Report

Financial Implications of Use of Chemical fertilizers along with Organic/Bio-fertilizers and Means to promote their Use

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Preface

This work is a part of the studies assigned by the Ministry of Agriculture, Government of India to Institute of Economic Growth. The significance of such a study lies in the changing economic concerns in India. After traversing about three decades through self-sufficiency targeted fertilizer based technology in agriculture, liberalisation on domestic and external fronts relocate the focus of agricultural policy on sustainability of development on both sound ecological and fiscal grounds. The current situation opens up a broader horizon of options of pursuing the so called modern and traditional technologies each with its grains of wisdom, merits and shortcomings and an acceptable solution possibly lies in a judicious combination of the two. This study makes use of currently available information on fertilizer use practices to make economic analyses of the technologies and household behaviours on farms and also to study the industry based performance of biofertilizer, a new input of organic nature.

At the outset my acknowledgement goes towards the contributions of Institute of Economic Growth and in particular, our Director Professor B.B. Bhattacharya for offering me the chance and facility to conduct the study. Encouragement, support and comments from Prof Ramesh Chand, Head of Department of the AER section of the Institute since the time he joined office proved extremely valuable. I should thank the Ministry of Agriculture, Government of India for their support especially in making some data available and the encouragement from Economic and Statistical Advisor Shri Nampoothiri and also Shri D. K. Trehan who was in office at the time the study was initiated. I also thank Mr T.K. Chanda of Fertilizer Association of India for rare data support on the biofertilizer industry. I benefited at various points from insightful discussions and comments from my colleagues Prof Kanchan Chopra, Prof Indira Rajaraman and Dr T.A. Bhavani of Institute of Economic Growth, Dr. B.C. Biswas of FAI and Dr Bimal Roy of Indian Statistical Institute , Kolkata. I also recall gratefully the influence of Prof N.S.S. Narayana of Indian Statistical Institute, Bangalore for introducing me to some of the econometric techniques followed in the present project while doing my Ph.D. dissertation. The suggestions made by the Referee have been of great help and the subsequent insight provided by my colleague Sri S.S. Yadav was essential for revising the Report. Closer to home is my deep sense of indebtedness and gratitude for the technical support and close cooperation I received from Mr. S. Sridharan in particular and from Mr Inder Kumar and Mr Rajesh Chatwal in the Institute's computer unit. A number of other colleagues and associates and my family have cooperated in completion of the work but the mistakes if any are my own.

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Chapter 1

Introduction

Traditional agriculture based on indigenous and natural inputs took a sharp bend in the 1960s and a new technology was launched in the quest for food security in a country torn by shortages. Inspired by the contemporary insights (Raj Krishna 1963, Schultz 1964), India accepted the new agrarian technology offered at that time by scientific advancements for adoption on Indian soil. Fertilizer was the crucial input in the package essential for the success of the new seeds and demanding irrigation facility for its uptake. The power of chemicals to replenish natural nutrients of the soil had been known since scientific breakthroughs were achieved in the west in the past century, but its actual application on Indian soils was negligible till then. The contingency of the time compelled a move towards extensive and intensive use of chemical fertilizer. Indian agriculture traversed nearly three decades struggling for and attaining some degree of success in this path, reflected by the growth rate, productivity levels and self-sufficiency attained in agriculture, until it reached its new crossroads again in recent years.

Fertilizer is not only one of the most important inputs in modern agriculture but the most debated one at that. The relatively low fertilizer use intensity in India in global comparisons has been viewed as a restraint on agricultural growth and the unequal dissemination is held responsible for some of the imbalances generated by the green revolution. The government's correctional measures however led to certain contrary problems like inefficiency of fertilizer use and other mismanagement mostly stemming from the supposedly wrong price signals induced by policy. The nineties decade brought further apprehensions of environmental adversities, drawing from experiences from within the country as also the warnings emitted by the more input intensive agriculture of developed countries. The nineties also started with severe macro economic problems and an awakening to the abysmal state of rural infrastructure due to shortage of funds all of which compelled stringent fiscal adjustments and a drive to cut the subsidy burden on budget. Finally, the WTO commitments brought the final parting of the paradigms that inspired agricultural policy in the last decades, asking the country and its various sectors to meet global market competitively. There is now a need for reviewing the strategy of fertilizer based modern agrarian technology.

1.2 Fertilizer Policy at Cross-roads

Chemical fertilizers, being essentially fossil fuel-based, have not constituted India's advantage so far and have meant imports of sizable amounts of final product and feedstock hydrocarbon from other countries along with budgetary support to enable economic access to farmers. The country attempted to reduce dependence on fertilizer imports and encourage domestic self-sufficiency by building up a strong domestic fertilizer industry through the Retention price and Subsidy system (RPS), meant to support the fertilizer industry while making fertilizer accessible to farmers. The RPS policy came under attack on grounds that these subsidies, doled out in the name of agriculture, actually serves the industry in a major way and encourages inefficiency. The RPS has been going through modifications through the decontrolled P and K fertilizers, yet under 'concessions', and a group based concession scheme emerging for urea industry but WTO requires India to ultimately remove all protection. Technological shifts coming through changes in feedstock choice and availability especially in view of India's possible advantages in natural gas accompany the transitions taken by the industry.

The changes on the farmers' side are much more difficult and sensitive. Firstly, despite parallel liberalisation in grain market, self-sufficiency in food cannot yet be discarded as a national goal owing to (a) India's yet growing population, (b) the volatility of global food market in terms of supplies and prices and (c) the present geo-political realities. There is moreover a large volume of subsistence farming where household food security depends on the farm supplies rather than market. Above all a large part of the farm households are either small or marginal, holding no more than 2 hectares of land and constitute the bulk of the poor in the country. The interest of this sensitive class located at the edge of subsistence as also the strong lobby of the largest sector in India has made fertilizer policy economically and politically problematical. That the likely implications of the changing regime on food security of the country and livelihood security of the farmers are cause of concern cannot be disputed.

1.3 Environmental Concerns

It is increasingly being realized that the intensive use of chemicals often verging on excessive, consequent to the policy-effected cheaper fertilizer price so long in acceptance, is harmful for soil and proves counter productive. The soil quality in terms of its physical, biological and chemical properties is undermined with prolonged and intensive use of NPK containing chemicals afflicting its ability to satisfy healthy plant growth and crop production. The environmental concerns have further dimensions. First, the dependence of Indian agriculture on chemical fertilizer for high crop yields implies a basic reliance on exhaustible fossil fuels with chances of pollution at the production stage. Second, there is also the adverse possibility of nitrogen leaching into ground water leading to possible health hazards[i] or phosphate/ nitrate pollution of surface water causing eutrophication[ii]. It is of some assurance that in India the intensity of consumption of inorganic fertilizers is much less than in countries like Japan and China and the intensity was found more than 200 kg/ha only in 4% of the districts in 1996-97 (Sharma and Sharma, 1999). Although ground water contamination in India is as yet within limits, the increasing tendency in some pockets and the slow reversibility of the contamination call for timely alertness.

Removal of domestic price distortions is not the remedy to the environmental threat, as market prices and increased competition could also be a source of stress. The linkage between trade liberalization and environmental degradation has been a subject of a lively debate with views expressed in favour of a congenial relation because the developing countries start from a lower base of resource use as compared to the developed world (Kym, 1996). While this is reassuring for the global economy the problems of fertilizer run off and pollution in many countries using fertilizer in high intensity rings an alarm bell for those to follow the path of development. With India' comparative advantage identified in many agro-products and potentials on many more, productive activity and resource use is likely to intensify as competition increases. With increasing crop production, even with growing use of chemical fertilizers, the gap existing between removal and replenishment of nutrients through conventional methods will only go up. The depletion of soil nutrients both through crop uptake and nitrate losses[iii] (Singh and Kansal, 1994) will exert additional pressure on feedstock resources and productive capacity of agriculture. Lastly, the global market is also becoming health conscious leading to the growth of a market of branded organic products and India's consumers cannot be left behind. India too needs to strengthen her efforts to reduce chemical residues in food products coming through use of agro-chemicals for both domestic use and exports.

1.4 Need for a New Strategy

The failure of the new technology that involved high doses of chemical fertilizer to attain global heights and to spread evenly has been a matter of concern. However, recognizing that fertilizers are inherently costly and beyond a point injurious to soil health, and keeping in view the agro-climatic diversity and the poverty prevailing in Indian agriculture as also the changing attitudes and preferences of today's consumers, the same shortcoming can in fact be exploited as a strength. A review of the modern and traditional methods of soil enrichment highlights the merits and demerits of both especially in the light of current national, global and rural realities. A judicious combination of both would provide a possible solution. The term 'judicious' is subjective and depends on the objectives of the government and the farmers, the weight to be attached to each objective. With diversity in resource and agro-climatic condition facing the farmer a combination that may judicious for one case may not be so for another. What is desirable is that the strategy should not come at the cost of economic losses to farmers and possibly, it should not compromise on production and food security also.

To understand the implications of a change in strategy it is pertinent to study the varying behaviour of farmers with respect to fertilizer practices and understand to the extent possible the underlying factors for the choice of these practices. These practices evolved under a distorted price regime and accompany certain other decisions relating to cropping patterns and input use. The regional conditions and availability of irrigation have a deep influence of such choices. The resource positions of farmers determining their access to inputs and the flexibility to use modern technology are important factors for individual farmers. Accesses to fertilizer through a sound infrastructure and the extension and propagation machinery help farmers to adopt chemical fertilizers though indigenous knowledge and experience still have their importance. The limitations of the market for organic manures, that has borne relative state neglect and the deep inter-linkage of this product with livestock and family routines in the rural economy have to be appreciated when considering a redirection of strategy. The constraints faced by this market coming from both demand and supply sides deserve their share of attention. On the commercial front, since fertilizers were promoted for their superior productive power the implication of a shift for reasons of market compulsions and long term sustainability needs to be studies with respect to possible impacts on production and returns. The strategy of using greater share of organic manure for soil fertilization can be adopted when the new technology can preserve production levels without bringing hardship to the farmers.

Apart from blending modern with tradition for achieving a desirable mix there is also a need to look for new technology that essentially serves the purpose of both without suffering from either of their drawbacks. The development of non-conventional inputs building up into an integrated nutrient supply system is considered imperative for several reasons. Manures, which improve soil health, suffer from low nutrient content and nutrient non-specificity, their sheer bulk, lack of organized market and institutional constraints. Fertilizers on the other hand are more productive in the short term but damage of soil health, leaching, pollution, inadequacy and the threat of rising prices are problems encountered. Fertilizer is based on mostly impost based non-renewable resources while manure though locally re-generable is still too inelastic in supply and is constrained by the land and livestock sector and rural institutional rigidities. Bio-fertilizers represent such an innovative experiment. Essentially organic in nature, they are constituted of the same microorganisms that render fertilizer and manure effective and harness nutrients available in nature for plant uptake. But like fertilizer they can be commercially produced in industry, are easily transportable and are renewable. If successful they can be immensely beneficial on Indian soil, which is generally deficient in nitrogen, and has low to medium content of phosphorous. With more than a decade of its trial though mostly in a rudimentary stage there is lack of farm level data giving any clue to the responses of the technology in any economic framework. Agronomic analyses however showed potential of this technology though the responses are yet to reveal consistency to make a firm conclusion. Like for any new product, bio-fertilizer industry has its start up and information problems but it has considerable promise to emerge as profitable business enterprise also.

1.5 Objectives

The changing perceptions about development and policy in today's world suggest certain unavoidable possibilities: (a) Indian agriculture cannot continue its excessive dependence on fertilizer for further growth, competitiveness and income security in agriculture, (b) There is a need to reconsider the merits of traditional organic-materials based technology and devise suitable blends of modern and traditional technology for soil enrichment and (d) Alternative and new inputs that avoid the drawbacks of chemical fertilizers and organic manures may be explored. This project addresses these issues through five distinct studies. The first two studies are introductory in character laying down the situation in the fertilizer sector and the manure economy in India. The first of these enquires (1) if fertilizer prices are likely to be affected as the economy opens up to global competition and (2) if fertilizer consumption in agriculture may be affected by these price changes and concludes that there is a cause of concern and a search for a new path in necessary. In the second introductory study, the use of organic methods in India is discussed considering the different alternative techniques, the importance of farm yard manure, the limited and local institution based market and the steps that have been taken by the government to promote and facilitate organic methods and organic farming in particular. It has been suggested that a 'judicious' combination of chemical fertilizer along with organic manure may be an answer to the situation though the financial implications of a shift towards organic manure raises a question mark. This issue is taken up in the following study that enquires (1) if manure can technically substitute for chemical fertilizer, (2) if a move away from fertilizer and possibly towards manure would mean financial gain or loss on the average at prevailing prices and to what degree the gain, if any, can be sustained if manure price responds to the increased usage and (3) if there is a distributional implication of the incidence of gains or losses. Based on estimated yield functions and prices facing farmers with cross-section data the exercise indicates the financial feasibility of a small shift in a significant number of cases so long as the losing sections are compensated through policy and the manure prices are held within bounds by active measures on supply side. The manure market is not an organized one as opposed to a vibrant fertilizer market characterized by state support and promotion. Farmers' access to manure depends on their own resources and informal rural exchanges based on local information, bargaining power and ownership of assets like livestock whereas access to factory-made fertilizer is facilitated by government/

cooperative agencies and corporate sector. Subsidies, campaigns and private sector advertisement support the process. The actual fertilizer practices of farmers in terms of usage of fertilizer and manure impacted by these influences can vary greatly due to the influences of their socio-economic circumstances apart from the agronomic considerations all of which determine the cost and benefit of input use in the farmer's perceptions. The third study attempts to study the fertilizer use practices of farmers through examination of cross-classified data and through a multi-nomial logit analysis. The results suggest that although with given crop-patterns, agronomic diversities including irrigation and the asset ownership configurations, the small and bigger farmers both tend to use fertilizer, but after correcting for other factors, the smaller farmers are found to be less likely to use the conjunctive use of fertilizer and manure. Finally the last study examines the progress with the promotion of new inputs Bio-fertilizers that can enrich soil alongside chemical and organic means but without suffering from some of the shortfalls of the latter and finds that though the progress has been slow there is a need to proceed with suitable policy measures to look for success.

1.6 Organisation of Study and Information sources

The study has three main components written in Chapters 4, 5 and 6. The current chapter is the introduction, which is followed in Chapter 2 by a backdrop to the studies provided by an overview of the fertilizer sector in Indian agriculture and its possible tribulations, the problems raised on whose premises are addressed by the technologies under study. Information published and provided by the Fertilizer Association of India (FAI) has been used. The less researched topic of using organic manures in Indian agriculture is addressed in Chapter 3 based on information provided by the Ministry of Agriculture on its recent policies and estimates, published and reported data on cost of cultivation and insights received from actual cultivators who operate as land holders, tenants or small farmers in various parts of the country. Chapter 4 considers the financial feasibility of altering the input mix currently in practice giving precedence to protecting the financial returns of farmers through yield functions based on household level data on Cost of cultivation of principal crops given by the Ministry of Agriculture on select crops and select states separately. In Chapter 4 household level categorical data provided by NSSO 54-th Round is analysed to look at fertilizer and manure use practices and their conjunctive uses by attributes like class, region, crop and use of other inputs. The Study on Biofertilizers reported in Chapter 5 is constrained by farm level data but in this case the success of this state-supported technology till date is assessed through the indirect indicator of the industry's performance revealed by FAI data in disseminating and commercializing the technology.

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[i] Nitrate per se is non toxic but converted to nitrite in the intestinal tract can interfere with oxygen carrying capacity of blood in some animals and human infants ('blue baby syndrome').

[ii] Eutrophication refers to a process of enrichment of surface water bodies with nutrients resulting in intense proliferation and accumulation of algae and higher aquatic plants in excessive quantities with detrimental changes on water quality, marine life and human consumption.

[iii] Different forms of nitrogen added in organic or inorganic forms are quickly mineralized in NH4+ and then to NO3- the conversion rate being fast in tropical and subtropical cultivated soils. Depending on the rate and method of application, the kind of crop grown and soil-climatic conditions 35-60% of applied nitrogen is usually recovered by crop plants, 10-20% may be converted to N_2 or other gases and volatalize into atmosphere and part of remaining N may move below the root zone and into ground water or be lost with surface run off and soil erosion.

Chapter 2

Fertilizer based Agriculture in India: A Background

Liberalisation and globalisation of the economy on the one hand and growing concerns about ecological damages and the sustainability of development on the other necessitates a realignment of emphases in favour of privatisation, fiscal prudence, free competition and eco-friendly technology all of which impinge on the fertilizer sector and impel a re-look at the fertilizer based agrarian strategy being followed in India. The long term and radical challenge to the sector lies in exposing Indian agriculture to the realities and vagaries of the global economy. In this chapter a review of the fertilizer economy of India will be made focussing on the following issues: (a) Progress in Fertilizer supply and Policy through time (b) A survey of usage of fertilizer by farmers and (c) Agricultural development and an exploration of alternative.

2.2 Policy directions for fertilizer supply

As in the case of any new product, which promises longer-term social gains, there was a case for infant industry protection via state intervention in the fertilizer sector. The socialist spirit of the time was an added force. Although the sector was open to private players, direct production in public and so called cooperative sector enterprises was taken up in addition to promotional campaigns at the farmers' end, subsidisation and import canalisation. The result was a phenomenal growth in production and consumption of fertilizer and growth in food grain production that ushered a period of self-sufficiency[i].

This phenomenal growth was possible despite the fact that India was intrinsically deficient in chemical fertilizer under available technologies. While demonstrations, campaigns and learning over time made farmers eager to adopt the technology, the industry side policy was no less important. Though a free trade policy could have been an option, the government restrained farmers' free access to global supplies of fertilizer by canalising imports. This compromise was accepted for the sake of a long-term strategy to encourage the domestic industry (Appendix 1 Note 3) to invest in the fertilizer sector. In other word, domestic self-sufficiency was an obvious aim.

Table 2.1.: Fertilizer Use iin India (NPK)				
Period	Production	Consumption	Import	Cons/Ha.
Triennium Average	('000tonnes)	('000tonnes)	('000tonnes)	(Kg/Ha.)
1976/77-78/79	2653.80	4271.23	1519.20	24.84
1981/82-83/84	4354.00	6721.30	1509.63	38.11
1986/87-88/89	7723.33	9489.80	1624.60	53.67
1991/92-93/94	9573.30	12416.30	2968.03	67.20
1996/97-98/99	12668.43	15764.51	2917.30	83.20
Year 1990s				
1995-96	11362.30	13876.10	4118.80	74.02
1996-97	11171.00	14308.20	2041.40	75.47
1997-98	13159.20	16187.80	3530.60	84.94
1998-99	13682.10	16797.54	3199.90	87.21
1999-2000	14320.90	18068.80	4163.90	93.81
2000-01	14676.90	16702.3.0	2179.40	86.71
Source: Fertilizer Statistics				

However, the high price at which the infant industry could supply the input and the international price volatility stemming from fertilizer’s close link with the oil/gas economy might have discouraged use especially by smaller farmers. The Retention Price and Subsidy Scheme (RPS) was a method by which the government took the responsibility of making the fertilizer affordable to farmers while protecting the domestic industry (Appendix 2.1). The RPS came under increasing attack in the nineties because of the subsidy burden (Table A2.1) imposed on the budget and its complex nature which translated to inefficiency on the production and consumption sides and inconsistency with WTO commitments. It is difficult to underestimate however the seriousness of impact that any new policy might have. The adversity of this effect on production levels and incomes can mean poverty, privation, migration, social and political unrest as also poor demand on industrial front too. The policy transition therefore takes a gradual and calculated course to minimise losses on any front and accompanied by a search for innovative and alternative strategies. Following the recommendations of an Expenditure Reforms Commission, the RPS is giving way to modified regimes to face the world economy (Appendix 2.2).

The steps taken to free the fertilizer market of state controls on the farmer since 1991 have been interrupted by vigorous political resistance and political indecisions. The decontrol of P and K fertilizers was undoubtedly a landmark reform in the fertilizer sector. Urea the most important nitrogenous fertilizer is still controlled and the industry is protected by canalised imports and the RPS now under modification. Urea still lacks a tariff binding but tariff would soon be the most compatible way to face the market in the post reforms and WTO committed era (Jha, 2001).

Table 2.2: Nutrient content, Share in nutrient supply in country and Policy scene for Fertilizers

FERTILIZER (NUTRIENT)	NUTRIENT CONTENT%	NUTRIENT SUPPLY %	POLICY
UREA (N)	46 (N)	63 (N)	RPS STATE TRADING GROUP BASED CONCESSION
DAP (N,P)	(18,46)	53 (P)	DECONTROLLED CONCESSIONS
MOP (K)	(60)	65 (K)	DECONTROLLED CONCESSIONS
Source : FAI			

3. Progress in Fertilizer use: A survey

The fertilizer use practices in India evolved through ancient times with a structural-break taking place when green revolution was launched. Traditional technology relied on organic methods for soil preparation and enrichment. With introduction of HYV seeds and initiation of active state policy there was remarkably fast diffusion of the use of chemical fertilizers. The state helped the process not only by its subsidy and trade policies but also through extensions and active distribution network. Both the cooperative sectors and the private sector worked hand in hand to distribute fertilizer through almost 2.8 lakh sale points in the country (FAI, 2.001-02) with the cooperatve and other institutional agencies having around 30% share in distribution. According to a study by NCAER a farmer is normally with 5 Km of a distribution point. From a minimal level of practice, (Vaidyanathan, 1989) the use of fertilizers spread to more than 70 % of cultivated area. The importance of organic manure was however still recognised but with overwhelming focus of chemical means the practice (Table A2.3) remained stagnated and unsung.

The success of the green revolution rested predominantly on the superior response of HYV seeds to chemical fertilizers and likewise, the shortcomings in the dissemination of the fertilizer based technology are also associated with the imbalances created by and largely discrediting the green revolution. The most insightful analysis of the spread of fertilizer technology in Indian agriculture conducted by Vaidyanathan showed that about 2/3 of fertilizer was cornered by irrigated areas and most notably by the two superior cereals rice and wheat. There are wide spatial differences in fertilizer use with the west ranking low at 59.5kg/ha compared to the 128kg/ha intensity in north. The hill areas, most notably the north-east have shown less preference for fertilizer–based technology whether arising from supply constraints on account of poor transport and infrastructure or due to the inherent character of the hill ecology which is fragile, demanding as also endowed in organic substances and critically interacting with the plain system through drainage and erosion (Sharma, 1980, Chand, 1997). From the eighties and especially in the Ninth and Tenth Plans, the emphasis in agrarian policy has been more on crop diversification, rainfed cropping and greater spatial spread of technology particularly towards the east.

Annual data reported by FAI tells us that fertilizer consumption in India rose from a low level of 70 thousand tonnes in 1950-51 to nearly 17 million tonnes half a century later and the intensity of use which was only 0.55 kg in 1951-52 went up to 16 kg in the mid 1970s and then increased by another 74 kg by 1998-99. However the nineties decade have witnessed a slow down in the growth rate of fertilizer use to 4.3% from 8% in the eighties and 10% in the seventies. More detailed view of practices across crops and farm classes is not easy. Mostly one has to rely on survey data as and when available. The most carefully designed survey is done by NSSO though countable few (The 5th and the 7th rounds in early 1950s followed by the 8th and 11th rounds that enquired about input use including manures and in the seventies the 26th and the 31st rounds reporting on use of chemical fertilizer and after a long gap the 54th round with reference period 1997-98). An alternative source is the All India Input survey (AIIS) as a follow up programme to the five yearly Agricultural census, the latter being a part of international obligation for world census of agriculture programme of the FAO.

The last report of the AIIS and the fourth in the series has reference period 1991-92 (July-June) and the latest survey with reference period 1996-97 is yet to report. Surveys conducted by NCAER 1975-77 and 1988-90 help to fill in the gap left by NSSO, though not entirely comparable in design and methods.

Possibly more relevant for the basic stability of the economy is the question of practices within the farm hierarchy. Any policy decision on fertilizer pricing becomes unquestionably difficult to implement to the extent it impacts the incomes of the smaller farmers even if in the short term because these small/marginal farms constitute about 80% of the agricultural holdings, a large section of the rural populace and a bulk of the poor in the country. Information available from AIIS and reported in Chapter 5 (Table 5.7) suggest that the fertilizer-based technology has been by and large scale neutral or even biased in favour of small farmers. NCAER's (1991) study based on its own survey too corroborates the findings suggesting that input intensities of fertilizer are higher in small farms although the diffusion and adoption rate are less. Once the constraints to adoption are overcome the small farmers have the ability to farm more input intensively. This reason as suggested by NCAER and also Sharma (1980) could be the greater share of irrigated acreage with small farmers and the positive effect of irrigation on fertilizer use. In any case, fertilizer spread itself is possibly not subject to a class bias even if this is causally linked to other aspects of farming. The use of fertilizer has been noted as universal barring a few states as in north-east and relatively limited in the kharif season. The survey also found some degree of crop bias mostly going against non-food crops like coarse cereals and pulses. Lack of awareness is stated as the main factor behind non-use though soil, credit and failure of timely availability are also responsible to some extent. The cooperative sector is found to be of greater use for larger farmers while smaller ones depend on private agents.

4. Fertilizer Policy and Globalisation

The fertilizer sector, which has been one of the most protected one in the economy, now confronts the globalisation process pervading the economy and world. The epoch started with India's signing of the Agreement on Agriculture in the Uruguay Round of the WTO in 1995 in which India committed to face and offer global competition. Fertilizer sector faces several contradictions on both the production and consumption fronts and the latter in particular provides severe challenge to the government in power. The ultimate globalisation of the sector would mean that not only the fertilizer producers but also the farmers as consumers would have to face the world prices. The question then arises whether farmers would find fertilizer affordable under free trade or require protection. The second question, which raises further questions on food production security of the country, relates to the possible responses that these prices would evoke from the input users.

Figures 1 and 2 represent the possible course of fertilizer prices in recent past, dismantled of any direct or indirect protection through the actual over time movements of C&F prices of urea, DAP and MOP with and without the reinforcement of exchange rate fluctuations (using prevailing exchanges rates). The fluctuations and trend in international prices and those in exchange rates may mean that Indian economy might have to brace for higher input prices.

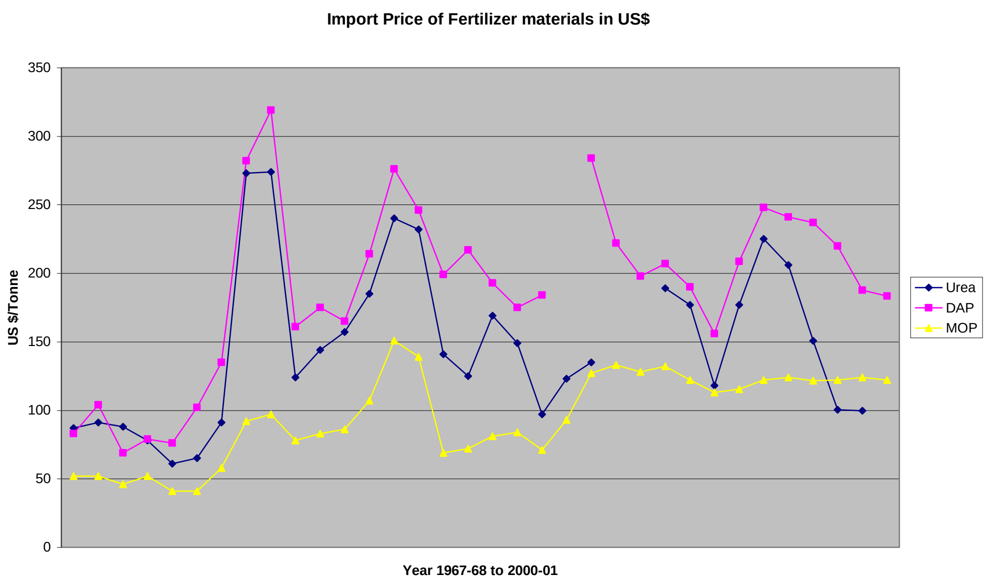


Figure 2.1

Note: The discontinuities in graph relate to years when imports were not made.

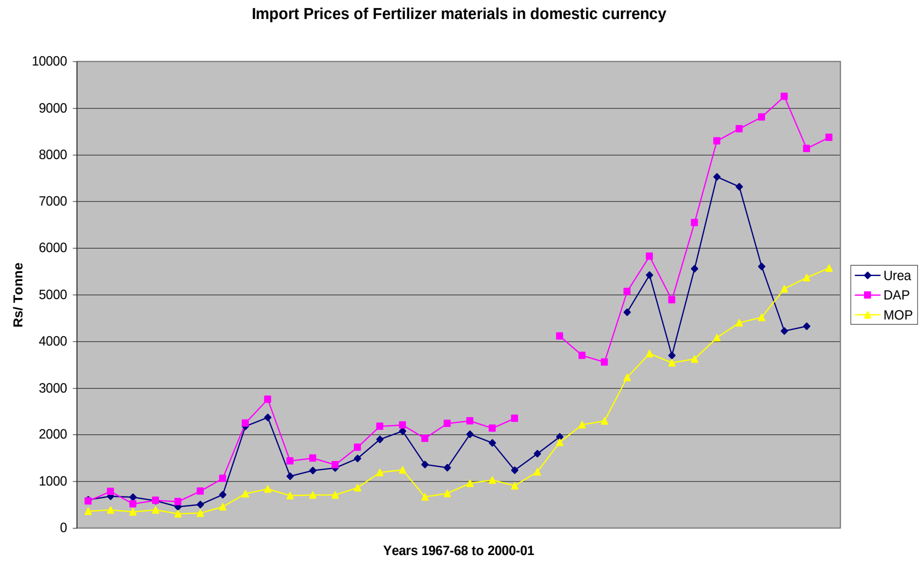


Figure 2.2

Note: As in Figure 2.1

How do the international prices compare with the administered domestic prices faced by farmers? Using prevailing exchange rates and the standard conversion of fertilizer to nutrient (FAI), a comparison can be made between C&F and domestic prices of fertilizers. Calculations presented in Table 2 (Ghosh, 2002) shows that for each of the main three nutrients, the farmer would have to make higher allotments and hence possibly reap lesser returns than they actually did if they operated in an opened up economy. The import prices to domestic prices ratio indicating the protection enjoyed by farmers in a still closed economy exceed one on average and in each case.

Despite simultaneous globalisation in grain market, India still cannot underestimate the objective of food security. The impact would come from responses to the price changes in terms of changes in input use. The concern has often been down played on the supposition that non-price factors such as distributional facilities are more important than price in influencing fertilizer consumption. While cross section data on fertilizer prices would not throw up significant variation due to the very nature of the pricing policy, pooling cost of cultivation data on input use and price of fertilizer over a number of years in the nineties between 1990-91 and 1997-98 and across major states[ii] provided regression estimates with broad region dummies of the following form:

$X_{st} = b_0 + b_1 p_{xst} + b_2 D_s + b_3 t$….. 4

Table 2.3 : Calculation of Farm-gate Fertilizer Nutrient prices and Comparison 1998-99 (Rupees per Tonne)				
Fertilizer/Nutrient				
Fertilizer	**Urea**	**DAP**	**MOP**	
Import Price ($)	100.41	219.88	122.00	
Import price (Rs)	4224.25	9250.35	5132.54	
Farmgate Import price (Rs)	5316.25	10342.35	6224.54	
Domestic sale price (Rs)	3660.00	8300.00	3700.00	
Nutrient	N	P	K	NPK
Import price (Rs)	11557.06	17961.04	10374.23	13030.91
Domestic price (Rs)	7956.52	14930.06	6166.67	9521.65
Import price/Domestic price	1.45	1.20	1.68	1.37

Source: Computation based on FAI data. Note: (i) Average Exchange rate was Rs 42.07. (ii) Farmgate price includes handling charge inclusive of freight at Rs 1092. No import duty was levied in this year. (iii) Sale price is statutory maximum price of urea under RPS and uniform sale price of DAP and MOP .(iv) Fertilizer prices are converted to nutrient prices (Table 2.2). (v) Domestic sale price includes concessions (Rs4400 for DAP and Rs3000 for MOP). (vi) Weighted by consumption shares.

where X is use of tradable input fertilizer (FRT) per hectare, p is relative (to output) price of the same input, D is region dummy, s is state, t is year and b_i are parameters of which b_1 is the response. The estimate gives a significant parameter and suggests that a price rise is likely to bring a cut in fertilizer usage. An analysis by Sharma and Sharma (1999) based on time series data from 1966-67 to 1996-97 and using non-price factors brought out similar indications.

Table2.4 : Estimated Regression Equation for Fertilizer Use (for Yield Adjustment)					
Dependent variable = FRT					
Variables	Constant	Time	P-f	Rsq	Obs.
Parameter	116.75	3.76	-35.25	0.72	36
	(2.73)	(1.42)	(1.80)		
Shifts					
East	28.11				
	(1.35)				
South	137.31				
	(5.79)				
North	105.54				
	(6.69)				
Note: Estimated linear regression equation. Data: COC. Source:Estimated					

Agricultural Development and the case for a new input strategy

The fertilizer based and input intensive agricultural strategy has largely been successful in increasing production and yield levels (Table A2.2) of crops and bringing a semblance of food security. Even in the context of globalisation, there arises a greater prospect of export potential than a concern for food insecurity. However by the mid or late eighties several adversities also emerged mostly in the form of the so-called soil fatigue resulting from too much use and extraction from soil. The crop and input use patterns that had evolved through years in consonance with the diverse agronomic conditions and the requirements of the population, responded to the government policy on food and inputs that came to provide a distorted signal. Even if domestic policy changes trade liberalisation may create a similar distortion by encouraging an intensified search for short run gains. Further thrust on some superior crops demanding high input use at the cost of crops that are adaptable to local conditions and indigenous inputs can be extremely injurious to competitiveness in the longer term. Besides, the competitiveness would itself erode if input prices become unaffordable.

The replacement of soil nutrients through chemicals cannot compete with the depletion from crop growth and a large gap between removal and replacement is inevitable. With increasing population and struggle for global competitiveness this is hardly likely to stabilise or subside. The green revolution seems to be at saturation in the leading states and there is thus a need to focus attention to eastern and other lagging parts of India while regaining any lost ground in the successful areas through suitable orientation of cropping and resource use patterns. At the same time, the fiscal considerations of the government and the international economic regime are binding compulsions for a departure.

The need of the hour is to evolve a sustainable agriculture that can provide growth impetus and competitiveness in years to come while protecting the interests of the poor and vulnerable sections of farm community. This would call for well-designed land use pattern through suitable crop choice and resource use. In view of the ecological hazards now in view and the trade related restraints on fertilizer use, there is a case for exploring other alternatives that can be used along with chemical fertilizer for best results. This would add up to a yet new agrarian technology in India in current situation that promise growth with social acceptability

Appendix 2
Notes

2.1.The RPS and Fertilizer subsidy

The Retention Price and Subsidy Scheme (RPS) was first adopted in November 1977 for urea following the suggestions of the High Power Fertilizer Pricing (Marathe) Committee. Triggered by the global oil crisis, it aimed to make fertilizer available to farmers at favourable prices on the one hand and to provide adequate incentive to the domestic fertilizer industry on the other. The RPS, which was later extended to other categories of fertilizer, assures a retention price to the producer to cover their normative cost and at the same time notifies a statutory sale price or farm gate price uniformly throughout the country. The difference adjusted for freight rate and dealer's margin is paid as subsidy. The subsidy has been increasing over the years partly because the farmgate price of fertilizer has not adjusted to the feedstock prices and partly because the scheme kept the fertilizer industry protected and generated inter-government transfers in the name of farm subsidy. The RPS is viewed incompatible and inconsistent with present times. Under the WTO commitment, urea units are to compete freely by 2006, which prompted the Expenditure Reform Commission (ERC) to be set up in 2000 and review all non-developmental expenditures of government.

2.2 The Expenditure Reforms Commission and the New Pricing Policy

The Expenditure Reform Commission (ERC) set up in 2000 reviewed all non-developmental expenditures of government and recommended a phased deregulation of fertilizer prices as follows: (1) The RPS is to be replaced by a Group based Concession scheme. The rates of concessions will be worked for urea units classified into groups based on nature of feedstock and other factors. The feedstock is to be available at import parity prices. The concessions will be gradually reduced as efficiency improves. (2) All non-gas based plants are to consider modernising and switching to LNG. (3) There will be 7% increase in urea price in real terms every year from 2001 April. (4) Distribution control mechanism will have to go. (5) The industry will be fully freed in 2006 and be able to compete with imports with very little protection. (6) There will be a dual pricing scheme to protect small and marginal farmers.

The recommendations are still debated with difficulties arising on both industry and farmer sides. The RPS is expected to give way to the group based concession scheme from 2003 based on the recommendation of the ERC. This will apparently help the urea units to move in the direction parity with international prices based on the use of most efficient feedstock and state of the art technology.

2.3 Fertilizer Industry

A strong fertilizer industry was sought to be built up by the government. Energy comprised 55-80% of energy cost of production but the feedstock was a domestically scarce resource. From the beginning the choice of feedstock and technology of units was based on time specific availability of feedstock and technology and the strategic consideration of the country all of which undergo gradual changes over time. As a result the preference shifted from naptha to fuel oil to LNG and then to gas. The phenomenal discovery of gas in Krishna-Godavari basin will bring further changes and can help the industry significantly in future. So long as the industry relies on imported hydrocarbons there is a cry for protection. The industry has all along been supported by differential concession on the price of hydrocarbons as against other users but with liberalisation and dismantling of APM the price is now linked to import parity, which leaves more freedom in the hands of the oil companies of the country

(Fertiliser News) than the industry or the government. The industry is now coping with difficulties thrown up by the changing RPS, the freed and unregulated feedstock pricing regime and the largely unchanging farmgate fertilizer prices.

Appendix Tables

Table A2.1 Subsidies on Fertilizer in India (Rs crores)				
	Imported Urea	Dsomestic Urea Urea	Decontrolled P & K	Total
1960-61	0	0	0	0
1970-71	0	0	0	0
1980-81	335	170	0	505
1990-91	659	3730	0	4389
2000-01	1	9480	4319	13800
2001-02	47	8257	4504	12808
Source: Economic Survey,2002-03				

[i] Though urea manufacture relied on indigenous naptha and fuel oil, these products having been essentially petro-products, imports were still important. Rock phosphate imports are essential for Phosphate is a domestically scarce resource in India. Potassic fertilizers (K) however continue to be imported as domestic production is not commercially viable on account of lack of raw materials and low demand.

[ii] The states covered are coverage (Ghosh, 2002) are Andhra Pradesh (AP), Haryana (HRY), Orissa (ORS), Punjab (PJB), Uttar Pradesh (UP), Madhya Pradesh (MP) and West Bengal (WB).

Table A2.2. : Area, Production and Yield of Major crops in States												
Crops/States	-----------	Rice	-----------	-------------	Wheat	-------------	----------	Groundnut	-----------	-------------	Sugarcane	------------
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
	('000ha)	('000tons)	(Kg/ha)	('000ha)	('000tons)	(Kg/ha)	('000ha)	('000tons)	(Kg/ha)	('000ha)	('000tons)	(Kg/ha)
Andhra P	4316	11878	2752	12	6	500	1992	2155	1082	214	16503	77117
Assam	2420	3254	1345	90	90	1010				29	1155	39677
Bihar	3639	5291	1454	2053	4292	2091	0.3	0.3	1119	92	3992	43391
Gujarat	622	1015	1633	701	1703	2427	1941	2578	1328	196	13566	69108
Haryana	1083	2425	2239	2188	8568	3916	0.9	1.1	1222	125	6880	55040
Himachal P	82	118	1435	377	641	1700				3	153	45000
Karnataka	1427	3657	2563	268	219	816	1230	1192	969	339	34771	102641
Kerala	353	727	2061				11	10	841	5.8	424	73155
Madhya P	1632	1385	848	4567	8255	1807	216	233	1078	36	1468	41120
Maharashtra	1483	2468	1664	1015	1308	1288	521	634	1217	530	47151	88998
Orissa	4447	5391	1212	4	4	1189	83	72	861	22	1469	65897
Punjab	2518	7940	3153	3278	14192	4330	6	5	833	103	6130	59515
Rajasthan	168	205	1222	2766	6874	2485	332	362	1091	23	1079	47700
Tamil N	2275	8141	3579				858	1570	1829	306	36020	117628
Uttar P	5576	10827	1942	8931	22781	2551	127	82	644	1862	109489	58796
West Bengal	5904	13316	2256	367	778	2117	30	35	1160	27	2001	74285
Source: CMIE												

Table A2.3 : Use of Fertilizer and Manure per hectare of area under crops in the 1990s.										
Paddy	Years	Fertilizer	Manure	Yield	Fertilizer	Manure	Yield	Fertilizer	Manure	Yield
Andhra P	1994-95,1995-96.1996-97	179.21	39.75	47.73	165.35	35.03	45.12	185.89	39.37	47.04
Assam	1994-95,1995-96.1996-97	1.54	1.99	20.50	2.53	3.39	21.47	1.84	1.38	21.01
Haryana	1992-93,1994-95.1996-97	167.54	5.60	36.48	216.30	0.00	38.21	185.00	8.85	43.44
Madhya P	1994-95,1995-96.1996-97	62.16	7.65	21.22	54.55	11.86	22.21	66.58	6.82	22.61
Orissa	1994-95,1995-96.1996-97	66.89	30.09	30.27	60.06	27.77	28.23	56.77	27.82	24.18
Punjab	1994-95,1995-96.1996-97	195.21	17.10	51.84	156.99	29.45	46.03	195.49	73.63	51.64
Uttar P	1991-92,1992-93,1996-97	72.93	4.25	29.75	90.07	7.38	28.85	104.38	15.49	34.02
West Bengal	1994-95,1995-96.1996-97	62.95	22.44	33.53	52.03	25.23	28.33	94.67	40.16	37.20
Wheat										
Gujarat	1993-94,1995-96.1996-97	130.67	1.27	24.99	125.11	8.08	25.22	117.62	3.73	28.85
Haryana	1994-95,1995-96.1996-97	159.42	0.00	38.56	174.37	0.00	38.85	178.37	0.35	40.80
Himachal P	1994-95.1995-96	30.39	27.43	13.60	44.42	39.42	14.08			
Madhya P	1994-95,1995-96.1996-97	78.44	0.26	18.22	69.52	0.16	19.38	87.39	0.15	18.09
Punjab	1994-95,1995-96.1996-97	203.18	2.58	39.41	203.66	14.92	36.06	220.17	10.07	43.48
Rajasthan	1994-95,1995-96.1996-97	72.20	1.63	33.71	66.91	3.82	31.05	109.78	8.04	32.06
Uttar P	1990-91,1995-96,1996-97	114.30	3.11	26.43	134.08	6.92	29.55	133.01	7.36	32.43
Groundnut										
Andhra P	1994-95,1995-96.1996-97	31.99	30.45	6.92	49.43	30.20	10.45	51.62	19.19	9.03
Gujarat	1994-95,1995-96.1996-97	68.90	14.68	10.46	52.73	35.95	6.75	51.14	35.20	11.33
Maharashtra	1994-95,1995-96.1996-97	32.26	21.82	8.73	26.80	32.99	10.37	34.11	16.36	9.57
Orissa	1994-95,1995-96.1996-97	44.14	20.91	12.93	42.38	22.95	12.13	54.48	18.03	11.25
Tamil N	1994-95,1996-97	38.62	34.10	14.46	69.11	26.10	15.26			
Sugarcane										
Andhra P	1992-93,1994-95,1996-97	336.42	19.87	796.88	208.85	17.35	783.04	219.06	36.54	816.01
Haryana	1992-93,1995-96,1997-98	125.73	14.31	455.82	114.43	7.46	535.32	114.52	0.00	517.15
Karnataka	1994-95,1996-97	358.48	22.33	847.13				316.10	17.96	902.13
Maharashtra	1994-95,1995-96.1996-97	445.97	12.27	812.85	465.78	30.88	860.89	251.05	11.15	705.53
Uttar P	1994-95,1995-96.1996-97	169.55	8.39	480.82	156.26	2.54	469.51	175.07	25.13	479.51
	Average	287.23	15.43	678.70	236.33	14.56	662.19	215.16	18.16	684.07

Note: Fertilizer in kilogram of nutrients, Manure in Quintals in bulk, Yield in Quintals.
Source: Cost of Cultivation of Principal Crops

Chapter 3

Use of Organic Methods in Indian Agriculture

During the first half of the twentieth century the dependence of agriculture on traditional means of soil fertilization was nearly total and chemicals were used only in pocket of commercial plantations of cash crops. Such methods generally involved either application of external inputs such as animal refuse, mostly cow dung, animal bones and vegetal matter like stalks of sun-hemp for soil fertilization or use of indigenous and nature based cropping practices like rotations, fallowing and shifting cultivation as in forest and hilly regions. As long as pressure on land to produce food was relatively low and no chemical technology was available at hand the system could serve its purpose. The drive to boost food production began even during the British Raj but the food problem turned to a crisis shortly after independence and the need for a new technology that could dramatically improve food output from land became urgent.

The success of HYV seeds for foodgrains during the 1960s owed greatly to their ability to remove higher amounts of nutrients from soil for quick growth. This could be effective with the application of adequate external nutrients to soil. Organic manure, with low nutrient contents alone could not have accomplished the green revolution unless possibly if applied in unmanageable doses. Besides manures being complex compounds, needed to be broken down for absorption by plants, a time consuming process in which the ambient soil temperature and moisture content were important factors. Lower temperature slows down decomposition and high temperature and period of dryness hinder the process of mixing organic material in the soil through human or animal labour. All this set natural limits to the ability of organic methods to satisfy the nation's needs. The nutrient specific and water-soluble chemical fertilizer came in useful in harnessing the potentials of HYV seeds and the first urea plant set up in India in 1959 initiated a new course of development in Indian agriculture.

A socialistic spirit guided the path to economic development in India for several years. Although agriculture was in private hands, the actions of farmers were also largely directed by state policy. The state intention to promote fertilizer use in agriculture through persuasive methods as well as powerful tools in the hands of the nation state and the farmers' fervent reaction to the policy can only be judged favourably under the then prevailing circumstances of scarcity. During the period 1950-51 to 2001-02 production of foodgrains increased by 315% while area rose only by 26%. The impressive rise in yield levels brought about by the modern inputs, most prominently chemical fertilizers could make this happen. But perhaps along way, the merits of traditional methods lost some of their shine and the consequences of that loss became visible when the economic system one again changed, this time from a controlled to a market oriented one and the green revolution started running out of steam.

Several shortcomings of the fertilizer-based technology were becoming apparent since the eighties. Despite all promotion, fertilizer use intensity remained low relative to those of many developed and even some developing countries. Consumption remained mostly confined to irrigated regions with rainfed areas that are predestined to dominate Indian agriculture getting a meagre share of 20% of fertilizer consumed in the country. The hill regions hardly responded and formed a large part of the 71 districts that still consume less than 25 Kg/Hectare of fertilizer in contrast to 171 Kg/Hectare in Punjab state and an all India average of over 91 Kg/hectare. The limitations of the state machinery, poverty of farmers as well as the agronomic and social realities all served to retain the disparities. The inefficiency of fertilizer use also became a concern when increasing use of valuable fertilizer did not result in expected gains in yield. Non-proportional and indiscriminate use relative to agronomic needs reported in some parts of the country raised questions on sustainability of agriculture. Concerns about nutrient imbalances and soil deficiencies related to NPK, sulphur, zinc and molybdenum are widespread. Too much reliance on chemicals led to depletion of soil organic contents not only undermining the quality of soil but also limiting the potentials of chemical fertilizer. Nitrate pollution of ground water as per WHO's minimum norm of 10mg/litre is threatening to become a reality in pockets of high fertilizer use with water samples exceeding the permissible limits reported in specific cases. Finally, to make fertilizer cheap and affordable to farmers increasing cost burden has weighed down on the union budget, coming not only out of subsidies to farmers but also those meant to keep a domestic industry dependent at least partly on imported materials, alive to serve the agriculture. It is increasingly apparent that the price of fertilizer cannot be held in check for long and that further growth in agriculture can be expected from the excessively fertilizer demanding technology only at the peril of higher cost, dwindling returns, worsening of rural poverty and greater ecological threats in terms of long term productivity and pollution of water and air. There is now a case for revisiting traditional technology to draw support for the modern one.

3.2 Organic manures

Organic soil fertilizers can be derived from various vegetal and animal wastes. The most commonly used organic fertilizer is the farmyard manure (FYM) in which cattle dung constitutes the major source of nutrients. FYM, as its name suggests, is generally a home produced soil fertilizer drawing on wastes and residues from home or field. The ownership of livestock, primarily for milk or for draught is widely prevalent among rural households, both land owning or landless, allowing domestic production of organic manure. The quality of the FYM is highly variable and depends on the quality and proportion of the vegetal and animal waste matter it incorporates. In reality even this animal waste has its origin in plant nutrients as the composition of manure depends on the feed provided to the animal. With farmers operating under conditions of poverty and land scarcity, the stock of animals and the quality of feed is compromised with the result that unlike factory made fertilizer, the nutrient contents in FYM across the country and across households vary with every chance of there being a bias against the poor. The lower nutrient intensity also necessitates use of larger volumes of the bulky material. The mobility and marketability of the product is restrained by the bulk and usually FYM is procured from local supplies to the extent that homemade resources are not sufficient.

The success of organic manure depends on its decomposition by microbes. A most efficient way of achieving this is by composting in which any organic (or once living) material is processed under suitable physical and chemical conditions. Various substances can serve the purpose such as animal waste, wood, sugarcane trash, fruits and vegetable remains, coconut husk etc. calling for a suitable carbon to nitrogen ratio. Deviation of this proportion can be compensated by addition of other substances or chemical. Composting is a labour intensive process done in household or community pits/bins which can also be operated mechanically by 'Turning' the heap to facilitate aerobic process which is more effective than the often practiced anaerobic fermentation associated with excessive and inconsistent temperatures, wrong pH levels for microbes and bad odour (Miller and Jones, 1995). The thermophilic decomposition also destroys pathogens and weeds. Composts, as matters stand are based mostly on vegetal wastes and by virtue of the ingredients have a lower nutrient content than usually FYM, which claims most of the animal wastes and cow dung. However, there is substantial scope of improving the quality of FYM used in Indian through composting techniques.

Rural biogas projects meant primarily for fuel supply can also provide more nutrient intensive sludge fertilizer than FYM at nearly no cost (Reddy at al, 1979) because while delivering fuel from dung, nearly all the nutrient content of the dung can be preserved and used for crops. Other forms of organic fertilizers include oilcakes made from edible oils and non-edible oils such as castor and manures of animal origin like dried blood, fish manure, bird guano and bone-meal. Most of these inputs are high in nutrient content, can be procured from an organised market and are expensive.

Table 3.1 :Average composition of some organic manures (%)

Manure	Nitrogen(N)	Phosphate (P)	Potash(K)
Farmyard manure (bulky)	0.5-1.5	0.4-0.8	0.5-1.9
Compost rural (bulky)	0.4-0.8	0.3-0.6	0.7-1.0
Green manure (bulky)	0.5-0.7	0.1-0.2	0.6-0.8
Oilcake (castor)	5.5-5.8	1.8-1.9	1.0-1.1
Oilcake (cotton seed)	6.4-6.5	2.8-2.9	2.1-2.2
Dried blood	10.0-12.0	1.0-1.5	0.6-0.8
Bone meal	3.0-4.0	20.0-25.0	0

Source: FAI

Various nutrient management systems have evolved in the country depending on the agro-climatic conditions, cropping patterns and practices and are actively studied by government and researchers. Incorporation of green manure and crop residue are traditional practices improving soil fertility and porosity depending on the cropping patterns and water availability of the region. Legume shrubs are important as green manures. Growing Sesabania (*Dhaincha*) during pre-rice fallow in only 60 days can save up to 60 Kg of Nitrogen per hectare in fertilizer application. Sunhemp and cowpea are possible other green manures that can be pre-sown and ploughed in for enriching the soil. The incorporation methods call for appropriate technology and desirable implements. Crop residues are however more often used as cattle feed in India and contribute only indirectly to soil fertility. Rotations are an alternative organic method. For example growing legumes such as cowpea and groundnut can transfer on an average 40 Kg of Nitrogen per hectare to the succeeding crop. Legume can also solubilise native phosphorus and mobilise lime. Apart from rotation, systematic methods like inter-cropping, sequence cropping and relay cropping are similar methods of drawing the benefits of particular varieties of crops and the acceptable method will be highly area specific. Bio-fertilizers in the form of micro-organisms like Rhizobium and Azotobacter constitute nature's method of soil nourishment and can be commercially used as a supplement to chemical fertilizer.

3.3 Markets for FYM and other Organic manures

Farmyard manure is the major source of organic manure in India. Although it is a home made blend of animal wastes and kitchen and field residues as opposed to factory made packaged chemical fertilizer, there exists, though small in size, a market in rural India for exchange of FYM. The market however is far from a formal or organised one. Local institutions and knowledge, local distribution of land and livestock and access to commons for grazing or collection and information and access to chemical fertilizers shape the market for manures. Agro-climatic and seasonal conditions also have some influence on both demand and supply sides.

The manure market is intimately linked with the livestock economy of a region. India has been the largest possessor of livestock population in the world. Conventionally animals have been reared in rural India for labour and milk and manure though useful, has been a by-product to the process. The predominance of agriculture and small farms in the economy and the agro-climatic conditions of the country emphasised the demand for animal labour especially where agro-climatic conditions made tillage difficult (Vaidyanathan, 1988) and mechanisation was a slow process to evolve. Stocks of animals held were disproportionately more compared to the limited fodder availability with the result that the quality of stock was poor. Religious sentiments also might have prevented reduction of stock. With time however the structure of livestock economy has been undergoing a profound change with mechanisation taking over and dependence on animal labour coming down significantly. For example the share of animal labour in operational cost has come down from 10 % to 3 % and from 5 % to less than 1 % between trienniums ending 1983 and 1997 for paddy cultivation in Andhra Pradesh and Punjab respectively. Correspondingly cost share on machine labour spiralled (Cost of Cultivation of Principal Crops, GOI). But on the other hand, changes in consumption patterns have made production of milk an important subsidiary or principal activity and as a source of income and nutrition in rural areas. The stock has moved towards milch animals and buffalo particularly in the north. Animal husbandry provides a significant supplement to income of the small farmers as well as the landless farmers and is a vital source of sustenance in hilly, tribal and drought prone regions where crop production cannot sustain a family. The maintenance of the livestock population however depends on availability of feed, which competes for land with food crops, calls for suitable agronomic conditions and draws on resources of the farm households. Manure is an incidental product of the activity and the factors conducive to quality milk usually apply to quality manure too.

The possession of livestock[i] is constrained by space and to some extent by land, which supplies fodder. The manure market is also linked to the land-livestock ratio. To the extent that land holding of a household is meagre as compared to livestock holding, there is likelihood to be a surplus of manure, which can be sold. Collections from common land could be a supplement to the feed or raw material though this is not a major source. The buyer analogously would be a household with higher demand for manure in relation to its home production. In general, farmers with little or no operational land appear to supply the bulk of the manure in market. The consumption preferences of the households and their fuel needs as compared to availability are determining factors for demand. Households with poor access to institutional fuel supply such as cooking gas or with preference for food cooked on traditional *chullah* for instance would be likely to have less of surplus wastes for manure. However, fuel use of dung becomes largely ineffective during the rainy season when drying is difficult and the trade off in use has a seasonal dimension. The demand also depends on the crops grown and agro-climatic conditions. The fragile and thin soils of hill regions need large quantities of manure application for soil maintenance (Sharma,1980).

The FYM is prepared in a household location called variously as *dher* in Punjab, *khatta* in Uttar Pradesh and *pogu* in Andhra Pradesh, where the animal excreta supplemented by household refuse and even cattle shed floorings are accumulated and decomposed. The manure is used throughout the year but the pile is usually cleared up before the onset of monsoon to start a new one. This is a time when supply is relatively copious. The manuring process associated with tillage calls for favourable conditions for decomposition of the organic material and mixing with soil in terms of pre-sowing incidence of temperature, rainfall and irrigation and the time constraint encountered in soil preparation before sowing a new crop. The incidence of vacant land and time for preparation depending on the climate and cropping pattern increases the demand for manure. On the other hand time constraint often calls for quick supply of manure resulting in use of inefficient and under-decomposed manure. The seasonal nature can therefore be area specific. Crops also vary by their demand for nutrients and their profitability, which reflect on the demand for manure.

The production and use of manure is a process integrated with the family routine anf members including children participate in collecting and storing manure. Since transportation is a problem the location of animals and the manure source with relation to family and hearth are of importance for the successful operation. The manure market is limited in size with only the surplus being traded and the exchange being largely on a door-to-door basis with no formal market infrastructure coming into picture. Since exchanges depend on local knowledge and informal guidelines and transactions are time constrained, the bargaining power of the buying or the selling household matter. The prices are influenced by the seasonality of demand and supply and by crops raised. The quality of manure varies widely and the prices fetched is a reflection of the nature of cattle feed used and skill and labour involved in preparation of the FYM as also the bargaining powers. All this is likely to induce variability in price across not only states but also crops and seasons and even households and data in Table A3.1 based on valuation by the Ministry of Agriculture's cost of cultivation data, show that manure price is more variable than fertilizer. Groundnut seems to face higher manure prices relative to other crops particularly in the south where the crop is raised as a rabi crop. Manure is reasonably cheap in Punjab.

The informal rural markets for manure have not been adequately studied despite the importance of this input in agriculture. Information based on discussion with farmer in various parts of the country show some variation in the institutions and significance attached to this market. In Punjab there is active buying and selling of household made FYM with the landless or small farmers dominating as sellers. There is a community-based and religious sentiment inspired institution of maintaining unproductive animals in *goshalas,* which also sell manure/dung to farm households. Another common arrangement for procuring manure is an arrangement with nomadic cattle owners periodically migrating from places suffering poor fodder supply. The farmer provides space or grazing facility for the cattle or remuneration in cash or kind in exchange for fertilization of the soil. By the accounts of a land-owner, a similar practice has been prevalent in Krishna district, Andhra Pradesh where groups of cattle herders locally called *Uttaradi* came in to provide manure to village farm lands. Increased mechanisation and greater appeal of packaged fertilizer however diminished such manure-based practices in the village over the decades. On the other hand a farmer from Alwar district of Rajasthan who has sown mostly bajra and grows some amount of vegetable and wheat with well irrigation in 2003-04, showed no interest in manure. The dryness of the region and the scantiness of fodder are possibly responsible for this indifference. Use of manure is however common in western Uttar Pradesh as remarked by a farmer who notes that the prevalence of buffalos with *murrah* breed in stock and use of draught power still necessary for certain operations in raising sugarcane, manure is not a constraint. However time is a constraint in land preparation and clearance of the stored dung. Abundance of water makes manure a relatively easy practice in West Bengal where a share tenant reported similar practices as elsewhere but a minimal dependence on purchases and importance of animal possession for milk, farm labour and manure. The accounts of a marginal farmer from Bihar is similar to the former and both highlight high cost of accessing tractors and purchased manure and even affording the chemical fertilizer that they do buy and use on field. Informal arrangements of manure sharing between landlords and tenants are not uncommon. All farmers using manure expressed their knowledge and appreciation of the valuable effect of manure on soil for most crops.

While there is little information to estimate the size of the market for organic manures, potentials and actual production/use of various organic matter have been recorded by the Government of India. The Ministry of Agriculture projects a potential to produce 500 million tonnes of FYM in the country of which the present utilisation is only 100 million tonnes. Much of the potential material is not exploited such as the uncollected animal and vegetal wastes from common lands and wastes from industry, crop and processing activities. The quality of the FYM used can be substantially improved by suitable composting techniques. Vermi-composting with earth-worms and decomposing with bio-fertilizers could be rich sources of nutrients from FYM. Further, 300 million tonnes of crop residues and 14 million tonnes of city refuse are available for possible composting. About 132 million tonnes of rural composts are produced and more than 2 million hectares are under green manure in 1996-97. The estimated availability of bio-gas slurry is 28 million tonnes about 10000 million tonnes of bio-fertilizers are used in the country.

3.4 Trend and tendencies in manure use practice

It appears that although the merits of manure use is appreciated by Indian farmers, the extent of use is mainly constrained by supply and by the availability of cheap and convenient to use chemical fertilizers in the market. Over time the practice of using manure have been impacted by the movements in the livestock economy and in the market for chemicals and in general by the farmers' access in both. Published data based on Ministry of Agriculture's periodic survey on cost of cultivation (coc) of principal crops (see chapter 4 for details) show that for paddy while fertilizer use per hectare has steadily grown through the last three decades, corresponding manure (FYM) use has been rather stable and in fact declined in Andhra Pradesh and Uttar Pradesh (Table A.3.3). The growth rates on a point to point basis is small even if positive, except Punjab, in contrast to fertilizer use which grew by more than 200% in each case. The share of each nutrient source in operational cost of farming also demonstrates divergence though the shares were comparably similar in 1970s and in fact manure had higher share in the eastern states Orissa and West Bengal. In all but Andhra Pradesh both shares registered an improvement in the first decade but declined in the 1990s. Andhra Pradesh showed a steady fall in share of manure in cost. In the 1990s the fertilizer share varied from 9% in West Bengal to 17% in Punjab in contrast to low and below 5% share of manure in all cases. The picture is similar for the other crops. The growth rate in fertilizer use is moderate for wheat compared to paddy which stared witnessing the technological revolution later and the growth is also absent for sugarcane except in Uttar Pradesh. Manure use decline for wheat, sugarcane and groundnut, one exception being Orissa. It may be noted however that manure, which is mostly home produced is valued at COC imputed price which is the price prevailing in the village. This price based on a supply-constrained market is likely to be higher than what is actually perceived by the farmer.

The COC data at household level for 1998-99 provided by the Ministry can throw some light on representative fertilizing practices in states and for four major crops in recent times. Such practices may be represented either by the different input mixes used or by the average intensity of use of each input. The sample data averaged over select states and crops only and summarised in Table 3.1 find that sugarcane followed by wheat rank high in the intensity of fertilizer use whereas groundnut followed by sugarcane lead in respect of manure**.** Wheat however ranks lowest in manure use intensity, which is considerably less than others but both inputs are used intensively for sugarcane. Groundnut that comes last in respect of fertilizer use intensity leads when manure use in considered. Fertilizer use intensity seems iniquitous among crops but that of manure hovers around 2 tonnes per hectare except for only

Table 3.2 : Statistics on Use of Fertilizer and Manure based on selected States sample

Crops	Unit	Paddy`	Wheat	Groundnut	Sugarcane
Manure use intensity	Qtl./Hectare	18.95	4.89	22.30	19.76
Manure Price(Bulk)	Rs/Qtl.	16.56	14.92	21.17	18.43
Fertilizer use intensity	Kg/Hectare	116.46	141.21	63.60	227.42
Fertilizer Price (NPK)	Rs/Kg	10.90	10.85	12.64	10.16
Price ratio (M/F)	%	422.02	381.98	465.23	503.88
Area	% of total area	53.21	30.65	11.21	4.93
Manure use	%	66.98	9.94	16.61	6.47
Fertilizer use	%	50.14	35.02	5.77	9.07
Coeff. of manure use	Ratio	1.26	0.32	1.48	1.31
Coeff. of fertilizer use	Ratio	0.94	1.14	0.51	1.84

Note: Coeff. of use is % of input used by crop divided by % of area under crop. Price ratio is based on manure conversion: 1tonne bulk equiv. 3.6 Kg nutrients (NPK). Sample states and crops: Paddy- Andhra Pradesh, Tamil Nadu, Kerala, Bihar, West Bengal, Assam, Uttar Pradesh, Punjab and Madhya Pradesh. Wheat- Bihar, Gujarat, Himachal Pradesh, Punjab, Rajasthan, Uttar Pradesh. Groundnut- Andhra Pradesh Karnataka, Tamil Nadu, Gujarat, Maharashtra, Orissa. Sugarcane- Andhra Pradesh Tamil Nadu, Maharashtra, Uttar Pradesh. Sample area under crops are used as weights.

wheat. Considering the crop shares in total, paddy as expected records the largest use of both fertilizer and manure while wheat comes second in fertilizer only. Sugarcane that has less a weightage in the crop composition has lower shares in both but groundnut claims much lower share of fertilizer than it does for manure or for acreage. Since the sample is limited in coverage of states, which also vary in cropping patterns, coefficients of input use for crops are computed, dividing the percentage of the input use in the sample states accounted for by a crop by the percentage of total sample acreage under the crop. A coefficient exceeding the value of unity would mean that the crop claims the particular input disproportionately more compared to its area and vice versa. Groundnut followed by sugarcane and paddy have high coefficients of manure use exceeding one, while only sugarcane and wheat take up more share of fertilizer than the share of area allocated to them. The coefficient of fertilizer use by paddy is close to one. Manure price is found way higher than fertilizer though it may be cautioned that going by NPK nutrients the computation does not capture other nutrients and benefits embodied in manure.

A more disaggregated picture across the sample states is available from Table A3.2. Manure use intensity for paddy on average is highest in West Bengal followed by Tamil Nadu and Andhra Pradesh with a value more than 3 tonnes per hectare, but falls short of 1 tonne in most states. For wheat, Himachal Pradesh is the only state where average manure use intensity exceeds 1 tonne but for groundnut and sugarcane the intensity is greater than 1 tonne in general and even exceeds 3 for groundnut in Gujarat and sugarcane in Tamil Nadu. For groundnut and sugarcane the use intensity of both inputs is similar among the states. Fertilizer also accounts for nearly all of the cost incurred in soil fertilization by the two means especially for sugarcane and wheat.

The choices of input mix across households between chemical fertilizer and organic manure in a distributional view can be specified by a simple categorization made on visual inspection of the data: (a) Low fertilizer and low manure (b) Low manure but high fertilizer, (c) Low fertilizer but high manure and (d) high fertilizer and high manure. *An input intensity of 10 units is considered as the cut off level below which input use is deemed to be low and otherwise high, where the unit is kilogram for fertilizer and quintal for manure.* The cut off level is decided by considering the actual distribution of the intensities over households. Sugarcane almost entirely constitutes of high fertilizer users and a large part of them also are high users of manure. The share of high fertilizer user households whether or not with manure is large for paddy, exception being the north-eastern hilly state Assam, where low external input use is a notable practice making up nearly 70% of households. For wheat however about 90% of households in four out of the six states report a practice of using low manure and high fertilizer, though Himachal Pradesh has greater incidence of high manure practice. Of the four crops studied groundnut shows relatively greater incidence of manure based practice and in the states Orissa and Maharashtra respectively 18% and 17% of households go for low fertilizer and high manure use. In the southern states Tamil Nadu and Andhra Pradesh low external input practice is observed for this crop. The low fertilizer but high manure use practice group is generally the thinnest except in the cases of groundnut and lone case of Himachal Pradesh for wheat. In the summary Table 3.3 Bihar has the highest portion of households that apply high fertilizer doses in paddy with poor conjunctive manuring (by Table A3.2 Bihar has lowest portion of households going for balanced or high level of manure use). Bihar also ranks lowest in manure intensity and the tendency is same for Bihar in case of wheat. In terms of cost crop fertilizer claims more resources than manure in all cases except the hilly states Assam (paddy) and Himachal Pradesh (wheat).

Table 3.3 : Dominant Practices of Soil Fertilization in States

	Dominant Practices (in terms of %Households)				Intensity of Use		High share M	Yield rate
	Low F Low M	Low F High M	High F High M	High F Low M	F	M		
Paddy								
1	MP	ASS	AP	BH	AP	WB	ASS	AP
2	ASS	MP	WB	UP	PJ	AP	MP	PJ
3	KRL	WB	KRL	PJ	TN,UP	PJ	KRL,WB	WB
Wheat								
1	RJ	HP	HP	PJ	PJ	HP	HP	PJ
2	HP	BH	GJ	BH	GJ	RJ	RJ	RJ
Groundnut								
1	TN	OR	GJ	MH	TN	GJ	TN	TN
2	AP	MH	KRN	KRN	AP	TN	KRN	GJ
Sugarcane								
1	MH	MH	TN	MH	MH	TN	-	TN
2	UP	UP	AP	UP	TN	AP	-	MH

3.5 Government efforts to promote Organic Methods

Organic methods are nothing new to Indian agriculture. These evolved since ancient times through experience and even today many farmers practice them in an unorganised manner. The concept of organic farming is now gaining importance the world over. In India too the concerns of sustainability necessitates relocating emphases on organic methods. If India is to embark on a high growth path in agricultural, livestock and agro-processing activities, the generation of wastes and their disposal problem will accelerate in cities and villages. Transforming agricultural technology in favour of organic methods could make use of these wastes and turn the menace into a gain.

Use of organic manures can have several advantages over chemical fertilizers. The waste products contain not only nutrients N,P,K but also other essential chemicals and micronutrients. The slow response imbedded in manure also means slow release, a definite advantage over the quickly used and lost or leached out fertilizer although soil microbes help to prolong the use in both cases by a process of recycling. Organic content in soil imparts porosity to soil, which is most important for providing space for air, water and root growth allowing the roots to breathe and permitting clear drainage of water while increasing the water holding capacity of soil. Apart from supplying necessary nutrients albeit in relatively small doses, it enhances the nutrient holding capacity[ii] and attaining the pH level of soil desirable for plants.

Although the government promoted and supported with subsidies the progress of the fertilizer based technology in India, the important role of manure has all along been underscored in policy and extension circles. There were public projects on compost pits, mechanization of the same and community and individual biogas plants since the seventies and eighties. The Ninth Plan emphasised sustainable development and judicious and optimum use of fertilizers and envisaged greater use of green manure and bio-fertilizers in states that used fertilizer intensively compared to national average. The Centrally sponsored Scheme on Balanced and Integrated Use of Fertilizers is implemented with an outlay of Rs 461 million aims to promote balanced use of mineral fertilizers conjunctively with compost, green manure and bio-fertilizers. The scheme aims to strengthen soil-testing facilities, set up mechanised compost plants and organise training facilities. Different efficient and modern methods of composting such as vermicomposting, NADEP composting and phosphocomposting are being promoted. Trials in Integrated Plant Nutrient Management Systems (IPNS) are conducted for further information on various types of conjunctive uses. An amount of Rs 11.57 crores has been spent during Eighth Plan and Rs 16.09 crores during Ninth Plan for the National Project on the Development and Use of Bio-fertilizers (NPDB).

With growing awareness of contaminated food and preferences showed by consumers in the developed world, a large market for organic food is emerging. It is estimated that the annual demand of organic food is worth US$ 35 billion with a growth rate of 10-3% (Government of India). Certain international guidelines on organic farming have been set. Keeping with the world trends and to tap the emerging export market India has also initiated a programme for organic farming as a specialised technique with specified norms. This is a holistic production management system which may be defined as " a production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives… and relies upon crop rotations, crop residues, animal manures, off-farm organic wastes, mechanical cultivation and biological pest-control to maintain soil productivity and tilth, to supply plant nutrients and to control insects, weeds and other pests" (U.S.DA.) Being a low chemical fertilizer consuming country especially considering the rain-fed areas and the north-east, India can take the opportunity for exports and domestic use. Although agriculture without use of chemical fertilizers might be less productive the premium fetched in the market for certified organic food can compensate for the loss and make the activity more profitable. As of now India possibly holds only 0.18% of global organic area[iii] and exports (2000-01) 0.002% of global export value. The Ministry of Commerce of the Government of India has launched a National Programme for Organic Farming (NPOF) assigning six accreditation agencies. In order to organise farmers to practice 'organic farming' the Ministry of Agriculture has formulated a National Project on Organic Farming with an outlay of Rs 100 crores to be implemented in the Tenth Plan subsuming in it the scheme the existing scheme NPDB and setting up a National Institute of Organic Farming subsuming the infrastructure of the National Bio-fertilizer Development Centre in Ghaziabad.

Appendix Tables

Table A3.1: Prices and Costs of Fertilizer and Manure							
	Sample average of Price		Coefficient of Variation of Price		Area	Total cost	Total cost
	Fertilizer	Manure	Fertilizer	Manure	Crop	Fertilizer	Manure
	(Rs/Kg)	(Rs/Qntl)	(%)	(%)	'000hect	Rs cr	Rs cr
Paddy							
Andhra Pradesh	11.55	13.00	10.39	53.31	4316.00	881.69	178.09
Assam	13.83	27.81	20.61	28.95	2420.10	21.55	22.08
Tamil Nadu	11.04	13.07	11.41	111.25	2274.90	466.13	100.50
Madhya Pradesh	10.11	35.58	17.51	32.15	2274.90	121.34	65.80
Kerala	11.71	53.64	14.60	56.34	2518.00	360.35	197.20
Bihar	9.89	11.93	14.56	32.77	3639.20	258.38	3. 60
Punjab	9.62	3.66	12.68	29.78	2518.00	413.76	24.03
West Bengal	11.73	15.84	10.74	54.23	5904.10	752.66	338.64
Uttar Pradesh	10.20	15.68	14.41	33.23	5575.70	713.75	57.09
Wheat							
Bihar	11.92	17.86	13.67	26.60	2052.70	302.33	11.84
Himachal Pradesh	8.98	14.68	20.38	45.44	377.40	14.07	15.37
Gujarat	10.71	9.87	11.58	53.09	701.40	97.21	2.00
Uttar Pradesh	10.96	18.26	11.04	18.67	8931.20	1387.04	48.60
Punjab	10.12	3.51	5.53	21.94	3278.00	664.10	6.14
Rajasthan	11.28	19.06	12.06	29.54	2766.30	310.32	48.09
Groundnut							
Andhra Pradesh	13.15	33.99	14.37	216.77	1992.00	178.20	109.35
Maharashtra	12.98	27.97	16.02	21.38	520.70	40.94	24.45
Karnataka	12.56	34.86	9.55	83.79	1230.00	103.15	61.10
Gujarat	12.60	11.40	8.25	29.21	1940.80	131.12	82.50
Orissa	11.06	19.89	19.35	3.92	83.40	5.41	1.77
Tamil Nadu	11.67	20.91	19.37	87.18	858.10	73.76	33.55
Sugarcane							
Andhra Pradesh	11.27	13.05	14.55	81.84	214.00	51.94	6.47
Maharashtra	11.32	28.44	8.30	44.06	529.80	207.90	19.98
Tamil Nadu	10.55	14.92	16.49	299.13	306.20	100.66	15.12
Uttar Pradesh	9.27	18.20	11.97	26.87	1862.20	312.54	64.46
Note: Coefficients of variation across households. Source: Computed (Data COC, CMIE)							

Table A3.2: Summary of Fertilizer use Practices of Households								
	Low Fertilzer Low Manure	Low Mnaure High Fertilizer	Low Fertilzer High Manure	High Fertilizer High Manure	Fertilizer per hectare (Mean)	Manure per hectare (Mean)	Fertilizer Share in Cost (Mean)	Yield per hectare (Mean)
	----------------------Percentage of Households-------------------				(Kg)	(Qntl.)	%	(Qntl.)
Paddy								
Andhra Pradesh	0.0	34.1	0	65.9	176.9	31.7	84.0	49.4
Assam	68.8	20.5	6.7	4.0	6.4	3.3	36.0	21.2
Tamil Nadu	0.0	53.0	0.0	47.0	185.6	33.8	85.0	46.9
Madhya Pradesh	5.1	48.1	9.3	37.6	52.8	8.1	61.0	18.1
Kerala	3.7	39.8	3.0	53.5	122.2	14.6	70.0	35.4
Bihar	2.2	94.4	0.0	3.4	71.8	0.8	99.0	23.5
Punjab	0.0	77.9	0.0	22.1	170.8	26.1	95.0	44.8
West Bengal	1.7	32.5	3.7	62.1	108.7	36.2	70.0	35.7
Uttar Pradesh	1.0	83.0	2.0	13.9	125.5	6.5	94.0	29.5
C.V.	2.4	0.5	1.2	0.7	0.5	0.8	0.3	0.3
Wheat								
Bihar	0.6	92.1	1.6	5.8	123.6	3.2	97.0	20.8
Himachal Pradesh	3.2	20.9	17.3	58.5	41.5	27.8	53.0	10.9
Gujarat	0.4	89.4	0.0	10.2	129.4	2.9	98.0	31.9
Uttar Pradesh	0.0	91.2	1.4	7.4	141.7	3.0	98.0	30.7
Punjab	0.0	92.6	0.0	7.4	200.2	5.3	99.0	40.7
Rajasthan	12.1	77.6	1.2	9.1	99.5	9.1	92.0	31.0
C.V.	1.7	0.4	1.9	1.2	0.5	1.1	0.2	0.4
Groundnut								
Andhra Pradesh	10.900	47.400	11.7	29.9	68.0	16.2	72.0	11.6
Maharashtra	8.800	57.500	17.5	16.3	60.6	16.8	75.0	10.6
Kanataka	1.800	47.700	3.6	46.8	66.8	14.3	72.0	7.5
Gujarat	1.700	38.300	10.2	49.8	53.6	37.3	66.0	12.9
Orissa	2.800	45.100	18.3	33.8	58.7	10.7	75.0	10.6
Tamil Nadu	11.800	44.500	13.6	30.0	73.7	18.7	63.0	16.5
C.V.	0.7	0.1	0.4	0.4	0.1	0.5	0.1	0.3
Sugarcane								
Andhra Pradesh	0.000	63.200	0.0	36.8	215.3	23.2	89.0	665.5
Maharashtra	1.200	81.000	1.2	16.7	346.7	13.3	93.0	814.5
Tamil Nadu	0.000	53.600	0.0	46.4	311.6	33.1	89.0	1034.7
Uttar Pradesh	0.400	66.300	0.4	32.9	181.1	19.0	89.0	485.2
C.V.	1.4	0.2	1.4	0.4	0.3	0.4	0.0	0.3
Computed from COC data (see Chapter 4). Conversion 1Qntl.= 100Kg= 0.1 tonne. C.V.= Coefficient of variation (based on simple mean)								

Table A3.3(a) : Changes in fertilizer and manure use over time: Paddy and Wheat								
	Paddy					Wheat		
	Andhra Pradesh	Orissa	Punjab	Uttar Pradesh	West Bengal	Punjab	Uttar Pradesh	Rajas than
Fertilizer nutrients (Kg/Hect)								
1970s	53.2	10.0	124.0	28.5	10.7	110.8	46.8	40.0
1980s	126.8	13.8	180.8	45.0	31.8	156.6	90.9	62.6
1990s	176.8	61.2	182.6	89.1	69.9	209.0	133.6	83.0
Manure use (Qtl./Hect.)								
1970s	58.1	26.7	25.7	19.8	27.3	15.7	21.2	6.4
1980s	67.5	26.3	56.9	26.4	48.5	10.1	16.6	2.7
1990s	38.0	28.6	40.0	9.0	29.3	9.2	7.1	4.5
Growth rate %								
Fertilizer	232	509	47	212	551	89	186	107
Manure	-34	7	56	-54	7	-41	-66	-30
Share in operational cost: fertilizer								
1970s	0.18	0.04	0.21	0.09	0.04	0.23	0.09	0.12
1980s	0.23	0.06	0.24	0.13	0.07	0.32	0.20	0.15
1990s	0.16	0.11	0.17	0.12	0.09	0.28	0.19	0.12
Share in operational cost:manure								
1970s	0.11	0.08	0.01	0.03	0.06	0.02	0.03	0.01
1980s	0.06	0.08	0.02	0.04	0.08	0.01	0.02	0.01
1990s	0.03	0.07	0.01	0.01	0.04	0.00	0.01	0.01
Note: Tables A3.3 (a) and (b) computed with COC Data								

Table A3.3(b) : Changes in fertilizer and manure use over time: Groundnut and Sugarcane						
	Groundnut			Sugarcane		
	Andhra Pradesh	Orissa	Gujarat	Andhra Pradesh	Uttar Pradesh	Maharashtra
Groundnut						
Fertilizer nutrients (Kg/Hect)						
1970s	17.6	16.6	16.1	256.4	36.9	236.1
1980s	26.3	23.0	50.3	266.0	80.8	404.5
1990s	44.3	47.0	57.6	213.9	162.9	387.6
Manure use (Qtl./Hect.)						
1970s	40.9	15.8	36.0	40.1	43.7	62.9
1980s	33.6	16.3	36.3	41.5	44.9	34.5
1990s	26.6	20.3	28.6	26.9	5.5	18.1
Growth rate %						
Fertilizer	152	183	257	-16	341	64

Manure	-35	31	-21	-33	-87	-71
Share in operational cost: fertilizer						
1970s	0.06	0.07	0.05	0.22	0.08	0.19
1980s	0.08	0.05	0.11	0.21	0.15	0.21
1990s	0.08	0.08	0.09	0.1	0.12	0.24
Share in operational cost:manure						
1970s	0.09	0.03	0.08	0.02	0.04	0.04
1980s	0.06	0.05	0.06	0.02	0.04	0.03
1990s	0.05	0.05	0.04	0.01	0.02	0.02

[i] A conservative estimate of 7.35 Kg wet dung per animal from overnight dropping was used by Reddy et al (1979) feasibility study. This is less than half the 16 KG per day estimate often assumed in biogas writings

[ii] This is measured by the Cation exchange capacity (CEC).

[iii] The world organically managed area is about 22 million hectares with Australia holding the largest coverage.

Chapter 4

Implications of a Shift in Fertilizer – Manure Mix

The reforms taking place in the domestic and external sectors of India and the desire for sustainable agricultural growth call for a review of our dependence on chemical fertilizer. After promoting the fertilizer intensive 'modern' technology for decades, the possibility of a shift of input mix towards indigenously available and environmentally more sustainable organic manure therefore deserves serious consideration. However, since fertilizer has been a prime source of productivity in Indian agriculture, such a move away raises serious uncertainty about its effect on output and income security of farmers and any policy towards such a shift needs to be taken with due consideration and caution.

The availability of detailed cost of cultivation (COC) data from the Ministry of Agriculture giving physical quantities of inputs used, makes it possible to estimate yield response functions that help address some important questions that follow (1) What would be the yield loss if farmers were to apply less fertilizer than they do currently? (2) Can chemical fertilizer be technically substituted by manure under existing conditions and does their conjunctive use improve each other's effectiveness? (c) If that is possible, since manures are costly, are their financial returns protected by the same substitution?

In this chapter yield functions based on COC data will be used to understand the interactions between the two associated soil-enriching inputs to address the above questions. The COC gives quantitative information on inputs and outputs in physical and monetary terms on its way to estimate the cost of cultivation and cost of production of principal crops for select states. This study is based on cross-section farm household level information provided by Ministry for the most recent year for 1998-99 and will attempt to estimate yield functions of four major crops that can be classed as cereals, oilseeds and cash crops, namely paddy, wheat, groundnut and sugarcane for dominant states for which the data is provided. The primary purpose of the estimation would be to capture the interaction and the technical relation between fertilizer and farm-yard manure in production which would pave the way to a better understanding of physical and financial implications of altering the mix of the two inputs. On grounds of the potentially emerging restraints on fertilizer use consequent to economic reforms and ecological considerations, the academic interest in this paper relates to a hypothetical case of diminishing fertilizer intensity.

From a priori understanding of production technology, the two inputs serve important functions in soil enrichment that are supplementary as well as complementary in character. Both are dominant sources of soil nutrients although manure, the traditional input, is bulky and less intensive or specific in nutrient contents compared to chemical based water-soluble fertilizers, which however have greater tendency to leach out leaving the soil hungrier for nutrients. At the same time manure has important soil enriching properties that enables chemical fertilizer, when applied, to be more effective and efficient when the soil is rendered more porous, aerated and biologically active. The existence of the dual relation of substitution and synergy makes the choices on input mix more complex as also significant in determining the loss or gain from cultivation in both physical and financial terms. Conditioned by soil-climatic characteristics and the price situations prevailing, the implications of changing inputs mixes are likely to vary by the crops cultivated, by regions and also across households with some sections gaining at the same time that others lose out.

This chapter will first give a background of the data to be used in sections 4.2. The problem at hand will be taken up subsequently in stages with econometric exercises for estimating the yield functions being explained and presented in section 4.3 and then estimated equations and computed returns in prevailing and hypothetical scenarios discussed in sections 4.4 and 4.5. Section 4.6 considers the implications of manure price response to the increased demand and 4.7 concludes the chapter.

4.2 Cost of Cultivation Data

The Comprehensive Scheme for Studying the Cost of Cultivation/Production of principal crops in India (COC) was initiated in 1970-71 following from the earlier Farm Management studies and evolved through two reviews by expert committees in 1980 and in 1991. The data collected by COC has rightly been described as a 'veritable goldmine' that has been somewhat undertilised (Sen and Bhatia, 2003). As such the main function served by the COC data is to guide the Commission for Agricultural Costs and Prices (CACP) in providing the annual recommendations of agricultural price policy. This paper attempts to utilize the valuable data for understanding technological and financial implication of changing fertilizer use practices.

The sample under COC is based on crop-complex approach (since 1981-82). Each state is demarcated into homogeneous agro-climatic zones based on cropping pattern, soil type, rainfall and the primary units are allocated to different zones in proportion to the total area of all crops covered in the study. The items of cost of cultivation cover both paid out cost and imputed costs of owned inputs and the imputation of owned input follows strict procedural norms. The COC has been questioned on certain grounds that reflect on the present study too. These include the valuation of certain inputs, such as land, capital and labour, the design of cost concept itself and limitation of the coverage. The non-inclusion of marketing cost and in particular the transport cost to *mandi* (local market) has been criticised but as of now the cost reported in essentially on-farm cost and excludes distribution cost. The COC provides a few alternative cost estimates and the choice of the estimate would depend on the problem at hand and the judgment of the user. Cost A2, representing the cost to the owner farmer along with the rent of leased-in-land and estimate C2 that includes all imputed costs are two concepts of general relevance for farm business income. The 'data also cannot help in finding out how cost of production varies with size of holding, or between rainfed and irrigated land or across traditional and modern farming systems using HYV and machines' ((Sen and Bhatia, 2003). Each cost concept carries its own assumptions about imputation and farmers' objectives and their perceptions about what are costs and what are returns. The imputations of owned or home/farm produced inputs are often based on prevailing village rates implicitly assuming that the market, despite its often narrow and imperfect existence, factors in the real cost involved in terms of time, effort and resource spent in generating the inputs.

The data used in this paper relate to the following cases:

Sample states and crops

Paddy

(1) Andhra Pradesh, (2) Tamil Nadu, (3) Kerala,

(4) Bihar, (5) West Bengal, (6) Assam,

(7) Uttar Pradesh, (8) Punjab and (9) Madhya Pradesh.

Wheat

(1) Bihar, (2) Gujarat, (3) Himachal Pradesh,

(4) Punjab, (5) Rajasthan, (6) Uttar Pradesh.

Groundnut

(1) Andhra Pradesh (2) Karnataka, (3) Tamil Nadu.

(4) Gujarat, (5) Maharashtra, (6) Orissa.

Sugarcane

(1) Andhra Pradesh (2) Tamil Nadu (3) Maharashtra

(4) Uttar Pradesh

Apart from the above, with data available, Haryana and Karnataka for paddy and sugarcane respectively were also taken up for analysis but could not be reported due to (a) multicollinearity problem in data on paddy for Haryana and (b) non-use of manure in any appreciable degree in Karnataka for sugarcane (only two sample households out of 21 using any manure). Only those households are selected for the present analyses, which have undertaken cultivation of the concerned crop in the year 1998-99 excluding those that show zero acreage under the crop[i].

This paper supposes C2 as the actual cost incurred, giving due importance to opportunity cost of own resources. Since C2 incorporates imputed costs of owned inputs, family labour in particular, negative returns are not uncommon implying non-profitability of enterprise. Agricultural operation is here treated as a commercial enterprise with profits being treated as returns. Returns from crop cultivation are computed as difference between gross product value and the cost. Cost of inputs are either paid out cost or imputed. Fertilizer is a material input in the former category, which is purchased while manure can be either purchased or owned. Purchased inputs are valued by the actual cost ('out of pocket expenses') incurred but in considering owned or 'farm produced manure' (which presumably is collected from own household wastes, farm droppings or from common lands) 'prevailing rates in the villages' are used for evaluation assuming they reflect to an extent the non-monetary cost of collection in terms of family members' time. As observed in Chapter 2, bulk of the manure used in Indian agriculture is constituted of home produced farm yard manure (FYM) with the market for sale and purchase handling only a limited residual portion. The foregoing calculations of returns are based on the supposition that the farmer's own subjective valuation of the owned manure matches with the market rate and use of home made manure is comparable to purchase and sale to own-self. The purchased part of the input is valued at actual cost, which reflects the prevailing rate and other expenses of procurement.

4.3 Econometric Issues

Estimation of yield functions in agriculture runs into various difficulties such as multicollinearity, structural differences and choice of a workable and appropriate functional form describing the production technology. The specification of the function made in consideration to such limitations and those posed by the coverage of the data, is laid down in terms of the choice of functional form, the economic interpretations of parameters, specifications of variables, the model and estimation procedure as elaborated. *The final choice of specification of an equation is made on the basis of the goodness of fit and the significance levels of parameters.*

Functional Form

The choice of functional form in econometric applications rests on flexibility, simplicity and appropriateness to the context (Desai, 1979). The linear and the simplest form will not provide the crucial interactions between inputs. Since neither of the two inputs of concern is 'essential' in nature for production, a desirable functional form must allow for the choice of not applying one or both of the inputs. Despite wide acceptability, the Cobb-Douglas (C-D) or log-linear function is clearly unacceptable. It does not also help in capturing the interactions. Though the trans-log form allows this, it too becomes meaningless when the inputs are not applied. Functions of the CES type pose greater complexity in estimation and may not be meaningful.

The simple quadratic form is chosen to describe the yield function in the present case for the following advantages[ii]:

(a) Simplicity: The function can be linearised in parameters after suitable transformation of variables and the parameters can be suitably interpreted.

(b) Flexibility: The function is sufficiently flexible in that (i) it allows for positive or negative interactions between variables, (ii) it allows the marginal effects of inputs to vary (unlike linear functions) and even change signs and (c) It makes no restrictive assumptions such as constant marginal products, constant returns to scale or constant elasticity of substitution.

(c) It allows for usual expected properties of agricultural yield functions as per theory and economic reality, and also allows for zero valued variables.

Interactions

Substitutability between inputs has been defined in different ways. The usual Hicksian definition from micro-economic theory is based on cross partial derivative to price of the other input. Several studies with industry data have used a cost function framework but the approach despite its simplicity in conceptualization and estimation, treats the producer as a cost minimiser making its applicability more appropriate to a highly commercialized agriculture (Chopra, 1985)[iii]. Also, price variability in cross-section data is likely to be low, at least less plausible than over time, making it difficult to capture the output effects in this way. The present questions are related more to production technology and technical substitution to prevent output loss and less to responses to market. Another definition used by Bliss and Stern (1982) runs in terms of cross effects on marginal products as follows:

If $d(dy/dx_1)/dx_2 < 0$ then x_1 and x_2 are substitutes and

If $d(dy/dx_1)/dx_2 > 0$ then x_1 and x_2 are complements.

This concept relies only on the parameter of the interaction term and relates to an underlying theoretic relation. Finally technical substitution between inputs is viewed as movements along an iso-output curve

MRS = $dx_1/dx_{2\ /y=\mathbf{y}} = -(dy/dx_2)/(dy/dx_1)$

where yield y is constant at **y** and MRS is the ratio of the marginal productivities. This measure based on the derivatives depends on all relevant parameters and is more complete and comprehensive for current purpose.

The specification also permits interaction with self through a squared term. Higher levels of input application are expected to diminish the marginal product turning out a negative second derivative. In cases where input application is not high in context of the situation, the quadratic effect may not be there.

Yield Function:

The general form of the yield function is as follows:

$$YLD = a_0 + a_1\ FRT + a_2\ MANU + a_{12}\ (FRT*MANU) + a_{11}\ (FRT*FRT)$$
$$a_{22}\ (MANU*MANU) + a_3\ LAB + a_4\ IRR + \Sigma a_{5i}\ DUM\text{-}Z_i \ldots\ldots (1)$$

Where dependent variable is

YLD =Yield rate (Quintals/Hectare)

And independent variables are

(1) FRT =Fertilizer (Kilograms/hectare)

(2) MANU=Manure (Quintals per hectare)

(3) LAB= Labour (hours per hectare)

(4) IRR=Dummy variable for irrigation

(5) DUM-Z_i = Dumy variable for i-th Zone

Variables and Specification

Cross-section household data for 1998-99 have been used for estimating yield functions of crops given the overall situation in the year. The estimated equation would seek to explain the variations in yield level across farms households by the variations in different explanatory variables with the constant term and region specific effects incorporated to capture the non-varying factors distinguishing the states or the regions within the states. The estimation is made separately for the states to allow the yield functions to vary with the differing conditions. The specification of the variables carries with it some of the constraints and limitations imposed by the nature of available data. The COC data gives item-wise information on specific inputs without bringing out the qualitative or varietal nature of the inputs. This is a drawback in many ways and affects variables like manure, irrigation and seeds. Manure is considered as a composite variable with no further distinctions for composition being possible. Irrigation data is not provided in physical terms and in that situation a simple binary quantification of the irrigated status has been attempted as discussed below without bringing in the intensity or quality. In the case of cereals there is also the possibility of varietal difference in seeds across households impacting on the yield rates or having interactions with fertilizer use. While for wheat the across household variation may be low (the adoption rate of HYV seeds at all India level is as high as 85%) and the effect is likely to be get incorporated in the constant term, for rice the coverage of HYV seeds is more incomplete (75% at all India level). One can only assume that the zones with their own agro-climatic and institutional distinctions would behave close to uniformly with regard to adoption rate and the effect would be subsumed in the region specific effects. However to the extent the households vary in HYV adoption within a region, there is likely to be an unavoidable bias in the estimates[iv]. Other factors, which are of institutional or infrastructural in nature such as credit and transportation, can also have their impacts on yield rates but these effects are likely to come indirectly through input applications that actually figure in the technological yield functions.

Another possible influence on the yield is the weather on which COC obviously does not give direct information. The weather effect, though extremely important in agriculture, however, is not expected to vary significantly across farm units in any region or even appreciably within any state. In the cross-section data variation in yield rate across households would not be explained by the weather factor, which is necessarily spatial in expanse. The effect is expected to be covariate i.e., if the weather factor affects one household it affects the others too similarly. While the region dummy can capture regional variation of weather if any for the reference year, the equations have been separately estimated for the states without assuming any uniformity. In any case it is pertinent to note that 1998-99 experienced a normal monsoon and the production performance in agriculture was satisfactory[v]. Some specific details of variable are given below:

Fertilizer and Manure: Fertiliser variable is nutrients (N P K) in Kg. Per hectare of area and the variable is treated as composite of all three nutrients. Manure is used in bulk with nutrient content being largely non-specific. The variable is taken as physical bulk in quintals per hectare.

Irrigation: COC data, meant for cost measurement, gives no clear qualification of this input like the proportion of area covered, quality, volume of water, perenniality of service or the type of drainage and water management undertaken by the farm. The physical measure, given as hours of irrigation with no indication of efficiency is clearly inadequate. Correspondingly, the cost of irrigation subdivided into owned, hired and canal charges components also serves little purpose since prices faced are affected by market imperfections, unequal bargaining power, local institutions and knowledge, informal interdependences and government regulations in various areas[vi]. Use of these doubtful measures of irrigation data as variables is simply not reliable.

The method adopted in this situation is to treat the farm household's irrigation status as a dummy variable. Household units are classified in two groups, those who used irrigation water, showing positive cost for this item and those who did not. The use of dummy variables cannot capture the physical dimension of irrigation (in terms of extent or quality) but makes a sharp demarcation in status. In certain states access to adequate and timely water supply is intimately related to the kind of water resources available. For instance, where ground water reserves are poor, expenditure on well irrigation may not mean the same as access to government canals. Differentiation of irrigation is attempted in terms of canal water and pumped (other forms) water. Three possible specifications in terms of irrigation status are defined as below where irrigation charges refer to either hired irrigation or owned irrigation or canal charges.

The following irrigation variables are employed in alternative specifications:

Irrigation specification 1: IRG = 1 if Irrigation charges>0
=0 otherwise.

Irrigation specification 2: IRCNL= 1 if canal charges paid>0
= otherwise.

Irrigation specification 3: IRPUM=1 if cost of owned irrigation>0 or cost of hired irrigation>0
=0 otherwise.

Labour: Labour input is an essential variable in agricultural production and can induce variations in yield levels of crops, given all other inputs. Information on human labour is provided by COC in standardized hours per hectare. With modernization of agriculture, machine labour also gained prominence in certain pockets and can be an important replacement for human labour[vii]. Human labour and machine labour denoted by HLAB and MLAB are considered alternatively in the specifications and machine labour is considered as a second choice in the specification only when its use improves the estimate of the equation.

Region: The overall agro-climatic conditions in terms of soil, water, climate and other endowments, practices, infrastructure and institutions can vary by regions but not significantly by households and have extremely important influence on the level of production. To allow for such differences, the yield functions are estimated separately for different states instead of pooling them to bring out structural differences in the function and the responses to inputs. Within a state too, the COC demarcates zones and these demarcations are used as dummies to get the differential impacts of a wide spectrum of endowments in terms of agro-climatic conditions as also to an extent institutional and infrastructural set up on yield level. These dummies are meant to bring out the structural or fixed effect of the zones on yield levels.

DUMMY-Z_i = 1 if the household belongs to zone i

=0 otherwise, i=1,2, n-1

where there are n zones in a state-crop combination and the nth zone is the base.

Interactions

Fertilizer and manure are the main subjects of this study. To look for the possible substitution or complementary relation between fertilizer and manure an interaction term is included, specified by the product of the two variables. Since the inputs may be subject to diminishing returns the squared terms are also incorporated. Irrigation and fertilizer also could be variables with possible synergic or substitutable relations[viii] but the absence of continuous data on irrigation limits the equation's ability to capture the interactions[ix].

Multicollinearity:

Since variables in agricultural production functions are often correlated, multicollinearity is a possibility in the estimated yield functions that may make regressions meaningless. In general, this problem shows up in poor estimates despite satisfactory overall fit. The significance of parameter estimates therefore provides a check against this affliction. Certain guards are taken nevertheless. Before undertaking the regression exercises the simple correlation between variables are examined as a possible check for multicollinearity and specifications in which any pair of variables are found to be linked by a correlation coefficient of 50% or above are ruled out. Fertilizer and manure, which technically have properties of both substitution and complementarity between them, show no clear correlation in any particular direction and except the case of Haryana where fertilizer and manure showed correlation, the results validate the feasibility of regression and further analyses. Correlation is detected between the labour input variables and one or other variable in certain cases and the appropriate specification which avoids this configuration was selected for reporting. The cases of high correlation coefficients are listed in Table A4.3. In addition, the regressions are also tried out with smaller samples by omitting observations at both ends to look for stability of estimates on grounds that multicollinearity renders regression estimates unstable across sample sizes and specifications[x].

Signs and Interpretations

The estimated coefficients affect the magnitudes and the signs of the marginal products (MP). While the MP of an input is expected to be positive, cases of inefficient and uninformed input use and possible effects of uncertainty can generate excessive use leading to negative MPs. While the coefficient of the interaction term (FRT*MANU) can come with positive or negative sign indicating the type of interaction, that of the squared term is expected to be negative. In cases where a negative effect is not found the squared term is not included, leaving the level variable to catch the input effect. The effect of the level term for any input can be positive or negative but a negative coefficient of FERT or MANU does not imply negative marginal product as the latter depends on the level of use of the associated input and even of the same input. Where the interaction is positive (negative) as indicated by parameter a_{12}, higher amount of any one input would increase (reduce) the marginal product of the other.

$$MPF = d(YLD)/d(FRT) = a_1 + a_{12}\,MANU + 2a_{11}FRT \ldots\ldots\ldots(2)$$

$$MPM = d(YLD)/d(MANU) = a_2 + a_{12}\,FRT + 2a_{22}MANU \ldots\ldots.(3)$$

The negative second derivatives a_{11} and a_{22} imply that higher amount of any input would diminish its own marginal productivity. While a_{12} depicts the interaction between fertilizer and manure in terms of each one's effect on the other's marginal productivity, the marginal rate of technical substitution

MRS= [d(YLD)/d(FRT)]/ [d(YLD)/d(MANU)] …………(4)

provides a measure of the amount by which manure use has to adjust following a unit change in fertilizer amount such that the yield rate is maintained.

4.4 Estimates from Yield Functions

The regression equations estimated on the basis of sample sizes ranging from a small of 21 households for sugarcane in Karnataka to 591 for paddy in West Bengal and correcting for heteroscedasticity that is possible in cross-section data are reported in Tables A3.4 for the four crops. The coefficients are then used for calculation of marginal products (and elasticities) that are further utilized for calculating returns at prevailing and hypothetical prices.

Parameters of Pure effects

The coefficients in the estimated equations measure the impacts of the variables on yield level. In the cases of fertilizer and manure the coefficients of the level variables can be termed as the pure effects of input use without consideration of the interaction or quadratic terms. Taken with the quadratic term the parameters measure the impact of the variable when the other variable is not used. The quadratic term where present indicates that the effect declines with increasing use of the variable and may reach zero at some positive or negative (impossible) level of use. The negative quadratic effect arises when the level of use is at a high enough level in context of the technological reality. For fertilizer the pure effect is usually positive and also statistically significant. Assam and Madhya Pradesh for paddy and Uttar Pradesh for wheat and Andhra Pradesh and Tamil Nadu for sugarcane are exceptions in which case the effect is insignificant and the sign is even negative in the paddy cases. For Assam greater use of fertilizer with no associated use of manure cannot help to improve yield. On the other hand the pure effect of manure is found negative or insignificant in many cases. For paddy the effect is not positive and significant in general except for Kerala and Uttar Pradesh. Positive effect is discerned for Assam and Punjab even where the t-statistic is short of significant level. For wheat manure use can be beneficial by itself for Gujarat, Rajasthan and Uttar Pradesh and cannot help in the Punjab, Bihar and even Himachal Pradesh. For groundnut and sugarcane only Maharashtra and Uttar Pradesh respectively are found to show positive and significant signs for manure. Most crop-state cases can gain from increase in fertilizer use even if manure use is not changed whereas for manure the benefit is not observable at least without the conjoint use of fertilizer. For wheat, a fertilizer intensive crop, the pure effect of manure is found positive in as many as three cases and for groundnut which is more intensive in use of manure than fertilizer, fertilizer is found to have a favourable contribution to yield in all cases and manure only in one. The squared term appears with a negative sign in more cases for fertilizer than manure but is not always significant.

The labour variable mostly appears with a positive and significant coefficient in the case of paddy though the southern states Andhra Pradesh, Kerala and Tamil Nadu are exceptions with insignificant parameters. For sugarcane and groundnut too the coefficient is insignificant for Karnataka. Machine labour has been preferred in the specification in two cases of paddy and one case each for groundnut and sugarcane. The irrigation effect is found positive for paddy and wheat barring one case each but is insignificant in most cases for groundnut and also sugarcane. While groundnut has lower requirement of water than many crops, the finding for sugarcane suggests possibility of water mismanagement.

Substitution or Synergy

The interactions noted from the signs of the cross terms (Table 4.1) differ from case to case. While in a majority of cases where the cross term appears in the selected specification the parameter is not significant, for paddy and groundnut a positive interaction dominates. Cases of negative (substitutive) interaction are noted in Punjab, Madhya Pradesh, Uttar Pradesh and Kerala for paddy with all the coefficients being insignificant and Karnataka and Maharashtra for oilseeds. Negative interactions are encountered for wheat (barring Punjab and Himachal Pradesh) and sugarcane (barring Uttar Pradesh). There is little technical synergy between the two sources of nutrients (except Punjab) for wheat though manure by itself can be helpful. Except for Himachal Pradesh the manure use practice already has small presence (Table A3.2).

Table 4.1 : Interactions between Variables FERTILISER and MANURE from estimated Equations				
	Crops			
State	Paddy	Wheat	Sugarcane	Oilseeds
Andhra Pradesh	Positive*		Negative*	Positive
Assam	Positive*			
Bihar	Positive	Negative		
Gujarat		Negative		Positive**
Himachal pradesh		Positive		
Karnataka				Negative
Kerala	Negative			
Madhya Pradesh				
Maharashtra			Negative	Negative**
Orissa				Positive
Punjab	Negative	Positive*		
Rajasthan		Negative**		
Tamil Nadu	Positive**		Negative	Positive*
Uttar Pradesh	Negative	Negative	Positive	
West Bengal	Positive**			

Note: Based on Appendix TablesA4.2 .* Significant at 10%, **Significant at .1%.

Responses to Fertilizer and Mnaure

The parameters estimated give the pure and interaction effects of input use but their total contribution to yield level at prevailing configuration of input use can be examined through the marginal products (MP) of the inputs. The MPs would depend on the parameters as well as the input levels prevailing at the household level (as explained section 4.3) and corresponding elasticities are derived to measure the responses of yield rates to input use. These are comprehensive measures of responses taking into account the pure effects, the quadratic effects and the interactions at the given level of input use. Reported in Tables 4.3 the elasticities are generally low and lower for manure than fertilizer. The elasticity with respect to fertilizer use is generally positive but negative elasticities are found for paddy in Madhya Pradesh and sugarcane for Andhra Pradesh perhaps indicating a sign of over-use or inefficient use where farms using higher intensities of fertilizer show no superiority in terms of higher yield rates. In the case of manure, for wheat Bihar and Punjab (where negative pure effects were noticed) and

Rajasthan have negative elasticities. Tamil Nadu and Madhya Pradesh for paddy, Orissa and Tamil Nadu for groundnut and Andhra Pradesh for sugarcane are other cases of negative elasticities. Paddy in Madhya Pradesh and sugarcane in Andhra Pradesh are the only two cases in which both fertilizer and manure are found to have adverse impacts though the pure effect of manure in paddy in Madhya Pradesh and fertilizer in sugarcane in Andhra Pradesh are not negative and the conjunctive use is not helpful.

For paddy fertilizer elasticity is highest in West Bengal followed by Kerala and Punjab, medium in other the southern states and low in Assam and Uttar Pradesh. For wheat it is higher in Himachal Pradesh and Punjab and for both groundnut and sugarcane it is highest for Maharashtra. The manure elasticity, even if positive is nowhere greater than 0.1 and highest level is registered at 0.065 for groundnut in Maharashtra.

4.5 Implications for Financial Returns from Shift in input mix

While physical production levels are important for national interests of food security, feasibility of a technology depends on the financial implications for the producers so long as market rules play any part. Though it may be technically possible to substitute manure to an extent for the intrinsically scarce and eco-damaging chemical fertilizer, this may not be economically acceptable to farmers if the shift in technology undermines the returns from cultivation by way of increased cost. The outcome depends on the relative prices of the two sources of nutrients as faced by the individual farmer. Certainly, such a switch is not feasible if a large section of households suffer losses on its account.

Method of calculation

What complicates the assessment is the observation that a large majority of farmers do use fertilizer along with organic manure. One way of analyzing the categorised data is to take a comparative view of the returns in different practice categories and observe any notable difference in average returns. However, these differences and even the practices themselves could be influenced by other exogenous factors like agronomic condition, conveying little information for policy making. An alternative would be to examine the implication of an extensive move towards a less fertilizer intensive and more manure intensive technology. So long as this is accompanied by a change in physical yield rate, the effect on the financial returns will not mean much. The fact is, a technology yielding higher returns to farmers cannot be adjudged superior if it comes with a reduction in physical output. Prices are hardly competitive in Indian markets and concerns of subsistence and food security are too pressing to take value as the yardstick. One of the variables must remain unchanged for a meaningful comparison.

The method taken in this paper is to simulate cases in which a certain small cut in fertilizer input is substituted by manure use so as to maintain the yield rates at existing levels and then work out the changes in returns. The change is computed at the household level at the given input use levels and prices faced by the household. The results are of course completely sensitive to the initial and existing resource use configuration of the households due to the very nature of yield function considered. Though the function is nonlinear with respect to the input variables, computation of substitutability and hence the changes in returns call for a linearization over small changes in fertilizer use. The details are present in Appendix 4.1.

The question then arises as to what would be the appropriate cut in fertilizer use to start with. In the absence of a clear policy constraint or separate projection the present approach is to consider an arbitrary and small proportional change, a 1% cut in fertilizer intensity. The farmer is considered to reduce the fertilizer input per hectare and then substitute it by greater (or less of) manure input by an amount, which keeps the yield level unchanged. The new level of returns per hectare described as Scenario2 along with the change over the base level is noted and the average returns and gains of the households are computed for reporting (Tables A4.1). An intermediate situation where the cut in fertilizer use reflects on yield level and is not replaced by manure is described as Scenario1. Since the impact of the shift can vary across households, not less important than the average impact is the distribution of gains or losses across households. An estimate of the percentage of households that draw financial gain and that suffer losses from the switch in technology is therefore useful for assessing the change. A further break down of the distribution of the level of financial gains or losses over the base situation is attempted for appraising the depth of the impact.

Gain large: Gain =Rs. 1000.00 and above.

Gain moderate: Gain =Rs. 10.00 and above but less than Rs. 1000.00.

No gain/loss: Gain = -Rs. 10.00 and above but less than Rs. 10.00.

Loss moderate: Gain = -Rs. 1000 and above but less than -Rs.10.00.

Loss severe: Gain = less than -Rs. 1000.00.

It is evident that the first two categories for which estimated returns work out to be not less than Rs. 10.00 represent the gainers while the last two categories with loss more than Rs 10.00 are the losers. An intermediate category making small gain or loss (of Rs. 10.00 or less) is considered not significantly affected by the change.

Alternatively a possible clue to an adjustment in fertilizer use could be the free trade situation that is expected to engulf the fertilizer economy in the foreseeable future. Table 2.3 (chapter 2) showed that the free trade (international) price could be higher than what farmers actually pay in the present regime assuming that world price would not be sensitive to Indian imports. The regression based on the pooled COC data for paddy provided a demand coefficient to price (Table 2.4). As an additional exercise this coefficient is applied on the projected price increase from domestic to international level as explained in Technical Notes in Appendix 3.2, in which case the incidence of fertilizer use cut varies in both absolute and relative terms. This exercise incorporates a rise in fertilizer price due to liberalization that is not considered in the earlier exercise.

In all cases the calculations are based on area weighted averages across households. The elasticities with respect to the inputs are obtained by applying the mean levels of marginal products to the mean yield and input levels. Marginal rate substitution (MRS), which is used for calculating the manure replacement for the cut in fertilizer intake, is obtained as the ratio between the marginal products.

Returns across Fertilizer Practice groups

The comparison across fertilizer practice groups as defined in section 3.4 in Chapter 3 is made difficult by the varied sizes of groups leading to minimal counts or even absence of any observation under some groups. Disregarding groups where the number of observations falls short of 10, the low manure and high fertilizer group is mostly associated with the highest mean returns (Table 4.2). For the other groups and especially for sugarcane, the high manure high fertilizer use group ranks first in returns. There are a few exceptions. In Assam the returns from even low fertilizer low manure use practice is comparable and in Madhya Pradesh too this practice is found to give highest mean returns followed by low fertilizer high manure regime. Groundnut is found to be unprofitable in all regimes. However whether this association is linked to intrinsic superiority and high responses specific to the holdings showing the high returns is not easy to say.

Simulations: A 1% cut in Fertilizer use

The results of this exercise (Table 4.3) give diverse implications depending on the signs of the elasticities. In some of the cases manure use produces negative effect on yield at the margin implying there is actually an associated reduction in manure use required to counter any adverse effect of the cut in fertilizer use. In the two cases of paddy in Madhya Pradesh and sugarcane in Andhra Pradesh both inputs are found to come with negative elasticities. Taking into account the net impacts on mean returns and the elasticities some idea can be formed on the desirability of the shift. In most cases there is little perceptible decline in mean returns (Tables 4.3) and in some cases notably in wheat returns in scenario 1 exceeds that in the base scenario indicating the loss in yield rate does not match the gain due to reduced cost of fertilizer. In such cases, the existing level of fertilizer use is not justified financially though the elasticity in terms of physical yields, is positive. Scenario 2 incorporates a movement towards manure so long as the elasticity is greater than zero. The shift is viewed as financially feasible if gains improve. The returns improve on the average from the adjustment in most cases.

Table 4.2: Returns per hectare for different Fertilizer practice classes				
Crop/State	Low Fertilzer Low Manure	Low Manaure High Fertilizer	Low Fertilzer High Manure	High Fertilizer High Manure
Paddy				
Andhra Pradesh	-	4962.41	-	3750.44
Assam	2537.44	2339.01	1653.92	2898.09
Tamil Nadu	-	6849.42	-	5489.29
Madhya Pradesh	2577.81	1092.27	2539.07	-1557.27
Kerala	-148.86	7129.88	68.62	1173.24
Bihar	-34.46	2280.07	-	2706.59
Punjab	-	3608.83	-	2792.88
West Bengal	4887.72*	3905.59	103.16	3030.36
Uttar Pradesh	6404.88*	2043.1	-3389.55	183.17
Wheat				
Bihar	2338.89*	2689.05	-2594.34*	4307.64
Himachal Pradesh	628.23*	-697.12	-59.34	1438.48
Gujarat	2047.94*	7456.9	-	4057.05
Uttar Pradesh		5857.69	-1744.48	5231.45
Punjab	-	7163.56	-	5951.15
Rajasthan	3016.18	7241.65	915.86*	2748.42
Groundnut				
Andhra Pradesh	-3591.06	910.85	-36.84	409.43
Maharashtra	-1386.49	2458.61	3840.65*	-1045.77*
Kanataka	-2461.99*	-47.93	-5537.72*	-1098.71
Gujarat	8041.84*	6213.85	6066.38	8517.31
Orissa		4257.13	-2214.31*	-1143.29*
Tamil Nadu	2128.67	8251.8	2771.93	-405.3
Sugarcane				
Andhra Pradesh		11874.81		2180.48
Maharashtra	29783.13*	12265	21342.05*	16375.28
Tamil Nadu		11818.29		15099.58
Uttar Pradesh	38526.89*	15531.25	-511.28*	15934.01
Note: * Total frequency less than 10.				

For paddy the southern states do not appear to gain from a shift towards manure at prevailing prices but Assam, Bihar, Punjab and Uttar Pradesh gain. In Madhya Pradesh less use of both inputs seem desirable and there is a need to look at the soil quality, cropping pattern and other ways of soil enrichment to identify the paradox. For wheat only Uttar Pradesh and Gujarat can gain and in Bihar too, less inputs may used more efficiently. Fertilizer is important for maintaining wheat yield in Punjab, Rajasthan and

Himachal Pradesh and may not be substituted by manure. The shift is helpful for groundnut despite the relatively higher prices of manure and for sugarcane except in Andhra Pradesh. The fertilizer to manure move is especially gainful to farmers in Uttar Pradesh. Bihar (wheat), Andhra Pradesh (sugarcane) and Madhya Pradesh (paddy) are cases where inefficient or excessive use of nutrients in indicated possibly originating from the farming and manuring practices. There appears considerable variation in returns across households though a large portion of farmers is not affected significantly. The percentage of gainers generally outweighs that of losers. The loser category is sizable for wheat in Himachal Pradesh where manure use is intensive to start with as also for groundnut in the southern states of Andhra Pradesh and Karnataka. However majority of these households make moderate loss though for the latter two cases the loss is severe for about 4% and 8% households (Table A4.1). Among the gainers too the share of large gainers is negligible.

Similar simulation conducted for hypothetical case of free trade for paddy with restrictive assumptions also shows that while a possible fall in fertilizer use due to price effect of fertilizer trade liberalization brings loss to a sizable lot (Table A4.4), a shift in input mix can to some extent mitigate the damage, bringing down the share of losers in most states though there is some interchange between severe loser and moderate losers and not always in a favourable direction. The share of gainers also improves significantly.

Table4.3(a) : Change in Returns due to Substitution of 1% Fertilizer use by Manure;Yield unchanged: Paddy								
	Mean Elasticity of Yield		Mean Return	Mean Return	Mean Return	Loss from	Gain from	Unaffected by
	Fertilizer	Manure	Base	Scenario1	Scenario2	Change	change	change
			Rs/hect. (R1)	Rs/hect.(R4)	Rs/hect.(R5)	%household	%household	%household
Paddy								
Andhra Pradesh	0.115	0.011	4152	4151	4138	28.4	57.6	14.0
Assam	0.004	0.027	2475	2475	2476	0.0	0.2	99.8
Tamil Nadu	0.139	-0.014	6225	6218	6376	1.4	97.6	1.0
Madhya Pradesh	-0.017	-0.007	645	652	663	11.9	18.9	69.2
Kerala	0.217	0.017	4295	4257	4232	62.5	23.0	14.5
Bihar	0.147	0.001	2217	2212	2224	0.6	21.3	78.1
Punjab	0.214	0.021	3417	3393	3432	0.8	77.5	21.7
West Bengal	0.241	0.038	3182	3153	3109	32.3	34.6	33.1
Uttar Pradesh	0.068	0.008	1788	1799	1800	0.2	45.4	54.4
Notes to Tables 3.5 (a) to (d): Scenario 1: Cut in Fertilizer use and no substitution, Scenario 2: With substitution; The Gain/Loss are calculated with respect to Scenario 2. Elasticities are at mean values.								

Table4.3(b) : Change in Returns due to Substitution of 1% Fertilizer use by Manure; Yield unchanged: Wheat								
	Mean Elasticity of Yield		Mean Return	Mean Return	Mean Return	Loss from	Gain from	Unaffected by
	Fertilizer	Manure	Base	Scenario1	Scenario2	Change	change	Fertilizer
			Rs/hect. (R1)	Rs/hect.(R3)	Rs/hect.(R4)	%household	%household	
Wheat								
Bihar	0.037	-0.003	2674	2687	2689	0.0	79.2	20.80
Himachal Pradesh	0.301	0.036	640	619	606	41.9	18.8	39.3
Gujarat	0.077	0.004	7232	7234	7246	0.0	78.3	21.7
Uttar Pradesh	0.023	0.009	5787	5799	5803	0.0	86.3	13.7
Punjab	0.286	-0.003	7084	7044	7108	0.7	97.3	2.0
Rajasthan	0.151	-0.019	6504	6491	6514	3.6	47.9	48.5

Table4.3(c) : Change in Returns due to Substitution of 1% Fertilizer use by Manure; Yield unchanged: Groundnut								
	Mean Elasticity of Yield		Mean Return	Mean Return	Mean Return	Loss from	Gain from	Unaffected by
	Fertilizer	Manure	Base	Scenario1	Scenario2	Change	change	change
			Rs/hect.(R1)	Rs/hect.(R3)	Rs/hect.(R4)	%household	%household	%household
Groundnut								
Andhra Pradesh	0.183	0.005	471	467	525	33.5	24.2	42.3

Maharashtra	0.350	0.065	1597	1546	1604	5.0	33.8	61.2
Kanataka	0.188	0.003	-746	-753	-983	58.6	13.5	27.9
Gujarat	0.074	0.056	7762	7761	7766	15.3	22.6	62.1
Orissa	0.221	-0.035	1926	1912	1934	1.4	33.8	64.8
Tamil Nadu	0.147	-0.038	4120	4125	4131	10.9	53.6	35.5

Table 4.4(d) : Change in Returns due to Substitution of 1% Fertilizer use by Manure;Yield unchanged: Sugarcane

	Mean Elasticity of Yield		Mean Return	Mean Return	Mean Return	Loss from	Gain from	Unaffected by
	Fertilizer	Manure	Base	Scenario1	Scenario2	Change	change	change
			Rs/hect.(R1)	Rs/hect.(R3)	Rs/hect.(R4)	%household	%household	%household
Sugarcane								
Andhra Pradesh	-0.170	-0.018	9416	9549	9461	5.3	76.3	18.4
Maharashtra	0.241	0.023	13494	13463	13525	8.3	82.2	9.5
Tamil Nadu	0.027	0.055	13634	13654	13675	3.6	92.9	3.5
Uttar Pradesh	0.086	0.031	15702	15684	15714	13.0	41.9	45.1

4.6 Manure Price and Gains from Shift

The calculation of the gains has been made under a supposition of unchanged prices. In the cases where the cut in fertilizer use is compensated by an increase in manure, given that the market for manure is constrained, localized and marked by inelasticties there is considerable chance that manure price will be sensitive to the increased demand at the aggregate or household level. The calculation of gains on the basis of elastic supply is therefore an underestimate. The cross-section data also does not help in computing elasticities with any reliable estimates. In the absence of the estimated elasticities from existing literature one can set certain limits within which the broad results can be validated. The gains calculated at prevailing prices would diminish as manure price responds to increased use and the gains can be sustained with the technological substitution only up to a point at which it is wiped out. Since revenue is unchanged with substitution (yield level is maintained), sustenance of gains require that the savings achieved from reducing fertilizer use is not surpassed by the additional cost of manure use even if manure price rises alongside. The limit price of manure at which the gains reach value of zero is expressed as a ratio to the actual prevailing price paid by the household to find the scope of increase admissible for the substitution (see Appendix 4.1). The averages of the ratios (LIM-P_m) is presented in Table 4.4 for the cases in which reduction in fertilizer use is compensated by increased manure us. The margin within which manure price can move up is low generally falling within a small margin of the prevailing price though this is higher for paddy in Bihar leaving some room for adjustment. The ratios fall below 1.0 in cases where loss is already indicated and the substitution can only be feasible if manure price falls.

Table 4.4: Maximum of Manure price to Prevailing price Ratio (LIM-P_m) : Sample averages

Paddy		Wheat		Groundnut			Sugarcane
State	Ratio	State	Ratio	State	Ratio	State	Ratio
Andhra Pradesh	0.76	Himachal Pradesh	0.88	Andhra Pradesh	0.61	Mahar ashtra	1.00
Assam	1.01	Uttar Pradesh	1.04	Gujarat	1.01	Tamil Nadu	1.10
Bihar	5.54	Gujarat	1.05	Karna Taka	0.69	Uttar Pradesh	1.01
Kerala	0.87			Mahar ashtra	1.00		
Punjab	1.04						
Uttar Pradesh	1.01						
West Bengal	0.94						

Note: Presented only for cases in which manure use increases and marginal products are postive.

4.7 Concluding Points

The pure effects of fertilizer without conjoint use of manure and ignoring the quadratic effect of its own use, are mostly favourable to crop yield especially paddy and wheat and for wheat the physical effect of manure is also positive in most cases. The interactions are dominantly positive for paddy but the synergy is weak in other crops. At prevailing levels of input use technical substitution of fertilizer by manure seems possible but financial implications of the change in input mix and the desirability would depend on the prevailing prices. At prevailing configuration of input use, the yield elasticity of fertilizer is positive in general showing that farms using fertilizer more intensively reap higher yield rates. But for manure this is not so in some of the cases, especially notable for wheat in which the negative interaction with fertilizer also plays a role. In Madhya Pradesh neither fertilizer nor manure can contribute to yield at the present conditions and there may be other exogenous constraints on their productivities especially with respect to fertilizer. By and large a change of input mix seems to be acceptable financially in a significant number of cases going by average returns although in the wheat growing states Punjab, Rajasthan and Himachal Pradesh fertilizer use is more important and not financially substitutable. Possibly responding to this technical reality, manure use is already low for wheat in the concerned states excepting Himachal Pradesh, in the hilly region. The shift can bring financial gain in raising paddy, wheat and sugarcane in Uttar Pradesh, wheat in Gujarat, paddy in Assam, Bihar, Punjab, Groundnut in Andhra Pradesh, Maharashtra and Gujarat and sugarcane in Maharshtra and Tamil Nadu. The southern states do not financially gain from the shift for paddy. The gains are worked out in the exercise by assuming that fertilizer prices remain invariant at prevailing levels but in an alternative exercise conducted on paddy only in which fertilizer price is considered to increase in a free trade regime and fertilizer use respond to this change, farm households are found to incur losses in returns. These losses may be mitigated by a shift towards manure to compensate the fertilizer impact on yield.

Since some households lose in the process of the shift, socially the feasibility of the solution would lie in the ability to protect them. Surely gains attained by certain sections cannot make good the distress of others. The safety net to combat rising fertilizer price or soil degradation by changing input mix away from chemicals can only be meaningful also if price of manure is in control. The gains if any can be eliminated when manure price responds to increased use even to a small extent. A limitation of the study is the treatment of the prices of home produced manure as reflected by the price prevailing in the limited village market. In reality manure supply may be highly inelastic iniquitous and depends on various socio-economic factors impinging on the households. The seasonal element of manure supply, the livestock situation and the sensitiveness to agro-climatic conditions need to be addressed when planning and studying the strategic changes in view of the results found for paddy in southern states and wheat in general. Although financial gain is the test for a feasibility analysis, in reality choice of input mix depends on household behaviour conditioned by various complex and often unquantifiable factors. A policy for promoting any input mix should take account of these ground level behavioural realities.

APPENDIX 4

Technical Notes

4.1. Calculation of Returns

The returns from cultivation at base level is total revenue (R) less total cost (C2) at given household level prices expressed as

$C2=P_f\, FRT + P_m\, MANU + OC2$ ….1(A)

$R = P\ X\ YLD$….2(A)

Here P_f and P_M are prices of fertilizer and manure and P is crop prices, OC2 is all other cost combined as reported and returns at base level R1 is given by

$R1 = R – C2$……….. 3(A)

It is supposed that each household reduces its fertilizer use uniformly by 1%. The change in fertilizer use and the revised returns R2 are then given by

$\Delta FRT= -FRT\ (1-0.01)$……4(A)

$R2= R – C22$……….5(A)

Where $C22 = C2+ P_f\ \Delta FRT$ reflecting only the reduced cost of fertilizer use presuming that the yield is unaffected by the cut. Now the yield function can be applied to measure the yield impact as product of marginal product of fertilizer times the change in fertilizer use giving the yield adjusted returns:

$\Delta YLD= MPF\ X\ \Delta FRT$………6(A)

$R3= (R+P(\Delta YLD)) –C22$…….7(A)

R3 reflects the complete effect of the cut coming through cost and yield adjustment. What we are interested is the impact when the cut is made good by adjusting manure use so keep yield and hence the revenue levels unchanged. The change in manure use is dictated by the substitutability

$\Delta MANU= MRS\ X\ \Delta FRT$…….8(A)

$MRS = MPF/MPM$…..9(A)

We then have the final returns level R4

$R4= R – C23$…..10(A)

Where $C23 = C2+ P_f\ \Delta FRT + P_M\ \Delta MANU$……..11(A)

Note that in the final analysis the yield and revenue are same as the base level but the cost is changed by adjustment in both fertilizer and manure use levels. Also the MPF, MPM and hence the MRS are computed at the initial level that is the base level in this case. In Table and Appendix Table Returns R1, R3 and R4 are reported as scenarios 1, 2 and 3 respectively.

When manure price increases with greater use of manure the returns will diminish and attain value of zero at the limit. This is when the savings in the cost of fertilizer use is just balanced by the increased manure cost at the increased manure price (P_M *max)*.

$P_f \Delta FRT = P_M \; max(Manu + \Delta MANU) - P_M \, MANU$

$P_M \; max = (P_f \Delta FRT + P_M \, MANU)/(Manu + \Delta MANU)$

$LIM\text{-}P_m = P_M \; max/ P_M$

4.2. Financial Implication of Fertilizer-Manure Substitution for Free Trade price:
Simulation Exercises for Paddy

This is an attempt to capture a scenario where the farmer has to pay the international market price for input fertilizer with no government control or subsidy. The free trade farmgate nutrient price is based on the C&F prices of N P K (Appendix 3.1) factoring in the handling and freight charges and then weighting them by consumption shares. The incidence of the import price can be quite diverse among households depending on the N-P-K ratios chosen and other factors like the local distribution networks and individual access and bargaining power in market reflected in the differences in paid out prices of fertilizer of households reported by COC. To capture this practical diversity, the farmgate household level free trade price (*FT-price)* is projected using the ratio of the *Actual price* (household level, administered) paid out by the household to the *Domestic price* (national level, administered) and the household level nutrient consumption as weights. It is assumed that given the bargaining power and other conditions, the incidence of the free trade price on any household will be similar to that of the national administered price.

FT-price= (Actual price/Domestic price)X Import price

Where

Actual price = Σ_{NPK}(Actual nutrient price paid out X weight)

Domestic Price = Σ_{NPK}(Farmgate uniform nutrient price X weight)

Import Price = Σ_{NPK}(Free trade farmgate uniform price X weight)

Weight = Household consumption of nutrient/ household consumption of total NPK.

To get the impact of the change in fertilizer price relative to product price fertilizer price is deflated by product price (P) and an equation based on state-time pooled data from COC is used

$\Delta FRT = 0.35 \; (FT\text{-}price - Actual \; price)/P$

where ΔFRT is the response at household level. The reduction in fertilizer use in this case is diverse both in absolute and relative senses across households. The corresponding changes in returns via the yield and cost effects are then computed for this ΔFRT in a fashion akin to the text and given in Appendix 3.1 assuming linearity over small changes again.

Appendix Tables

Table A4.1 : Estimated gainers and losers from using Fertilizer and Manure with Substitution (Scenario 2)

Crop/State	Gain in Returns Rs/hect.	Return loss severe %household	Return loss moderate %household	Return gain moderate %household	Return gain large %household
Paddy					
Andhra Pradesh	-13.90	1.20	27.30	57.10	0.50
Assam	0.80	0.00	0.00	0.20	0.00
Tamil Nadu	150.33	0.00	1.40	92.60	5.00
Madhya Pradesh	18.06	0.00	11.9	18.1	0.80
Kerala	-63.00	1.90	60.60	23.00	0.00
Bihar	7.30	0.00	0.60	21.30	0.00
Punjab	15.00	0.00	0.80	77.50	0.00
West Bengal	-73.40	1.00	31.30	32.70	1.90
Uttar Pradesh	11.70	0.00	0.20	45.40	0.00
Wheat					
Bihar	14.70	0.00	0.00	79.20	0.00
Himachal Pradesh	-33.20	0.70	41.20	18.80	0.00
Gujarat	13.70	0.00	0.00	81.00	0.00
Uttar Pradesh	15.50	0.00	0.00	86.30	0.00
Punjab	23.40	0.00	0.70	97.30	0.00
Rajasthan	9.80	0.00	3.60	47.90	0.00
Groundnut					
Andhra Pradesh	53.34	3.60	29.9	23.40	0.70
Maharashtra	6.89	0.00	5.00	33.8	0.00
Karnataka	-236.29	8.10	50.5	12.60	0.90
Gujarat	4.70	0.40	14.9	22.2	0.40
Orissa	7.95	0.00	1.40	33.8	0.00
Tamil Nadu	11.00	0.90	10.0	53.6	0.00
Sugarcane					
Andhra Pradesh	45.04	0.00	5.30	78.30	0.00
Maharashtra	30.69	0.00	3.60	82.20	0.00
Tamil Nadu	40.24	0.00	2.70	92.2	0.00
Uttar Pradesh	12.38	0.00	3.30	41.9	0.00

Scenario 2: Fertilizer intensity cut down by 1% and Manure intensity adjusted so as to have yield unchanged. Source: Computed.

[i] The sample of households once selected is surveyed for three consecutive years.

[ii] This function has in the past been used for estimating agricultural production functions by Narayana and Parikh (1987), Bliss and Stern (1982) and Ghosh (1998) for the purpose of capturing the second derivative of fertilizer use and for studying the between-input interactions such as water and fertilizer.

[iii] Chopra (1985) takes a multi-input perspective and with exhaustibility of natural resources in view explores if they can eventually be replaced by labour, capital and renewable resources. Using COC data for paddy for Haryana, cost share equations based on an underlying translog production function were estimated and Allen partial elasticities of substitution (AES) were obtained to measure the substitutability. Different inputs were considered but its was noted that there was very little use of organic manures.

[iv] The omitted variable bias depends on the unknown coefficient of the omitted variable (HYV seed) and the unknown auxiliary coefficient of regression of the unknown variable on the known variable. So long as there is no occasion to believe that the variables are dependent the bias diminishes. In this case however, use of HYV seed is known to be associated with fertilizer use though fertilizer may be used with traditional seeds too, and the parameter for fertilizer may pick up the effect of seeds also. The only nearest information given by COC in regard to seed use is the price of seed which could have been an indicator of the use of improved seeds if the market was perfect and households faced similar prices for similar strains. However, once again the market is far from perfect with unequal bargaining power characterizing the farm economy. A substantial part of the seeds used is home grown and is valued at prevailing rates in the village at the time of sowing and it is not clear whether the variety of seed has been factored in. The seed price therefore may reflect factors other than the variety and the meaning of the coefficient would not be clear. The inclusion of this variable as a proxy for HYV adoption did not give any meaningful result as could be expected. In the present specification, to the extent that farms vary in HYV adoption too, with or without fertilizer use, the marginal product estimate of fertilizer is likely to have an upward bias and a reduction in use will have a smaller effect on yield and call for a smaller substitution by manure.

[v] The monsoon which has a dominant influence on agricultural performance in both kharif and rabi seasons, was more than satisfactory in 1998 with only 2 of the meteoroglogical sub-divisions recording 'scanty' rainfall, 81% of districts in the country enjoying normal or excess rainfall and the rainfall level of the country measuring 106% of the long period average rainfall (Economic Survey,2002).

[vi] Canal charge could in principle serve as measure for irrigation water used since water rates are not likely to vary by households in any state. However this specification is limited only to irrigation from surface water sources (usually government canals) only. Use of this variable in a specification gave results similar to that from using the dummy variable used in the model in the cases where canal irrigation (IRCNL) is specified.

[vii] Machine labour, predominantly as tractor, is used for ploughing and is logically expected to substitute for human labour. Empirical evidence to this effect have been provided by Krishna1975, Chopra, 1995, Agarwal,1983)

[viii] While the complementary relation between fertilizer and irrigation is a common observation especially with the high yield package in practice, the possible substitutability has also been studied and suggested in literature with empirical evidence. The complementarity has been viewed as a sufficiency relation up to a threshold level beyond which substituion can be possible (Chopra, 1985, Ishikawa, 1967) and there have been suggestions that subsidy cuts and consequent reduction in fertilizer consumption may be compensated by investment on irrigation which involves lower subsidy cost (Parikh and Suryanarayana, 1992).

[ix] In any case the cross-terms between the irrigation related dummy variables and fertilizer were tried as possible specifications but inclusion did not yield any improved or meaningful relation and are not reported.

[x] For example the estimated equations for the sample and a sub-sample omitting 10 observations at each end in the case paddy- Uttar Pradesh (sample size=489) are as follows:
Sample: 14.3 +.07 FRT+.05 MANU-.0001FRT*MANU-.0002 F-SQ+.003 HLAB+3.4 IRPUM + Zone effects.
Subsample: 18.0+.05 FRT+.06 MANU -.0002 FRT*MANU-.0001 F-SQ+.003 HLAB +3.3 IRPUM +Zone effects.

Appendix Table A4.2 (a) : Estimated Parameters of Yield Equations: Paddy

Variables	Andhra Pradesh	Assam	Bihar	Kerala	Madhya Pradesh	Punjab	Tamil Nadu	Uttar Pradesh	West Bengal
CONSTANT	26.49	14.04	9.87	29.86	11.9	11.32	28.99	14.31	11.37
	(6.16)	(12.05)	(9.7)	(18.17)	(7.42)	(2.12)	(7.13)	(8.79)	(7.20)
FERTILISER	0.091	-0.02	0.083	0.079	-0.0006	0.175	0.132	0.072	0.124
	(2.03)	(-.44)	(4.78)	(3.51)	(-0.05)	(3.67)	(3.36)	(1.86)	(7.32)
MANURE	-0.017	0.106	0.022	0.087	0.016	0.073	-0.06	0.046	-0.018
	(-.498)	(1.56)	(0.45)	(2.39)	(0.433)	(1.53)	(-2.76)	(2.88)	(-0.77)
FERTILISER* MANURE	0.0002	0.01	0.0002	-0.0004	-0.0006	-0.0002	0.0003	-0.00008	0.0006
	(1.61)	(1.868)	(0.847)	(-1.13)	(-1.04)	(-.77)	(2.68)	(-0.67)	(5.67)
FERTILISER-SQUARED	-0.0002		-0.00025	-0.00004		-0.0003	-0.00029	-0.0002	-0.0003
	(-1.795)		(-3.14)	(-.48)		(-3.27)	(-2.76)	(-1.32)	(-4.437)
MANURE-SQUARED	-0.00012		-0.001			-0.00003			-0.00015
	(-.983)		(-1.69)			(-2.46)			(-2.07)
HUMAN-LABOUR	0.00005	0.006	0.008	0.0005			0.0009	0.003	0.006
	(0.499)	(3.32)	(8.03)	(.31)			(.836)	(1.92)	(5.08)
MACHINE-LABOUR					0.190	0.139			
					(2.28)	(3.86)			
IRRIGATION	1.725	3.12	7.63	2.89	1.63	9.56	0.147	3.36	5.00
	(2.053)	(1.75)	(8.38)	(1.60)	(2.22)	(2.80)	(0.14)	(3.58)	(5.52)
ZONE-DUMMY2	12.32	5.79	0.46	-11.19	1.11	0.59	1.91	8.54	5.93
	(9.01)	(8.75)	(0.83)	(-6.61)	(0.61)	(0.26)	(1.29)	(4.27)	(4.35)
ZONE-DUMMY3	7.91	16.67	-2.56	-4.08	2.93	1.19	3.74	14.12	3.61
	(4.25)	(9.19)	(-3.94)	(-2.17)	(1.64)	(0.52)	(1.97)	(7.1)	(3.48)
ZONE-DUMMY4	9.85	8.95	8.65		-3.32		1.71	10.76	4.52
	(6.59)	(9.26)	(11.56)		(-1.58)		(1.14)	(5.53)	(4.22)
ZONE-DUMMY5	13.53		-5.51		-3.44		9.41	9.27	5.79
	(8.59)		(-5.72)		(-2.08)		(5.98)	(3.19)	(5.05)
ZONE-DUMMY6			-2.38		0.35		6.42	-6.84	
			(-4.94)		(0.20)		(3.32)	(-3.87)	
ZONE-DUMMY7			-2.71		4.62			9.13	
			(-5.46)		(2.98)			(4.90)	
ZONE-DUMMY8					8.82			2.69	
					(5.11)			(1.42)	
ZONE-DUMMY9								3.67	
								(2.27)	
RBAR-SQUARED	0.30	0.40	0.68	0.48	0.43	0.14	0.19	0.26	0.54
F-Statistic	17.69	38.98	87.55	31.7	15.9	5.31	9.9	13.5	62.9
Sample	422	449	534	269	237	240	417	489	591
Irrigation Specification	IRCNL	IRG	IRCNL	IRG	IRG	IRG	IRCNL	IRPUM	IRG

Note: Figures in parentheses are t-statistics. Specifications for irrigation are IRG=irrigation by any source, IRCL= irrigation by canal, IRPUM=irrigation using pumped water.

Appendix Table A4.2(b) : estimated parameters of yield equations: wheat

Variables	Bihar	Gujarat	Himachal Pradesh	Punjab	Raja sthan	Uttar Pradesh
CONSTANT	14.51	6.38	4.85	10.30	8.80	4.44
	(8.99)	(1.99)	(3.29)	(2.12)	(3.44)	(2.26)
FERTILISER	0.025	0.045	0.087	0.23	0.09	0.012
	(1.62)	(1.90)	(4.18)	(4.81)	(3.56)	(0.43)
MANURE	-0.012	0.057	0.035	-0.097	0.045	0.096
	(-0.66)	(2.08)	(1.41)	(-1.96)	(3.12)	(2.35)
FERTILISER* MANURE	-0.000051	-0.0001	0.000064	0.0004	-0.001	-0.00001
	(-.201)	(-0.65)	(.224)	(1.67)	(-4.29)	(-.098)
FERTILISER-SQUARED	-0.000077	-0.0001	-0.0001	-0.0004	-0.0002	-0.00002
	(-1.55)	(-1.51)	(-.645)	(-3.67)	(-1.90)	(-.26)
MANURE-SQUARED			-0.0004			-0.0003
			(-2.14)			(-2.25)
HUMAN-LABOUR	0.005		0.015	0.006	0.01	0.005
	(3.75)		(4.20)	(1.96)	(4.91)	(2.69)
MACHINE-LABOUR						
IRRIGATION	2.04	16.35	6.69	2.32	5.25	0.056
	(4.03)	(5.49)	(5.98)	(2.02)	(2.55)	(.018)
ZONE-DUMMY2	-0.82	8.06	-3.38	-3.05	6.82	21.70
	(-1.58)	(3.09)	(-4.18)	(-2.34)	(2.89)	(5.56)
ZONE-DUMMY3	5.56	10.31	0.43	-1.02	2.0	23.95
	(4.50)	(4.30)	(.56)	(-1.11)	(0.93)	(6.15)
ZONE-DUMMY4	2.14	2.25			-2.73	25.1
	(3.76)	(0.91)			(-1.08)	(6.43)
ZONE-DUMMY5	1..00	1.14			6.08	24.89
	(1.23)	(0.43)			(3.16)	(6.40)
ZONE-DUMMY6	-480	-0.45			12.34	15.87
	(-5.17)	(-1.09)			(5.84)	(3.98)
ZONE-DUMMY7		4.36			7.05	23.5
		(1.68)			(3.15)	(6.02)
ZONE-DUMMY8					4.24	19.56
					(1.85)	(5.03)
ZONE-DUMMY9					6.20	17.25
					(2.57)	(4.49)
RBAR-SQUARED	0.28	0.61	0.4	0.25		
F-Statistic	18.5	33.2	21.9	13.1		
Sample	504	226	277	299	330	
Irrigation Specification	IRPUM	IRPUM	IRG	IRPUM	IRG	IRG

Note: See Table A4.2 (a).

Appendix Table A4.2(c): Estimated Parameters of Yield Equations: Groundnut

Variables	Andhra Pradesh	Gujarat	Karn ataka	Mahara Shtra	Orissa	Tamil Nadu
CONSTANT	5.29	5.71	5.62	8.26	8.59	21.39
	(4.02)	(2.93)	(3.62)	(6.04)	(7.19)	(12.00)
FERTILISER	0.063	0.032	0.036	0.075	0.072	0.042
	(2.98)	(1.62)	(1.93	(8.84)	(3.15)	(2.60)
MANURE	-0.001	0.009	0.002	0.101	-0.039	-0.038
	(-.06)	(.479)	(.19)	(2.71)	(-1.49)	(-1.45)
FERTILISER* MANURE	0.00007	0.0003	-0.00001	-0.0008	.00007	0.0002
	(.34)	(2.61)	(-.089)	(-3.34)	(.166)	(1.61)
FERTILISER-SQUARED	-0.0002	-0.0002	-0.0001		-0.0003	-0.0012
	(-2.71)	(-1.94)	(-1.17)		(-1.89)	(-1.76)
MANURE-SQUARED		-0.0001		-0.0003		
		(-1.25)		(-1.13)		
HUMAN-LABOUR	0.0068	0.008	0.0003			
	(6.57)	(5.32)	(.317)			
MACHINE-LABOUR					0.37	
					(2.58)	
IRRIGATION	-0.54	4.48	2.534	-0.21	0.26	
	(-.68)	(8.04)	(2.13)	(-0.16)	(0.28)	
ZONE-DUMMY2	-8.97	-4.84	-1.33	-5.57	-0.57	-5.45
	(-4.31)	(-3.36)	(-1.54)	(-4.04)	(-.49)	(-2.87)
ZONE-DUMMY3	-1.42	0.474	2.88	-1.35	-1.38	-10.91
	(-1.13)	(.33)	(2.27)	(-.80)	(-1.73)	(-3.81)
ZONE-DUMMY4	-1.79	-7.32	1.85	1.53	-1.55	-8.38
	(-1.07)	(-4.37)	(1.91)	(1.29)	(-1.76)	(-4.21)
ZONE-DUMMY5	-2.3	-10.29	-0.67	-4.95		-7.01
	(-1.07)	(-5.46)	(-.62)	(-1.99)		(-4.28)
ZONE-DUMMY6		8.76	0.124	-0.67		-5.92
		(4.00)	(.084)	(-1.18)		(-3.13)
ZONE-DUMMY7				-1.72		
				(-1.14)		
ZONE-DUMMY8				10.44		
				(7.97)		
ZONE-DUMMY9				-5.60		
				(-3.67)		
RBAR-SQUARED	0.38	0.56	0.26	0.44	0.53	0.19
F-Statistic	9.38	25.6	4.46	5.77	9.93	3.86
Sample	137	235	111	80	71	110
Irrigation Specification	IRCNL	IRG	IRPUM	IRG	IRG	IRG

Note: See Table A4.2 (a).

Appendix Table A4.2(d) : Estimated Parameters of Yield Equations: Sugarcane

Variables	Andhra Pradesh	Karn Ataka	Mahar Ashtra	Tamil Nadu	Uttar Pradesh
CONSTANT	85.63	582.19	437.38	275.41	350.48
	(0.89)	(5.26)	(4.83)	(1.29)	(7.656)
FERTILISER	0.21	0.88	1.20	0.744	0.229
	(.421)	(1.67)	(3.42)	(0.543)	(1.796)
MANURE	2.313		2.03	3.399	0.841
	(-0.154)		(1.39)	(1.374)	(2.086)
FERTILISER* MANURE	-0.013		-0.0016	-0.004	0.0001
	(-2.889)		(-1.53)	(-0.628)	(0.091)
FERTILISER-SQUARED	-0.001	-0.0001	-0.0009	-0.0008	
	(-1.748)	(-0.261)	(-2.83)	(-0.352)	
MANURE-SQUARED	-0.0011		-0.004	-0.007	-0.002
	(-.221)		(-0.264)	(-0.744)	(-2.227)
HUMAN-LABOUR	0.117	0.0028		0.149	0.059
	(3.776)	(0.051)		(4.789)	(3.977)
MACHINE-LABOUR					
IRRIGATION	90.78	11.29	13.96	148.87	54.348
	(1.116)	(0.174)	(0.24)	(2.546)	(1.716)
ZONE-DUMMY2	547.26			158.38	
	(5.446)			(2.08)	
ZONE-DUMMY3	381.01			66.91	-9.283
	(6.379)			(0.634)	(-0.254)
ZONE-DUMMY4				225.71	-72.32
				(2.327)	(-2.12)
ZONE-DUMMY5	250.9		165.96	-103.25	83.89
	(2.883)		(2.49)	(-0.887)	(2.572)
ZONE-DUMMY6			118.3	203.43	-13.47
			(2.24)	(2.499)	(-0.362)
ZONE-DUMMY7			116.8		-170.76
			(1.65)		(-4.54)
ZONE-DUMMY8			109.13		-142.769
			(2.04)		(-3.992)
ZONE-DUMMY9			143.54		
			(1.90)		
ZONE-DUMMY10			17.48		
			(0.24)		
RBAR-SQUARED	0.73	40.00	0.14	0.33	0.31
F-Statistic	11	4.32	2.12	5.64	10.14
Sample	38	21	84	112	246
Irrigation Specification	IRPUM	IRPUM	IRCNL	IRCNL	IRG

Note: See Table A4.2 (a).

Table A4.3: Cases of high Correlation between Pairs of input Variables

Crop/ Variables	Fertilizer H-Labour	Fertilizer M-labour	Fertilizer Manure	Fertilizer Irrigation	Manure H-Labour	Manure M-labour	Manure Irrigation	Irrigation H-Labour	Irrigation M-labour
Paddy	Madhya Pradesh		Haryana						
Wheat	Gujarat								
Groundnut	Tamil Nadu			Tamil Nadu	Maharashtra Orissa				
Sugarcane	Karnataka Maharashtra								Karnataka

Note: Correlation is deemed high if the correlation coefficient exceeds 50%. In all other cases not listed the correlation is not high. H-Labour=Human labour; M-Labour=Machine Labour.

Appendix Table A4.4: Estimation of Financial gainers and losers from Adjustment in Fertilizer use at free trade prices: Paddy

	(Percentage of Households)					(Percentage of Households)				
	Without Substitution by Manure					With Substitution by Manure				
	Large Gains	Moderate Gains	No Loss/ Gain	Moderate Loss	Severe Loss	Large Gains	Moderate Gains	No Loss/ Gain	Moderate Loss	Severe Loss
Andhra Pradesh	0.00	0.00	0.00	86.50	13.50	15.90	8.50	0.20	51.70	23.70
Assam	1.10	20.50	61.50	13.60	3.30	1.10	36.30	61.70	0.90	0.00
Tamil Nadu	0.00	0.00	0.00	61.20	38.80	15.10	30.50	1.20	51.30	1.90
Madhya Pradesh	0.00	71.30	16.00	12.70	0.00	13.10	29.50	16.00	33.80	7.60
Kerala	0.00	0.00	6.70	22.70	70.60	0.40	0.70	6.70	42.80	49.40
Bihar	0.00	0.00	1.90	98.10	0.00	0.20	77.50	3.90	18.20	0.20
Punjab	0.80	1.30	0.40	49.20	48.30	0.00	4.60	0.40	94.20	0.80
West Bengal	0.00	0.20	5.40	24.20	70.20	12.90	15.60	5.90	42.00	23.70
Uttar Pradesh	0.00	1.80	4.10	94.10	0.00	0.00	36.20	7.40	56.20	0.20
Simple average	**0.21**	**10.57**	**10.67**	**51.37**	**27.19**	**6.52**	**26.60**	**11.49**	**43.46**	**11.94**

Chapter 5

Fertilizer and Manure Use Practices among Indian Farm Enterprises

Diversity and contrasts are a feature of India agriculture. Even though the government supported and promoted a fertilizer based technology during the last three to four decades of agricultural development, Indian farmers are hardly a homogeneous lot even today. Farmers have opted for various regimens of fertilizer use and while many have moved up the scale in their use of chemical use leaving old practices behind, there are others who still retain the practice of solitary use of organic manure. There is even a section of farmers who scarcely apply any external input whether chemical or organic in character and yet many farmers use both chemical fertilizer and organic manure in conjunction, the most desirable practice, even with nearly no external incentive.

What makes a farmer choose a particular fertilizer regimen in preference to others? In reality, the answer constitutes a basket of interlinked and complex factors as they appear in the light of the farmers' perceptions based on their own knowledge and understanding of nature, production and market along with their cultural norms and attitudes. They constitute the farmer's strengths and constraints. The answer if known for certain could be useful on many counts. Firstly, it could provide a direction for targeting any technology policy for its best success. Second, it could help designing policy to motivate and encourage farmers to adopt the desired technology. Third, the constraints, if identified, often bring out the failure of past policy and its implementations and pave the way for correction. When a technology promoted is found to have bypassed certain sections, regions or crops, there arises a concern for distributional justice that has deep implications for poverty and welfare in rural India.

One way of probing the above question is by examining actual fertilizer use behaviour cross-classified by different attributes of the enterprises such as crop, regions, class and other endowments. Such results pertaining to any group would incorporate the influences of other attributes also. Although the behavioural outcomes revealed by cross-classified data help to understand the behaviour of one group as compared to others and then assess the implication of a policy change on different groups given that the conditions remain unchanged, the same deductions become invalid once other conditions change such as when small farmers alter their cropping pattern or are given access to new resources. The pure effect of any attribute after accounting for the presence of others can be captured by econometric modelling. This chapter will examine the farmers' behaviour with respect to their choice of fertilizer regimens defined categorically in terms of their use of chemical fertilizer and organic manure based on the information provided by NSSO 54th Round survey. The broad areas of enquiry would relate to the following: (1) Do fertilizer practices show diversity despite decades of a policy towards fertilizer directed technology? (2) Is there any notable regional dimension of the regimens chosen reflecting also on the dissemination of the technology promoted so far? (3) Do the practices show any degree of class distinction and is there any evidence that the so called 'modern' fertilizer based technology bypassed the resource poor and scale constrained farmers? (4) Do the particular crops make any significant difference in the choice? (5) Is fertilizer based technology associated closely with use of other modern inputs and in that sense does organic manuring practice really remain traditional? (6) What factors influence the choice of fertilizer regimens by farmers? The central question however would be : What attributes of farm enterprises go with conjunctive use of fertilizer and manure and how can this practice be promoted?

5.2 Use of Categorical data from NSSO

The analysis here is based on NSSO's 54 th round survey on Cultivation Practices conducted over 78990 households with agricultural year 1997-98 as the reference period. The survey offers a large dimension of information though largely categorical, yet richer in coverage than most other sources. The unit of observation is a single crop enterprise adding up to a total of 122565 cases. Each of these crops belongs to a set of the five most important field crops (FFC) raised by an individual household from among the following 12 crop season combinations: paddy-kharif, paddy-rabi, wheat, other cereals, pulses, oil seeds, mixed crops, sugar cane, vegetables, fodder, fruits and nuts, other cash crops and others. Addressed to the use of technology, the survey provides an impression of the fertilizer use behaviour of farmers through the responses to questions on whether they used chemical fertilizer and manure. Summarising the above one gets information on use of fertilizer, use of manure, conjunctive use of both fertilizers and manures and use of none. The data are however categorical with little quantitative dimension. Since quantitative data on acreage is available for crop enterprises, an estimate of diffusion in terms of share of area treated under the above given regimes can however be obtained apart from that of the share of the total number of crop enterprises under the regimes. Data on use of other inputs are similarly available in the data set. The sample survey data is analysed using the combined-sample multipliers in the data. Certain classifications are made for the analyses to follow.

Regional classification

The present study is based on only selected major states falling into six broad agronomic regions namely,

Region1: South (S),

Region2: North East Hills (NEH),

Region3: East and North East Plains (ENEP),

Region 4: North (N)

Region 5: North-West, West and Central (NWC)

Region 6: Northern Himalayan (N).

The classification of states (see Sarvekshana 2000) is provided in Appendix 4 .1.

Fertilizer use Categories

To understand the variation in fertilizer use practices among farmers four exhaustive sets of behavioural categories covering the whole range of possibilities have been employed as follows.

1. only fertilizer,
2. only manure,
3. both fertilizer and manure
4. non-users.

In the above classification, the first is the so-called modern technology while the second and the fourth are natural and recyclable resource based traditional methods with the former being the so-called organic method. The third category is the conjunctive use technology which is considered agronomically desirable, represents a blend of traditional and modern and is of current interest in the study. Further, to distinguish between users of the two inputs of concern, broader but overlapping user classes have been identified by combining categories (1) and (3) and categories (2) and (3) respectively. The first represents fertilizer users (with or without the use of manure). Similarly the second broad class constitutes the manure users. These broad classes of fertilizer and manure users are also employed in the study. A fertilizer or manure user would refer to any farmer who uses it either partly or entirely. Fertilizer is defined by NSSO as 'pure compounds of NPK' used as plant nutrients 'manufactured in factories' while all other nutrients of plants are manures. Manures are subdivided into compost, biogas slurry and other forms, mainly farm yard manure. Bio-gas slurry, which may be a remarkably sustainable form of organic treatment because of its synergy with biogas production, forms a small part of the manure used (Table A4.).

Farm classes and Assets

To distinguish among farm classes the usual classification of size classes (FSZCLASS) are considered as follows:

Marginal: Upto1 hectare,

Small : 1.01 hectare to 2 hectare,

Medium : 2.01 hectare to 10 hectare

Large : greater than 10 hectare.

Farm classes in this chapter are defined in terms of land possession rather than ownership, adjusting for leasing in and out of land as this is more relevant for application of a technology. However, farm classes are also alternatively considered in terms of asset ownership that includes land among other things. Ownership of land can be permanent and heritable (with or without transfer rights) and a farmer owning more than 2 hectare of land is treated as landed. Other indicators of endowment are ownership or access to different productive amenities such as irrigation, own livestock and own farm machinery. Farm machine covers either tractor or harvesting machine which is owned and actually used for the enterprise.

Common Property Resources

Apart from these conventional endowment indicators, the study also includes access to common property resources (CPR) as an additional indicator. In a rural set up where poverty is widespread and ownership of assets is highly skewed people often have to fall back on the common resources for a living in different ways. Biomass in various forms and grazing facility are common harvests gained from common lands and forests where access is possible. Since these products or services have a direct bearing on use of manure, the importance of these resources cannot be overlooked. However it is common knowledge that this access means gains largely for the otherwise poor farmers with limited ownership of assets and poor financial access to hired assets. Common property resources are defined as 'resources accessible to and collectively owned/held/managed by an identifiable community and on which no individual has exclusive property rights'. An identifiable community can mean all inhabitants of a village from an identifiable community such as a social group that is caste based or religion based or occupation based. Village Panchayat grazing land/pasture land, village forest or woodland are common forms of CPR but in a broader sense, even forest land under government control or in private ownership can form common property when they actually provide resources to the poor. In this study CPR is considered in a *de facto* sense where the property has been actually used. NSSO reports on various uses of CPR but there are two ways CPR use can be meaningful for fertilizer use practice; (a) use of CPR for livestock feeding, i.e., either by grazing or collection of fodder and (b) use of CPR directly for collecting manure.

Crop Enterprises as the Units

The measurement of the tendency (probability) of any group to belong to any particular practice can be made in terms of the share of crop enterprises (or crop-household cases) falling under that category. A higher share under the category is taken to be an indication of greater tendency of the enterprise to opt for that category. While area share could be a reasonable indicator of the tendency owing to its correspondence to technological diffusion, where economic and political significance of decision units are more relevant, the share in crop enterprises appears to be more meaningful. Since there is no reason to assume that average area under an enterprise is uniform especially between fertilized and non fertilized land areas, this latter concept has its own separate relevance. Each crop enterprise means one new decision making process with its own concerns, though not always by a new household unit. A higher number of enterprises opting for a certain input regime draws attention to the regime even if the area share is low, especially when small sized farms are a norm.

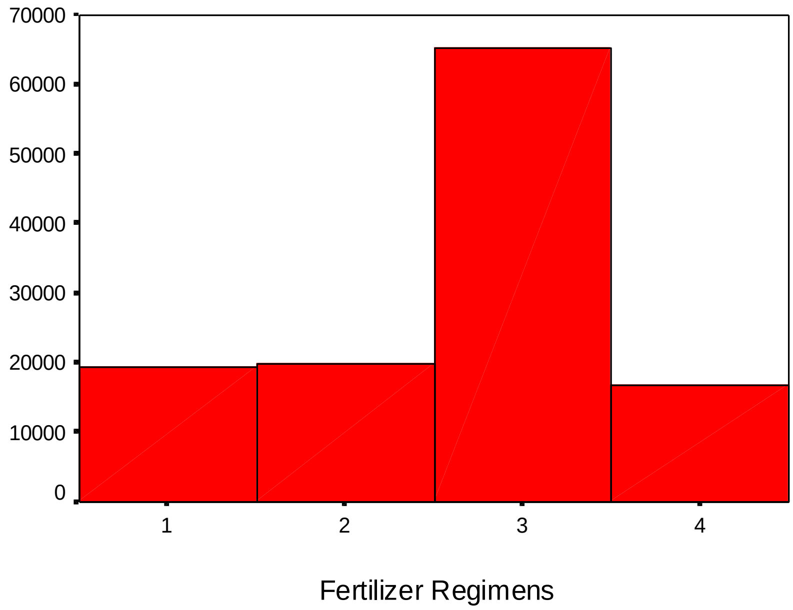
The enterprises are treated as altogether new units with their endowments, practices and choices assuming that decisions across crops are independent.

5.3. Fertilizer use and Regional fertilizer Practices

The NSSO data clearly brings out the existence of diverse fertilizer practices but the largest section of enterprises actually opt to use both chemical fertilizer and organic manure i.e., regimen (3) while the rest is nearly uniformly divided among the other three regimens[i]. In fact the last and the smallest group that eschews use of any one of the two nutrients also constitutes nearly 10% of the total number.

Figure 1:

Distribution of Sample Fertilizer use Categories



Frequency= Number of crop enterprises in the category

About 34% of the enterprises uses only either of the two plant nutrients and 74% of enterprises are characterised by use of chemical fertilizers (Table 5.1). The extensive use of manure in today's agriculture (71%) may be explained either by the awareness of the positive and complementary effects of the two nutrients or simply by the limited access to fertilizer or the credit required to buy the same. In terms of area the figures are similar though the area shares in traditional soil enrichment methods are lower than the number shares of enterprises. The region wise picture is quite diverse, with the northern region having least tendency for traditional means and highest tendency for solitary use of fertilizers. The southern region has a high share under conjunctive use of fertilizers and manures and the least under category fertilizers only if the two hilly regions are overlooked. The share of conjunctive users ranges from 18% in region 2 to 73.5% in the northern hilly region. Share of enterprises under manures is highest in north east where a very large part is also cropped with no external input used. The coefficients of variation mark moderate variation across the major regions with those of the first and last categories being relatively high and those for area share being higher.

Table 5.1 :Distribution and Diffusion of Fertilizer use Categories Across Regions

	Fertilizer Use Categories							
	1	2	3	4	1	2	3	4
	Percentage of Enterprises				Percentage of Area			
Total	18.50	15.40	56.40	9.70	18.75	11.61	62.32	7.32
Region1-S	10.40	13.30	67.10	9.20	11.43	8.10	75.71	4.76
Region2-NEH	7.80	26.80	18.00	47.40	7.13	27.63	18.63	46.63
Region3-ENEP	22.80	15.00	50.40	11.80	22.20	12.20	56.20	9.40
Region4-N	22.20	13.50	58.60	5.70	25.88	3.82	67.35	2.94
Region5-NWC	16.10	18.30	53.90	11.70	15.75	16.97	57.85	9.43
Region6-NH	7.70	17.20	73.50	1.60	7.30	16.05	75.42	1.23
CV	47.65	29.23	36.20	113.85	52.25	58.39	36.30	137.90

5.4. Fertilizer Practices across Classes

The green revolution has often been blamed for imbalances across crops and regions. and with the creation of duality in the rural society, where one section of farmers, presumed to be wealthy and land rich forged ahead with the technology while the lesser endowed farmers lagged behind. Farmers would then vary in their behaviour with respect to the technology and smaller farmers with relatively low purchasing power and poor access to institutional credit may be expected to have a relatively traditional practice. While this possibility of iniquitous incidence of the farm technology and its diffusion within the farm hierarchy (Chopra and Kapuria(2001)[ii] might raise questions about the distributional justice of the technology policy implemented, an outcome of this difference might be that a new policy generating a rise in fertilizer price would make little impact on the well being of small farmers any way, while releasing valuable fund for public investment. The impact would fall largely on endowed farmers better capable of coping with the adversity and adjusting to it. To the extent the smaller farmers, disadvantaged by the scale of operation and resource position, are bypassed by modern technology the price situation anticipated in a changed regime may not in particular hit that class and there may be alternative possibilities of developing organic agricultural practices among these classes. On the contrary, to the extent there is homogeneity in practices across sections it is reasonable to argue that that the public policies based on subsidies and protection have played an essential role in sustaining an equilibrium, and any regime change without back up policy actions could threaten the survival of a large section of the country's population.

Land possession as an indicator

Table 4.2 however fails to reveal any such distinction. Across farm size classes the behaviour is much more uniform than among regions. The area shares too support the same conclusion. Between 17 and 20 per cent of enterprises falling in the marginal farm size category use only fertilizer or only manure, the share being a little higher in terms of area for the first category and lower for the second. In each of the size classes more than half of the enterprises and area go for conjunctive use with the share going up only marginally with size class while the share under category 4 is low in general and lowest for the highest size class. The variation across size classes is low, below 10% in most cases. In a further disaggregated view (Table A5.2), the behaviour is found similar across classes within any region but that variation is far more marked among regions even for the same size class. An F-test employing these two different segregations is conducted to have a more precise statistical test of the similarity of behaviour across farm size classes.

Statistical F-Test

A statistical test based on an analysis of variance (ANOVA) can be conducted over the data of fertilizer use practices across regions and farm size classes to further test

Table 5.2: Distribution and Diffusion of Fertilizer use Categories by Farm size classes

	Categories				Categories			
	1	2	3	4	1	2	3	4
	Percentage of Enterprises				Percentage of Area			
Farm size class 1	19.60	17.30	53.30	9.80	21.17	11.83	59.83	7.17
Farm size class 2	18.40	13.60	58.30	9.70	19.35	11.29	61.29	8.06
Farm size class 3	16.20	12.60	61.50	9.70	16.57	11.79	64.33	7.31
Farm size class 4	17.40	13.30	61.30	7.80	21.73	11.73	60.06	6.48
CV	8.03	14.85	6.53	10.46	11.79	2.15	3.37	8.96

the hypotheses that practices do not vary significantly across farm size classes and geographical regions. This is done by considering the proportion of enterprises falling under a category as a variable signifying the tendency to adopt that regimen, and farm size class and region as two separate factors. The analysis (See Appendix 5.2.1) is done for a variable with each factor to define a group consecutively. Parallel to this, the proportion of area is also treated as a variable for further support. The F-statistics reported in Table 5.3 signify that the hypothesis cannot be rejected across farm size classes in any of the cases but is rejected across regions in all. The results corroborate the earlier indication that the on the whole the farmers' fertilizer use behaviour differs so far as they belong to geographically disparate regions even if they belong to a similar farm size class. The fertilizer based technology promoted by the existing policy regime has on the whole proved scale or class neutral but shown regional dispersion especially to the disadvantage of hilly states.

Table 5.3 Test for SIMILARITY in Fertilizer user pattern across farm size classes and Regions (F-Statistics)

Fertilizer use Category	Across Farm Size Classes		Across Regions	
	By share in Crop Enterprises	By Area Share	By share in Crop Enterprises	By Area Share
1	0.12	0.27	17.67*	11.49*
2	0.14	0.03	8.75*	9.57*
3	0.08	0.04	58.95*	47.90*
4	0.03	0.03	142.99*	131.56*
Degrees of Freedom				
Between groups	3	5	5	5
Within groups	20	20	18	18
Total	23	23	23	23

* Significant at .1%

The dominance of the small and marginal class of farmers[iii] in Indian agriculture gets reflected in their shares in all the broad user categories as seen in Table 5.4 with the marginal class contributing to more than half of each of the categories though somewhat less for the conjunctive category in which the medium size classes have greater weight than others.

Table 5.4. : Distribution of different User Enterprises into Farm size classes (Percentages)

Farm size class	Fertilizer user	Manure user	Conjunctive user	Non-user
1	52.2	52.8	50.7	54.0
2	23.0	22.6	23.3	22.50
3	23.4	23.3	24.6	22.4
4	1.4	1.3	1.4	1.0
All	100.0	100.0	10	100.0

Other indicators of Asset

A farm class is usually defined by its possession of land, owned or operational. However, though important, land is only one of the defining assets for farmers and ownership of or access to other assets can contribute to higher production and income earning capacity. Also there may be a discontinuity in access to credit and other facilities with respect to land possession so that below a certain minimal possession even land can make little difference to economic viability. Taking into account landed status, ownership of farm machinery[iv] (tractors/harvestors), access to irrigation facility possession of livestock and use of CPR for manure, fodder or grazing it is possible to have a broader view of whether fertilizer users belong primarily to more endowed farmers. Farmers above small farmers i.e., those possessing land above 2 hectares are classed as landed. Table 5.5 shows that only 26% of fertilizer users are landed, rest being marginal or small farmers or landless. More than 90% of the users have no farm machinery but fairly large part of them have irrigated land or own livestock.

For manure it is no different, only the share of endowed farmers in this user class is even less with respect to farm machinery and irrigation but as could be expected, the share is actually more when livestock and access to CPR are considered since both these forms of endowment may actually improve the farmer's access to manure. Curiously the landed farmers constitute a comparable chunk of the non-users (perhaps a section of landed do not cultivate input intensively owing to quality of land or their priority to other non-farm enterprises). Again those with access to CPR contribute more to non-users and even those with livestock have a sizable (though not higher) share compared to the other two user classes and possibly comprise the poor who depend on CPR and their animals and derive greater value from the animal refuse from sale or fuel use than as manure. The share of landed farmers and those having machinery and especially access to irrigation is expectedly much less. Viewing all this from the other end (see figures in parentheses) higher proportions of enterprises tend to use fertilizer than manure when they are endowed with farm equipment and access to irrigation and when they are landed. A relatively small percent of the endowed farmers would choose to be non-user. Endowment is appreciably high with conjunctive users.

Table 5.5 : Fertilizer Use behaviour and Asset holding of Enterprises (% of user category)					
Wealth indicator Category	Landed	Own Farm machinery	Irrigated land	Own Livestock	CPR Access
Fertilizer user	26.0	7.3	76.4	82.0	14.8
	(77.5)	(89.4)	(89.7)	(74.9)	(61.2)
Manure user	26.0	6.4	65.5	85.0	19.5
	(74.2)	(74.8)	(73.6)	(74.3)	(77.1)
Conjunctive user	27.3	7.5	75.8	84.7	15.7
	(61.4)	(69.0)	(67.0)	(58.2)	(48.9)
Non-user	24.8	3.0	24.0	76.0	19.7
	(9.6)	(4.7)	(3.7)	(9.0)	(10.6)
Note: Figure in parenthesis is % share of asset holders The first two categories are overlapping.					

The tendency is similar across regions (Table A5.3). Relatively asset poor farmers who are nevertheless fertilizer users are more often encountered in eastern and north-east India and to some extent in hilly northern India and less often in the north and west. T sum up fertilizer use (Table 5.6) is found to be prevalent widely among the smaller farmers in terms of land ownership, irrigation is found to accompany fertilizer use while manures user are more often found to use CPR and possess livestock. Land ownership did not reflect any particular association with either but a higher proportion of conjunctive users seem to be landed.

Table 5.6: Percentage of Fertilizer user Enterprises having access to different Assets					
Asset Indicators	Land owned (>2hect.)	Own Farm machinery	Irrigated Land	Own Livestock	CPR use
Region1	27.5	4.7	65.7	70.2	11.7
Region2	12.6	4.3	43.0	54.6	6.3
Region3	12.8	3.0	73.0	76.0	10.6
Region4	21.2	11.4	94.3	86.2	12.0
Region5	46.2	7.9	65.8	25.9	25.9
Region6	11.2	1.7	39.6	89.7	5.6
All Regions	26.0	7.3	76.4	82.0	14.8
Note : Fertilizer users include solitary and conjunctive users.					

Over time and quantitative View: An Alternative Source

The analysis of NSSO data leaves two prominent lacunae. First, related to a single period of reference the results drawn may not reflect any degree of stability over time. Second, as mentioned the categorical nature of data imposes some limitation as the results are qualitative and hence merely indicative. The above discussions imply that small and marginal farms do use fertilizers as do their larger counterparts but this may have little bearing to whether they use the input in far smaller intensities. To examine the veracity of results at the temporal and quantitative dimensions data reported by All India Report of Input Survey 1991-92 (the latest survey is still awaited) is reported in Table 5.7 The alternative source based on an earlier survey suggests the tendency of small and marginal farms to use chemical fertilizers is more than larger ones in extensity and also intensity.

Table 5.7 : Use of Fertilizer by Farm size classes by Intensity and Diffusion 1991-92

	Paddy		All crops	
	Use Intensity	Area fertilized	Use Intensity	Area fertilized
	Kg/hect.	%	Kg/hect.	%
Size classes				
<2hectare	84.07	71.47	68.61	63.09
2 -9.99hect	80.18	66.52	58.87	59.40
10hectand above	56.91	45.37	46.03	46.94
All	79.77	67.0	60.71	59.08

Source: All India Report of Input Survey 1991-92

5.5. Do Crops make a difference?

That different crops would call for different fertilizer practices not only in intensity but in regime may be well expected. The dissimilarity would largely

Table 5.8 Distribution of Enterprises into Fertiliser use categories by 5 Major Crops (Percentages)

Category	Paddy Kharif	Paddy Rabi	Wheat	Oilseeds	Sugarcane
1	19.0	25.8	25.8	18.3	15.9
2	13.4	4.4	9.2	19.7	3.7
3	60.6	64.5	62.6	51.0	77.9
4	7.0	5.3	2.4	11.0	2.5
All	100.0	100.0	100.0	100.0	100.0

arise from unequal bio-chemical demands and responses of the species just as the cropping pattern suitable for one kind of region may be unsuitable in another. However, the variety can also hide some extent of crop imbalances that have featured Indian agriculture arising from market signals, that are more often distorted than not. Table 5.8 covering only five major crops shows that higher share of enterprises in paddy-rabi and wheat tend to go for fertilizer only category than others. These enterprises also have small portions that opt for manure only category. On the contrary enterprises in oilseeds followed by paddy-kharif allocate higher shares to manure only regimen than the others. All crop enterprises uniformly have highest percentage of enterprises choosing the conjunctive category 3 with sugarcane leading and oilseeds coming last. Oilseeds have higher share of enterprises not only under manure only regimen but also those that avoid use of fertilizer or manure while only 2.4 of wheat enterprises are in regimen 4. The broad observations hold at regional levels and there are only marginal distinctions in the behavioural patterns across regions (Table A5.4).

The five crops constitute more than half of the user categories and only about 30% of non-user category in terms of enterprises (Table A5.5). Paddy as expected claims the largest share of the crops in each category of enterprises but paddy-kharif contributes to 16% of all enterprises who use neither of the inputs. Sugarcane constitutes less than 1% of non-user class. Paddy and wheat together constitute 48% and 44% of fertilizer using and manure using enterprises respectively though the shares are somewhat higher in terms of area. Oilseeds occupy larger shares in the manure user and non-user classes than it does in fertilizer user class. Thus any change in policy balance in favour of fertilizer use is likely to affect wheat farmers relatively more while that in favour of manure use will have greater effect on paddy and oilseeds.

5.6. Fertilizer use practices and Use of Modern Technology

Fertilizer use is associated in general perception with green revolution and modern technology. On the contrary manuring is a traditional practice often abandoned in favour of the so called modern input fertilizer. Basically fertilizer is viewed as a crucial part of the package which consists of such core inputs as improved seed and mechanised irrigation and associated productivity enhancing inputs like farm equipment, pesticides and weedicides. Joint use of all these inputs is in no way basic for higher productivity or efficiency. Fertilizer is used for growing traditional varieties of grain despite their lower responses and use of machinery is constrained in labour rich and land scarce farming systems which do not however restrain use of fertilizer. That organic manure is desired for soil health and greater efficacy of fertilizer is communicated by research and extension services and may be known and accepted by many farmers. Soil test depends on the facility available and the progressive attitude of the farmers.

A cross-tabulation of technology practices, with improved seeds, mechanised devices (pumps, tractors or harvestors), pesticides (including weedicides/fungicides) and soil test taken as indicators of modern technology against the four fertilizer regimens (Table 5.9) shows that largest portions, exceeding 65% of each of the technology user classes belong to the category of conjunctive use. This suggests that the choice of the category is more a recognition of the complementarity between the two inputs and rational calculation than financial or institutional constraints. The corresponding shares are understandably least for non-users followed by solitary manure users. Taking the reverse view, among the solitary user of fertilizer more than 50% used

Table 5.9 :Use of Modern Methods and Fertilizer use behaviour

	Fertilizer use Categories				
	1	2	3	4	All
Inputs	Percentage of Enterprises using different methods				
Improved Seeds	19.7	6.8	70.0	3.5	100
	(51.5)	(2.13)	(60.4)	(17.5)	
Mechanised Devices	23.0	6.8	65.5	4.7	100
	(75.9)	(27.0)	(71.0)	(29.3)	
Pesticide/ Weedicide	19.5	4.9	73.7	1.9	100
	(43.1)	(13.1)	(53.5)	(7.9)	
Soil test	14.0	6.8	72.5	6.7	100
	(2.8)	(1.7)	(4.9)	(2.6)	

Note: Figure in parenthesis is share within fertilizer use category.

improved seeds, 76% used machines, 43% used either pesticides and a mere 3% had soil testing done. The corresponding ratios are much lower for solitary users of manure. Large proportions of conjunctive category go for modern technology. The technology dissemination among non-users is low in general but it is interesting to know that a section, though small, of farmers who do not add external soil enrichment is also modern in technology otherwise. In general soil testing is done by a very small share of enterprises in all categories. The disaggregated picture (Table A4.6) is no different. Larger enterprises who opt for conjunctive technology tend to show some improvement in respect of soil testing.

A more comprehensive way to get the relation between fertilizer practice and modern methods is through use of statistical measures of association (see Appendix 5.2.2). The measures are computed using the broad classes and the summary of the measures is provided in Table 5.10. It is noted that on the whole both fertilizer use and manure use are positively associated with use of modern technology. In other words manure users need not be traditional in practices and may be driven by productivity consideration in consistency with their other practices. However, use of machine power is found to be negatively associated with manure use in two of the size-classes.

In Table A5.7 the Contingency coefficient (CC) measures nominal association and Kendall tau-c (KC) measures ordinal association between variables and the sign in KC indicates the direction of association. The former measure allows comparison of χ^2 values from various sample sizes. Though the association is mostly positive for both fertilizer and manure users, in nearly all cases the magnitudes suggest that the association is much weaker for manure user class. That fertilizer users are more likely to show preference for technology was also indicated by the proportions in Table A5.6. The association appears comparable only in case of soil test.

Table 5.10: Direction of Association between Fertilizer use behaviour and Use of Modern methods by Farm size classes

	Improved Seeds	Machine Power	Pesticide or Weedicide	Soil Test facility
All classes				
Fertilizer user	Positive	Positive	positive	Positive
Manure user	Positive	Positive	positive	Positive
Non-user	Negative	Negative	negative	Negative
Farm size class1				
Fertilizer user	Positive	Positive	Positive	Positive
Manure user	Positive	Negative	Positive	Positive
Non-user	Negative	Negative	Negative	Negative
Farm size class2				
Fertilizer user	Positive	Positive	Positive	Positive
Manure user	Positive	Positive	Positive	Positive
Non-user	Negative	Negative	Negative	Negative
Farm size class3				
Fertilizer user	Positive	Positive	Positive	Positive
Manure user	Positive	Positive	Positive	Positive
Non-user	Negative	Negative	Negative	Negative
Farm size class4				
Fertilizer user	Positive	Positive	Positive	Positive
Manure user	Positive	Negative	Positive	Positive
Non-user	Negative	Negative	Negative	Negative

Note: (i) Results based on Kendall's tau-c in Table A5.7 (ii) Associations are all significant at 0.1%.

5.7. Explaining the Fertilizer use practices of Farmers:

Econometric methods offer a comprehensive way to examine the direction and strength of impact of any influential variables after accounting for other possible influences. The constraint is the nature of data that is more categorical than quantitative and continuous in nature. In this situation econometric methods can be used by posing the question: In what way does a change in any variable affect the probability that a farmer chooses any particular fertilizer regimen.

The Multinomial Logit Model

The model attempts to understand the decisions of farmers with regard to the choices of fertilizer regimes. The exercise draws on literature on human choice behaviour when the alternatives are qualitative or 'lumpy' (Mc Fadden, 1974). Problems of this nature are described by the (1) object of choice and sets of alternatives available to the decision maker, (2) Observed attributes of the decision maker, and (3) The actual choices made.

The farmer is here viewed as choosing from m alternative fertilizer regimes which form an exhaustive set of fertilizer use practices $F= \{F_1, F_2,\ldots F_m\}$ and conducting a cost benefit analysis, unobserved to the researcher, and opts for the regime that maximises his *expected* returns R from cultivating a hectare land.

$\text{Max } R_i (F_i/A)$ ……1

Where F_i is any fertilizer regime belonging to a set F ($F_i \varepsilon F$) given a set of measurable attributes $A=[x_1, x_2, ..x_t]$. Variable R is latent and depends on intrinsic agronomic factors and market conditions as well as the farmer's own perceptions about cost and responses. Because of the subjective elements involved, the model is considered to follow a process analogous to McFadden's random utility function(1974) in that the expected returns have a non stochastic component V_i where $V_i =\beta'_i x$ and an idiosyncratic random component ε_i which are iid. It follows that

$P_i = P(F_i/A,F) = P[\varepsilon_j < \varepsilon_j + V_i - V_j$ for all j not equal to i] …..(2)

represents the probability that a farmer drawn at random from the population will choose fertilizer regime F_i, given the measured attributes in A and choice set F.

Defining an observable variable Y_i such that

$Y_{ki} = 1$ when $R_{ki} > R_{kj}$, for all j not equal to i and

=0 otherwise,

we have Prob (Y_{ki}=1) = P_{ki} which gives the probability that the k-th farmer will choose the i-th fertilizer use regime. Equation (2) generates a cumulative distribution function that can be assumed to be logistic (S-shaped).

$$P_{ik} = \frac{e^{\beta_i^1 x_k}}{1 + \sum_{i=2}^{n} e^{\beta_i^1 x_k}} \qquad 3$$

Equation (3) represents the multinomial logit model when the first category is considered as base assuming $\beta_1 = 0$. To interpret the parameters (β) equation 3 is transformed by (a) dividing P_{ik} by base category probability P_{i1} and (b) taking the log transformation on both sides. The resulting expression is the 'logit' which is logged odds of drawing the i-th category as against the base obtained as a linear expression in β and signifies the expected number of draws of the i-th category for each draw of the base category. The parameter β is therefore the change in the logged odds due to unit change in the independent variable and is comparable across different categories by magnitude. However since the variable giving logged odds has no clear interpretation the exponent of β is usually presented as the effect on the actual odds. Thus a value of Exp(β) exceeding 1 implies that the odds are increased and vice versa while a unit value of β would indicate that the odds are unaffected. The independent variable may be continuous with the usual interpretation of the derivative or may be categorical or dummy with the effect signifying a movement from one state to another. Since the data in the present case records the choice set of four fertilizer regimes, the actual choice and several measured attributes of the crop enterprise units it is possible to estimate a multinomial logit model by defining a set of dummies created for the choices made.

The model is estimated over all India data pooled across units from the states in the six broad agro-climatic regions and covering eleven crops falling in the FFS category. The variables are either categorical or binary in character but the explanatory variables can be continuous. The fertilizer regimes[v] which represent the realised choices and hence also the dependent variable are as follows: (i) F1: No use of fertilizer or Manure, (ii) F2: Use of Manure only, (iii) F3: Use of Manure and Fertilizer conjunctive and (iv) F4: Use of Fertilizer only.

The unit specific attributes that lead to these decisions relate on the one hand to output responses of regimes and on the other the cost of accessing the inputs as could be understood and perceived by the farmer. The likelihood of choosing any fertilizer regime is expected to depend on the nature of crop and the agro-climatic conditions(including soil) of the region as productive responses (and hence profit potentials) would vary. Similarly the season of the enterprise kharif or rabi carries its own implications of weather and risk. Availability of irrigation is another variable that affects the response potential. Under the present system, cross section data would not throw up significant variations in fertilizer prices across farms or even across regions. However, as is well known real cost of fertilizer lies not just in monetary market prices but in accessing it which is conditioned by the region's endowment of infrastructure and farmer's purchasing power as determined by his wealth and access to credit. Cost of manure in unregulated local systems would carry a large part of non-monetary cost depending on the farmer's valuation of the time lost in collection, other occupations, local institutions and access to village commons, other biomass constraints and local manure markets. On the whole cost of accessing both inputs would be influenced by farmers' economic and social position and access to resources, borrowed or owned.

The farmers' resource position is judged by land possessed that is reflected by the farm size class to which the household belongs, the main interest being the behaviour of small and marginal farmers. The farm size can also signals technological possibilities and constraints through scale. Although the farm size class (FSZCLASS) is treated as an indicator of wealth and possibly of access to institutional or non-institutional credit, some alternative specification of class or scale are explored through models 1 to 4. Using a dummy variable the choice implications of small/marginal farm enterprises in particular is examined in Model 2 and in Model 1 a continuous variable of land possessed is the proxy for class rather than the four broad size classes. Ownership of farm machinery (tractors/harvestors) by the enterprise is considered by including the additional variable in Model 3 and finally in Model 4 the crop specific area of the enterprise is the class indicator though the variable is essentially a proxy for scale economy.

Possession of livestock (LVST) and use of CPR are other indicators of access that are relevant in this particular problem. Livestock possession is a direct access to manure though the same waste product can be used for other purposes like fuel. CPR can be used directly for collection of manure and indirectly for feeding livestock which yield manure. CPR is therefore treated as two different individual variables one as CPR for collection of manure (CPRMANU) and other is CPR for livestock feed by grazing or collection of fodder (CPRLVST). It is also interesting to understand certain important interactions such as when a small/marginal farm enterprise also possesses some livestock and further when a household also has access to CPR for feeding the same. Since use of CPR for feed is relevant when livestock ownership is indicated the variable CPRLVST is considered only in the interaction term with variable LVST. Although in principle CPR may be utilised by households without livestock for collection of fodder for sale and the proceeds used for buying manure for cultivation, the sample data did not contain households owing no livestock and yet using CPR for feed (i.e., CPRLVST>0). The technical details of the model and the specification of the used variables are explained in Appendix 5.2.3.

Results

The results reported relate to last three categories (one less than total number) with the first category F1 as base. The coefficients and the exponents of the coefficients are presented in Table 5.11. The region and crop variables, representing the broad agronomic and unordered attributes are treated as factors and the other variables are covariates. Measuring the goodness of fit, (the accuracy with which the model approximates the observed data), is a problem in such a model where the observed dependent variables take values only 0 or 1. As suggested in the literature an estimate of pseudo R^2 based on likelihood ratio (LR) test statistics is the estimate of the goodness of fit of the model where the (LR) for the null hypothesis that the coefficients of the variables used are zero is obtained by dividing the likelihood of the complete model by that of the reduced model with only the constant term included. Additionally, the χ^2 tests conducted on the likelihood of drawing the observed sample, also presented (Tables A4.8, A4.9), test the null hypothesis that the coefficients for all the terms in the current model, except the constant, are 0 and further the improvement of adding each subsequent variable to the model is nil.

The signs of the coefficients show the direction of impact relative to base practice but in interpreting the coefficients or their exponents it is important to emphasise that the it is the odds against the base category (in which neither fertilizer nor manure is used) rather than probability that is obtained in each case on the left hand side[vi]. As such, then the signs of the coefficients carry limited relevance and a comparison of magnitudes all three corresponding coefficients can convey the relative strength of

Table 5.11: Factors affecting Fertilizer use behaviour of Enterprises (Coefficients from MNL Model)

Base category is Non use	Manure use only		Fertilizer and Manure use		Fertilizer use only	
Variables	**B**	**Exp(B)**	**B**	**Exp(B)**	**B**	**Exp(B)**
FSZCLASS	-0.014	0.986	0.373	1.452	0.165	1.179
IRGTD	0.439	1.551	2.249	9.477	2.210	9.118
KHARIF	0.411	1.508	0.280	1.323	0.014	1.014
LVST	0.549	1.731	0.896	2.449	-0.067	0.935
CPRMANU	1.374	3.949	-0.805	0.447	-1.253	0.286
LVST*FSZCLASS	-0.048	0.953	-0.258	0.773	-0.099	0.905
LVST*CPRLVST	0.715	2.043	0.027	1.028	0.0035	1.003
FSZCLASS*LVST*CPRLVST	-0.225	0.799	-0.066	0. 936	-0.137	0.872
REGIONS	**Base Region is 'NORTHERN-HILL'**					
SOUTH	-1.795	0.166	-1.985	0.137	-1.685	0.185
NORTH-EAST-HILL	-2.986	0.050	-4.963	0.067	-3.573	0.028
EAST+NORTH-EAST-PLAINS	-2.393	0.091	-3.277	0.038	-1.832	0.160
NORTH	-2.15	0.116	-2.757	0.064	-1.408	0.245
WEST-CENTRAL	-1.985	0.137	-2.897	0.055	-1.735	0.176
CROPS	**Base Crop is 'Other cash crops'**					
PADDY	0.203	1.225	0.377	1.458	0.28	1.323
WHEAT	0.894	2.444	0.848	2.336	0.75	2.116
OTHER CEREALS	0.249	1.283	-0.271	0.763	-0.374	0.688
PULSES	-0.253	0.776	-1.078	0.340	-1.144	0.319
OILSEEDS	-0.009	0.991	-0.544	0.580	-0.402	0.669
MIXED CROPS	-0.507	0.602	-1.087	0.337	-1.031	0.357
SUGAR CANE	-0.234	0.791	0.395	1.484	-0.062	0.940
VEGETABLES	0.682	1.978	-0.256	0.774	-0.706	0.494
FODDER	-1.083	0.339	-1.579	0.206	-1.472	0.229
FRUITS NUTS	-0.462	0.630	-1.895	0.150	-1.831	0.160
INTERCEPT	1.626		2.645		1.528	
Pseudo R-square (Nagelkerke)	0.37					

Note: Coefficients are significant at 0.1%. B is the coefficient of regression and Exp(B) is the factor by which the odds of belonging to the category change.

preferences for the practices. The impacts are discussed taking each variable at a time.

Class: In Table 5.11 farm size class by four categories is taken as the variable indicating the class of the enterprise. Although the distributional behaviour noticed in Tables 4.2 and 4.3 raised a conjecture of scale or class neutrality both regimens F3 and F4 involving fertilizer use show positive sign of the coefficients while F2 shows a negative sign. This seems to suggest that larger enterprises, given other things, do move towards fertilizer use and away from solitary use of manure which becomes the least preferred option. Regimen F3 of current interest and conjunctive use shows the strongest class responsiveness going by this variable suggesting that as size increases the enterprise becomes more likely to adopt this practice relative to base than the other two regimens. By the specification of the equations allowing for interactions, the class effect itself would be sensitive to the enterprise's ownership of livestock and use of the CPR. The negative signs of interactions suggest that the positive class effects are moderated by the endowment of these resources whereas the negative class effect in case of regimen F2 is reinforced. The smaller size classes gain further inclination to adopt the manure only use practice when they possess livestock resources and further when they can use the CPR for supporting the livestock. The interaction between class and livestock ownership is strongest for the conjunctive use practice but that with CPR is weak. However the probability of taking up solitary fertilizer use also increases relative to base category for small classes with access to livestock and CPR possibly due to income effect.

Mainly to explore the class implications other specifications are tried and reported in Table A5.10. The variables considered alternatively do not convey the same implications but by far they do not contradict the findings in Table 5.11 In Model 1 which includes class variable in terms of actual farm size, as farm size increases continuously, the enterprise is more likely to choose any of these regimens relative to base F1 but the tendency is stronger for F4 and F3 in order and weakest for F2. In Model2 the class is handled by a dummy variable for small farmers who are found to go less for all three regimens relative to the base but least so for the conjunctive regimen F3. The result on class non-neutrality is unaltered when asset ownership too is additionally included in the model with FSZCLASS, where asset ownership has strong positive influence on choice of F4 and F3 and weaker positive effect on choosing F2. Finally the CROPAREA finds positive scale impacts on choosing the regimes F3, F4 and F2 in that order. On the whole, the models suggest positive class/scale impact for the conjunctive regime in particular and fertilizer use in general.

Season: The kharif season seems to have a bearing on the choice of manure based regimens with the odds of choosing solitary fertilizer (manure) use regimen being least (most) in the kharif season. The seasonal element in manure market through its link with the fuel market and time constraints is discussed in Chapter 3. The intensification of fertilizer leaching may also have some role in this apathy to fertilizer use in the rainy season.

Irrigation: The odds increase in all cases against the base but as expected, solitary manure use has less chances of being chosen if irrigation is available than fertilizer use. Conjunctive practice is the most likely one to be taken up when this facility is present.

Livestock: Livestock ownership affects the odds of choosing the fertilizer only regime F4 in a negative way (choice of F4 would mean non-utilisation of the available resource for agriculture) but the effect on the two manure based regimes are both positive and all parameters are significant. There appears to be a motivation to make use of the in-house manure resources for farming in consideration to the limitation of the manure market. The effect is strongest on the conjunctive use regime. The interactions are also revealing. The negative signs of the FSZCLASS*LVST term suggests that the negative impact of livestock ownership on regime 4 is strengthened when the farm size class is higher but its conducive impact on conjunctive use class (F3) as also on solitary manure use (F2) is more for smaller classes. The positive effect of livestock ownership is also reinforced by the use of CPR. The chances that the enterprise would go for the conjunctive regime would improve if it possesses livestock, when the farm size is small and the farm uses the CPR for livestock feeding.

CPR: The variables CPRMANU generally has negative effects on the odds of choosing the fertilizer based regimes, especially the fertilizer only regime, but has a positive effect for the manure only F2 regime. These results probably signify a dependence of the poorest sections on CPR who may possibly tend to choose organic or the base practice. The interactions of CPRLVST as already discussed show that the positive effects of livestock ownership on choices of F2 and F3 are reinforced by the use of CPR and enterprise being a smaller farm.

Crops and Regions: These two attributes of the enterprise are treated as factors with coefficients obtained for each region or crop (barring one each as base) giving the specific effects. The relatively high magnitudes of the intercepts suggest that the base regimen i.e., the non-use of inputs is less likely to be taken up than other practices at the base level of region and crop and the conjunctive regimen is the most preferred one. The base region, the northern hills, also appears to have the least tendency towards the non-use of inputs as against other practices compared to all other regions. This is borne out by the negative signs of the regional impacts indicating that the odds of having these practices decline when one moves from base to another region (Table 5.1 also reflects the low share of the base level practice in the base region). Comparing the magnitudes of region effects only, all regions are found to show a relative preference for solitary fertilizer use (the decline is least) except the north eastern region which prefers the manure only regime. The actual odds of selecting a regimen relative to base practice in any region can be obtained by adjusting the intercept for the region effect. These appear to be is less than one in many cases showing that non-use of the inputs would be the preferred option. However this is an indicator of the pure preference of the regions if hypothetically they operated in similar other conditions including the crops grown.

The preference pattern relative to base is judged by comparing the magnitudes of the crop coefficients with one another. Paddy shows maximum tendency for conjunctive use followed by solitary use of fertilizer, while for wheat the choice of manure use only regime is comes first, closely followed by conjunctive practice. Sugarcane is a more likely candidate for conjunctive use than the base regimen but the chances of solitary regimens are less. Other cereals and vegetables would be most inclined to be under manure based regime and least under fertilizer only option. Oilseeds, pulses, mixed crops, fodder and fruits/nut are crops that most likely come under the base regime with no use of external soil treatment regime. The odds of taking up the non-use of inputs regime is generally high in most cases especially for the above crops but paddy and wheat mostly are associated with the all input use practices and vegetable with manure use only practice relative to the base practice. If all other conditions were same, paddy, wheat and sugarcane are candidates for conjunctive use while all the other crops are likely to come under organic practice or purely traditional one.

5.8 Concluding points

Fertilizer use practices vary among farmers with conjunctive use of fertilizer and manure having a dominant place. Under existing conditions small farm size classes are found adopters of fertilizer based or conjunctive technology as much the larger ones and there is no evidence that the small farms remain more traditional. Fertilizer based technology is evidently practiced more by holders of irrigated land whereas the manure use is prevalent more among those who possess livestock and use the CPR. Relatively asset poor farmers who are nevertheless fertilizer users are more often encountered in eastern and north-east India and to some extent in hilly northern India and less often in the north and west. The regional dimension of behaviour indicates unequal dissemination of technology. The Southern region shows greater prevalence of conjunctive use while both North and East lead in solitary use of fertilizer. The hilly regions of North and North-east are greater adopters of manure only regime[vii].

Among the five major crops, paddy as expected claims the largest share of enterprises under all four regimes. Oilseeds are often raised with manure or even without manure compared to others, wheat and paddy-rabi with fertilizer only regime while sugarcane has the highest share under conjunctive regime though for each of the five crops this regime dominates. Manure use is found to accompany use of other modern inputs but the association is far weaker than with fertilizer.

The estimated multinomial logit model show some results contrary to the average behavioural outcomes observed under the existing interplay of influences. Corrected for these affects, conjunctive use of fertilizer and manure appears to be preferred by larger farms while small farms or less endowed farms under similar conditions of crops and endowment might opt for solitary manure use or non-use of inputs. Conjunctive use is also more likely to be adopted for enterprises in kharif season and with irrigation and the probability also improves if the household possesses livestock. The small farm can be also drawn to this regime if possession of livestock and access to the CPR for fodder and grazing is possible. Irrigation raises the probability of taking up fertilizer based regimes as against manure only regime. Sugarcane, wheat and paddy are likely choices for conjunctive use while vegetables are most likely to go under manure only regime. However all the regions show higher preference for fertilizer only regime barring North east hills which prefers manure.

Appendix Tables

Table A5.1: Area (%) treated with Manure by types of Manure

	Compost	Biogas slurry	Other
Paddy-kharif	53.0	2.2	44.8
Paddy-rabi	57.2	1.5	41.3
Wheat	48.0	1.6	50.4
Oilseed	43.1	3.0	53.8
Sugarcane	65.1	1.8	33.1
Vegetable	47.6	2.7	49.7
All crops	49.6	2.1	48.3

Source: Sarvekshana, 2000

Table A5.2: Distribution of Fertilizer use Categories by Farm size Classes and Regions

	Categories				Categories			
	1	2	3	4	1	2	3	4
	Percentage of Enterprises in the Class				Percentage of Area in the Class			
Region1								
Farm size class 1	9.80	17.10	60.80	12.30	12.08	10.00	71.04	6.88
Farm size class 2	11.00	8.90	74.50	5.60	11.99	9.34	73.62	5.05
Farm size class 3	11.00	7.90	76.20	4.90	10.18	7.85	77.85	4.12
Farm size class 4	14.20	6.90	75.20	3.70	14.19	4.75	76.97	4.09
CV	15.13	39.53	9.37	49.28	13.57	29.25	4.19	26.00
Region2								
Farm size class 1	8.60	25.20	22.30	43.90	10.74	21.32	29.56	38.38
Farm size class 2	7.10	26.40	14.90	51.60	8.84	23.08	21.54	46.54
Farm size class 3	6.30	31.80	8.80	53.10	5.60	34.87	7.98	51.55
Farm size class 4	0.00	51.40	6.10	42.50	0.55	54.73	4.86	39.86
CV	68.88	36.04	55.02	11.20	69.36	45.91	72.52	13.87
Region3								
Farm size class 1	25.10	14.80	48.80	11.30	25.24	12.20	53.51	9.05
Farm size class 2	18.60	15.70	51.90	13.80	20.42	12.08	56.53	10.97
Farm size class 3	17.20	15.00	56.00	11.80	17.82	11.99	62.12	8.07
Farm size class 4	13.10	12.70	63.10	11.10	41.51	3.07	49.85	5.57
CV	26.92	8.88	11.25	10.10	40.50	45.85	9.35	26.69
Region4								
Farm size class 1	21.40	18.00	54.50	6.10	24.75	7.56	64.07	3.62
Farm size class 2	23.10	9.20	62.30	5.40	25.96	4.48	66.70	2.87
Farm size class 3	23.50	3.70	67.90	4.90	23.88	1.48	72.55	2.08
Farm size class 4	32.00	2.70	58.40	6.90	38.95	0.43	57.05	3.57
CV	19.02	83.96	9.41	14.65	25.00	92.07	9.87	23.80
Region5								
Farm size class 1	17.70	20.20	50.70	11.40	19.52	17.90	51.77	10.81
Farm size class 2	17.80	17.70	52.80	11.70	18.00	17.00	54.00	11.00
Farm size class 3	13.90	17.50	56.50	12.10	14.39	16.52	60.15	8.94
Farm size class 4	14.80	17.90	58.50	8.80	15.35	18.17	59.01	7.47
CV	12.45	6.88	6.45	14.06	14.03	4.44	7.11	17.52
Region6								
Farm size class 1	8.60	17.20	72.60	1.60	8.77	16.27	73.77	1.19
Farm size class 2	4.50	18.30	75.80	1.40	4.27	15.90	79.15	0.68
Farm size class 3	6.60	15.50	77.10	0.80	6.14	12.08	81.27	0.51
Farm size class 4	0.00	16.40	83.60	0.00	0.03	12.14	87.80	0.03
CV	74.83	7.06	6.03	75.66	76.66	16.31	7.21	80.12

Note : Categories are 1=fertilizer only, 2=Manure only, 3=Conjunctive, 4=Non-using

Table A5.3 : Fertilizer Use behaviour and Asset holding of Enterprises by Regions (% in User enterprises)					
Region1					
Wealth indicators / Category	Landed	Own Farm machinery	Irrigated land	Own Livestock	CPR Use
Fertilizer user	27.5	4.7	65.7	70.2	11.7
	(87.3)	(84.2)	(87.7)	(81.7)	(80.1)
Manure user	25.6	4.3	62.0	69.9	11.3
	(84.5)	(81.0)	(85.8)	(84.5)	(80.9)
Non-user	11.9	3.3	22.6	47.4	10.3
	(4.5)	(7.0)	(3.6)	(6.6)	(8.4)
Region2					
Fertilizer user	12.6	4.3	43.0	54.6	6.3
	(15.2)	(48.1)	(61.4)	(22.5)	(16.7)
Manure user	19.7	2.8	28.0	64.8	5.7
	(41.4)	(53.3)	(69.6)	(46.4)	(26.2)
Non-user	23.6	1.7	7.8	61.5	13.3
	(52.4)	(35.0)	(20.5)	(46.6)	(64.5)
Region3					
Fertilizer user	12.8	3.0	73.0	76.0	10.6
	(72.3)	(75.9)	(89.9)	(72.3)	(52.2)
Manure user	13.9	3.0	60.4	81.7	17.5
	(70.2)	(67.5)	(66.5)	(69.4)	(77.0)
Non-user	13.3	2.0	18.0	74.8	18.8
	(12.1)	(8.5)	(3.6)	(11.5)	(15.0)
Region4					
Fertilizer user	21.2	11.4	94.3	86.3	12.0
	(92.0)	(94.7)	(92.7)	(79.4)	(49.1)
Manure user	18.6	9.8	81.1	90.3	21.8
	(71.9)	(72.6)	(71.1)	(74.1)	(79.7)
Non-user	14.9	5.0	49.4	88.4	23.2
	(4.6)	(3.0)	(3.4)	(5.8)	(6.8)
Region5					
Fertilizer user	46.2	7.9	65.8	25.9	25.9
	(70.4)	(87.9)	(85.6)	(73.8)	(73.8)
Manure user	46.9	7.0	58.0	90.2	25.3
	(73.8)	(80.1)	(77.9)	(73.8)	(74.6)
Non-user	47.5	2.7	18.3	84.9	24.0
	(12.1)	(5.0)	(4.0)	(11.2)	(11. 4)
Region6					
Fertilizer user	11.2	1.7	39.6	89.7	5.6
	(83.7)	(89.6)	(91.4)	(80.9)	(80.8)
Manure user	11.2	1.3	32.8	91.0	5.3
	(94.1)	(74.5)	(84.5)	(91.7)	(86.7)
Non-user	5.5	2.5	38.0	81.2	6.9
	(0.8)	(2.5))	(1.7)	(1.4)	(1.9)

Note: Figure in parenthesis is % share of asset holding enterprises. The first two fertilizer categories are overlapping.

Table A5.4 Distribution of Crop enterprises into Fertiliser use categories by Regions										
	Percentage of crop enterprises					Percentage of Area				
Fertilizer Category	Paddy kharif	Paddy rabi	Wheat	Oilseeds	Sugar cane	Paddy Kharif	Paddy rabi	Wheat	Oilseeds	Sugar cane
Region1										
1	9.10	14.50	16.80	13.40	14.70	7.82	15.08	13.92	14.83	14.40
2	1.70	1.30	14.60	15.40	5.00	0.79	1.52	13.36	9.31	3.50
3	88.20	83.30	61.90	64.80	78.00	90.93	81.95	67.25	72.41	80.22
4	1.00	0.90	6.70	6.40	2.30	0.46	1.45	5.47	3.45	1.88
Region2										
1	10.30	14.60	15.50	3.00	0.00	8.60	14.38	12.70	14.51	0.0
2	18.60	18.60	8.90	42.80	6.80	21.8	15.21	35.11	35.04	28.13
3	28.50	31.10	61.10	4.60	0.00	23.80	25.21	52.19	5.58	0.0
4	42.60	35.70	14.50	49.60	93.20	45.8	45.21	0	44.87	71.88
Region3										
1	21.60	37.10	31.20	20.80	11.00	18.93	31.97	31.94	20.05	6.32
2	15.00	4.90	5.10	18.30	11.50	13.93	6.96	3.56	15.74	7.89
3	53.60	51.10	62.00	45.00	67.90	58.93	49.11	64.49	49.46	76.02
4	9.80	6.90	1.70	15.90	9.60	8.21	11.96	0.01	14.75	9.77
Region4										
1	23.50	20.10	25.40	18.50	15.90	23.26	11.00	27.45	34.09	13.77
2	10.90	2.90	8.90	33.60	1.70	2.53	0.00	1.83	8.63	2.02
3	63.70	75.20	64.40	40.80	80.90	73.26	89.00	70.53	48.64	82.52
4	1.90	1.80	1.30	7.10	1.50	0.95	0.00	0.19	8.64	1.71
Region5										
1	13.20	9.60	25.10	19.60	19.30	11.85	6.77	24.52	22.38	12.08
2	23.10	11.90	11.40	15.70	7.20	21.70	8.85	8.98	11.14	5.42
3	52.60	74.40	58.30	50.90	69.80	56.49	83.02	61.80	58.18	80.97
4	11.10	4.10	5.20	13.80	3.70	9.96	1.37	4.70	8.30	1.53
Region6										
1	11.60	33.70	3.60	13.30	17.00	11.54	32.72	2.98	25.55	35.76
2	9.70	15.40	22.30	8.90	9.70	6.53	31.23	17.98	3.52	22.73
3	78.20	50.90	73.60	76.50	73.30	81.89	21.23	78.70	70.15	41.51
4	0.50	0.00	0.50	1.30	00	0.04	14.82	0.34	0.78	0.00
Note : Categories are 1=fertilizer only, 2=Manure only, 3=Conjunctive, 4=Non-using										

Table A5.5: Distribution of User Enterprises into Crops cultivated								
	Fertilizer User	Manure user	Conjunctive user	Non-user	Fertilizer user	Manure user	Conjunctive user	Non-user
Crops	Percentages of Enterprises				Percentages Area			
Paddy-kharif	24.1	23.3	24.4	16.4	26.4	27.0	26.4	22.0
Paddy-rabi	3.5	2.8	3.3	1.6	2.9	2.6	2.8	2.4
Wheat	20.7	17.6	19.5	4.3	24.6	21.0	21.8	5.1
Oilseeds	6.8	7.3	6.7	8.4	9.1	9.1	8.8	9.4
Sugarcane	3.1	2.8	3.4	0.6	2.5	2.5	2.8	0.4
Others	41.8	46.2	42.7	68.7	34.5	37.8	37.4	60.7
All	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A5.6: Fertilizer use Categories and the Use of Modern Methods (Percentage of Enterprises using different methods)					
	Fertilizer use Categories				
Fszclass 1	1	2	3	4	All
Improved Seeds	21.8	6.9	67.7	3.6	100
	(48.7)	(17.4)	(55.8)	(16.0)	
Mechanised Devices	26.3	6.3	63.1	4.3	100
	(74.9)	(20.3)	(66.3)	(24.4)	
Pesticide/ weedicide	22.7	5.5	69.9	1.9	100
	(43.3)	(12.0)	(49.2)	(7.3)	
Soil test	16.5	9.7	66.0	7.8	100
	(2.1)	(1.4)	(3.1)	(2.0)	
Fszclass 2	1	2	3	4	All
Improved seeds	19.3	6.0	71.0	3.7	100
	(53.2)	(22.1)	(61.6)	(19.7)	
Mechanised devices	22.2	6.0	67.3	4.5	100
	(75.7)	(27.8)	(72.3)	(28.9)	
Pesticide/ weedicide	17.8	4.5	75.9	1.8	100
	(40.5)	(13.8)	(54.4)	(7.9)	
Soil test	14.4	6.1	73.0	6.5	100
	(3.3)	(1.9)	(5.3)	(2.8)	
Fszclass 3	1	2	3	4	All
Improved seeds	16.3	7.0	73.5	3.2	100
	(56.8)	(31.8)	(67.8)	(18.8)	
Mechanised devices	18.0	8.0	68.7	5.3	100
	(78.2)	(44.7)	(78.6)	(39.0)	
Pesticide/ weedicide	15.3	4.2	78.6	1.9	100
	(44.7)	(16.0)	(60.5)	(9.5)	
Soil test	11.5	5.1	77.7	5.7	100
	(4.3)	(2.4)	(7.6)	(3.5)	
Fszclass 4	1	2	3	4	All
Improved seeds	17.4	9.6	70.9	2.1	100
	(64.2)	(46.6)	(75.0)	(17.9)	
Mechanised devices	18.2	12.8	61.7	7.3	100
	(89.1)	(82.4)	(86.5)	(81.0)	
Pesticide/ weedicide	18.2	2.2	78.4	1.2	100
	(57.3)	(9.0)	(70.8)	(8.5)	
Soil test	11.5	0.4	80.8	7.3	100
	(7.1)	(0.3)	(14.3)	(10.2)	
Note : Categories are 1=fertilizer only, 2=Manure only, 3=Conjunctive, 4=Non-using Figure in parenthesis is share within category.					

Table A5.7 : Nominal and Directional Association between Fertilizer use behaviour and use of Modern Methods by Farm size classes								
	Improved Seeds		Mechanised devises		Pesticide/ Weedicide		Availed of Soil Test facility	
Measures of Association	CC	KC	CC	KC	CC	KC	CC	KC
All classes								
Fertilizer user	0.315	0.288	0.367	0.333	0.331	0.299	0.053	0.017
Manure user	0.109	0.099	0.016	0.014	0.126	0.112	0.033	0.011
Conjunctive user	0.259	0.266	0.225	0.223	0.279	0.283	0.064	0.024
Non-user	0.200	-0.121	0.209	-0.124	0.215	-0.128	0.020	-0.005
Farm size class1								
Fertilizer user	0.314	0.292	0.387	0.370	0.324	0.295	0.034	0.009
Manure user	0.078	0.071	0.029	-0.026	0.082	0.073	.018	0.005
Conjunctive user	0.248	0.254	0.218	0.221	0.250	0.245	0 .040	0.013
Non-user	0.182	-0.109	0.205	-0.124	0.201	-0.118	0.011	-0.002
Farm size class2								
Fertilizer user	0.310	0.275	0.365	0.321	0.322	0.284	0.053	0.018
Manure user	0.113	0.14102	0.041	0.035	0.157	0.141	0.033	0.012
Conjunctive user	0.252	0.257	0.230	0.225	0.289	0.294	0.062	0.025
Non-user	0.119	-0.120	0.223	-0.131	0.220	-0.132	.023	-0.005
Farm size class3								
Fertilizer user	0.314	0.272	0.314	0.251	0.344	0.3.5	0.071	0.028
Manure user	0.166	0.146	0.178	0.089	0.185	0.164	0.050	0.021
Conjunctive user	0.271	0.272	0.220	0.201	0.315	0.322	0.084	0.039
Non-user	0.243	-0.147	0.220	-0.122	0.241	-0.147	0.035	-0.010
Farm size class4								
Fertilizer user	0.298	0.244	0.061	0.035	0.436	0.393	0.114	0.058
Manure user	0.179	0.151	.0.011	-0.006	0.151	0.132	.052	0.028
Conjunctive user	0.258	0.248	0.019	0.013	0.364	0.379	0.138	0.085
Non-user	0.275	-0.147	.042	-0.016	0.264	-0.146	0.006	-0.002

CC : Contingency coefficient , KC : Kendall tau-c
Note: Hypothesis (of no association) is rejected at .1% for all cases.

Table A5.9 :Model Fitting Information				
Model	-2Log Likelihood	Chi-Square	df	Sig.
Intercept Only	1037306371			
Final	351671310.7	6.86E+08	69	0

Table A5.8 : Likelihood Ratio Test for Multinomial Logit Model				
Effect	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Intercept	351671310.7	0	0	.
REGION	426202559.3	74531249	15	0
CROP	446034443.8	94363133	30	0
KHARIF	357086317.5	5415007	3	0
FSZCLASS	354658830.4	2987520	3	0
IRGTD	584657752.6	2.33E+08	3	0
LVST	360867230.9	9195920	3	0
CPRMANU	387472779.8	35801469	3	0
LVST * CPRLVST	354772560.2	3101250	3	0
FSZCLASS * LVST	352788737.6	1117427	3	0
FSZCLASS * LVST * CPRLVST	352554197.1	882886.4	3	0

Note: The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model.
The reduced model is formed by omitting an effect from the final model.
The null hypothesis is that all parameters of that effect are 0.

Table A5.10: Factors affecting Fertilizer use behaviour of Farm Enterprises (Coefficients from MNL Model with alternative specifications)				
Variables	Model 1	Model 2	Model 3	Model 4
	CLASS= FSZ	CLASS= SMALL	CLASS= FSZCLASS	CLASS= CROPAREA
Base category is Non use				
Manure use only				
CLASS	0.0005	-0.347	--0.015	0.001
ASSET			0.002*	
IRGTD	0.436	0.437	0.438	0.434
KHARIF	0.410	0.410	0.411	0.403
LVST	0.511	0.078	0.551	0.468
CPRMANU	1.424	1.414	1.373	1.411
LVST*CLASS	-0.0006	0.431	0.048	-0.0007
LVST*CPRLVST	0.495	-0.04	0.716	506
CLASS*LVST*CPRLVST	-0.001	0.471	-0.225	-0.003
INTERCEPT	1.583	1934	1.629	1.581
Fertilizer and Manure use				
CLASS	0.002	-0.675	0.358	0.005
ASSET			0.459	
IRGTD	2.25	2.249	2.234	2.243
KHARIF	0.280	0.279	0.281	0.265
LVST	0.720	0.127	0.912	0.642
CPRMANU	-0.792	-0.813	-0.794	-0.783
LVST*CLASS	-0.0019	0.476	-0.266	-0.002
LVST*CPRLVST	-0.085	-0.218	0.027	-0.048
CLASS*LVST*CPRLVST	-0.00006	0.174	-0.06	-0.001
INTERCEPT	2.939	3.751	2.657	2.973
Fertilizer use only				
CLASS	0.001	-0.284	0.155	0.004
ASSET			0.386	
IRGTD	2.206	2.211	2.20	2.204
KHARIF	0.013	0.014	0.015	-0.002
LVST	-0.142	-0.369	-0.054	-0.181
CPRMANU	-1.215	-1.245	-1.244	-1.198
LVST*CLASS	-0.0008	0.193	-0.106	-0.001
LVST*CPRLVST	-0.187	-0.439	0.004	-0.158
CLASS*LVST*CPRLVST	-0.0003	.269	-0.136	-0.001
INTERCEPT	1.673	2.00	1.535	1.635
Pseudo R-square (Nagelkerke)	0.320	0.319	0.321	0.321
Coefficients are significant at .1% level.* Coefficient is significant at 10% level.				

Appendix 5.1

Classification of Regions (Abbreviations)

SOUTH (S): ANDHRA PRADESH (AP), KARNATAKA (KRN), KERALA (KRL), TAMIL NADU (TN).

NORTH-EAST HILL(NEH): ARUNACHAL PRADESH (ARP), MANIPUR (MNP), MEGHALAYA (MGH), MIZORAM (MZO), NAGALAND (NGL), SIKKIM (SKM), TRIPURA (TPR).

EAST+NORTH-EAST HILL (ENEP): ASSAM (ASM), BIHAR (BHR), ORISSA (ORS) WEST BENGAL (WB).

NORTH (N): HARYANA (HRY), PUNJAB (PJB), UTTAR PRADESH (UP).

NORTH-WEST+WEST+CENTRAL (NWC): GUJARAT (GUJ), RAJASTHAN (RJ), MADHYA PRADESH (MP), MAHARASHTRA (MH).

NORTHERN HIMALAYAN (NH): HIMACHAL PRADESH (HP), JAMMU& KASHMIR (JK).

Appendix 5.2

Technical Notes

A4.2.1 Analysis of Variance (ANOVA)- F-Test (Section4)

The statistical procedure commonly used to test the hypothesis that several population means are equal is ANOVA. The observed variability in the sample is subdivided into two components – variability of the observations within a group about the group mean and variability of the group means.

The variable of interest is the proportion of enterprises opting for any given regimen of fertilizer use. The means squares for each variable is obtained at two levels i.e., between groups and within groups by dividing the respective sums of squares (SS) by their degrees of freedom where

SS (within group) = $\Sigma_i (N_i-1)S_i^2$
SS (between groups)= $\Sigma_i N_i (M_i-\mu)^2$

S_i^2 = variance of group i,
M_i = mean of group i
μ = mean of entire sample
N_i = number of cases in a group
And i=1,2…k where
k= number of groups.
N= number of cases in the entire sample.
The between groups degrees of freedom are k-1 and within groups degrees of freedom are N-k.

For each variable and a grouping factor the F-statistic is calculated as:

$F_{k-1,N-k}$ = Between groups mean square/Within groups mean square

Where the degrees of freedom is obtained from k= number of groups and N=number of cases. In this data set there are four sets of variables standing For the fertilizer regimens. In the first instance there are 4 farm size classes (groups) and 6 regions (within group cases) and a total of 24 cases. The reverse case is then considered.

A4.2.2 Measures of Association (Section 6)

Indexes that attempt to quantify the relationship between variables in a cross classification are called Measures of Association. The strength and nature of the relationships between fertilizer practices on the one hand and the other indicators of modern technology on the other are to be examined in this case. The basic hypothesis is that two variables of a cross tabulation (Yule, 1958) are independent of each other. The Pearson chi-square statistic provides a basis for some of the measures.

To estimate the chi-square statistic χ^2 the probability of an observation falling in cell ij given as P(ij) is worked under the hypothesis of independence, as product of the marginal probabilities of the two categories defining the cell:

P(ij) = (count in row i)/N X (count in column j)/N.

The expected number falling in cell ij is then

E(ij) = P(ij) X N

The statistic then measures the difference between expected E(ij) and observed number of observations O(ij) summed over all cell to obtain

$\chi^2 = \Sigma_i \Sigma(_j O(ij) - E(ij))^2/E(ij)$

which has a degree of freedom of (r-1)X (c-1) where r and c are numbers of rows and columns respectively.

The χ^2 test of independence itself provides little information about the strength and nature of association and is sensitive to the sample size. To overcome this, alternative measures try to minimise the influence of the sample size and to restrict the values within 0 and 1 for assessing the strength.

The contingency coefficient (CC) suggested by Pearson will lie between 0 and 1 as

CC= Sqrt (χ^2 /(χ^2+N))

CC is a nominal measure which gives no indication of the direction of association. Ordinal measures do take account of the ranking and cases are compared to find if they are concordant or discordant or tied. A pair of cases are concordant if values of both variables for one case are higher (or both lower) than corresponding values of the other case and they are discordant if the value of one variable for a case is larger than corresponding value for the other case and the direction is reversed for the second variable. Considering all possible pairs of values, if the preponderance of pairs is concordant (discordant) the association is said to be positive (negative). The ordinal measures differ in the ways the difference between the number of concordant pairs (P) and that of discordant pairs (Q) is normalised considering the possible ties. A measure that can nearly attain values +1 or –1 for any r X c Table 4. with m as the smaller number of the rows and columns, is the Kendall tau-c (KC) where

KC= 2m (P-Q)/(N^2 (m-1))

A4.2.3 Multinomial Logit Model (Section)

This model falls under the class of dummy dependent variable. In the simplest form such a model is binary for example relating to the question whether the farmer uses fertilizer or not. It is reasonable to assume an underlying response variable y^* and define a dummy variable y

$$.y^* = \beta^1 x + \varepsilon$$
$$y = 1 \; if \;\; y^* > 0$$
$$y = 0 \quad otherwise$$

So that

Prob (y* > 0) = Prob (y = 1)

= Prob (ε> - β^1 x)

This can be expressed as a cumulative density function F(β’x) which becomes the underlying probability function of the choice. The final form for F depends on the assumptions made about u_i. If u_i are normally distributed as N(0,σ^2) with σ^2 =1 the CDF provides the probit (normit) model. However an assumption of logistic CDF gives a closed expression of F in the Logit model as

$$F(-\beta^1 x) = \frac{1}{1+e^{\beta^1 x}}$$

$$1 - F(-\beta^1 x) = \frac{e^{\beta^1 x}}{1+e^{\beta^1 x}}$$

Polychotomous variables

A further extension of the model allows for multiple choices where the dependent variable can be classified into many categories. Unordered choice models are motivated by 'random utility model' where the probability that the i-th individual chooses the j-th category is

$$\Pr ob\,(y_i = j) = \Pr ob\,(U_{ij} > U_{ik}) \;\; for\ all\ k \neq j$$

so that utility (U) from j-th category is highest among the alternatives.

And thence to the usual CDF as discussed so that

$$\Pr ob\,(y_i = j) = \frac{e\beta^1 x_i}{\sum_j e^{\beta^1 x_i}}$$

A distinction arises between the so called conditional logit model (McFadden , 1973) and the multinomial logit model, though often confused, with the latter considering attributes specific to individuals and those specific to choices.

Equation is then written as

. $$\Pr ob\,(yi = j) = \frac{e^{\beta^1 x_{ij}}}{\sum_j e^{\beta^1 x_{ij}}}$$

Which can be estimated by creating dummy variables for the choices to be multiplied to the individual specific variables.

In the typical multinomial logit model, economic data as in the present case normally warrant that this model applies when data gives individual specific attributes and expressed as

Prob (y_i=j) = $$\frac{e^{\beta_j^1 x_i}}{1+\sum_{k=1}^{j} \beta_k^1 x_i}$$

Estimation

Multinomial logit model is specified by equation and dummy variable y_{ij} such that

Y_{ij} =1 if the i-th individual falls in j-th category
=0 otherwise.

The likelihood function for observations with n individuals and m categories is

$$L = \Pi^{n} (P_{i1}^{\ yi1}, P_{12}^{\ yi2} \ldots P_{im}^{\ yim})$$

$$Log\ L = \sum_{i=1}^{n} \sum_{j=1}^{m} Y_{ij} \log P_{ij}\ Suchthat \sum_{j=1}^{m} y_{ij} = 1$$

The first order condition gives

$$.\sum_{i=1}^{n} (y_{ik} - P_{ik}) x_i = 0$$

The nonlinear equation can be solved by suitable iterative procedure.

Specification

The variables in the Multinomial logit model are specified in the following manner:

1. FSZCLASS: This is an indicator of the farm households status in terms of land operated. The variable is categorised as

(i) FSZCLASS=1: Marginal, (ii) FSZCLASS=2: Small, (iii) FSZCLASS=3: Medium and (iv) FSZCLASS=4: Large.

2. IRGTD: This is a binary variable to indicate farm's irrigation status such that
(i) IRGTD=1 if crop is irrigated
(ii) IRGTD=0 otherwise.

3. KHARIF: This is the season indicator of the crop enterprise with
(i) KHARIF= 1 when the season is kharif
(ii) KHARIF=0 if not.

4.LVST: This indicates livestock ownership of the household where
(i) LVST=1 if household owns livestock
(ii) LVST =0 otherwise.

5.CPRLVST: This indicates access to CPR by household for livestock, i.e.,
CPRLVST=1 if CPR is used for grazing or if CPR is used for fodder collection,
CPRLVST=0 otherwise.

6. CPRMANU: This also indicates access to and use of CPR for manure collection
(i) CPRMANU=1 if CPR is used for manure collection
(ii) CPRMANU=0 otherwise.

7. CLASS: This is a broad and alternative indicator of farm class to which the enterprise belongs. CLASS is defined in four different ways

(a) Model 1: Class=FSZ :This is the size of farm in hectares of land possessed and is continuous.

(b) CLASS= SMALL: This looks for choices peculiar to small and marginal farmers only and is binary
(i) SMALL=1 if FSZ < 2hectare,
(ii) SMALL=0 otherwise.
(c)CLASS= FSZCLASS, ASSET: This takes in addition to FSZCLASS, ownership of other assets ASSET such that
(i)ASSET=1 if enterprise possesses tractor or harvesting machine.
(ii) ASSET =0 otherwise.

(d) CLASS=CROPAREA: This is a scale indicator in terms of area under the particular crop and is continuous such that

CLASS = CROPAREA

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[i] If this data-set is considered comparable to the sample used in Chapter 3 then a large part of this class (Regimen3) comprises of farmers who use low manure and high fertilizer.

[ii] In an attempt to capture the impact of subsidies in agriculture Chopra and Kapuria (2001) used regression analysis on data from All India Input Survey and NSSO, and found no evidence that the sizes of farms have any significant bearing on fertilizer use

[iii] According to the same NSSO survey, 62% of field crop cultivator households belonged to 'marginal' category and, together with 'small' category, they constituted four fifths of the total, while only 1% of the households belonged to category 'large'. However, the share of area under the field crops considered was 45% for the combined class compared to 8% of the 'large' category.

[iv] Although ownership of the asset by household would itself be an indicator of wealth and creditworthiness irrespective of its use in the particular enterprise, the constraint imposed by the data set made it imperative to consider two criterion for its inclusion in the variable 'farm machinery', namely (a) used for the crop enterprise and (b) owned by the household.

[v] The dependent variable is treated as an unordered categorical variable though the arrangement conveys an idea of sequence to 'modernisation' as so far held conventionally. Sequencing apart the categorization is identical to the (1) to (4) regimens classified in Section 2

[vi] The assumption of the independence of irrelevant choice if followed.

[vii] The result is consistent with COC analysis of Chapter 3.

Chapter 6

Biofertilizers in Indian Agriculture

Failure of a market to build up calls for public intervention when the expected social gains from a relatively new product outweigh the costs whereas the private gains do not. Uncertainty about the product performance coupled with long periods of learning involved can lead to poor demand from end users who are farmers. Even in the context of market liberalization, the government has some role to play to induce a socially optimal investment level and set up an effective market so long as market information is imperfect. However the exact nature of the role and the policy instruments to be used must be decided with a clear understanding of the strengths and weakness of agents involved (Stiglitz, 1989). Biofertilizers make nutrients that are naturally abundant in soil or atmosphere usable for plants. Field studies have demonstrated them to be effective and cheap inputs, free from the environmentally adverse implications that chemicals have. Biofertilizers offer a new technology to Indian agriculture holding a promise to balance many of the shortcomings of the conventional chemical based technology. It is a product that is likely to be commercially promising in the long run once information becomes available adequately to producers and farmers through experience and communication.

There is an ongoing attempt to promote biofertilizer in Indian agriculture through public intervention, and in keeping with the spirit of the times, the policy motivates private sector and profit motive to propel the new technology. The question raised in this paper is how successful has the intervention policy been in Indian agriculture. The Government of India and the various State Governments have been promoting the nascent biofertilizer market both at the level of the user-farmer and the producer-investor through the following measures: (i) farm level extension and promotion programmes, (ii) financial assistance to investors in setting up units, (iii) subsidies on sales and (iv) direct production in public sector and cooperative organizations and in universities and research institutions. Over time as the industry emerges from infancy with public guidance, the following observations will be expected: (a) increasing sales volumes and diffusion across the country, (b) greater role of profit motivated private enterprise. Since information on farm level usage of biofertilizers or profitability of units are not reported till date, one way to get about is by following the secondary indicators as incorporated in (a) and (b).

6.2 What are Biofertilizers?

Biofertilizers, more commonly known as microbial inoculants, are artificially multiplied cultures of certain soil organisms that can improve soil fertility and crop productivity. Although the beneficial effects of legumes in improving soil fertility was known since ancient times and their role in biological nitrogen fixation was discovered more than a century ago, commercial exploitation of such biological processes is of recent interest and practice.

The commercial history of biofertilizers began with the launch of 'Nitragin' by Nobbe and Hiltner, a laboratory culture of Rhizobia in 1895, followed by the discovery of Azotobacter and then the blue green algae and a host of other micro-organisms. Azospirillum and Vesicular-Arbuscular Micorrhizae (VAM) are fairly recent discoveries. In India the first study on legume Rhizobium symbiosis was conducted by N.V.Joshi and the first commercial production started as early as 1956. However the Ministry of Agriculture under the Ninth Plan initiated the real effort to popularize and promote the input with the setting up of the National Project on Development and Use of Biofertilizers (NPDB). Commonly explored biofertilizers in India are mentioned below along with some salient features.

Rhyzobium (RHZ): These inoculants are known for their ability to fix atmospheric nitrogen in symbiotic association with plants forming nodules in roots (stem nodules in sesabaniamrostrata). RHZ are however limited by their specificity and only certain legumes are benefited from this symbiosis.

Azotobacter (AZT): This has been found beneficial to a wide array of crops covering cereals, millets, vegetables, cotton and sugarcane. It is free living and non-symbiotic nitrogen fixing organism that also produces certain substances good for the growth of plants and antibodies that suppress many root pathogens.

Azospirillum (AZS): This is also a nitrogen-fixing micro organism beneficial for non-leguminous plants. Like AZT, the benefits transcend nitrogen enrichment through production of growth promoting substances.

Blue green Algae (BGA) and Azolla: BGA are photosynthetic nitrogen fixers and are free living. They are found in abundance in India[i]. They too add growth-promoting substances including vitamin B12, improve the soil's aeration and water holding capacity and add to bio mass when decomposed after life cycle. Azolla is an aquatic fern found in small and shallow water bodies and in rice fields. It has symbiotic relation with BGA and can help rice or other crops through dual cropping or green manuring of soil.

Phosphate solubilizing (PSB)/Mobilizing biofertilizer: Phosphorus, both native in soil and applied in inorganic fertilizers becomes mostly unavailable to crops because of its low levels of mobility and solubility and its tendency to become fixed in soil. The PSB are life forms that can help in improving phosphate uptake of plants in different ways. The PSB also has the potential to make utilization of India's abundant deposits of rock phosphates possible, much of which is not enriched.

Responses, and Limitations

Crude calculations of bulk and cost in terms of N presented in Table 6.1 on the basis of reported nitrogen equivalence indicates that biofertilizers are cheap and convenient relative to chemical and farm organic fertilizers (FYM) and therefore have considerable promise for crops like cereals, oilseeds, vegetables and cotton. However, it is safer to note that the nitrogen equivalences reported for biofertilizers are only indirectly approximated through controlled experiments since the way of accessing nutrients itself in indirect unlike nutrient *containing* chemical fertilizers and manures, and the comparative values of bulk and cost may not be realistic. Nevertheless, a crude estimation is attempted for indication of the potential without attaching significance to the magnitudes as such.

Biofertilizers have various benefits. Besides accessing nutrients, for current intake as well as residual, different biofertilizers also provide growth-promoting factors to plants and some have been successfully facilitating composting and effective recycling of solid wastes. By controlling soil borne diseases and improving the soil health and soil properties these organisms help not only in saving, but also in effectively utilising chemical fertilizers and result in higher yield rates.

However while positive responses have been observed in a wide range of field trials, there is remarkable inconsistency in responses across crops, regions and other conditions. Even for a given crop the range of response is quite high. For example in a sample of 411 field trials carried out across districts, plant responses to inoculation with Azotobacter in irrigated wheat was observed to be significant in 342 cases and ranged from 34 to 247 Kg./Ha. (Hegde and Dwivedi, 1994). Legume inoculation by Rhizobium is the most long established practice but the responses

Table 6.1: Relative Cost of Access to Plant Nutrient (N)

Crop	Fertilizer Type	Treatment	Incoculant/ unit weight Kg	Price Rs/Kg	For 1 Kg Nitrogen	
					Bulk Weight Kg	Cost Rs/Kg
Biofertilizers						
Rice	AZS	seedling	2.5	29.12	0.13	3.64
Wheat	AZT	seed	1.5	34.37	0.75	2.58
Oilseeds	AZT	seed	0.2	34.37	0.01	0.34
Groundnut/Soyabean	RHZ	seed	1.5	30.89	0.07	2.26
Maize/Sorgum	AZS/AZT	seed	0.5	29.12-34.37	0.025	0.73-0.86
Potato	AZT	soil/tuber	4.5	34.37	0.225	7.73
Vegetables	AZS/AZT	seed	0.5	29.12-34.37	0.25	0.73-0.86
Sugarcane	AZT	soil	4.5	34.37	0.225	7.73
Cotton	AZT	seed	0.8	34.37	0.04	1.37
Flowers	AZS/AZT	seedling	1.75	29.12-34.37	0.09	2.55-3.01
Chemical	Urea	soil	1000	4.8	2.17	7.96
Organic	FYM	soil	1000	0.14	555.56	79.37

Note: Vegetables- radish, spinach and ladysfinger; Oilseeds-Mustard sesamum
Flowers - merigold, other seasonal plantation and ornamental plants
Nitrogen equivalence of inoc./unit: AZS and AZT -20Kg N and RHZ-19-22Kg N;
Urea - 46% N; FYM – 3.6Kg NPK (2:1:1) per Tonne as per FAI. Unit weight of inoculant is as recommended dosage. ***Important: The comparisons with Biofertilizers are only indicative as quantitative values are only approximations***.

Source: Computation based FAI figures.

indicated by the All India Coordinated Agronomic Research Project in the cases of mungbean, uradbean, soyabean, cowpea and groundnut all under irrigated condition were significant only in a small proportion of locations tried and failed in others. Residual effect on soil pool was not noted in most cases. The variance of responses is similar for AZT and AZS. Dryland agriculture constitutes a very large part of agricultural area in India and also houses the majority of the poor. More than 90% of coarse cereals, 80% of groundnut and 85% of pulses come from these regions. Low productivity, unpredictable climatic swings and low dosage of chemical fertilizers also characterise agriculture in drylands. Biofertilizers, particularly Rhizobium, could be a bridge between removals and additions to soil nutrients where farmers can scarcely afford costly inputs and that too in a risky environment. But consistency in gains again eludes the trials conducted by All India Coordinated Pulse Improvement Project.

The responses usually depend on several environmental factors. (a) The type of soil as measured by its water holding capacity, its levels of other nitrates, phosphate and even calcium and molybdenum (that help in protein synthesis in Rhyzobia) and the alkalinity, salinity and acidity of soil all affect the response. Higher dose of mineral nitrogen as starter suppresses nodulation, reducing response of Rhyzobium but phosphate deficiency can be an inhibitor also. (b) The inadequacy of organic matter especially common in dryland agriculture is a deterrent more for the non-symbiotic strains, which essentially depend on soil organic matter for energy. Phosphobactrin response was found to be positive only in soils with high organic content and low available phosphorous. (c) Soil water deficit and high temperature (hyper-thermia) are prominent abiotic factors that affect nitrogen fixation in dryland agriculture. (c) Native microbial population opposes the inoculants. In general predatory organisms, often already present in the soil are more adapted to the environment and out compete the inoculated population.

Apart from environmental factors, deficiencies in handling procedure are a major cause of under performance in real life application. The high sensitivity to temperature and other external conditions of these 'living' inputs, calls for enormous caution at the stage of manufacture/culture, transportation/distribution and application. This involves investment and time in research (for more tolerant strains), packaging, storage and use of suitable carrier materials.

6.3 Government Intervention in Biofertilizer Market

To attain production targets, the Government of India implemented a central sector scheme called National Project on Development and use of Biofertilizers (NPDB) during the Ninth Plan for the production, distribution and promotion of biofertilizers.

A National Biofertilizer Development Centre was established at Ghaziabad as a subordinate office of the Department of Agriculture and Cooperation with six regional centers. The purpose of the scheme covered organization of training courses for extension workers and field demonstrations and providing quality control services. Production and distribution of different biofertilizers were also undertaken but subsequently discontinued as the centers redefined their role towards R&D and HRD related activities. Capacity creation and production was however encouraged through one time grant for new units.

The financial assistance, given as grant-in-aid to the tune of Rs 13 lakh and now increased to Rs 20 lakh per unit and thrown open for all, was routed through the State governments but owing to delays in release of grants the onus is transferred to NABARD/NCDC. The public sector organizations form a bulk of the units in the industry, while similar units in the private sector are also coming forward. Different State governments also provide subsidies sometimes up to 50% of the sales realization but the manner of subsidization is rather unsystematic. In many cases the discrimination and manipulation in subsidizing lead to a lot of intra industry variation in prices. The government also plays a dominant part in marketing biofertilizers in three possible channels: (a) State government via District level Officers and Village level workers to faremrs, (b) State Marketing federation via cooperative bodies to farmers and (c) State Agro-industries Corporations via Agro service Center to farmers. The producers are however free to sell through their own sales network or through market, (i.e., wholesalers and private dealers).

6.4 Data

The Fertilizer Association of India (FAI) periodically presents information compiled on capacity and distribution of biofertilizers by various units. In the absence of reported information on farm level use of the inputs, this can help in understanding the progress of the technology and its adoption in India. The period covered by the data is 1992-93 to 1998-99.

The FAI report gives the distributions of different strains for recent years by states that can proxy for usage by farmers. For a better understanding of the demand for use, firm level information on capacity, distribution and prices would be more useful.

However the FAI could not report for all existing producing units due to their non-responses and this irregularity is more for distribution and prices. So the inferences drawn in the present study are only based on the samples that report the required information. The FAI reports (1996, 1998, 2001) give information of annual distribution levels of various inoculants and their sale prices for consecutive years by firms. In addition the annual capacity as of March is provided for the three years 1995, 1997 and 1999.

6.5 Success of Biofertilizer Technology

Government of India and the different State Governments have been promoting use of biofertilizers through grants, extension and subsidies on sales with varying degrees of emphasis. With time farmers too learn about the technology forming their perception on the basis of agronomic realities of their regions, the knowledge gained from experiences of farmers around them and including themselves and the information provided by different disseminating agents and form their own decisions of adoption. Above all the enterprise of the firms working through their marketing, research and development efforts would lead to the widespread use of the inputs once the prospect of profit and commercial appeal is sensed with the passage of time and government support.

Progress of the Industry

Based on the data for 1995, 1997 and 1999 it appears that the industry witnessed a steady increase in the number of units producing the input (Table A6.4). Over the period of four years the number of units went up by 53% from 62 to 95 and further to 122 in 2002 (Ministry of Agriculture, GOI). The total capacity expanded by 102% going by the information on units reporting their capacities. New private units joined the industry improving their numeric share while the public sector, after the initial burst slowed its pace. However, a deeper look would be more illuminative.

The total distribution as reported by the units[ii] on an annual basis increased over time at an impressive rate of over 50% (Table A6.4). However it is clear that the bulk of the growth took place by 1992-95 of the sample period and stagnated thereafter. There are also changes in shares by types with moderate success in AZT and by far the best performance by PSB (Table A6.1). The decline in RHZ indicates success in groundnut and pulses was below expectation.

Table 6.2 gives the distribution and annual capacity of units deflated by the number of units. A measure of capacity utilized is obtained relating actual distribution (as opposed to production) to capacity. The industry has been going through an adjustment of size as average capacity of a unit came down from 261.8 tonnes to 205.6. The capacity addition in the industry was less relative the addition of new units due to entry of lower sized new units. The average distribution also declined in the first two years possibly signaling the need for a down size and picked up subsequently. The average capacity utilization has been poor but the down sizing may have arrested the declining trend.

Diffusion

The chemical based fertilizer technology incorporated in the green revolution was successful by its rapid adoption rate but the unbalanced spread across the country, especially in the eastern region marks a crucial failure. The central government's role in the new biofertilizer technology would be justified by greater spatial dimension of the success.

Table 6.2 : Average Capacity, Distribution and Capacity utilization of Units

Year	Capacity (Tonnes)	Distribution (Tonnes)	Capacity Utilisation
1994-95	261.8	111.3	0.43
1996-97	225.8	87.91	0.39
1998-99	205.6	94.37	0.46

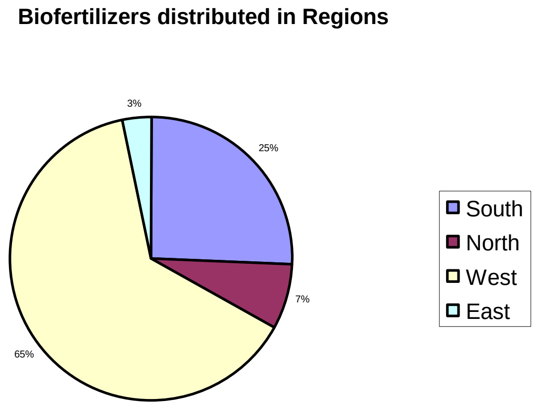
Note: Calculated for only Units reporting Capacity, DistributionNBFDC and RBDCs are treated as single unit
Capacity utilization is measured as distribution divided by capacity
Capacity of 1994-95 is as of March 1995 and so on.

Table 6.3: Regional distribution of Bio-fertilizer Plants (%)

	1995	1997	1999
Region			
East	17.74	13.89	12.63
North	29.03	27.78	17.89
West	22.58	26.39	38.95
South	30.65	31.94	30.53
Source:FAI			

Since biofertilizers are perishable and sensitive to quality of handling, the distribution of plants would to some extent reflect the regional distribution pattern. However this is only partially valid as units with large distribution networks do distribute over larger areas. As an example distribution levels of public sector fertilizer giant IFFCO (a late starter) are given in Table A6.2. Located in Phulpur in Uttar Pradesh, IFFCO's MLN Farmers' Training Institute produces all strains of biofertilizers and have distributed in states other than the home state. Eastern states like Bihar and Orissa are also served though the share has gone down notably for West Bengal where distributions came down to nil in 2000-02. Table 6.3 shows how the industry started with a fairly even dispersion of units gave way to a concentrated locational pattern. While both east and north lost their shares, there was continuous and significant expansion in the western region. The share of south remained stable. This tendency is further reinforced by the state wise distribution of plants presented in Table A6.3. Some of the states saw closure of units and in fact over the period the number of units in north actually came down.

The region wise distribution of biofertilizers is more dispersed relative to chemical fertilizers as apparent in Figure 5.1 with highest share going to west followed by south while north and east claimed lower shares. The distribution does not follow that of chemical fertilizers they supplement, where north is the largest claimant. However the eastern region comes last in share in both chemical and biofertilizers though the share in the latter case is even more diminutive. The comparison however is not complete without bringing in the cropped area in the regions. The use intensities in Table 6.4 also suggest relatively poor adoption in east and north.



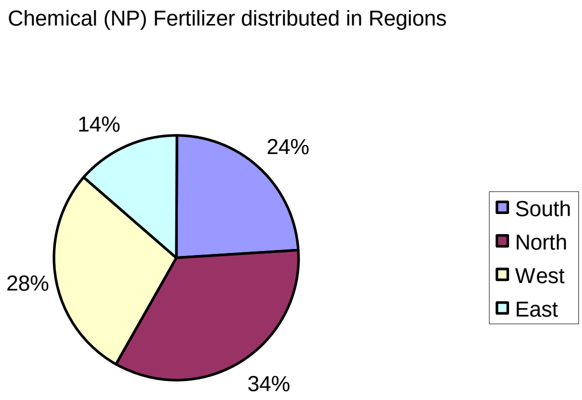


Figure 6.1

Private enterprise

In the nineties India stepped a market oriented regime and the desired role of the government became one of facilitator. In the past public sector units including state owned cooperative organizations played a crucial role in implementing government's social objectives on a continuing basis, compromising commercial interests in the process. In a more competitive environment failure to attain commercial viability does not augur well for the sustenance of the organizations as also for the public budget. In the case of biofertilizers too the initiative taken by the public sector along with numerous universities and research units that are also state funded must with time lead to commercial success once the technology is transmitted to the field and this in turn is expected to draw private enterprise since the market is open for entry. The government is also encouraging private entry by extending financial grant to all and

Table 6.4 : Use intensity of Biofertilizers (BF) and Chemical fertilizers in Indian Agriculture				
Region	Chemical (NPK) (Kg/hect.)	Cropped area (%)	Chemical (NP) (Kg/hect.)	Biofertilizers (Kg/hect.)
South	125.21	18.46	107.06	0.05
North	130.43	22.32	127.65	0.01
West	60.82	40.91	57.07	0.06
East	70.63	18.32	61.73	0.01
Total	90.04	100.00	82.90	0.04

Source: Computed from FAI data. Biofertilizers distribution data reported by units are used.

sundry. Table A6.4 suggested that slow down in private commercial sector distributions is more pronounced than total.

Although many of the new entries between 1995 and 1999 are private commercial enterprises, their share in total capacity came down steadily as revealed by the reports (Table 6.5). This is because of scaling down of size from a relatively high level of 504 tonnes to 300 tonnes as already noted. The coexistence of smaller new units with the larger ones of higher vintage has increased the variety in industry as measured by the coefficient of variation. The share in distribution however has been relatively more stable despite showing a slight declining trend in the last five years reported (Table A6.5). Over the years the industry as a whole distributed about 35.6 thousand tones of which a little less than half is accounted by the commercial private firms. The latter also charged higher prices on the average and there is slight rise in prices between 1995 and 1998.

Table 6.5: Capacity of Privately owned Units			
	1995	1997	1999
Average Capacity (tonnes)	504	437	308
Coefficient variation (%)	120	143	162
Share in total capacity (%)	74.55	69	67

Note: Calculated for Units that reported Capacity

Structure of Industry and Econometric Analysis to explain Distribution

Based on the 50 units that reported capacity (details given in Appendix A-II), distribution and prices in 1998-99, accounting for nearly 85% of distribution Table A6.5 presents the structure of the industry. An econometric analysis will attempt to use this information to explain the distribution performance by the structural components of the industry. The capacity of a unit is defined by the various facilities of production including equipment for various operations, infrastructure and space. Labour and raw materials are essential variable inputs for actual production as summarized in Appendix A-I for a given capacity and using this general norm and the actual production levels, annual man-days of employment generated by a unit can be estimated. Due to the complex nature of the process involving laboratory culture of life forms, that requires definite combinations of space, equipment and time, there is little substitutability among the inputs.

Numerous studies on technological evolution emphasized the developmental role of a firm (Chandler, 1993) and the strength of its sales network, creating market and drawing market feedback, for its success. In general, firms with larger production facilities are expected to invest more on networks to understand and access the market but it is not uncommon for firms with larger distribution networks to act as marketing agents for smaller units who are lacking and in few rare cases like that of NAFED the distribution even exceeds capacity[iii]. The sales networking would be stronger also for concerns that are in some way already in the business of selling agricultural inputs. Since the exact scope and nature of the units or possibly their parent companies is not clear from the data, past experience in selling biofertilizers may be considered as an indicator of their marketing capabilities. Judging by the sample information, units that records a cumulative distribution of more than 100 tonnes over the previous 3 years are deemed to be enjoying greater selling experience and broad based net-workings. While the cumulative distribution performance takes care of 'learning by doing' opportunity of the firm a possible additional characteristic could be the age or vintage of the unit, which also allows for 'learning by looking' opportunity. Since data on vintage is not readily available, those that existed and reported for March 1995 are classified as older units (VINT). Units that produce both nitrogen fixers and phosophate solubilisers are categorized as joint producers (JOINT).

Production of biofertilizer started in India with significant government involvement with active participation of the public sector that is directed more by public policy and social objectives than profit. The extent of commercial success would be indicated by the participation of private commercial units so long as market is free for entry. The private firms that reported can be categorized as private (PVT) and others that include universities, research institutes, cooperative, agro-marketing and other public sector organizations. Finally, the regional distribution of the firms is of interest in view of the tendency of concentration observed.

Going by a size categorization of units based on sample average capacity of the units as the cut off size, less than 30% of units are classed as large, with majority being relatively small units. The share of private sector is much larger (64%) for the smaller units than the larger ones (36%). More than 70% of the large units are of longer vintage reiterating that new entry has been mostly in small units. About 70% of the small units came into being after March 1995. The small units show some tendency to specialize in either nitrogen fixers or phosphate solubilisers while all the large units produce both kinds. Both size categories show regional bias for west, followed by south, though smaller units have relatively greater presence in south as also in east where there is no presence of large units. The average capacity differs widely between the two categories, as does employment generation but large units record higher capacity utilization. Average price charged is marginally in large units.

The following equation is estimated to explain distribution:

$$D_j = \alpha_0 + \alpha_1 P_j + \alpha_2 \text{CAPACITY}_j + \Sigma\alpha_{3k}\, \delta_k$$

Where D is distribution in tonnes in the completed year, P is sale price in Rupees per kilogram, CAPA is capacity in tonnes at the year end and δ are k dummy variables corresponding to unit j. Price, calculated as weighted average price of different biofertilizers (PBIO) with distribution shares as weights, varies moderately among the units. As a deflator the price (PCHEM)[iv] of chemical fertilizers, N and P, are taken for the year and weighted by consumption shares in the state concerned. The deflated price variable P-DEF is expected to show a negative effect so long as there is some competition between chemical and biofertilizers. A specification including both prices separately is also estimated. CAPACITY of the unit accounts for scale of the unit and the dummy variables place the units in different categories that could have a bearing on distribution. Variable DUM-EXP is used to capture units with selling network as indicated by past experience as discussed. Another variable for experience is VINT. Dummies WEST, EAST and SOUTH delineate the units by three major regions to see if any one region makes a difference over all others including north. Variable PVT is used to examine the performance of units in private commercial sector. Similarly, variable JOINT helps find out if varied production pattern is an added advantage. Heteroscedasticity consistent estimates of parameters are provided in Table 6.

Table 6.6: Estimated Regression equations for distribution					
Dependent variable is DISTRIBUTION					
	Specification 1			Specification 2	
Variables	coefficient	t-statistics	Variables	coefficient	t-statistics
CONSTANT	34.648	0.539	CONSTANT	-463.44	-0.642
P-DEF	-2.919	-0.145	PBIO	-0.123	-0.074
CAPACITY	0.328	9.409	PCHEM	49.369	0.648
DUM-EXP	73.349	2.495	CAPACITY	0.326	9.406
DUM-PVT	-46.714	-2.203	DUM-EXP	76.609	2.387
			DUM-PVT	-50.572	-2.048
R		0.75			0.76
DW		1.6			1.50

The equations coming with reasonably good fit show expected signs of price and scale variables though there is no significant effect of price. The scale variable CAPACITY has a positive and significant coefficient. Firms with greater selling experience (DUM-EXP) also distribute significantly higher amounts given other conditions unchanged. Variable PVT comes with a negative coefficient suggesting that private commercial units distribute less than others after controlling for price capacity and experience. The estimates presented in Table A6.6 also suggest this implication even with varied specifications and with an altered sample where the largest and smallest distributing units are excluded. The region dummies too peculiarly indicate the near absence of regional dimension in the distribution after controlling for relevant factors. Even units located in the western region, which claimed the maximum expansion of the industry, shows no remarkable advantage over others and the variable comes with an insignificant and even a negative coefficient. Joint production of different biofertilizers gives no added advantage over specialized units and older units shown by variable VINT do distribute more, possibly gaining from being in the field for long.

Empirical findings: Summary

The analysis conducted with the limited data available throw some light on the progress of the technology through the indirect indicators from industry. The empirical findings can be summarized as follows:

First, the distribution of biofertilizers, proxying for its adoption rate has not consistenty grown over time and has slowed down in the late nineties. Starting from a small base one would have expected a faster and possibly accelerating growth performance as the input finds greater acceptance. Second, although there have been more and more new entries in the market, the average capacity came down characterizing the industry by a large number of small units. While size adjustment in infant industry is normal, it must be borne in mind that distribution of an agro input also calls for substantial sales networking and a deep understanding of the field reality in agriculture. Whether the smaller units will have the necessary expertise and incentive for meeting farm demands or synergical associations with bigger producers or simply distribution agents or local bodies would be the desired institution is matter of review. Third, there has practically been no diffusion of the technology despite the central government's interventions and the distribution among units has tended towards greater concentration especially in Maharashtra and other states of the west and south. As with chemicals, the impact on the east has been poor. Possibly the interventions and the policy of the State governments proved more decisive and in some cases, the recommendations of the agricultural universities or lack of them (as in Punjab) had a role in the farmers' lack of interest in the technology. Fourth, despite entry of private players, the share of the private commercial sector in distribution remains below 50% and over time the private firms have neither improved their share in capacity or distribution nor their growth rate of distribution. This casts doubt on whether the business is as of now viewed as a commercially gainful prospect. Fifth the regression analysis further brings out some aspects of concern. There seems to be little intrinsic justification for the regional preferences shown by units since the distribution performance does not appear better in any region, even the west, than others after controlling for unit size and price. Further, given the capacity of the unit, private ownership has an adverse effect on distribution performance and this once again raises questions on commercial viability of the industry.

6.6 Why the government needs to intervene

The result of the analysis is not positive with respect to government intervention in the market is concerned. Till date the central government has spent several crores of rupees as grants to invite investment and state governments have also spent large sums for subsidizing and promoting use. The questions that now arise are (a) Does the government need to intervene and support the market to build up? (b) If so what should be nature of intervention?

Despite the lack of expected response there still is a strong case for government to intervene and possibly subsidize in the market. The reasons can be broadly classified in two groups:

Social gains or 'First best' reasons

If biofertilizers impart certain social and long-term gains for which private individuals may not be willing to pay at least until the gains become 'visible', there is a rationale for spreading the cost over a larger group of beneficiaries or the society at large (Yokell, 1979). The government can act on behalf of the society through appropriate policy even if the market is otherwise competitive.

1. Biofertilizers have important environmental and long-term implications, negating the adverse effects of chemicals. At the farm level, the gains from increased use of the technology can spill over to other farms and sectors through lesser water pollution than chemical fertilizers and even to an extent organic manures can create.
2. The gains from the new technology coming through the arrest of soil damage may not be perceived over a short span of time unlike for chemical fertilizers, which yield quick returns. At the same time the farmer has to incur considerable initial cost in terms of skill acquisition, trial and failure and risk. In agrarian situations where agents often operate with bounded rationality, adoption may be slow and influenced greatly by neighbours' experiences over time. Empirical evidences in agriculture around the world show that adoption

of new practices take time to pick up and the earliest adopters are often conservative about the percent of acreage (Griliches, 1957) devoted to the new technology. The state has a role to play in inducing farmers to adopt improved practices.

3. The producer firms have serious uncertainty about the demand or saleability of the product, which deters investment, particularly if it is irreversible (Guiso and Parigi, 1999). The success or failures of early entrants who take the initiative or those who indulge in research for an improved product convey important information to others (Stiglitz, 1989) and thereby to society. The market however does not always reward the initiative. The capital market is also not always ready to provide the risk capital at reasonable rates.

Non-competitive Market or 'Second best' Reasons

In many cases the market itself is not competitive and although the first best solution would be to promote competition, there are other ways of dealing with the situation.

1. Although biofertilizers have been promoted as supplement or complement of chemical fertilizers, in reality they are two alternative means of accessing plant nutrients. The strength of complementarity as against substitution between the two inputs is open to empirical verification, but there is no denying that farmers and producers do perceive the subsititutability relation to an extent. The pricing of chemical fertilizers is far from marginal cost based. In particular urea is under administrative pricing and there are serious economic and political compulsions to continue the protection although the movement in spirit has been towards openness. In such circumstance the price of biofertilizers along with the risk and responses will be weighed with those of chemical fertilizers, and promotion of the technology for environmental reasons would call for some degree of protection to minimize the inter-fertilizer price distortion.
2. The external or environmental cost of using chemical fertilizers, though not measurable may also be taken into account when comparing with biofertilizers if the latter is to be promoted.

The next question that arises is what should be the nature of intervention. With the results at hand, the central government needs to improve its strategy towards a more broad-based and integrative role in order to provide the correct environment for the adoption of the technology.

One of the main barriers faced by the producers and investors is inadequate demand and the inconsistent and seasonal nature of the existing demand. It may be recalled that the technology is as yet nascent and evolving. The rice dominated eastern region remains a non-starter and the wheat-rice growing north has not shown much interest either. Research on developing efficient, temperature tolerant and hardy strains is a vital step to the actual success of the technology. In particular, there can be some focus on the potentials of the technology in rice and cereals in general although its significance for crop diversification is of equal concern. Similarly development of suitable carriers, better packaging and longer shelf life are also important for commercial acceptance of these living inputs. The government has a dominant role to play in encouraging and funding research either by universities or private firms to make up for shortfall in private commercial research initiative. As is well recognized now, in a market-oriented system, information is often scarce and costly and hinders many business activities. For biofertilizers, the government has a dominant role of disseminating the technology through demonstration, training and other activities. A proposal to make it mandatory for biofertilizer units to contribute in the process through their own demonstration is a welcome step. Research and extension/promotion both must be to the extent possible specific to local conditions and constraints.

It is a good practice to promote biofertilizers as an input conjunctive to other forms of fertilizers, but keeping in view the protection given to chemicals, there is some ground for subsidizing the former to encourage their use. However, there is a need to work out a systematic and uniform way to give out subsidies so that they do not distort inter unit prices and help some units at the cost of others. The States should be strongly guided on this norm. The main purpose of the subsidies would however be to induce farmers to try out the input at affordable and acceptable prices rather than to support certain producers directly. As far as producers are concerned, a healthy competition would only help develop a market in the long run and benefit the farmers.

Open sales in the market may be encouraged to improve the capability of the units in marketing products. Any attempt to fix a minimum price for the sake of quality or other consideration will only go against the spirit of competition and harm the interests of the industry and the farmers. The present study finds some but not conclusive role of the price factor but scientific studies may be conducted on the farmers' 'willingness to pay' for the new input to determine the need and extent of subsidies.

The subsidy, if it is considered desirable, could be routed through the Ministry of Environment since the main aim of the policy is to encourage environmentally improved practices.

Quality is an essential element in this market and the entry of new units also heightens the threat of poor strains appearing in the market and ruining the farmers' confidence in the technology and their incentive to adopt the same. There is a strong case of quality control and legal safety nets, which could possibly draw the involvement of local bodies backed by the expertise of specialized agencies. Since the microorganisms are extremely perishable and sensitive to local conditions and handling the farmer always encounters some risk in opting for the input. To the extent the farmers' risk perception is responsible for inadequate adoption there is a case for spreading the risk over a larger society. An insurance or a buy back scheme could work with the cost shared by the government and the producers but this would call for some monitoring of farmers' behaviour. Such a scheme would also reduce the need for subsidies.

The grant in aid given for new units and possibly in future for upgrading older units is not really a desirable method. To the extent that inadequate demand is the main hindrance to producers, the financial aid would not help at all. In fact the method embodies an incentive for *moral hazard* where the firm receives the grant but does make enough 'effort' to sell. The transfer of the responsibility to NABARD would only impose undue burden on the bank in monitoring sales attempts. The regression analysis says that even with the same capacity build up (with the help of grant), a private commercial unit sells less than others. In actuality, business organizations have their own dynamism and sales effort would definitely follow from commercial prospects, which can come from greater acceptability on the users' front. Concessional finance could be arranged for investment to encourage investment as well as efficiency in follow up business.

The scaling down of average size of unit must be associated with a review of sales and development capability of units. It is noted that smaller units do not necessarily enjoy higher capacity utilisation in terms of distribution. The broader networks, deeper understanding of market and greater sales experience of older and larger units, specifically the cooperative sector units involved in marketing other agro inputs may be commercially exploited for the marketing of products produced by smaller and less experienced units and the development of a synergic system in this regard may be useful.

Policy Options: Summary

There are two layers of challenges with regard to incentive and risk that the government has to encounter in the process of launching the biofertilizer based technology in agriculture, one at the level of farmers or users and the other at the level of the producing units or investors. This paper suggests that the government emphasizes the former since the field level acceptance of the technology will gradually bring commercial viability of producers. For greater farm level acceptance the government can do the following:

Research: Promote and fund research for improved strains suitable for the different conditions, especially for the east and for crops like rice. Greater crop diversification will also stimulate diffusion. Encourage farm level studies on responses and economic implications of bio-fertilizer use to understand farmers' problems.

Risk insurance: Explore the possibility of insurance or buy-back of products to reduce farmers' risk, with the cost of the scheme being shared by the government and the distributing/producing firm.

Subsidies: (i)Assess the need for subsidizing sales through scientific studies on 'willingness to pay' and provide for affordable inputs to encourage acceptance at this stage. Discriminatory and non-uniform subsidies must be removed at once for effective and undistorted incentive to firms.

(ii) Involve the Ministry of Environment in subsidization and the local bodies for effective monitoring and regulation.

Information: Organise promotional campaigns and demonstrations drawing the cooperation of producers and gather market feedback for effective utilization in further research and in improving the operations and management of producers.

On the producers side the recommendations are few as the above measures, if effectively implemented could go a long way in benefiting the producers too. The study however suggests:

Research grants: Funding of possible research for improvement of strains.

Sales networking: Work out suitable sales and development networks among distributors and producers.

Market support: Provide some market protection through government purchases for specific time period subject to stringent quality control. This is to be phased out and open market sales encouraged.

Finance: Concessional finance for investment may be made available. Financial outright grants are not advisable.

6.7 Conclusion

Critics have argued that Green Revolution simply borrowed production from future generations as it impoverished soils and destroyed ecological balances. Environmentalists have further pointed out that the emerging free trade regime would raise the scale of activity, especially with respect to products with comparative advantage, leading to greater environmental damage. While all this may be an extreme view and a debatable one, the need for undoing to the extent possible of ecological problems of the past and introducing more sustainable patterns in future cannot be over-emphasised.

The Government of India has been promoting the use of biofertilizers in agriculture through the NPDB and the state governments also added to the process via subsidization and extension. Based on living micro-organisms these inputs can make nutrients abundantly available in atmosphere and soil accessible for plant use without the adverse impact that chemical fertilizers have on soil, water and air. The national scheme sought to spread the new biofertilizer based technology through field demonstration, research and financial assistance to investors.

Based on the data provided by the Fertilizer Association of India this study finds that despite efforts the use of the input as indicated by the distribution has not grown steadily over time, has been way below projected levels and the there has been practically no diffusion across states, with about 90% of use accounted by western and southern regions. There has been entry of new units and significant capacity built up but average capacity has come down with a marginal improvement in capacity utilization. Private commercial units though open to entry have not improved their share in distribution. A regression analysis suggests that given the same capacity and other relevant conditions a private unit distributes less than others casting doubt on the commercial success of the industry. The analysis also indicates there is no intrinsic advantage that accounts for the evident concentration of the industry in specific regions. The State governments’ own initiative possibly had greater role in guiding the spread of the technology than the central government’s schemes.

Public intervention through monetary or other means is justified for building up a market for an input promising social and longer term gains. The emphasis of any government policy would be in popularizing the use at the farmer level through varietal improvement, information dissemination, risk coverage and also sales subsidies if justified by scientifically conducted studies. The acceptance at the farmers' end would go a long way in providing commercial benefits to producing units and encouraging investment. The government must however help the units financially or otherwise in developing suitable strains and carriers, in accessing affordable finance for investment and in working out viable schemes for distribution especially since smaller and less experienced units are tending to dominate the market. More studies on farm level responses and economic implications of the use of Biofertilizers are welcome.

Appendix

Tables

Table A6.1 : Changing composition of Biofertilizer distribution

Year	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99
Total (tonnes)	1600.01	2914.37	4988.90	6288.32	6681.44	6295.63	6700.27
% share							
Rhizobium	57.27	40.50	29.41	21.15	20.84	19.85	18.62
Azotobacter	13.00	22.20	18.47	18.46	15.51	17.30	17.74
Azospirillum	12.54	11.11	14.08	17.99	11.34	10.17	11.77
Nitrogen fixers	82.81	73.80	61.96	57.61	47.69	47.32	48.12
Blue green algae –	0.00	0.00	0.06	0.04	0.01	0.02	0.04
phosphate solubiliser	17.19	26.20	35.77	40.46	49.88	48.75	48.98
acetobacter	0.00	0.00	2.21	1.90	1.13	1.06	1.00

Table A6.2: Despatches of Biofertiliser by IFFCO to states

States	Years	%Total
Uttar Pradesh	1996-97	93.29
	2001-02	47.97
Uttaracnchal	2001-2002	6.12
Punjab	1996-97	0.00
	2001-2002	10.64
Haryana	1996-97	0.00
	2001-2002	5.53
Rajasthan	1996-97	0.00
	2001-2002	5.53
Maharashtra	1996-97	0.00
	2001-2002	2.63
Madhya Pradesh	1996-97	0.00
	2001-2002	0.01

Bihar	1996-97	0.00
	2001-2002	7.01
West Bengal	1996-97	6.71
	2001-2002	0.00
Orissa	1996-97	0.00
	2001-2002	0.00
Source: IFFCO		

Table A6.3: State-wise distribution of Bio-fertilizer Plants (nos.)

	Number	Number	Number	Net Addition	
State	31.3.95	31.3.97	31.3.99	1995-97	1997-99
Assam	2	1	2	-1	1
Bihar	2	2	3	0	1
Orissa	2	2	1	0	-1
West Bengal	4	3	5	-1	2
Manipur	1	1	1	0	0
Tripura	0	1	0	1	-1
East	11	10	12	-1	2
Haryana	2	2	2	0	0
Himachal Pradesh	1	1	1	0	0
Punjab	1	1	1	0	0
Uttar pradesh	13	15	12	2	-3
Delhi	1	1	1	0	0
North	18	20	17	2	-3
Andhra pradesh	4	3	3	-1	0
Karnataka	6	5	11	-1	6
Kerala	0	1	1	1	0
Tamil Nadu	9	13	13	4	0
Pondicherry	0	1	1	1	0
South	19	23	29	4	6
Gujarat	3	3	3	0	0
Madhya Pradesh	4	4	7	0	3
Maharashtra	5	8	24	3	16
Rajasthan	2	4	3	2	-1
West	14	19	37	5	18
India	62	72	95	10	23

A6.4: Table : Structural composition of the Industry

Category	Total units number	Private Units %	Old units %	Producing both NF and PS %	Regional distribution of units % West	South	North	East	Average Capacity Tonnes	Average Distributio/ Capapcity%	Average Price Rs/Kg	Employment Mandays/ year
Large	14	36	71	100	50	36	14	0	613	50	29	4360
Others	36	64	31	86	50	36	3	11	100	36	30	447

Note: Only units reporting capacity, distribution and prices in 1998-99. NBFDC considered in North region.
Price is simple average of firms.
Large unit is defined as having capacity above sample average (243.53 tonnes).
Older units are units that reported for 1995 March

Table A6.5: Distribution and Price of Biofertilizers by Privately owned Units

year	Distribution(Tonnes) Total	Private	Private(%)	Price of NF (Rs/Kg) Total	Private	Private/ Total%	Price of PS (Rs/Kg) Total	Private	Private/ Total%
1992	1599.90	738.70	46.17	27.47	31.12	113.29	30.55	39.20	128.31
1993	2914.30	1763.80	60.52	29.27	33.50	114.45	31.30	39.70	126.84
1994	5008.60	2449.90	48.91	27.10	30.89	113.99	27.39	30.61	111.76
1995	6363.28	3341.35	52.51	27.80	31.52	113.38	28.28	32.16	113.72
1996	6681.50	2823.22	42.25	23.79	28.87	121.35	25.39	30.46	119.97
1997	6295.60	2714.22	43.11	24.99	29.78	119.17	26.93	32.55	120.87
1998	6699.90	2769.92	41.34	27.90	32.13	115.16	29.38	32.27	109.84
1992-98	35563.08	16601.11	46.68	26.90	31.12	115.66	28.46	33.85	118.94
Annual average Growth rate%									
1992-95	99.24	117.44	4.58	0.40	0.43	0.03	-2.48	-5.99	-3.79
1995-98	1.76	-5.70	-7.09	0.12	0.65	0.52	1.30	0.11	-1.14
1992-98	53.13	45.83	-1.74	0.26	0.54	0.28	-0.64	-2.95	-2.40

Note: Units that report capacity and distribution only considered. Prices are simple averages across units. For period 1992-98 total distributions and simple average prices are reported. Growth rate is based on point to point comparison.

Table A6.6 : Estimated regression equations including different dummy variables

Dependent variable is DISTRIBUTION

	Specified with VAR=VINT		Specified with VAR=JOINT		Specified with Regions VAR =WEST		VAR=EAST		VAR=SOUTH		Estimated for smaller sample SAMPLE SIZE=48	
Variables	coefficient	t-statistics	coefficient	t-statistics	coefficient	t-statistics	coefficient	t-statistics	coefficient	t-statistics	coefficient	t-statistics
CONSTANT	26.113	0.413	28.948	0.494	36.82	0.634	34.681	0.535	32.371	0.416	34.877	0.500
P-DEF	-2.079	-0.104	-3.276	-0.158	-2.696	-0.126	-2.675	-0.127	-2.337	-0.099	-2.124	-0.095
CAPACITY	0.325	9.209	0.328	90.334	0.330	9.499	0.328	9.281	0.330	9.482	0.306	10.551
DUM-EXP	60.674	2.088	71.986	2.473	72.504	2.289	72.597	2.348	71.894	2.058	75.916	2.665
DUM-PVT	-44.111	-2.149	-46.780	-2.174	-47.607	-2.300	-46.678	-2.173	-48.241	-2.391	-48.170	-2.327
VAR	26.315	1.066	8.272	0.504	-4.738	-0.175	-5.275	-0.202	4.610	0.140		
R		0.75		0.75		0.75		0.75		0.75	0.66	
DW		1.53		1.5		1.5		1.5		1.6	1.4	

Appendix 6A-I

Requirement of Some Inputs for Production of Biofertilizers

Production capacity 75 tonnes/year equivalent to 375000 packets (each packet 200 grams)

Labour use

Number of working days 240 days

Number of shifts 1 = 8hours

Number of daily wage labour

Unskilled	3
Skilled	1

Total man hours per year

7680

Carrier for 1000 packets 120Kg (Peat, Lignite, Charcoal)
Equipment (Autoclave, Refrigerator, Hot air oven, microscope etc.*)*
Packaging material (LDPE, HDPE, Polypropylene*).*

Rooms for Inoculum, Carrier, Office.

Source: BioFertilizer Statistics 1999-2000

Appendix A-II

Units considered for Regression Analysis accounting for 85% of Distribution 1998-99

Names of Units

<0.2% total distribution	State
Micro Biological laboratory ,Pattambi	Kerala
Pyrites, Phospahates and Chemicals, Amjhore	Bihar
College of Agriculture, Marathwada Agricultural University, Parbhani	Maharashtra
University of Agricultural Sciences, Dharwar	Karnataka
Bharat Laboratory &Biological House for Agriculture, Dhule	Maharashtra
Godavari Fertilizers &Chemicals Ltd., Secundrabad	Andhra Pradesh
Lakshmi Bio-techs, Cuddalore	Tamil Nadu
Regional Soil Testing Laboratory. Rajendranagar	Andhra Pradesh
Ecosense Labs (I) Pvt. Ltd., Goregaon	Maharashtra
Nodule Research Laboratory, BCKV , Mohanpur	West Bengal
Bio Science Laboratories, Salem	Tamil Nadu
Micro Bac India, Shyamnagar	West Bengal
A.V.S. Agro Products, Ahmednagar	Maharashtra
Institute of Nationla Organic Agriculture (INORA), Pune	Maharashtra
Nav Maharashtra Chakan oil Mills Ltd., Pune	Maharashtra
0.2% to 1% of total distribution	
Biological Nitrogen fixation Scheme, College of Agriculture, Pune	Maharashtra
Kisan Agro Chem, Dhanegaon	Maharashtra
Magnum Associates, Chennai	Tamil Nadu
Monarch Biofertilizers and Research Centre, Chennai	Tamil Nadu
Samarth Bio Tech Ltd., Hubli	Karnataka
K-Ferts Lab, Nanded	Maharashtra
Samruddhi Agrotech, Pune	Maharashtra
Rhizobium Scheme Deptt. Of Agriculture, Durgapura	Rajasthan
Maharashtra Bio-tech Industries, Pune	Maharashtra
Maharashtra Bio-tech Industries, Pune	Maharashtra
Vasantdada Sugar Institute, Pune	Maharashtra
Nitrofix Laboratories, Calcutta	West Bengal
The Sima Cotton Dev. &Research Association, Coimbatore	Tamil Nadu
M.A.I.D.C. , Pune	Maharashtra
Niku Bio-research Lab, Pune	Maharashtra

1% to 5% of total distribution	
T.N.Agricultural University, Coimbatore	Tamil Nadu
Tejasvi Biofert, Pune	Maharashtra
Gujarat State Cooperative Marketing Federation Ltd., Kankaria	Gujarat
HMG Biotech Pvt. Ltd., Shimoga	Karnataka
MLN Farmers Training Institute (IFFCO), Phulpur	Uttar Pradesh
SPIC Bioproducts, Chennai	Tamil Nadu
Main Bio Control Research laboratory (TN Cooperative Sugar Fedn.) Changalpattu	Tamil Nadu
Deptt. of Agriculture, various	Uttar Pradesh
M.P.State Cooperative Oil seed Growers' Federation, Dhar	Madhya Pradesh
Rashtrya Chemicals & fertilizers Ltd., Mumbai	Maharashtra
Bio Agro Fertilizers, Pune	Maharashtra
terra Firma Biotechnoilogies Ltd., Hubli	Karnataka
Kribhco, Hazira	Gujarat
Bio-fertilizer Production unit, Deptt. Of Agriculture, Pudukottai	Tamil Nadu
G.S.F.C., Vadodora	Gujarat
Bio-fertilizer Production unit, Deptt. Of Agriculture, Salem	Tamil Nadu
National Biofertilizer Development Centre, Ghaziabad etc.	Uttar Pradesh etc.
Madras Fertilizers, Manali	Tamil Nadu
>5% of total distribution	
Nafed Bifertilizer, Indore	Madhya Pradesh
Ajay Bio-tech India, Pune	Maharashtra
Kumar Krashi Mitra Bio Products (I) , Pune	Maharashtra

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[i] BGA's role in maintaining natural fertility of water logged rice fields by scientists back in 1939, when there was no use of chemical fertilizers to speak of.

[ii] Since all units have not reported their performance these distributions relate only to those that reported them, chances being that non-reporters are non-significant distributors.

[iii] The scope of selling from carried over stocks is limited as shelf life is short, around six months.

[iv] The weighted average price of biofertilizer is over the different material products while that of chemical fertilizer is over nutrient contents. The two averages are not entirely comparable, but at this early stage of the technology, the absence of information of available and stable conversion rate of biofertilizer into nutrients offers no better specification opportunity. The deflated price variable P-DF may be taken as a multiple of the true relative price, which can be estimated only when the true conversion rate is known. Nitrogen equivalences given in Table 1 are not used, as their meaningfulness is still debatable.

Chapter 7

Concluding Remarks

In the 1960s Indian agriculture had to take a departure from the traditional to the modern for the sake of development and today again there is a case for a turn this time from the modern towards a judicious blend of the modern and the traditional for sustainable development. The compulsion for a change comes from ecological, fiscal and external concerns. This study attempts to make economic analyses of data addressed to the issue of such a change.

The study draws some inferences based on analyses of available data. Although the data taken from Government of India, NSSO and FAI sources are of high quality in general, inadequacy in certain respects have limited the scope and relevance of the study. The inability to take a farming system approach (chapter 4 and 5), to use qualitative (and sometimes quantitative) indicators of input variables (Chapter 4), to consider quantitative input data (Chapter5) and farm level data (Chapter 6) are some of limitations.

7.2 Inferences drawn

The fertilizer sector in India is facing turmoil on both production and consumption fronts. India has entered a programme of fiscal adjustment and prudence since the early 1990s and also signed the WTO agreement to open up the economy to global competition. Free trade is likely to expose Indian agriculture to higher global prices and with subsidies withdrawn or significantly reduced, farmers will have to face higher fertilizer prices than they do now. So far as fertilizer demand is responsive to price, this may also force a reduction in fertilizer use as demonstrated by an exercise with paddy and by other studies in the field. The possible implication of this on food security and farmers' income are of serious concern. As the productive effect of green revolution wanes, there are also signs of soil fertility erosion leading to slowing down of growth in agriculture. Inefficient use of valuable chemical fertilizer, impoverishment of soil organic quality and possibility of water contaminations are growing threats to be faced. The fertilizer-based technology certainly needs to be reviewed. While fertilizer is a fossil fuel based and intrinsically scarce input, there may be scope of utilising the wastes generated with the growth process for soil enrichment as an alternative.

The data on cultivation practices show that the convention of using fertilizer and manure are both observed in Indian agriculture but in varying degrees across different crops and regions. However with technological progress and a policy towards promotion of fertilizer use the traditional practice of using manure for soil preparation has diminished and while intensity of use of fertilizer improved dramatically, that of manure has often gone down and in any case is not impressive. This is despite the widespread knowledge and appreciation of the merits of manuring land.

Organic methods have evolved through time from ancient times and the government could promote these practices, prevalent in unorganised form among Indian farmers, in a systematic manner for reaping ecological benefits. At the same time this can provide economic relief to poorer farmers about to face the challenges of a free market and opportunity for profit through domestic sale and export of ‘organic’ food produced through specific norms. Farm-yard manure (FYM), which is the major source of organic manure in India has a limited and informal market in rural areas and most of the supply seems to be sourced from domestic waste materials generated by animals and domestic activity. FYM competes with fuel use and due to the nature of the production process has a seasonal dimension on demand and supply sides. The crops grown and the agro-climatic conditions are also possible influential factors in the manure market. Livestock ownership along with the ability to feed them is main constraint on use of manure. The quality and efficiency of manure use depend on the quality of livestock and feed as also the techniques of preparing manure.

Although manuring is known to help cultivation of most crops, wheat and sugarcane are found more intensive in intake of fertilizer while groundnut, sugarcane and paddy show emphasis on manure use in that order, and manure usage shows more uniformity among these crops than fertilizer. Manure price in terms of nutrients NPK is very high compared to fertilizer and also varies more across crops and even households.

Farms using fertilizer more intensively are found to have higher yield rates as indicated by the positive impacts and elasticities of fertilizer in most cases. Manure use does not always generate higher yield, which may be reflective of the inefficient use/production made by households that use manure more intensively. The interaction between the two inputs of soil fertilization through effects on mutual productivities is mostly positive for paddy but the interaction is not strong for other crops. Technical substitution possibilities exist between fertilizer and manure as two alternative sources of nutrients and there is a case for changing the mix towards manure without hurting average yield levels in most cases if desirable on other grounds. Financial returns on the average also improve in a number of cases for paddy, groundnut and sugarcane following the substitution when input prices are unchanged. However a sizable section of farms, on account of their specific conditions, also lose from the change while others gain and a shift if necessary can be promoted with due safeguards for losing sections. Wheat, which uses low manure input, cannot benefit from any move towards manure under present conditions. The gain however cannot be sustained if manure prices go up in response and this seems highly likely considering the constraints on the manure market.

Given the conditions prevailing across classes, there is remarkable similarity of practices in terms of choice of fertilizer, manure and their joint use among them and the smaller farms under the situation are as much likely to embrace a fertilizer only technique or conjunctive use technique or any other as the bigger farms. There is however regional diversity of practices. Fertilizer use is also associated more strongly with other improved methods in agriculture than is manure affirming that fertilizer is more a part of the modern technology package and manure, despite its agronomic importance, is sometimes a poor farmer's only recourse.

The size neutrality of fertilizer use practice has been noted by other studies although distribution of other factors like irrigation has sometimes been linked to this equity. To account for different effects an econometric model has been used to look for the size effect and a positive effect has been found both for solitary and conjunctive use of fertilizer. Given that crop choice, seasonality, irrigation and resource endowment are unchanged, if the smaller farm gains assets and entry to a more privileged higher class it is more likely to shift to the conjunctive use regime and least likely to the manure only regime. This is a sign of class bias and promotion of the new technology would require a distributional policy too. However it is found that the probability of a small farmer to take up the desired conjunctive practice improves when he has ownership to livestock and access to CPR for feed. The conjunctive use technology is thus found to be positively associated with endowments of land, assets, irrigation, livestock and grazing/fodder land.

All regions have a tendency to take up fertilizer only practice in comparison to the conjunctive practice but among crops the cereals wheat and paddy and cash crop sugarcane have greater tendency towards the conjunctive practice and vegetable towards manure use only practice. Most crops are likely to have the non-use of inputs practice. Hilly regions have a natural tendency to take up manure-based agriculture. The south shows the greatest blend of the technologies that are fertilizer and manure based translating to the modern and the traditional while most part of north India prefer fertilizer only. In general the kharif season is the preferred season for manure use in isolation or conjunction owing to conditions of rainfall and fuel market.

Biofertilizers are identified as an innovative farm technology with considerable social benefits that require time to prove commercially viable. The technology is yet evolving and much research is need in attaining desirable strains and field level studies and reaction from farmers can help the process. The public interventionary policy to support the industry and the product use has had limited success in terms of dissemination and commercial success yet but there is a case for public support to continue though with some modification.

7.3 Ways to Promote use of organic methods with fertilizer use

After coming to the conclusion that India may have to consider a change in agricultural strategy towards a blend of fertilizer and organic based technology for ecological and economic compulsions the study on the financial feasibility of a shift towards organic methods brings out the binding influence of the manure market in making this shift possible. Identifying some constraints to the households' accepting the practice helps to pinpoint the areas of strength and weakness of households in taking up the regime.

- ❖ The greatest constraint to the technology comes from the inelastic supply of organic manure, the predominant dependence on own resources, the limited access of the small farmers to the market due to informal local dealings and lack of organised market leading to wide price variations. The inefficiency of production due to time, feed and technology constraints can lead to lower nutrient supply despite the bulk. The smallness of the exchange market and the seasonality aspects are important influences. A primary requirement of the government is to address this issue.

- ❖ At the outset there is a need for determining the desirable technology and the appropriate blend, which is specific to the situation. Soil testing is an important practice whose prevalence is less than desirable. It is suggested that in the fashion of macro-economics and social economics it is useful to have land quality indicators (Pieri et al 1995).

- ❖ Promotion of dairy sector with adequate investment is synergic to the success of the technology and the government can promote the former with the additional aim of supplying input to crop based agriculture. Along with milk and several other useful products of livestock adding up to its value, the importance of waste product needs to recognised. A modelling of land use patterns can be attempted distinguishing between land for field crops and that for cattle to take account of the inter-linkages so that each can provide room for the other for mutual benefit. As yet, there is unfortunately only a competition for land between the two uses with field crops deemed as the winner. However the vicious cycle of poverty, poor quality cattle, need for food may be leading to an underestimation of the livestock sector. The promotional policy must however give priority to the viability of poorer farmers in livestock farming.

- ❖ The use of fresh dung is usually advised against, and efficient composting facilities (Miller and Jones, 1995) with public support are a necessity but the local institutions and the PRI must have a strong role in making them a success. Biogas projects at community level can provide more nutrient intensive sludge fertilizer at nearly no cost (Reddy at al, 1979), while delivering other benefits likes fuel, which usually competes with manure. The composting and biogas projects would also lead to increasing rural employment but for this wage and labour management should be on market lines even if that means a rise in product price. Improvement of farmer's own manure production techniques and recognition of the domestic and rural institutional restraints on the process are necessary. There is again a need for institutional involvement with greater local information and participationand a correct integration of the process in rural household life to make these projects successful.

- There must be some attempts to generate a market for this crucial agricultural input with some semblance of organisation. The variation of prices across households may reflect a bias against the resource poor, which is undesirable. There are various institutional arrangements in the world that uses the synergy of crop and livestock based agriculture that may be looked into[i].

- Apart from livestock there are other sources of manure. The growing food processing sector is another source of synergy that can be reaped. Urban food wastes can also be channelled but a focus on rural areas especially in terms of processing units and necessary facilities of transportation and refrigeration can help the rural sector through employment generation and manure supply and the urban sector's environmental cleanliness. Ways to harness the farm wastes also need to develop. Mechanisation of waste disposal and recovery for recycling is a possibility perhaps feasible only for cities at the moment for use in sub-urban farms.

- Hill areas are found to be natural zones for manure based farming and this should be encouraged and promoted but for this, transportation and infrastructure are a must. Access to professional facility to market the product is necessary.

- The policy for use of CPR deserves the attentions it is receiving now for the benefit of the poor. It is important to ensure that the poor livestock owners have access and right to fodder.

- Conventional and non-conventional methods of collecting raw materials for manure may be considered. Utilisation of all usable waste products, efficient and scientific processing of the same and other sources such as collection of river-bed or tank-bed silt though appropriate technology are some of the solutions.

- Bio-fertilizers have significant potential but as in the case of any agrarian technology there is a significant time lag for its adoption and commercial success through learning. The State should go on promoting the input but the method of promotion should be to encourage adoption, risk coverage and institutional support rather than strategies that induce price distortion and inefficiency of investors. Subsidies, buyback schemes, quality control, concessional loans to industry and above all demonstrations and training are the suitable strategies. Farm level information relating to their use should be available for economic analyses to monitor the progress.

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[i] Arrangements such as where the crop farmers offer overnight stationing facility to the livestock farmers and fertilize the soil as a payment are interesting.

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