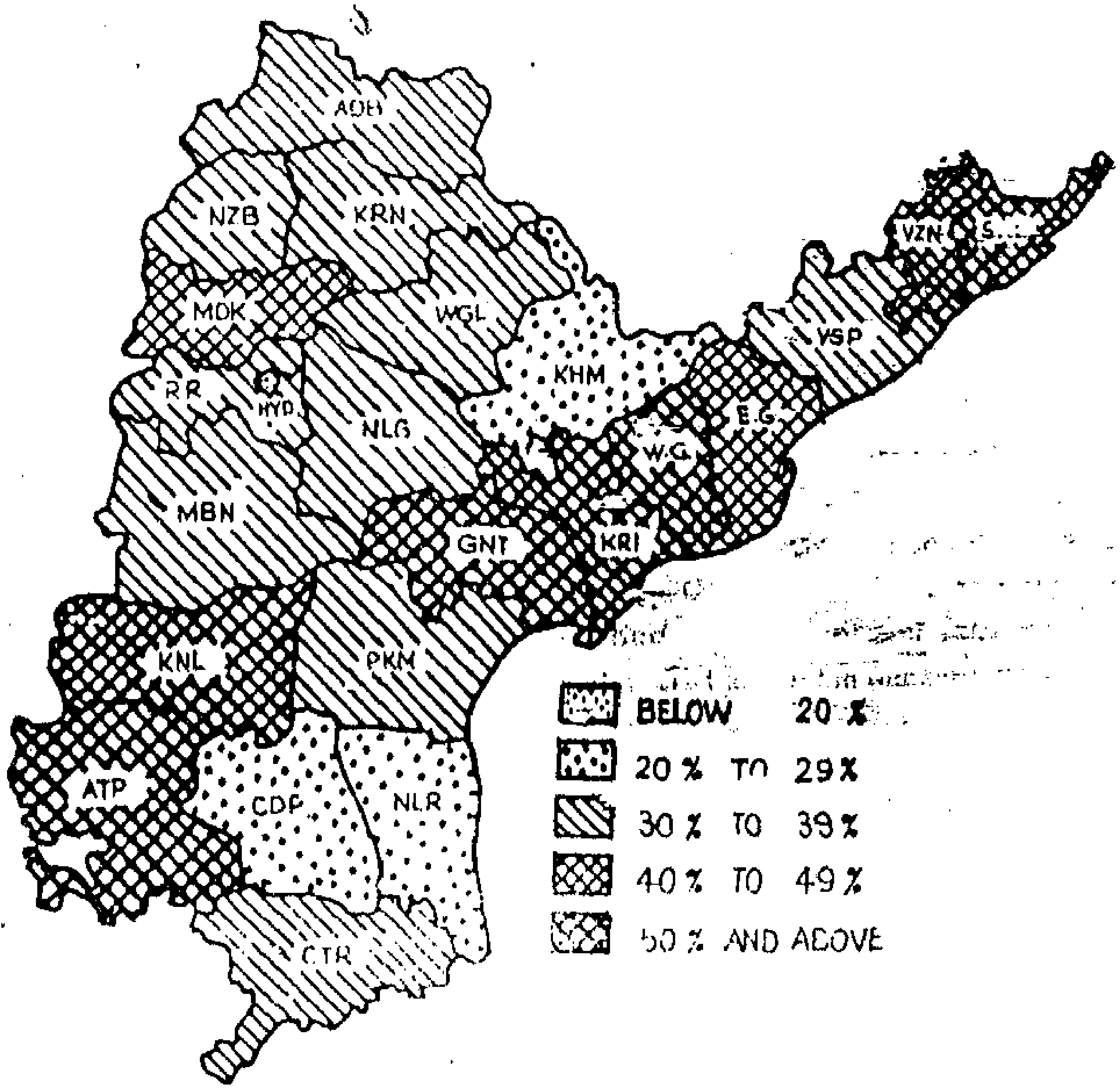
Table 9(B): Importance of Cereal crops District-wise in Andhra Pradesh

	SHARE(%) IN 5 CEREAL OUTPUT IN DISTRICT 1984-85					DISTRICT SHARE(%) IN STATE OUTPUT 1984-85				
DISTRICT	RICE	JOWAR	RAGI	MAIZE	BAJRA	RICE	JOWAR	RAGI	MAIZE	BAJRA
1	2	3	4	5	6	7	8	9	10	11
SRIKAKULAM	78.05	1	9.76	1.12	10.07	7.4	0.54	29.54	1.69	32.04
E.GODAVARI	98.39	0.29	0.14	0.28	0.9	12.76	0.21	0.59	0.58	3.91
W.GODAVARI	99.63	0.2	0.01	0.17	0	17.29	0.19	0.03	0.47	0.01
KRISHNA	97.27	2.52	0.01	0.17	0.03	12.13	1.78	0.02	0.35	0.13
GUNTUR	87.12	6.24	3.14	0.15	3.35	16.7	6.63	18.78	0.44	21.03
KURNOOL	33.09	64.49	0.03	0.03	2.36	1.82	20.18	0.06	0.02	4.36
ANANTAPUR	41.8	37.86	12.06	0.33	7.94	1.22	6.26	11.23	0.16	7.77
CUDDAPAH	49.36	34.77	6.46	0.02	9.39	1.51	6.04	6.31	0.01	9.65
CHITTOOR	80.28	3.9	11.38	0.08	4.36	3.25	0.9	14.7	0.05	5.91
RANGA REDDY	45.13	43.65	6.73	3.72	0.77	1.31	7.21	6.25	1.73	0.75
NIZAMABAD	67.79	6.88	0.17	25.09	0.06	4.1	2.36	0.33	24.22	0.13
MEDAK	54.29	28.9	0.73	15.98	0.09	2.19	6.62	0.94	10.28	0.12
MAHABUBNAGAR	48	39.71	9.4	0.33	2.56	1.78	8.36	11.12	0.2	3.18
NALGONDA	88.15	8.24	0.03	0.24	3.35	6.74	3.58	0.07	0.29	8.59
WARANGAL	64	19.24	0.01	15.24	1.51	2.5	4.27	0.01	9.51	1.98
KHAMMAM	41.66	54.9	0	3.1	0.33	1.52	11.36	0.01	1.81	0.41
KARIMNAGAR	62.27	4.54	0	33.18	0	5.17	2.14	0	43.93	0
ADILABAD	31.13	61.7	0	8.16	0.01	1.02	11.33	0	4.28	0.01

FIGURE 1(B)

MAP-2.2

PERCENTAGE OF NET AREA SOWN TO GEOGRAPHICAL AREA DURING — 1992-93.



Appendix C

8. SUPPLY RESPONSES AND POLICY ACTIONS: A MACRO STUDY AT THE ALL INDIA LEVEL

8.1 INTRODUCTION

In our quest for a scheme to bring out supply responses of foodgrains to policy actions and for a more flexible expectation formulation, we have considered the Rational Expectations Hypothesis (REH) worth trying as an alternative to the Nerlovian scheme. Although Muth's(1961) original paper had examples drawing from agriculture, REH has been least commonly used in the field. But it may be relevant for modelling agricultural supply in India since the government intervenes in the food market. With changing policies, a fixed expectation formulation can be unrealistic. Although experience from past and information from neighbourhood are still important influences, the farmers today do have access to information on technology and policy changes through the media and government extension and information services and REH, which embodies informed predictions, can well be a possibility.

Before going into the modelling exercise, we will discuss the performance of the national food grain economy and the policy regime with emphasis on rice and wheat. Theoretical models for price expectations will be discussed along with some of their applications and the relevance of REH in the Indian context in sections 8.4 through 8.7. Our model for Indian foodgrain market is presented in 8.8. After clarifying the data use in this work in 8.9, results are provided in 8.10 followed by some concluding remarks in 8.11.

8.2. SUPPLY PERFORMANCE AND POLICY ACTIONS

The per capita availability of cereals and food grains in India increased by 14.5 and 34 grams per day respectively between 1964-65 and 1988-89. Per capita foodgrain production moved from 187 to 203 kilograms between 1964-65 and 1989-90 i.e., by about 9% while total output actually doubled. The performance of the two main cereals are quite distinct. While wheat output showed steady progress, that of rice was erratic and not so remarkable in any case[1].

Table 8.1: Per capita production of Foodgrains (tonnes)

YEAR	1964-65	1969-70	1974-75	1979-80	1984-85	1989-90
RICE	0.08	0.075	0.067	0.065	0.080	0.089
WHEAT	0.025	0.037	0.041	0.048	0.058	0.060
FOODGRAINS	0.187	0.186	0.169	0.168	0.194	0.203

Imports are said to be made in years of shortfall. As domestic production improved, imports came down from 1964-65 to 1989-90 by 60% and 101% for rice and wheat respectively. From 1964-65 to 1970-71 imports were high with wheat imports ranging from 4.8 to 7.8 million tonnes per year but rice imports remained within 1 million tonnes. In the seventies imports came down and except for 1974-75 to 1976-77, even wheat imports were low, and by 1978-79, both cereals started showing net exports. However, at the per capita level, rice imports showed poor correlation with production and market price [2]. Import decisions are actually based on stocks, procurement and distribution targets as well as production performances. Between 1965-66 and 1985-86 per capita procurements grew by 110% and 194% for rice and wheat respectively. Public stocks gew by 44% and 63% for rice and wheat between 1965-66 and 1985-86 and the stocks of wheat usually exceeded rice in the entire period 1963-64 to 1985-86 barring a few years. In the same period there was depletion of stocks only on seven occasions for rice and nine for wheat. While procurement and buffer stock operations impose enormous burden on the government, by and large, they served in evening out the effects of fluctuations in production and in helping to tide over years of shortage (Dantwala, 1996).

Procurement prices are set to be remunerative to farmers, guiding them in allocating resources and choosing a crop mix but at the same time they seek to safeguard interests of consumers and their gains in better technology. A balance between the two interests is necessary for the ultimate interest of the public. Though procurement price announced has evidently gone up over time, deflated by the whole sale price index of all commodities, it does not show any rising tendency see also Sidhu, 1990). Per capita distribution came down from 21 kg in the mid sixties to about 15 kg in the seventies but again went up in the eighties. While in the case of rice it ranged between 5 to 10 kg between 1965-66 and 1984-85, that of wheat was much higher, but came down from a high of 16 kg in the sixties to about 10 kg in the eighties. Although rationed distributions are expected to move in line with market prices, no significantly positive relation between the two was noticed (the correlation coefficients being -.42 for rice and .086 for wheat in the period 1965-66 to 1985-86). Once again we note that the relations in the food market are quite complex, with rationed distribution possibly also influencing price. The distribution targets have also been the result of socio-economic and political considerations (Ahmed,1988).

Finally, since production is said to be price elastic (for example the elasticity values are .69 and .56 for wheat and rice respectively as estimated by Sidhu and Kaul, 1990 for Punjab), it is worth looking at the behaviour of prices. Real prices (wholesale price indices and procurement prices of deflated by WPI of all crops) were fairly high until mid seventies but dipped subsequently. While this adverse turn is bound to affect food supply, one positive implication is the possibility of grain exports. Even compared to the world prices, domestic prices are low (.72 for rice and .80 for wheat at official exchange rates as estimated by Ahmed, 1988) indicating the country's comparative advantage in foodgrains.

8.3. RICE AND WHEAT: INTERRELATIONS

Rice and wheat are the two main cereal crops of India accounting for 70% of the food graoin output. They have some distinct geographical requirements. Rice needs high temperature, abundant water and alluvial soil for best effect while wheat thrives in moderate watering, low humidity, plenty of sunshine and loamy soil. Thus rice dominates the warmer and wetter regions of south and east and wheat in the northern states. But the territory cannot really be partitioned into rice and wheat growing areas as upland rice is raised on hilly tracts and availability of irrigation and new seeds have helped some non-traditional states like Punjab and Haryana come up in rice production. It is also observed that southern and also eastern states might fare well in growing wheat but demand pattern is also a dominant influence on cropping patterns. Rice, because of its demand for water, is dominantly a kharif crop while wheat is raised as a rabi crop. But the seasonal demarcation is also not sharp as irrigation makes rabi rice cultivation not only possible but also a highly attractive proposition. The non photosensitive seeds also rendered the timing of cultivation less rigid. To some extent, therefore the two cereals may be competing for acreage as also other resources including the time and effort of the farmer[3].

On the consumption side, the distinction is even less clear. Food habits do vary in India and roughly, the people of south and east are basically rice eaters while north Indians are known to eat *chapatis* made from wheat. But the latter also consume rice and wheat is entering the diet of the rice zones. Besides, people all over India consume food processed from rice and wheat and the two cereals can substitute one another on the demand side as well as in the supply side in varying degrees.

8.4. PRICE EXPECTATIONS AND THE DYNAMICS OF PRICE

Human beings often have to make decisions in an environment of uncertainty. In understanding human behaviour and and in building up economic models expectaions therefore occupy an important place. The special character of agriculture as distinct from many industrial activities is the long production period involved, so that the planting decisions are taken long before the crop is harvested, marketed and prices are realised. The farmers' decisions regarding planting and input use and the soil climatic conditions prevailing during the growth period shapes the actual supply. This supply then interacts with demand to determine price. Thus the planting decisions and thereby the actual supply depends on how farmers make expectations about the future. One common view holds that expectations are formed on the basis of past experience. That is, human beings remember past events and extrapolate into future. The simplest hypothesis is that they simply assume previous year's price to hold in the current period and this formulation leads to the so called *cob-web* model. The instabilty implied by the cob-web model and the conditions for convergence implied are not consistent with real life evidence. Assumptions of longer memories can be made with several past prices entering into lag models. The celebrated *adaptive expectation* formulation holds that human beings learn not only from past experience but also past errors. The farmers are assumed to have a notion of a normal price which they keep on revising according to experiences. The hypothesis of *partial adjustment* of acreage combines with the adaptive expectations formulation to produce a dynamic process of price(see chapter 5) whose convergence condition is more likely to be met in real life than that of the cob web model. The latter is also a special case of the adaptive expectation formulation. Another view is that expectation in each period differ from realised price by a random disturbance and the farmers take account of the past prices as well as the disturbances when forming expectations (this is also a special form of adaptive expectation) and leads to the *ARIMA* process (Box and Jenkins, 1970). Finally, following Muth's (1961) seminal proposition, many particularly in macro economics have chosen to reject the view that farmers go by past only, condemning themselves 'to a world of limitation and bound.' They believe that farmers expectations resemble how the economy works and how the actual variables are determined and they are rational expectations. The REH has no implication on the sochastic process the price will follow, which will depend on the same for the exogenous variables and the disturbance terms.

8.5 RATIONAL EXPECTATIONS OF MUTH

Basically, the Cob-web, the adaptive expectations and the ARIMA[4] process expectations are all extrapolative formulation and have little resemblance to how the economy works. The formulations consider the supply side in isolation without heeding demand and other factors prevailing which also affect price. Such fixed expectation formulae cannot suggest how expectations might change in certain circumstances like when the structure of the system changes. In a world where people have access to information through newspapers and other media, the models cannot be adequate. A farmer following a fixed price expectation process will plan production on the basis of her past experiences, unaware of the possible effect of a significant hike in the procurement price by a farm friendly new government or an announcement of larger public distribution plan of a govemement facing electoral or other compulsions. The use of such a model for policy making may amount to an advice that depends on how 'economists think the public behaves' (Sheffrin,1983). Muth (1961) suggested that expectations are 'informed predictions of future events and are essentially the same as the predictions of relevant economic theory'. Muth argued that existing economic models do not assume enough economic rationality in that the agents' expectations[5] are not consistent with the models used to explain their behaviour. Muth raised the possibility that the the agents use the very model that determine the variables. REH essentially equates two distinct concepts - (a) the economic actor's subjective psychological expectations of the variables and (b) the mathematical conditional expectations of those variables ie.,

$$X_t^e = E(X_t / I_{t-1}) \text{ ....8.5.1}$$

where the left hand side is the subjective expectation and right hand side is the mathematical expectation of X at time t and I is the information available.

REH is however different from perfect foresight because it allows for uncertainty. Expectations are rational if, given the economic model, they produce variables that will *on the average* equal the expectations. But expectations diverge from actual values because of unpredictable uncertainty in the system.

8.6. THE SHEFFRIN MODEL OF RATIONAL EXPECTATIONS

A simple model of agricultural market is as follows.

$$QD_t = -bP_t + eY_t + e_t \text{......8.6.1}$$

8.6.2

$$QS_t = cP_t^e + fW_t + v_t \text{......8.6.2}$$

$$QD_t = QS_t \text{ ....8.6.3}$$

$$E(P_t) = P_t^e \text{ ....8.6.4}$$

where QD and QS are the quantities demanded and supplied respectively, P is price, with superscript e standing for expected value, Y is income, W is weather and t is time, e and v are the disturbance terms (mean zero and serially uncorrelated). Taking conditional expectations and using the REH leads to

$$P^e_t = (eY^e_t - fW^e_t)/(c+b)..8.6.5$$

where expected price is a function of the expected values of the exogenous variables income and weather and the parameters that derive the model. When the expected price variable is put back in the supply equation, supply becomes a function of expected values of the exogenous variables, the variables of supply equation and the parameters.

$$QS_t = f(Y^e_t, W^e_t, W_t)..8.6.6$$

Supply at the time of harvest appears as a fixed or inelastic variable and demand only is price determined. The agents are assumed to know the underlying structure of the system they operate in and take account of the interrelationships among variables when forming expectations about endogenous variables (Wallis, 1980).

Now, the REH applies both to exogenous and endogenous variables. The difference between the two is as follows: *Exogenous variables* are defined to be determined outside the system considered. The agents' expectations about them are important but but do not affect the actual value of the exogenous variables. *Endogenous variables* are determined by the model and the expectations about them will affect the dynamics of the endogenous variables. With exogenous variables too, expectations are rational if the actual values of exogenous variables on the average turn out to be equal to the expectations. The agents either (i) have prior information of the variables or (ii) have the economic model determining them or (iii) know the stable stochastic processes of their evolution.

8.7. ESTIMATION OF REH MODEL

The REH model gives expected price and the supply in terms of expected values of some exogenous variables which are unobservable. These variables are predicted in the following possible ways as already indicated in 8.6.

(i) The exogenous variable are known at the time of sowing so that they are 'forecasted' with certainty

$$E(X_t) = X_t...8.7.1$$

(ii) A model is built to predict the variables and if necessary further models to produce the inputs for the model (Sheffrin,1989). This involves collection and utilisation of a large amount of information which is also costly. Although predictions derived from structural forms will tend to be more efficient compared to a time series approach as in (iii) (for the same reason as REH models give more efficient forecasts than autoregressive models), Goodwin and Sheffrin (1982) argue in favour of the latter on the basis of cost and benefits.

(iii) The exogenous variable is assumed to follow a stable stochastic process and economic theory has no role in its evolution. Wallis (1980) proposes that $X_t$is the optimal predictor of X_t based on

X_{t-1}, X_{t-2} assuming there is no 'structural' information available regarding the generation of the variables, and 'there is no third group of variable outside the model and independent of the disturbance terms of the model.' Wallis considers a simple autoregressive process for the exogenous variable

$$X_t = \theta X_{t-1} + e_t \text{.........} 8.7.2$$

There are more sophisticated ways of predicting exogenous variables based on Box-Jenkins models. Wallis also includes the possibility of some variables being policy variables so that

$$X_t = G(\Sigma_{t-1}) + e_t \text{..} 8.7.3$$

where Σ denotes information available at the time.

While it is common to use the forecasts as data in the main model (Goodwin and Sheffrin,1982), Aradhyula, 1987) the treatment may appear unrealistic. Wallis suggests that the equations incorporate the stochastic processes by substituting X_t^e wherever it appears in the model and the stochastic models of the same variables be estimated jointly estimated to make optimal use of past information. The potential gain in efficiency and a chance to test for restrictions implied by REH (in a systems approach) are overweighed by econometric difficulties and computational burden. It is more often preferrable to use time series forecasts as data as if ' they are given to the suppliers by a forecasting agency.' The problem of joint forecasting can be avoided by replacing X_t^e in the model by past values or explanatory variables without jointly estimating the process. Such 'regression based proxies for the expectation variables are consistent with the model to the extent that the correct set of exogenous variable is employed' (Wallis 1980).

There are two ways of estimating a supply function one following a single equation approach and the other a systems approach. We categorise the two approaches as Limited Information method (*LIM*) and Full information method (*FIM*).

LIM approach

This is based on the instrumental variable method and essentially estimates the supply function separately from other equations of the model. Under REH the expected and the true price can differ by an unpredictable random error that is uncorrelated with any information available.

$$P_t = P_t^e + Z_t..8.7.4$$
$$E(Z_t/I_{t-1}) = 0..8.7.5$$

Substituting the expected price in supply equation 8.6.2we have

$QS_t = c\ P_t + f\ W_t + (v_t - c\ Z_t)..8.7.6$

As the error term is correlated with P, OLS is not applicable so that (i) P_t is regressed on a set of variables uncorrelated with the composite error, (ii) the forecasts P_ts are calculated and (iii) these forecasts are replaced for P_t in the supply equation and the latter is estimated by OLS.

This method has the advantage of (a) being computationally easy and (b) allowing investigator to focus on the suply equation without being concerned about the specifications of other equations.

FIM approach

The LIM does not mke use of all available information and more efficient parameters can be obtained when information from all equations can be utilised. This is particularly relevant in a REH model because expectations are a property of the system as a whole. Methods like the Three Stage Least Squares or the Full Information Least Squares methods can be used to estimate the system. When the interest of the investigator lies in the structural form equations, identification restrictions on specific parameters and the way some lagged variables enter are of concern.

8.8. SUPPLY RESPONSES OF FOOD GRAINS IN INDIA: REH MODEL FOR RICE AND WHEAT

Before presenting our model some clarifications may be made.

(i) Only two cereals rice and wheat which together claim 70% of food grain output are studied. .

The model is built separately for the two crops but the interrelations are considered where appropriate.

(ii) The model relates to free market where demand and supply interact to determine price. Government interventions are considered to the extent that they are expected to affect market demand and supply. Market price is assumed to be determined simply by the market clearing process.

(iii) No distinction is made between farm sector's own consumption and the consumption of the nonagricultural sector. The farmer's own consumption is viewed as if she is selling to and buying from herself with the margin accruing to herself. Also, no distinction is made beween demand for grains for consumption and for private inventory stocks. Demand is sum of consumption and stock demand of all individuals including farmers.

(iv) Although the model embodies several structural relations, our ultimate interest is to learn the farmers' supply responses to basic variables which are predetermined and exogenous to the system (and are known to farmers at the time of sowing)or are in the control of policy makers.

Variables

D = Demand, P = Price, Y = Income, S=Supply,

SP = Private closing stock holding,

R = Ration or public distribution,

M = Import (net), PC = procurement,

SG = Govmment closing stock holding,

Q = Production, I = Irrigation, F = Fertiliser,

W = Weather, S = Supply, PP = Procurement Price,

G = Addition (depletion) to government stocks.

Subscript t stands for time, superscript e for expected value and superscript * will be used when the variable refers to the substitute crop. For example,

P_t^e = expected price of crop at time t

P_t^{e*} =expected price at time t of substitute crop.

Market Relations

Price is determined by two main market relations - market demand and market supply. Market demand is that part of the total demand that is met from market ie., it excludes public distributions. Market supply is the total supply in the open market comprising current inflow less the withdrawals from the market by the state. The inflows consist of production and imports and withdrawals are made for the PDS or are added to stocks (occasionally some withdrawals find their way back to the market when government resorts to open market selling). Market supply is given by the following relation.

$$S = Q + M - R - G \quad \text{.........8.8.1}$$

Demand

In a country where per capita income is low, it is expected that consumers will turn to the open market for their residual demand after collecting their quota or ration. In general the amount rationed out sets a limit to the purchases from market. So, rationed distribution will normally have a negative effect on demand[6]. When rice and wheat are substitutes in the consumers' diet, public distribution of any one cereal can affect the other's demand in the same way. Income, another determinant of demand, is normally expected to have a positive effect. But negative effect is possible if the commodity is deemed inferior, with people shifting to food as dictated by current dietary knowledge and calorific needs as income improves. In any case, the income effect on demand for cereals is not likely to be large in India. The greater is the stock of food grains with farmers, traders and consumers, less must be the current demand from the market at any given price. Finally, price of the crop is expected to have a negative influence in the absence of perversity, though it may not be strong for an essential good. The price of the substitute crop may also affect demand when both figure in the consumers' diet. The direction of impact however depends on the intensities of substitution effect (positive) and income effect (negative).

Imports

Food grain imports are made out of compulsion and are generally avoided. Import is not a market driven activity in India, which has always faced foreign exchange scarcity. Ratios of international and domestic prices have hardly acted as signals in the past . In a year of shortage, such as drought years, when public stocks prove inadequate, imports cannot be avoided to keep the population from starving even in the face of soaring world prices. The country, if necessary has to go for loansor aid. Exports however do depend on intematonal prices but they have been meagre and confined to some limited superior varieties of grains and their supplies too may be determined more by domestic factors than international prices. We have therefore not chosen to consider international price as a variable for (net)imports.

Import of a grain is considered necessary by the government on the basis of its procurement performance and the stocks. The government's commitment towards public distribution also influences imports.

Rationed distribution

This is one portion of the withdrawal from free market market, but it reaches the consumer through a different channel. It is essentially a policy action. It is meant for the welfare of the masses and takes account of the needs of the different sections of the population, rural-urban differences, social and political objectives, the strength and efficiency of the food department, the storage capacity and cost involved, budgetary resources and the prevalent rationing policy. If necessary, imports are resorted to for meeting rationing commitments. On the whole rationed disributions are taken to be autonomous decisions of the government.

Addition to government stocks

This is another portion of the current inflow that is withdrawn from the market but this does not reach the consumer in the current period. Unlike imports, additions to stocks may not be entirely intentional. In years when procurements are high relative to distribution targets accumulations of stocks are inevitable. More the distribution less is the addition (there may be depletion)to public stocks.

Production

Production, the most important source of supply is our primary interest. It is partly the decision of the farmers, who plant acreages and employ inputs and put in effort. They are guided by their expectations about future prices. To the extent that the two crops vie for acreage, resources and farmers' attention, expected prices of both crops will matter in the production decision of each crop. In the national context, falling price of rice can divert resources from rice growing to wheat growing areas for achieving higher wheat production. While a positive relation between crop output and its own price is normal, the relation is expected to be reverse with respect to the competing crop. It is widely recognised that technology has a significant role in the production dynamics of Indian agriculture. Expansion of irrigation facilities and intensive use of chemical fertiliser have been credited for the success. Application of inputs are farmers' decisions to a large extent. But government policies towards subsidies, investment, infrastructural and institutional development and research and extension programmes have been responsible for the adoption of modern technology. Though the farmers allocate irrigated acreage among the crops, the freedom in this matter is limited by the geographical and seasonal distinctions. Thus extension of irrigated acreage in Punjab, is more likely to benefit wheat than rice, particularly if the soil is not suited to rice. The same in

Bengal or Andhra Pradesh will have little effect on wheat .The use of chemical fertiliser has hardly been market determined. The government's role in (i) production and imports, (ii) providing budegetary support (iii) promoting efficient and timely distribution of fertiliser and (iv) arranging required credit for purchase is a clear influence on fertiliser intensity used. But beyond the control of farmers and the government is the weather factor which also shapes actual production. Finally, past practice can have a restraining effect on changes prodution decision in agriculture. A 'partial adjustment' tendency can arise from customs, food habits as well as other institutional constraints. In many rice growing areas with an overwhelming preference for that cereal, available technology may be used for higher output of rice even if there are changes in price incentives against it.

Model Specification

The Demand equation : $D = f(P^e_t, P^{e^*}_t, Y_t, R_t, R^*_t, SP_{t\_1})$ ... 8.8.2

Import equation : $M_t = f(PC_t, R_t, SG_{t-1})$......8.8.3

Stock addition equation: $G_t = f(PC_t, R_t, SG_{t-1}, SG^*t\text{-}1)$....8.8.4

Production equation: $Q_t = f(P_t^e, P_t^{e^*}, I_t, F_t, W_t, Q_{t-1})$ 8.8.5

Supply: $S_t = Q_t + M_t - R_t - G_t$......8.8.6

Market clearing condition: $D_t = S_t$ 8.8.7

REH: $P_t^e = E(P_t)$ and $P_t^{e^*} = E(P_t^*)$....8.8.8

Equations 8.8.2 through 8.8.8 give price expectation equation as

$$P^e_t = f(P^{e^*}_t, R^e_t, PC^e_t, SG_{t-1}, SP_{t-1}, Q_{t-1}, R^{e*}_t, PC^{e*}_t, SG^*_{t-1}, SP^*_{t-1}, Q^*_{t-1}, Y^e_t, I^e_t, I^{e*}_t, F^e_t, W^e_t)$$

....8.8.9

We have the above form of equation for each of the two cereals where expected price of the substitute crop $P_t^{e^*}$ appears as a variable. Solving the two equations for price expectation of the two cereals, we can have expected price of each cereal in terms of predetermined and expected values of exogenous variables relating to both crops

Specification of variables

The stock variables SP and SG are actually predetermined variables but the certain problems arise in specifying them as nonstochasic variables for the model. Firstly, data on SP ie. private holding are not available. Secondly, these variables are themselves determined by other variables like production performance and market conditions of the previous period and some of the variables representing these factors already appear as variables in the model. The stock variables are thus not basic variables in the model and their inclusion in conjunction with basic variables which also affect their own evolution, may impart some element of endogeneity. Thirdly, the relations between the stock variables and the basic variables can create a problem of multicollinearity. The stock variables are therefore specified in terms of some basic variables. The closing stock is likely to increase with the production level. An increase in market price will lead to depletion. We have the following equations for stock addition with Q_{t-1} and P_{t-1} having a positive and negative effect respectively in each case.

$$SP_{t-1} = f(Q_{t-1}, P_{t-1}) \text{ ....8.8.10}$$

$$SG_{t-1} = f(Q_{t-1}, P_{t-1}) \text{.....8.8.11}$$

Variables I, F and W are specified as known with certainty at the time of cultivation so that

$$I_t^e = E(I_t) = I_t \text{...8.8.12}$$
$$F_t^e = E(F_t) = F_t \text{....8.8.13}$$
$$W_t^e = E(W_t) = W_t \text{...8.8.14}$$

Income is specified as a simple one period autoregressive process with θ being a positive coefficient.

$$Y_t = \theta Y_{t-1} + ut \text{....8.8.15}$$

Procurement may be expected on the basis of the procurement price announced at the time of sowing and also the market price with the former having a positive effect and latter a negative one.

$$PC_t = f(PP_t, P_t) \text{....8.8.16}$$

Rationed distribution which is taken to be an autonomous policy decision may be forecasted by the farmers on the basis of past practice of policy makers as also previous period's stocks.

$$R_t = f(R_{t-1}, Q_{t-1}, P_{t-1}) \text{...8.8.17}$$

with the expected impacts of lagged terms being positive for R_{t-1}, positive for Q_{t-1} and negative for P_{t-1}.

The reduced form supply eqution

The forecast equations for the exogenous variables (equations 8.8.10 through 8.8.17) are substituted in the expected price equation (equation 8.8.8) of each cereal and the whole expression is put back in the supply/production equation to replace the expected price variable P^e_t. The supply of a cereal is obtained as a function of relevant basic variables relating to both cereals as in equation 8.8. The derivation of the reduced form supply equation from the structural equations in linear form is provided in the Appendix of this chapter.

$$Q_t = f(Y_{t-1}, W_t, F_t, Q_{t-1}, Q^*_{t-1}, P_{t-1}, P^*_{t-1}, R_{t-1}, R^*_{t-1}, I_t, I^*_t, PP_t, PP^*_t,) \quad ...8.8.18$$

8.9 DATA, SAMPLE AND ESTIMATION

The equations of the model for the two cereals rice and wheat are estimated simultaneously using a systems approach. The equations for the exogenous variables are embodied in the model during estimation so that the estimated equations are in terms of basic variables known to the farmer at the time of cultivation. The quantity variables are in tonnes at per capita levels. Price is whole sale price index at base 1970-71. The prices are deflated by the consumer price index. Per capita income is at factor cost at constant (1970-71) prices. The weather variable is taken as a dummy D, where D =1 in a good year and D= 0 in others. Rainfall data and overall production performance have been used to judge the weather[7]. Irrigation is the proportion of crop area irrigated and fertiliser is the overall fertiliser intensity in kilograms per hectare (cropwise data not being available). The data on all variables are considered for 26 years, 1964-65 to 1989-90. But out of this sample, the data for first 15 years (ie., 1964-65 to 1978-79) have been used for the regression analysis and the remaining 11 for testing the model. The entire period starts with 1964-65, the beginning of the green revolution era and the start of a vigorous price policy and ends prior to the beginning of structural changes in India. The data have been taken from India Data Base, Bulletin on Food Statistics and Statistical Abstract of India.

The estimation is made in the following stages:

(a) In the first stage, reduced form price equations are obtained by regressing each crop price on all the exogenous and basic variables. Using alternative specifications, the best equation is selected on the basis of significance of parameters and fit of the equation. Using these specifications, forecast prices PHAT and PHAT* are calculated to serve as instruments for prices in the demand equations.

(b) Demand (D), Import(M), Addition to stocks(G) and production (Q) are regressed (using OLS)on the relevant variables as explained in 8.8, and replacing the stock variables SG and SP by the basic variables (Q,P, P*) deriving them. The disturbance terms got from these regressions are used to compute the variance-covariance matrix (O) . We postulate that the error terms of the different equations are cotemporaneously correlated but they are serially uncorrelated

(c) In the final stage eight equations, four for each cereal, relating to demand import, addition to stock and production are *estimated simultaneously* using the instruments generated for prices in the demand equations and the variance-covariance (O) matrix estimated in (b) (the 8 equations assumed to be correlated cotemporaneously).

8.10 RESULTS

We have reported equations where the t-values of variables are not less than unity (COV criterion, Maddala, 1989). The equations are reported in the Appendix in Table 8.1A(8). When estimating the equations, not all variables could be included. The inclusion of variables past income, past production and price together have led to meaningless results possibly because the three are likely to be related, agriculture having been a dominant influence on overall economic performance in India. The weather dummy could not be ratained with variables for input intensities (the latter probably depends on the rainfall. performance). We have retained those variables in whose responses we are primarily interested, mostly variables relating to agricultural technology and price policies. The bias in estimates owing to the effects of the omitted variables are acknowledged. The reduced form price equations give theoretically consistent signs of parameters. Prices are found to be related positively to procurement and negatively to public distributions (of both cereals in the case of wheat) and technology.

The substitution of rice and wheat have been found rather weak on the demand side except for the presence of the term R* in the demand equation for wheat. The subsidised distribution of rice enters the wheat eaters' demand, but the reverse is not found true. While distribution of both cereals affect wheat demand, demand for rice is affected by stocks carried over as signified by the P_{t-1} term. (a higher lagged price implies lower stocks carried over). In fact, the parameters for variables price and rationed distribution in the demand function of rice are both insignificant. Imports in each case is determined by the procurement and rationed distributions of the government. For rice the past production level also affects imports. Likewise, additions to government stocks are determined by procurement and past production or stocks. The intercept terms in equations for demand, import and addition to stocks are all positive and they are significant for the two demand functions and also, remarkably, for the stock addition functions. This suggests that the govemement had a tendency to add to the stocks even if there were no procurement ie, through imports.

The supply equations are estimated with good fit. For rice, lagged price has a positive impact on production possibly through the effect of stocks on demand. The presence of the lagged production term with a negative coefficient also indicates the impact of stocks via the demand function. In contrast, the effect of lagged production is found positive with a high t-value for wheat where the production side force seems to dominate. Rationed distribution can have contradictory effects on productions decision through the demand and the supply sides. But the effect of the demand side seems to be stronger and lagged distribution is found to have a negative effect on supply decision. In the case of wheat, we noted the impact of rice distribution on its demand. This effect is also borne out in the supply response of wheat where the rationed distribution of rice in the previous period has an adverse effect on wheat supply. Procurement price can promote supply significantly in both cases as can technology. Irrigation in the case of rice and both irrigation and fertiliser in the case of wheat have significant positive effects on supply. The intercept term for rice supply is negative significant indicative of the great importance of price and technology in sustaining supply. The intercept is insignificant for wheat.

The production of both rice and wheat respond to policy variables. Procurement prices fixed by the government appear with significant parameters for both rice and wheat. Public distributions affect supply and the effect is negative in each case. Technology has also been important in determining supplies. While a significant impact of irrigation is identified for rice, both irrigtaion and fertiliser inputs have had significant impact on wheat supply (the absence of fertiliser variable for rice may be on account of multicollinearity between the twoinputs).

Elasticities

The response of supply and other behavioural variables of the market to relevant variables may be measured by their elasticities at mean values of variables. The price elasticity of demand for rice is found poor but wheat demand is found price elastic. Wheat demand also shows higher response to rationed distributions than rice. Demand for rice is found to be fairly elastic to past price, pointing to the importance of inventory stocks determining rice demand.

Rice import is highly elastic to procurement, rationed distribution and past production. Elasticity of wheat import to procurement is however lower relative to rice but it is greater than unity towards the distribution variable R_t. Addition to government stocks is elastic to both procurement and past production for both crops. Only, the elasticity falls short of unity for past production in the case of rice

Table 8.2 Estimated Easticities with respect to Variables

VARIABLE	RICE				WHEAT			
	D	M	G	Q	D	M	G	Q
1	2	3	4	5	6	7	8	9
P_t	-0.415				-1.01			
R_t	-0.205	6.14			-0.588	1.087		
PC_t		-3.24	3.754			0.401	10.205	
P_{t-1}	0.637			0.364				
R_{t-1}				-0.092				0.26
Q_{t-1}		-3.89	-0.89	-0.421			-18.16	0.21
PP_t				0.852				0.517
I_t				2.134				0.266
F_t								0.27
R^*_{t-1}					-0.86			0.203

The elasticities of supply to the explanatory variables are less than unity for both cereals barring that of rice to irrigation. The elasticity of rice supply to lagged price (this is sometimes considered as a measure of price elasticity of supply) is 0.36 and that to lagged rationed distribution is low at .092. The response to procurement price is fairly high and the highest elasticity is towards irrigation. For wheat, the elasticity of supply to variables for rationed distributions is high compared to rice. The elasticities are nowhere exceeding unity and the response is highest to procurement price.

Implications of model for growth

Technology and price policy are meant for bringing about growth in food grain production to feed the growing population. Using the model estimated with REH let us examine how far they served the purpose and what were the effects of such factors on production over the sample period. We have chosen two points of time 1964-65 and 1978-79, both years of good rainfall . . Taking one variable at a time, setting it to its 1978-79 value, while keeping other variables at their 1964-65 values, the expected production level is estimated using model parameters. The difference between this value and the base year estimated value of production is measured as the contribution of that particular variable to supply change. In terms of the model predictions we find that contributions of all the variables have not been favourable for growth. For *rice* we find that the (i)contributions of policy towards procurement price has been quite adverse, (ii) public distribution at subsidised prices has also been unfavourable to supply, (iii) lagged production level (through its effects on stocks) has not helped either, (iv) Only irrigation has been responsible for the growth contributing 265%, with other policy variables having offset much of the impact and (v) past price, through its effect on stocks has also helped. Thus procurement and distribution policies of the government has largely been responsible for the fall in output. Only technoly has helped. For wheat we once again note that (i)procurement price increased slightly and promoted growth in supply, (ii) concessional distribution had an unfavourable effect, (iii) fertiliser had a remarkably favourable effect and (iv) irrigation too had similarly helped growth. (v) The tendency of past supply having a positive effect on current behaviour provided an impetus to growth. Thus in the case of wheat, technological development was aided by the price policy in increasing production and the influence of the lagged variable reinforced the effect. Although irrigation intensity went up impressively, the contribution is not as remarkable as in rice, but the near 500% improvement in fertiliser intensity seems to have helped wheat output significantly. The net result of the diverse forces on the expected production levels was a meagre 7.2% increase for rice and an impressive 109.9% increase for wheat.

Table 8.3 Contributions of Explanatory Variables to Growth of Supply (1964-65 to 1978-79)

	$QHAT_t$	R_{t-1}	R^*_{t-1}	PP_t	I_t	F_t	Q_{t-1}
1	2	3	4	5	6	7	8
Rice							
Increase (%)	7.2	30	-	-10.3	9.5	-	5.26
Contribution (%)	100	-23.2	-	-130.7	265.3	-	-31.8
Wheat							
Increase (%)	109.9	24.2	30	19.8	68.6	497.5	138.7
Contribution (%)	100	-6.1	-5.2	10.5	17.7	60.2	22.9

Note: QHAT is estimated production level.

When we note the varied role of different policies in promoting growth we keep in mind that growth of food production is not the sole aim of a sound food policy. Growth itself is not enough for food security of the population and distribution policies and support to farmers both deserve attention. Often, there are trade offs between these aims and growth of production. It is up to the policy maker to choose the correct mix of measures according to the country's priorities.

Test of the REH model

The performance of the model in describing the supply responses of the cereals indicates the acceptability of the REH in describing farmers' behavior. The supply equations for rice and wheat are estimated each with a good fit, the R^2 being 0.89 and 0.99 respectively for rice and wheat respectively. The test for the model may be the appropriateness of the signs of parameters satisfying the underlying constraints for the structural parameter (discussed in 8.8) and by a simple predictive test of the model (Sheffrin, 1983).[1] We noted that the signs of the parameters were consistent with our expectations based on theory. We will also examine the predictive ability of the model.

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[1] A more stringent test for REH may be made by incorporating overidentifying restrictions on parameters implied by REH and comparing the estimates with and without restrictions as applied by Goodwin and Sheffrin (1982).

Firstly, we will see how well the model simulates for the sample period. Table presents the observed and estimated values of production per capita of the cereals for all 15 years along with the percentage errors. The model has estimated fairly accurately, the errors lying within 10%. The percentage root mean square error (RMSE(%)) is arrived at in the following way.

$$e_t = Q_t - QHAT_t$$

$$MSE = \sum e_t^2/n$$

$$RMSE = \sqrt{MSE}$$

$$Mean(Q) = \sum Q_t/n$$

$$RMSE(\%) = RMSE/Mean(Q)X100$$

where QHAT is estimated output, e is error, MSE is mean squared error and n is the sample size.

The RMSE(%) work out to be 3.6% and 4.6% for the two cereal rice and wheat respectively.

The model has more or less been able to trace the movements of supply including the dips encountered in 1965-66 and 1966-67 and 1972-73 through 1974-75. (Figures 2 and 3 give a graphical representation of the movements of observed against predicted output evels).

Table 8.4 Errors in Estimating Supply

	Rice			Wheat		
	Observed	Estimated	Error%	Observed	Estimated	Error%
1	2	3	4	5	6	7
1964-65	0.0258	0.0267	3.45	0.0828	0.0774	6.46
1965-66	0.0214	0.0216	1.10	0.0630	0.0626	0.62
1966-67	0.0228	0.0238	4.38	0.0610	0.0642	5.25
1967-68	0.0324	0.0321	0.84	0.0736	0.0760	3.21
1968-69	0.0356	0.0353	0.84	0.0759	0.0713	6.06
1969-70	0.0374	0.0398	6.34	0.0753	0.0778	3.29
1971-72	0.0433	0.0434	0.25	0.0767	0.0800	4.35
1972-73	0.0479	0.0448	6.49	0.0781	0.0796	2
1973-74	0.0439	0.0441	0.52	0.0696	0.0715	2.72
1974-75	0.0383	0.0415	8.22	0.0760	0.0721	5.16
1975-76	0.0410	0.0388	5.28	0.0670	0.0677	1.07
1976-77	0.0480	0.0458	4.52	0.0811	0.0826	1.88
1977-78	0.0473	0.0464	1.89	0.0684	0.0723	5.7
1978-79	0.0507	0.0513	1.21	0.0842	0.0789	6.29
1979-80	0.0556	0.0560	0.70	0.0840	0.0830	1.14
RMSE(%)			5.51			5.99

Notes: Quantities in tonnes per capita.

Forecasts are also made for a period of 11 post sample years. Barring two years, 1979-80 and 1982-83, the errors lie within 10%. The actual and forecast for years 1979-80 to 1985-86 are given in Table 8.5.

Table 8.5 : Predictive Performance of Model

YEAR	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86
Rice							
Actual	0.065	0.0785	0.0761	0.0658	0.082	0.0778	0.0836
Prediction	0.084	0.0771	0.0778	0.0756	0.0823	0.0813	0.0797
Error%	29.12	1.81	2.18	14.95	0.38	4.56	4.59
Wheat							
Actual	0.0489	0.0531	0.0536	0.0594	0.0621	0.0588	0.0613
Predicted	0.0557	0.0494	0.051	0.055	0.0585	0.0634	0.0662
Error%	13.87	6.99	4.7	7.4	5.69	7.89	4.8

Note: Quantities in tonnes per capita.

8.11 CONCLUSION

The Rational Expectations model of supply for the two major cereals has been able to explain supply in the present context and may be an acceptable tool (with further possible refinement) in supply response modelling in Indian agriculture. The model is useful in evaluating the role and contribution of policy and technology in supply performance.

The model estimated in this chapter indicates that technology as well as price policy in Indis favoured wheat but the same is not true for rice.

[1]Linear and semi-log time trends fitted to data covering 1964-65 to 1990-91 showed poor fit for rice and food grains ($R^2 < 0.2$) as a whole. The results are however good for wheat which shows significant positive trend.

Wheat: 1964-65 to1990-91

$$\ln q = -3.57 \underset{(0.00343)}{+0.035388\,t} \qquad R^2 = .81 \quad D.F. = 25$$

[2]The correlation coefficient between production and imports is found -0.15 for rice (in a number of years such as 1974-75 and 1975-76 production and imports moved in the same direction, even resulting in net exports as in 1971-72 and 1979-80!) while that for wheat is stronger at -0.8. Rice imports are also not so much correlated with its market price with coefficient 0.19 but that of wheat is moderately so at 0.63.

[3]In the years since 1960, the outcome of the competition has gone in favour of wheat. About 83% of wheat area is under HYV compared to 57% for rice. Nearly 60% of rice area is rainfed whereas wheat enjoys an irrigation intensity of above 75%. Wheat has claimed more share in fertiliser use than rice and is also found to be more remunerative to the cultivator with capital resources. There was stagnation in rice growing states but the

tendency is said to be reversing since the eighties as fertiliser use spreads to unirrigated eastern regions and its consumption in the kharif season grows faster than in the rabi season.

[4]The farmers are assumed to observe the level of prices and be aware of the random shocks of short term nature to which the variable is subjected to. The farmer is assumed to understand the stochastic process of price evolution. The price expectation can be expressed in terms of past values of stationary and random components by autoregressive (AR) and moving average (MA) parts after suitably differencing the series.

$$\pi_t^* = \pi_t - \theta_t = \theta_1\pi_{t-1} + \theta_2\pi_{t-2}....\theta_p\pi_{t-p} + m$$

$$+ \psi_1 w_{t-1} + \psi_2 w_{t-2}...\psi_q w_{t-q} + w_t$$

where π = price suitably differenced, π^* = expected price, W = white noise, θ, ψ are parameters and p and q are orders of AR and MA.

[5]REH does not require individual farmers to have identical expectations which reflect reality. Although the farmers spread all over India in regions with various conditions and history have their own way of thinking and have differing access to information, but what we suppose is that *on the average* the Indian farmer's behaviour conforms with informed prediction of the REH. REH only requires that individual expectations based on individual experience and information should be distributed around the true value of the variable to be forecasted. And the average individual forecast would be the expected value of the true variable. Lucas revolutionised macro economics by the use of REH, arguing that to employ economic theory in practice it is necessary to know the probability distributions agents actually use. Predictive theories cannot be easily built on the principle that agents have subjective probability distributions that cannot be related to objective reality. Muth's hypothesis however concerned itself with the mean or the expected value of future variables and not with higher moments such as variance.

[6]A positive effect is possible when the increased distribution has a favourable income effect on consumption of one or both cereals (Chakrabarty, 1977).

[7] National level annual rainfall data are not available. The years are therefore classified as good or bad using dummy variables (1 and 0 respectively) in terms of weather. Regional rainfall and overall acreage and productions performance of the country are used to judge the weather performance. The comments made in Economic Survey and the figures provided by Narayana and Parikh (1987) have been of help. The dummies used for the years 1964-65 to 1985-86 are as follows: 1, 0, 0, 1, 0, 1, 1, 1, 0, 1, 0, 1, 0, 1, 1, 0, 0, 0, 0,1, 1, 0.

Appendix A8:

Statistics on Foodgrain Market in India

A8: Table 8.1 (A8): Public Operations in Food Grains in India

YEAR	POPULATION (MILLION)	PRODUCTION (mill.TONNES)	IMPORT (mill.TONNES)	PROCUREMENT (mill.TONNES)	CLOSING STOCKS (mill.TONNES)	PUBLIC DISTRIBUTION (mill.TONNES)	PC AVAILABILITY ('00GRAMS)	FOOD SUBSIDY (RS CRORE)
1	2	3	4	5	6	7	8	9
1965-66	363.2	72. 3	10.3	4.01	2.2	14.1	4.1	-
1966-67	504.2	74 .2	8.7	4.5	1.9	13.2	4	93.3
1969-70	538.9	99 .5	3.6	6.7	5.6	8.8	4.6	30.7
1970-71	551.3	108.4	2	8.9	8.1	7.8	4.7	18
1971-72	563.9	105. 2	-0.5	7.7	3.4	10.5	4.7	49.7
1972-73	576.8	97	3.6	8.4	3.1	11.4	4.2	117
1973-74	590	104.7	5.2	5.65	2.7	10.8	4.51	251
1974-75	603.5	99. 8	7.5	9.56	8.3	11.3	4.05	306.9
1975-76	617.2	121	0.7	12.9	18.9	9.2	4.24	262.1
1976-77	631.3	111. .2	0.1	10	17.3	11.7	4.29	521.3
1977-78	645.7	126. 4	-0.6	11.1	17.2	10.2	4.68	480.6
1978-79	660.3	131. 9	-0.2	13.9	17.5	11.7	4.76	578.3
1979-80	675.2	109.7	-0.3	11.2	11.7	15	1.1	600.6
1980-81	688.5	129. 6	0.7	11.4	11.5	13	4.54	657.7
1981-82	703.8	133. 3	1.6	15.4	12.8	14.8	4.55	708.6
1982-83	718.9	129. 5	4.1	15.5	15.5	16.2	4.37	714
1983-84	734.5	152. 4	2.4	18.7	22.5	13.3	4.8	851.2
1984-85	750.4	145. 5	-0.4	19.7	25.2	15.8	4.54	1,110
1985-86	766.5	150. 4	-0.5	15.7	23.6	17.3	4.78	1,671.9
1986-87	782.7	143. 4	-0.2	14.1	14.1	18.7	4.71	2,032.1
1987-88	799.2	138. 4	3	17.9	9.5	18.6	4.48	2,241.2

Notes: Col 3 gives net production (after allowances for feed etc.) .; Col 8 gives is per capita daily net availability. *Source:* DFS and Economic Survey of India

A8: Table 8.2(A8) Whole sale Price Indices of crops in India (Base = 1970-71)

year	Rice	Wheat	Jowar	Maize	Ragi	Bajra	Food grains	All commodities
1960-61	51.2	47.4	56.9	52.2	60.5	62.2	49.3	55.1
1965-66	67.9	71.5	88	90.2	114.3	98.2	74.6	72.7
1970-71	100	100	100	100	100	100	100	100
1975-76	178.8	159.6	175.6	173.7	185.8	196.9	174.1	173
1976-77	156.9	152	163.6	145.4	154.8	146.3	152.7	176.6
1977-78	162	156.5	157.4	177.9	166.3	169.1	170.4	185.8
1978-79	160.8	153.8	154.8	173.4	137.6	147.2	172.6	185.9
1979-80	183.8	160.7	167.6	185.4	140.4	164.8	185.4	217.6
1980-81	205.6	176.2	194.2	206.4	188.6	196.1	216.7	257.3
1981-82	226.1	191.6	241.5	235.4	234.1	228.2	237.4	281.3
1982-83	257	214.2	221.7	251.6	214.1	222.9	248.8	288.7
1983-84	292	218	241.1	263.4	250.6	231.1	273.8	316
1984-85	273.3	209.6	241.5	220.8	243.5	214.1	276.2	338.4
1985-86	284.4	225.8	240.1	285.6	256	267.8	295.7	357.8
1988-89	363.7	292	311.4	348.2	308.5	309.6	389.9	435.3

Source: India Data Base.

Appndix A8: Estimated Regression Equations

A8: Table 8.3 (A8) Estimated Model for Rice and Wheat

Equation No.	1	2	3	4	5
Independent Variables	Demand (D)	Import(M)	Stock Addition(G)	Output (Q)	Price(P)
1	2	3	4	5	6
Rice					
Constant	0.0663 (2.9731)	0.0009 (1.000)	0.0059 (1.8438)	-.1368 (-2.9483)	4.8549 (5.1163)
P_t	-0.0263 (-1.453))				
P_{t-1}	-0.0403 (-2.985))			.0254 (2.6738)	
R_t	-2.1537 (-1.3706)	.4193 (4.4989)			-100.549 (-3.9578)
R_{t-1}				-1.0923 (-1.1003)	-38.8578 (-2.0957)
PC_t		-.2227 (-4.8413)	.5593 (3.29)		26.4553 (2.2264)
PP_t				.2520 (3.6207)	
Q_{t-1}		-0.0231 (-1.9267)	-.1148 (-2.8917)	-.4228 (-3.3239)	
I_t				.4419 (4.9153)	-7.9516 (-3.7384)
R^2	0.4	0.86	0.53	0.89	0.64
Wheat					
Constant	0.1198 (7.8301)	.0025 (.7576)	.0071 (1.9722)	.0077 (1.4259)	1.3869 (2.8013)
P_t	-.0324 (-3.3061)				
R_t	-1.7690 (-5.0746)	.7467 (3.4049)			-15.2745 (-1.0522)
R^*_t	-4.641 (-4.0998)				-53.9949 (-1.4712)
R_{t-1}				-.9053 (-5.9209)	
R^*_{t-1}				-1.2719 (-4.6522)	
PC_t		-.5895 (-2.5192)	1.5119 (3.3869)		
PP_t				.0548 (6.6829)	1.0212 (1.7631)
Q_{t-1}			-0.39 (-2.7197)	.2283 (2.8537)	
I_t				.0194 (1.7017)	
F_t				.0007 (7.0)	-.0113 (-1.9825)
R^2	0.87	0.72	0.48	0.99	0.52

Notes: Equations 1 to 4 are estimated simultaneously and equation 5 is estimated reduced form price equation used to compute instruments for price variables. Figures in brackets are t-statistics.

A8: Derivation of the Reduced form Equation

In section 8.8 we postulated the structural form equations for demand, import, addition to stocks and production and also specified some of the exogenous variables as function of pre-determined or other more basic variables. The final reduced form equation for supply is thence obtained in terms of the pre-determined and basic variables. The linear model and the derivation of the reduced form supply equation are as follows.

$$D_t = k_1 + a_1P_t + \beta_1Y_t + \gamma_1SP_{t-1} + \pi_1P_t^* + \theta_1R_t + .\psi_1R_t^* + u_t \ldots\ldots 1$$

$$M_t = k_2 + a_2PC_t + \beta_2R_t + \gamma_2SG_{t-1} + u_t \ldots\ldots 2$$

$$G_t = k_3 + a_3PC_t + \beta_3R_t + \gamma_3SG_{t-1} + u_t \ldots\ldots 3$$

$$Q_t = k_4 + a_4P_t^e + \beta_4I_t + \gamma_4F_t + \pi_4Q_{t-1} + \psi_4P_t^{*e} + \theta_4W_t + u_t \ldots 4$$

$$S_t = Q_t + M_t - R_t - G_t \ldots\ldots\ldots 5$$

$$D_t = S_t \ldots\ldots\ldots 6$$

$$P_t^e = E(P_t) \ldots\ldots\ldots 7$$

$$SP_{t-1} = a_8Q_{t-1} + \beta_8P_{t-1+}u_t \ldots\ldots 8$$

$$R_t = a_9R_{t-1} + \beta_9Q_{t-1} + u_t \ldots\ldots 9$$

$$PC_t = a_{10}PP_t + \beta_{10}P_t^e + u_t \ldots\ldots 10$$

$$Y_t = a_{11}Y_{t-1} + .u_t \ldots 11$$

$$SG_{t-1} = a_{12}Q_{t-1} + \beta_{12}P_{t-1} + u_t \ldots\ldots 12$$

The variables are defined in section 8.8 .From equations 1 to 6 we can write

$$k_1 + a_1P_t + \beta_1Y_t + \gamma_1SP_{t-1} + \pi_1P_t^* + \theta_1R_t + \psi_1R_t^* = k_4 + a_4P_t^e + \beta_4I_{t-1} + \gamma_4F_t + \pi_4Q_{t-1}$$
$$+\psi_4P_t^e + \theta_4W_t + k_2 + a_2PC_t + \beta_1R_t + \gamma_2SG_{t-1} - R_t - k_3 - a_3PC_t - \beta_3R_t - \gamma_3SG_{t-1} \ldots \quad 13$$

Solving for P_t from equation 13 and using equations 7 to 12 we have

$$P_t = a_0 - a_1Y_t - a_2Q_{t-1} - a_3P_{t-1} - a_4P_t^{*e} - a_5R_{t-1} + a_6I_t + a_7F_t + a_8W_t + a_9PP_t \quad \text{where}$$
$$- a_{10}R_{t-1}^* - a_{11}Q_{t-1}^* \ldots\ldots 14$$

$$a_0 = (k_2 - k_3 + k_4 - k_1)$$
$$a_1 = \beta_1a_{11}/Z_1; a_2 = Z_2/Z_1; a_3 = Z_3/Z_1; a_4 = Z_4/Z_1; a_5 = Z_5/Z_1;$$
$$a_6 = \beta_4/z_1, a_7 = \gamma_{4/Z_1}; a_8 = \theta_4/Z_1, a_9 = Z_6/Z_1, a_{10}/Z_1, a_{11} = Z_{11}/Z_1$$

and

$$Z_1 = a_1 - a_2\beta_{10} - a_4 + a_3\beta_{10}$$

$$Z_2 = \gamma_1 a_8 + \theta_1\beta_9 - \pi_4 - \beta_2\beta_9 - \gamma_2 a_{12} + \beta_9 + \beta_3\beta_9 + \gamma_3 a_{12}$$

$$Z_3 = \gamma_1\beta_8 - \gamma_3\beta_{12} + \gamma_2\beta_{12}$$

$$Z_4 = \pi_1 - \psi_4$$

$$Z_5 = \theta_1 a_9 - \beta_2 a_9 + a_9 - \beta_3 a_9$$

$$Z_6 = a_2 a_{10} - a_3 a_{10}$$

$$Z_{10} = \psi_1 a'_9, Z_{11} = \psi_1 \beta'_9$$

Substituting the value of P^{*}_t in equation 14 we have the final reduced form price equation:

$$P_t = A_0 - A_1 Y_t - A_2 Q_{t-1} - A_3 P_{t-1} - A_4 R_{t-1} + A_5 I_t + A_6 F_t + A_7 W_t + A_8 PP_t - A_9 Q^*_{t-1}$$
$$- A_{10} P^*_{t-1} + A_{11} R^*_{t-1} + A_{12} I^*_t + A_{13} PP^*_t \ldots\ldots 15$$

where

$$A_0 = (a_0 - a_4 a'_0)/b$$

$$A_1 = (a_1 - a_4 a'_1)/b$$

$$A_2 = (a_2 - a_4 a'_{11})/b$$

$$A_3 = a_3/b$$

$$A_4 = (a_5 - a_4 a'_{10})/b$$

$$A_5 = a_6/b$$

$$A_6 = (a_7 - a_4 a'_7)/b$$

$$A_7 = (a_8 - a_4 a'_8)/b$$

$$A_8 = a_9/b$$

$$A_9 = (a_{11} + a_4 a'_2)/b$$

$$A_{10} = a_4 a'_3/b$$

$$A_{11} = (a_{10} - a_4 a'_5)/b$$

$$A_{12} = a_4 a'_6/b$$

$$A_{13} = a_4 a'_9/b$$

$(b = (1 - a_4 a'_4)$ where a_i' denotes coefficient of variable of substitute crop).

FIGURE 2(B)

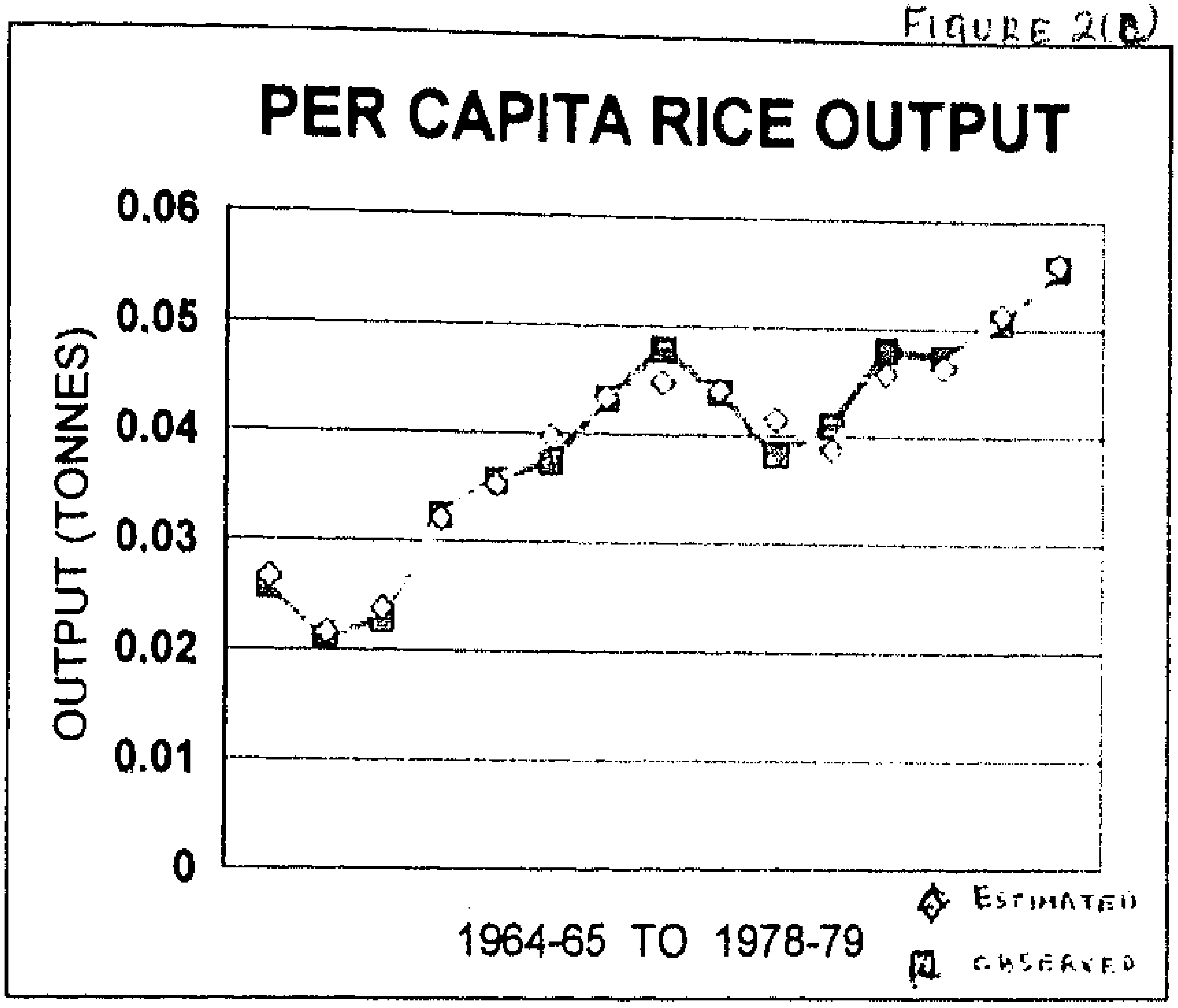
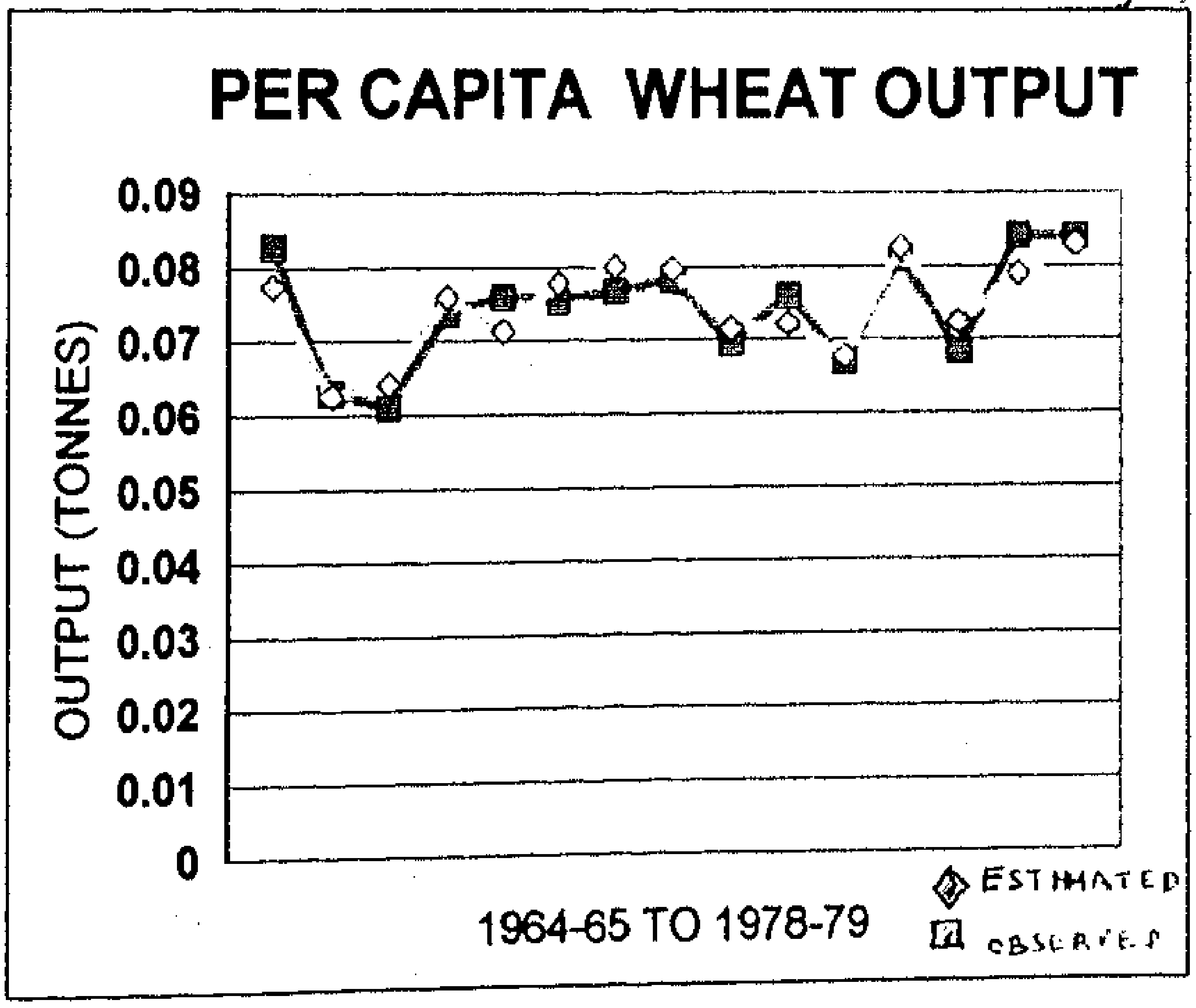


FIGURE 2(C)



APPENDIX D:

RESPONSES TO EXAMINERS' COMMENTS

Responses to Referee 1

The Referee points to the 'lack of integration' in the thesis as an important shortcoming and suggests recasting 'primarily in the writing and presentation'. We felt that non integration is largely a result of the inadequacy of the thesis, the most important being the absence of a study on acreage, as the Referee also pointed out in his/her comments. We have attempted to rectify the lacking by some additional work on the issues missing in the earlier version. We thank the examiner sincerely for pointing out the weakness and hope the revision confers necessary integration to the entire work.

The specific responses are as follows:

Chapter1 to 3 have been described as 'not very promising'. The introduction (Chapter1) is said to be adequate but 'an alternative organization might be possible'. Chapter 2 on Indian agriculture does not address the topics of the thesis and could have been in the introductory chapter. The Data chapter in preceding the models and their specification is out of place. To sum up, the Referee suggested some reorganisation of the chapters which we have made.

The introduction has been reorganised as we thought appropriate, bringing out the importance of the studies to be presented in the light of present economic objectives, problems and prospects. We tried to express the significance of the study as well as the approach of study. The review of Indian agriculture, earlier appearing as Chapter 2 has been incorporated in the introductory chapter (Chapter 1) although not as a separate review section. The chapter on Data has been removed and the contents i.e., details of the data used, are provided in the respective chapters along with the specification of the models to be estimated.

While Chapter 2 and 3 have been reorganised and embodied into other chapters as suggested, we have presented a chapter (Chapter2) on the agricultural economy of Andhra Pradesh. Since much of the work is based on the state Andhra Pradesh, we thought it reasonable to provide an overview of the state's agriculture as a background to the succeeding analyses. In fact, since the study is conducted at the district level, it is necessary that the reader has an understanding of the agro-climatic dissimilarities among the districts. The results of the analyses in subsequent chapters are made keeping in mind the heterogeneities described in Chapter 2.

In the comments on Chapter 4 , described as 'disappointing' the examiner noted our failure to study crop acreage and our consideration of cropping intensity instead. This omission is primarily responsible for the non-integrated character of the thesis and we agree that cropping intensity does not really depict acreage cultivated. The acreage cultivated encompasses crop wise acreage cultivated (as the examiner mentions) as well as overall land utilisation of which cropping intensity is a part.

We have found it relevant for the purpose of study to conduct studies on crop acreages. These are presented in Chapter 5 as additional analysis done to integrate and complete the study of supply responses undertaken.

Cropping intensity is an 'important topic' but the examiner found weakensses in the modelling. We have tried to improve the study, looking into the impact of irrigation infrastructure and input intensities in determining cropping intensity. The examiner raises a point regarding the endogeneity of fertiliser input in the analysis. However, we do not find such a view convincing although this is often the normal assumption (cropping intensity is determined by the availability of irrigation and fertiliser use in turn is influenced by cropping intensity). Such an assumption puts too much emphasis on irrigation input and may not reflect reality, especially where rainfed cultivation is possible (such as Andhra Pradesh). Anyway, we have tried to explain our rationale in Chapter4.

The examiner commended the observations on land use made in Chapter 4 and even suggested greater emphasis on these discussions relative to the econometric work. We have updated the discussions somewhat. Also, to make the study of land utilisation more complete we presented an analysis on the extent of cultivation and combined it with the qualitative discussion on land use. This part is presented in Chapter 3 of the revised thesis.

The chapter on yield responses which now come in Chapter 6 has also undergone changes, mostly in the model employed. This is mentioned in the responses to Referee 2's comments. We have thankfully accepted the present examiner's comments on the use of Tables. The model built up in the earlier version of this thesis is presented in the Appendix to chapter 6, but has not been estimated again.

Chapter 6 is a study of the complete supply response of a crop using the REH. However, this chapter is also greatly responsible for the lack of integration probably because (i) its consideration of total supply fails to add to the yield-acreage approach in the thesis and (ii) based on all India level data, it departs from the rest of the work which is devoted to Andhra Pradesh. The examiner has even suggested changing the name to Three Essays to make integration of the chapter possible. Since we have taken pains to bring integration to the rest of the work by incorporating some additional studies and reorganising the work, the above name again becomes inappropriate for the revised thesis (although the suggestion is thankfully appreciated). The work in Chapter 6 is very much pertinent in the context of supply responses of food grains but since it adopted a different approach from that of the remaining work and is based on India, we decided to include it as an Appendix to the main thesis. But, we repeat our feeling that the work is pertinent and very much part of the entire study.

Since a study of rice alone lacks justification (referee's comment), we conducted the work for wheat also taking account of the interrelations among the two major foodgrain crops of India. These are the crops which benefited from the technological progress and been subject of the government's price policy. We have considered the years following the launch of the high yielding variety seed and the new technology (as explained in Chapter1) and so there was possibly no varietal change during the sample period. Irrigation and other technology variables are considered along with price policy. Standard errors are presented.

Responses to Referee2

The referee states that a 'few issues (albeit not major)' need to be resolved. These issues are mostly in econometric procedures and presentations. In order to resolve certain issues, some changes in data and model choice were necessary although the problem of research essentially remained same. We are thankful for bringing to notice some drawbacks in the econometric work.

With respect to Chapter 4, where we had conducted a regression analysis using pooled cross-sectional data, the examiner asks for clarification regarding presence of heteroscedasticity and autocorrelation. While heteroscedasticity problem was originally got around by working at homogeneous region level (some common tests could be conducted to rule out the possibility), autocorrelation was a problem that had no easy solution. The complexity caused by the cross sectional nature of data was not realised while submitting the earlier version.

To take this into account and also to get a better view of the differing supply responses, we have considered time series data of districts for the entire work. This has increased the volume of this work somewhat but we hope the serious problem cited by this examiner is avoided. The time series data for analysis (Chapter 4 and other chapters as well) is not expected to suffer from heteroscedasticity as it covers the years following the launch of the new technology and during which time no significant structural or other changes took place in Indian agriculture. The problem of autocorrelation, which may still be present, is dealt with using the HILU method. The time series nature of data can also give rise to possibility of 'spurious regression' and Dickey-Fuller tests have been conducted on the residuals and the stationarity in each case is checked by visual study of graphs of residuals (not presented in the work).

The sample period is extended as far as possible given the availability of consistent and continuous time series data at district level at the time of estimation. The sample periods are mentioned in the respective texts and with the equations. Factual numbers have been presented whenever relevant and possible as suggested.

Some comments have been made about the yield response model in Chapter 5. I thank the examiner for the suggestion of alternative models which might be more appealing and simpler for estimation. The estimation of the model was rather complex, at least for an individual research scholar to conduct, especially after the computer system and data retrieval method underwent drastic changes with time. Besides, it is our opinion as well as those of leading economists of the country, that in India, technology adoption (and therefore yield rates) was influenced more by institutional factors than by price factors (discussed in Chapter6 in revised thesis). Before the onset of the nineties decade, supply of agricultural products and inputs was not market determined as government supported farmers through the dual market system and encouraged input use via subsidies, concessional finance, input distribution networks and extension services.

Thus influence of prices on yield levels is likely to be weak. The technical relation between crop yield and input use is considered more relevant than a price based function for reasons explained in Chapter 6.

We thank the examiner for pointing out the simultaneous equation bias implied in our treatment of price variable in Chapter 6 of the earlier version. We have now included another major cereal wheat along with rice in the model and employed the three stage least squares method of estimation (as suggested). The derivation of equations is provided and the standard errors reported. Goodwin and Sheffrin's work has been mentioned.

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