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Reducing dependence on chemical fertilizers and its financial implications for farmers in India

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Abstract

The fertilizer intensive technology so long promoted in agriculture produced a green revolution but has brought long-term damages to soil quality. The technology now appears unsustainable for future agricultural development in India both on account of its ecological implications and the burden on the budget. There is now a need to revisit the traditional methods once used in agriculture and to look for a judicious blend of chemical fertilizer based technology with organic manure.

Since manures are relatively less productive in the short run there is an alarm that a shift in technology away from the chemical fertilizer towards organic manure may mean a compromise in production or may hurt the incomes of farmers. This paper emphasizes the environmental benefits of a possible shift in agricultural technology, while keeping in view the importance of sustaining crop yield levels and protecting farmers' incomes. Considering two major crops in India in specific states the paper finds that over time while fertilizer use intensified several times over, the use of manure in agriculture either stagnated or declined. The manure market remained localized, limited and unorganized and its price was significantly higher than fertilizer in terms of nutrients in contrast to the organized and state supported fertilizer market. The paper estimates quadratic yield functions based on cross-section household level data and using the prices faced by farmers as reported by official survey finds that in majority of the cases there will not be any financial loss resulting from a small shift in technology towards organic manure. Such a shift can however be considered feasible if the losing households are compensated and if manure price is kept in control by promoting a more dynamic manure market.

Keywords: Technological choice in agriculture; Organic manure; Chemical fertilizer; Financial gains

1. Introduction

It is increasingly being realized that the intensive use of chemical fertilizers, so long promoted for higher productivity in agriculture, is harmful for soil and proves counter productive in the long run. Prolonged use of the chemical based technology has undermined soil quality in terms of its physical, biological and chemical properties afflicting its ability to satisfy healthy plant growth and crop production. Continuous nutrient mining while using chemical fertilizer leads to an ever-increasing gap between depletion and replenishment leaving the soil hungrier and proves unsustainable. Further, the dependence of Indian agriculture on chemical fertilizer for high crop

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yields implies a basic reliance on exhaustible fossil fuels with chances of pollution at the production stage. There is also the adverse possibility of nitrogen leaching into ground water leading to possible health hazards through pollution of both surface and ground water resources. The subsidy backed price policy for fertilizer has often been blamed for non-transparency and indiscriminate and irrational use (Gulati, 1989) but the correction of domestic price distortions is not the remedy of the environmental threat, as market prices and increased competition of the free trade regime could also intensify resource use in the search for higher productivity from soil (Anderson and Strutt, 1996). Besides, withdrawal of subsidies and exposure to global competition inevitable in the present context could deal a setback on production and income of farmers in the absence of an alternative technology in hand (Ghosh, 2003).

Traditionally, Indian agriculture was driven by indigenous knowledge based methods using locally re-generable materials for soil fertilization, making up an organic technology. The advent of the modern methods based on HYV seeds and chemical fertilizer and the challenge of shortages that was a reality in the 1960s impelled a turn from traditional to modern technology that ran its course through the decades. Today, in the wake of changing perceptions and approaches on market and ecology there is a need to revisit the traditions and work for a judicious mix of the modern and traditional technologies for greater sustainability of development. Since chemical fertilizer imparts greater productivity than manure that constitutes bulk of the organic technology, the shift in input mix towards organic methods raises some alarm with respect to its impact on productivity and on the returns to farmers in the short run. A shift in technology from the so called modern and chemical based one to a blend with the traditions is environmentally beneficial over a longer time horizon but can be feasible in India only if that has the ability to protect output levels and most important, the incomes of the farmers even in the short run.

2. Objectives and data

This paper considers one major cereal paddy and one cash crop groundnut in India and is devoted to studying the tendencies observed in Indian agriculture, the issues in the manure and fertilizer markets and the implication of a reversal towards a more sustainable technology for farm incomes, suggesting possible limitations. The paper takes up the cause of a possible technological shift in Indian agriculture from the chemical based technology of green revolution period towards a more organic manure based one and evaluates the implications, keeping in view the future environmental benefits from the shift as also the ability of the new technology to sustain crop yield levels and to protect the financial returns of farmers. Certainly, such a switch is not feasible if a large section of households suffer losses on its account.

Broadly, the paper dwells on (1) the technological tendencies actually shown by Indian agriculture with respect to use of manure and fertilizer, (2) the issues arising in the manure and fertilizer markets in India as they are and (3) financial implications of a shift towards organic manure. The analysis is based on sample data provided by the periodic[1] official survey of the government of India entitled 'The Comprehensive Scheme for Studying the Cost of cultivation of principal Crops' denoted as COC henceforth. A three-stage stratified sampling design is employed in this nation wide survey with farm holdings as the third and ultimate stage. Each *state* in the country is demarcated into homogeneous agro-climatic zones based on soil type, climate and other factors and the primary units (which are subdivisions or *tehsils*) are allocated to the different zones. In each village or cluster of villages forming the second stage[2] the operational holdings are classified by farm size-classes and from each size class two holdings are selected by random sampling without replacement. The items of cost cover both actually paid out cost and imputed cost for owned inputs. The survey also presents information on certain inputs in physical dimensions. Sampling design and imputations with special attention to family labor and land are all done following rigorous methodology (see Government of India, 2000). The present paper

[1] The official and published data are available over years but are rather uneven in coverage of the years and the states.

[2] The primary sampling units are selected in each zone with probability proportional to the area under selected crops and with replacement and within each such unit the village/cluster is selected following similar procedure.

makes use of published data, which are summarized at the state level for various years, for temporal comparisons and household level data for the year 1998–1999 for further analyses.

3. Fertilizer use practices in India and changing circumstances

During the first half of the twentieth century chemicals were used in India only in pocket comprising of commercial plantations of cash crops. Traditional agriculture based on indigenous and natural inputs took a sharp bend in the 1960s. In the quest for food-security, 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 (Table 1).

The government promoted farm level adoption of fertilizer use practice by not only financial support, but through active campaigns and demonstrations and by inviting private and commercial initiative to build up a vibrant market linked with the cooperative and credit sectors for agricultural development. During the period 1950–1951 to 2001–2002 production of food-grains increased due to the impressive rise in yield levels brought about by the modern inputs, most prominently chemical fertilizer. 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 once again changed, this time from a controlled to a market oriented one and the green revolution started running out of steam. It is becoming clear that agriculture cannot rely on intensive fertilizer use for future development.

Table 1
Fertilizer use in India (NPK)

Period	Production	Consumption	Import	Cons/ha
Triennium Average	('000 tons)	('000 tons)	('000 tons)	(kg/ha)
1976/1977–1978/1979	2653.8	4271.2	1519.2	24.8
1981/1982–1983/1984	4354.0	6721.3	1509.6	38.1
1986/1987–1988/1989	7723.3	9489.8	1624.6	53.7
1991/1992–1993/1994	9573.3	12416.3	2968.0	67.2
1996/1997–1998/1999	12668.4	15764.5	2917.3	83.2
1999–2000	14320.9	18068.8	4163.9	93.8
2000–2001	14676.9	16702.3	2179.4	86.7

Source: Fertilizer Association of India (2002), Fertilizer Statistics, 2001–02 New Delhi.

Several shortcomings of the fertilizer-based technology were becoming apparent since 1980s (Vaidyanathan, 1989). Despite all promotion, fertilizer use intensity remained low relative to aspirations. Consumption remained mostly confined to irrigated regions with rain-fed 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. The limitations of the state machinery, poverty of farmers as well as the agronomic and social realities all served to contain the dissemination of the green revolution. 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 was reported in some parts of the country. Concerns about nutrient imbalances and soil deficiencies related to major nutrients NPK[3] as well as to 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 the chemical fertilizer applied. Nitrate pollution of ground water (exceeding WHO's minimum norm of 10 mg/l) is threatening to become a reality in areas of high fertilizer use and water samples crossing the permissible limits are reported in specific cases. Finally, to make fertilizer cheap and affordable to farmers, mounting cost burden has weighed down on the union budget. It is becoming increasingly apparent 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. Awareness on food con-

[3] NPK stands for nitrogenous, phosphatic and potassic fertilizers.

tamination has been growing too on consumers' part and the call for a change in technology also comes from the emerging market for food with minimal chemical residue. There is now a case for revisiting the cleaner traditional technology to draw support for the modern one.

4. Organic manure and its market

Organic soil fertilizer 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 component. FYM is generally home produced and its quality is highly variable depending on the quality and proportion of the vegetal and animal waste matters it incorporates and the process of decomposition. Inadequate facilities and pre-sowing time constraint often result in use of inefficient and under-decomposed manure compromising on the productivity effect. Manure is however traded in rural India among farm households in a market, small in size and heavily determined by local informational, agronomic, domestic and seasonal factors.

It appears that although Indian farmers and policy makers have always known and appreciated the merits of manure use, the extent of use has shown little dynamism over the years. Summarised data based on COC surveys show that for paddy while fertilizer use per hectare has steadily grown through the last three decades, corresponding FYM use has been rather stable and in fact declined in Andhra Pradesh and Uttar Pradesh (Table 2). The growth rates on a point-to-point basis are small even if positive, in contrast to fertilizer use which grew by more than 200% in each case. Groundnut shows similar trends.

The COC sample (household level) data for 1998–1999 averaged over select states and crops only and summarized in Table 3 indicate that manure price

Table 3
Statistics on use of fertilizer and manure based on selected states sample: 1998–1999

Crops	Unit	Paddy	Groundnut
Manure use intensity	Qtl./ha	18.9	22.3
Manure Price (bulk)	Rs/Qtl.	16. 6	21.2
Fertilizer use intensity	kg/ha	116.5	63.6
Fertilizer Price (NPK)	Rs/kg	10.9	12.6
Price ratio (M/F)	%	422.0	465.2

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. **Groundnut**—Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, Maharashtra, Orissa. Sample area measures under crops are used as weights. Source: COC.

Table 2
Changes in fertilizer and manure use over time: paddy and groundnut

	Paddy					Groundnut		
	Andhra Pradesh	Orissa	Punjab	Uttar Pradesh	West Bengal	Andhra Pradesh	Orissa	Gujarat
Fertilizer nutrients (kg/ha)								
1970s	53.2	10.0	124.0	28.5	10.7	17.6	16.6	16.1
1980s	126.8	13.8	180.8	45.0	31.8	26.3	23.0	50.3
1990s	176.8	61.2	182.6	89.1	69.9	44.3	47.0	57.6
Manure use (Qtl./ha)								
1970s	58.1	26.7	25.7	19.8	27.3	40.9	15.8	36.0
1980s	67.5	26.3	56.9	26.4	48.5	33.6	16.3	36.3
1990s	38.0	28.6	40.0	9.0	29.3	26.6	20.3	28.6
Growth rate %								
Fertilizer	232	509	47	212	551	152	183	257
Manure	– 34	7	56	– 54	7	– 35	31	– 21

Computed with COC data taking averages of first triennium for 1970s and 1980s and last triennium for 1990s for which data are available. Biennium is considered when sufficient data are not reported.

expressed in terms of the nutrients (NPK) is not less than four times that of fertilizer. Groundnut comes low in respect of fertilizer use intensity but leads when manure use in considered.

5. Implications of a shift in fertilizer—manure mix

Since fertilizer has been a prime source of productivity in Indian agriculture, a move away from fertilizer towards organic manure 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 (COC) data 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 manure is costly, are their financial returns protected by the same substitution? This study is based on cross-section farm household level information for the most recent year for 1998–1999 and will attempt to estimate yield functions of paddy and groundnut for dominant states for which the data are provided.

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 fertilizer, which however has 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 combinations 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.

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

Sample states and crops

Paddy: Andhra Pradesh, Tamil Nadu, Kerala, Bihar, West Bengal, Assam, Uttar Pradesh, Punjab and Madhya Pradesh.
Groundnut: Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, Maharashtra, Orissa.

Only those households are selected for the present analyses, which have undertaken cultivation of the concerned crop in the year 1998–1999. This paper considers cost[4] to include opportunity cost of own resources including family labour so that negative returns are a possibility when production is not commercially profitable. Fertilizer is a purchased input while manure can be either purchased or owned. The COC values purchased inputs 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.

5.1. Econometric issues

The functional form for the yield function had to be chosen from among a number of forms including Linear, Quadratic, CES, the Cob-Douglas and the Trans-log functions. While the Trans-log function has several advantages, in the present case the presence of zero valued variables in the sample or in other words, the choice of not using any of the inputs of concern by farmers makes the function useless or at the most inappropriate in which case a number of observations and valuable information has

[4] This is known as concept C2 = Cost to owner farmer including rental value of + owned land, rent paid for leased in land and imputed value of family labour.

to be lost. The simple quadratic form is preferred over others to describe the yield function (Desai, 1976; Narayana and Parikh, 1987; Bliss and Stern, 1982; Ghosh, 1998). for the following advantages: (a) Simplicity, (b) Flexibility and (c) Suitable properties[5]. The cross terms between fertilizer and manure allow for positive or negative interactions (see Technical note 1) and interaction with self is captured through a squared term. In cases where input application is not high in context of the situation, the negative quadratic effect may not be there. The technical rate of substitution along an iso-quant is used to assess the possibility of substitution between the inputs and is used for simulation of returns (Technical note 1). The general form of the yield function is as follows:

$$\begin{aligned}\text{YLD} = {} & a_0 + a_1\text{FRT} + a_2\text{MANU} + a_{12} \\ & \times (\text{FRT*MANU}) + a_{11}(\text{FRT*FRT})a_{22} \\ & \times (\text{MANU*MANU}) + a_3\text{LAB} + a_4\text{IRR} \\ & + \sum a_{5i}\text{DUM} - \text{Z}_i \end{aligned} \tag{1}$$

where dependent variable is YLD = Yield rate in Quintals (= 100 kg)/ha. And independent variables are

(1) FRT = Fertilizer in kg/ha,
(2) MANU = Manure in Quintals/ha,
(3) LAB = Labour in h/ha,
(4) IRR = Dummy variable for irrigation,
(5) DUM-Z_i = Dummy variable for ith Zone.

To allow for agro-climatic and institutional differences, the yield functions are estimated separately for different states and dummies are used for agro-climatic zones within a state.

$$\text{DUMMY} - \text{Z}_i = 1 \text{ if the household belongs to zone } i$$
$$= 0 \text{ otherwise}, i = 1, 2, n - 1$$

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

Fertiliser variable is measured in nutrients (NPK) and the variable is treated as a composite of all three nutrients. Manure is used as physical bulk in quintals. Irrigation data is not available in physical terms and in that situation a simple binary quantification of the irrigated status has been attempted and since in certain states access to adequate and timely water supply is intimately related to the type of irrigation 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 are incident on hired or owned or canal facility.

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

Labour input can induce variations in yield levels of crops, given all other inputs. With modernization of agriculture, machine labour also gained prominence and can be an important replacement for human labour[6]. 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

[5] The advantages of the Quadratic form are: (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. Suitable Properties: It allows for usual expected properties of agricultural yield functions as per theory and economic reality, and also allows for zero valued variables since the inputs are not always essential in nature.

[6] 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 Krishna (1974), Chopra (1985), Agarwal (1983).

Table 4a
Change in returns due to substitution of 1% fertilizer use by manure: Paddy

Paddy	Mean elasticity of yield		Mean return	Mean return	Mean return	Losers	Gainers	Unaffected
	Fertilizer	Manure	Base	Scenario1	Scenario2	% Household		
			Rupees/ha					
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

Scenario 1: Cut in Fertilizer use and no substitution, Scenario 2: With substitution; The Gainers/Losers are calculated with respect to Scenario 2 over Base. Elasticities are at mean values of input use.

improves the estimate of the equation. The weather effect, though extremely important in agriculture, has not been included as it is necessarily spatial in expanse and is not expected to vary significantly across farm units in any region or even appreciably within any state. It is pertinent to note that 1998–1999 experienced a normal monsoon and the production performance in agriculture was satisfactory[7]. 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.

5.1. Estimates from yield functions

The regression equations estimated after correcting for heteroscedasticity are reported in Appendix Tables A1 and A2. The coefficients are then used for calculation of marginal products and elasticities at mean levels of input use that are further utilized for calculating returns at prevailing and hypothetical situations. The coefficient of the cross term between fertilizer and manure signifies the interaction between the two inputs and while the signs vary, the larger numbers of positive (significant) and favourable interactions suggests that a complementary relation dominates for paddy.

The marginal products (MPs) and corresponding elasticities derived to measure the responses of yield rates to input use would depend on the parameters as well as the input levels prevailing at the household level (Technical note 1). These are comprehensive measures of responses taking into account the pure effects (coefficients) of the input variables, the quadratic effects and the interactions at the given levels of input use. Reported in Tables 4a and 4b the elasticities are generally low and lower for manure than fertilizer. The elasticity with respect to fertilizer use is generally positive but negative elasticity is found for paddy in Madhya Pradesh where farms using higher intensities of fertilizer show no superiority in terms of higher yield rates.

Though it may be technically possible to substitute manure to an extent for the intrinsically scarce and eco-damaging chemical fertilizer without yield loss as indicated by the positive elasticities in most cases, 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. The approach taken in this paper is to examine the implications of an extensive move towards a less fertilizer intensive technology through replacement by manure and to simulate cases in which a certain small cut in

[7] The moonsoon which has a dominant influence on agricultural performance in both kharif and rabi seasons was more than satisfactory in 1998 with only two of the meteoroglical subdivisions 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).

Table 4b
Change in returns due to substitution of 1% fertilizer use by manure; yield unchanged: Groundnut

Groundnut	Mean Elasticity of Yield		Mean Return	Mean Return	Mean Return	Losers	Gainers	Unaffected
	Fertilizer	Manure	Base	Scenario 1	Scenario 2	% Household		
			Rupees/ha					
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

See Table 4a.

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 method used is given in more detail in Appendix (Technical note 2). 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 going by the estimated yield function. 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 financial gains of the households are computed. An intermediate situation where the cut in fertilizer use reflects on yield level and is not replaced by manure is described as Scenario 1. Since the impact of the shift can vary across households, especially in view of the localised manure market, 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. 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.

6. Results

The results of this exercise (Table 4a and 4b) give diverse implications depending on the signs of the elasticities. For paddy in Madhya Pradesh both inputs are found to come with negative elasticities at existing input use levels. Output elasticity of manure is negative in Tamil Nadu for both paddy and groundnut and in Orissa for groundnut. 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 small perceptible decline in mean returns in Scenario 1 owing to loss of productivity from reduced fertilizer intake. Scenario 2 portrays the effect of adjustment in both fertilizer and manure. It incorporates a movement towards manure so long as its elasticity is greater than zero but away from manure otherwise. The shift is viewed as financially feasible if gains improve over base level. The returns improve on the average from the full adjustment in scenario 2 in most cases.

For paddy the southern states Andhra Pradesh and Kerala do not appear to gain from a shift towards manure at prevailing prices but Assam, Bihar, Punjab, and Uttar Pradesh gain financially from the technological change. In Uttar Pradesh there is in fact an indication of over-use of fertilizer. In Madhya Pradesh there is a need to look at the soil quality, cropping pattern and other ways of soil enrichment to identify the paradox arising out of a negative impact of fertilizer use. Manure replacement does not seem to offer a solution under the prevailing conditions and the state of FYM production. The shift is found mostly helpful for groundnut in which case the mean financial returns improve in scenario 2. The southern state Karnataka, where the practice itself does not appear to be commercially profitable is the exception. Viewing the distribution of gains across sample households, there appears considerable variation in returns though a large portion of farmers is not affected significantly. The loss if any is not generally severe and in most cases there is moderate gain (Table A3). The percentage of gainers generally outweighs that of losers though the interests of the latter group deserve due attention. Thus looking at the mean level financial gains and the distribution of gains and losses across holdings there appears to be a case for the technological shift but with due cautions about the losing units and also manure price changes.

6.1. Manure price and gains from shift

The calculation of the financial 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 use, given that the market for manure is constrained, localized and marked by inelasticities, there is a considerable chance that manure price will be sensitive to the increased demand at the aggregate or even at the household level. The calculation of gains on the basis of elastic supply may therefore be an underestimate. The cross-section data also does not help in computing supply elasticities with any reliable estimates. In the absence of the estimated price responses of manure 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 some gain 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 requires that the savings achieved from reducing fertilizer cost are 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 notes 2). The averages of the ratios ($LIM-P_m$) are presented in Table 5 only for the cases in which reduction in fertilizer use can be compensated by increased manure use. The margin within which manure price can move up is low generally falling within a small margin of the prevailing

Table 5
Maximum of manure price to prevailing price ratio ($LIM-P_m$) : sample averages

Paddy		Groundnut	
State	Ratio	State	Ratio
Andhra Pradesh	0.76	Andhra Pradesh	0.61
Assam	1.01	Gujarat	1.01
Bihar	5.54	Karnataka	0.69
Kerala	0.87	Maharashtra	1.00
Punjab	1.04		
Uttar Pradesh	1.01		
West Bengal	0.94		

Presented only for cases in which manure use increases and estimated elasticity is positive.

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 can be brought down.

7. Concluding points

In view of sustainability problems associated with a chemical intensive way to agricultural development there is a case to revisit traditional wisdom and work for a judicious blend of modern and traditional technologies in agriculture. A shift in technology away from highly chemical based practices to organic manure use can be an answer but the productivity effect of the shift has called for caution about the likely impact on farmers' incomes. Thus, despite its known environmental benefits, the feasibility of the technological shift can only be judged by its ability to sustain crop output levels without bringing hardship and losses to large sections of farming community.

With the advent of the high yielding technology in India, agriculture has moved away from the practice of using manure for soil enrichment and this vital input seems to have been neglected despite widespread recognition of its merits while fertilizer use showed dynamics. The fertilizer market was greatly promoted by the government as well as by commercial enterprise in India but rural manure market remained limited, unorganised and local. This paper examines the effect on farm returns of a small shift in technology towards manure use keeping productivity unchanged through estimated yield functions for paddy and groundnut. These in general corroborate the superior productivity effect of fertilizer use in the short term though there are instances of inefficiency and over-use. The interactions between the two inputs vary but a synergic effect dominates for paddy. But substitution of organic manure for chemical fertilizer seems technically possible to protect yield levels and simulations suggest that a shift towards manure from fertilizer on the whole may not hurt income in most cases. However since the effect differs by households and depends on the response of manure price to increased use, the shift can be practicable if losing households are protected or compensated by policy and by promoting a more dynamic manure market to control manure prices. Higher premiums on output prices if possible in a market for a product embodying a more sustainable technology could be another way in which farm incomes can be protected.

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Appendix A. Technical Notes

A.1. Substitution

Substitution (or complementarity) can be defined in terms of the interaction between the two inputs (see Bliss and Stern, 1982). 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.

$$\begin{aligned}\text{MPF} &= \text{d}(\text{YLD})/\text{d}(\text{FRT}) \\ &= a_1 + a_{12}\text{MANU} + 2a_{11}\text{FRT}\end{aligned} \tag{2}$$

$$\begin{aligned}\text{MPM} &= \text{d}(\text{YLD})/\text{d}(\text{MANU}) \\ &= a_2 + a_{12}\text{FRT} + 2a_{22}\text{MANU}\end{aligned} \tag{3}$$

A negative interaction may be a sign of substitution. 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 along an iso-quant that can be expressed as

$$\mathrm{MRS} = [\mathrm{d}(\mathrm{YLD})/\mathrm{d}(\mathrm{FRT})]/[\mathrm{d}(\mathrm{YLD})/\mathrm{d}(\mathrm{MANU})] \quad (4)$$

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.

A.2. 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

$$\mathrm{C2} = P_{\mathrm{f}}\mathrm{FRT} + P_{\mathrm{m}}\mathrm{MANU} + \mathrm{OC2} \quad 1(\mathrm{A})$$

$$R = P \times \mathrm{YLD} \quad 2(\mathrm{A})$$

Here P_{f} and P_{M} are prices of fertilizer and manure and P is crop price, OC2 is all other cost combined as reported and returns at base level R1 is given by

$$\mathrm{R1} = R - \mathrm{C2} \quad 3(\mathrm{A})$$

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

$$\Delta\mathrm{FRT} = -\mathrm{FRT}(1 - 0.01) \quad 4(\mathrm{A})$$

$$\mathrm{R2} = R - \mathrm{C22} \quad 5(\mathrm{A})$$

where $\mathrm{C22} = \mathrm{C2} + P_{\mathrm{f}}\ \Delta\mathrm{FRT}$ 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:

$$\Delta YLD = \mathrm{MPF} \times \Delta\mathrm{FRT} \quad 6(\mathrm{A})$$

$$\mathrm{R3} = (R + P(\Delta YLD)) - \mathrm{C22} \quad 7(\mathrm{A})$$

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

$$\Delta MANU = \mathrm{MRS} \times \Delta\mathrm{FRT} \quad 8(\mathrm{A})$$

$$\mathrm{MRS} = \mathrm{MPF}/\mathrm{MPM} \quad 9(\mathrm{A})$$

We then have the final returns level R4

$$\mathrm{R4} = R - \mathrm{C23} \quad 10(\mathrm{A})$$

where

$$\mathrm{C23} = \mathrm{C2} + P_{\mathrm{f}}\Delta\mathrm{FRT} + P_{\mathrm{M}}\Delta\mathrm{MANU} \quad 11(\mathrm{A})$$

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 4a and 4b Returns R1, R3 and R4 are reported as scenarios base, 1 and 2 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).

$$P_{\mathrm{f}}\Delta\mathrm{FRT} = P_{\mathrm{M}}\mathrm{max}(\mathrm{Manu} + \Delta\mathrm{MANU}) - P_{\mathrm{M}}\mathrm{MANU}$$

$$P_{\mathrm{M}}\mathrm{max} = (P_{\mathrm{f}}\Delta\mathrm{FRT} + P_{\mathrm{M}}\mathrm{MANU})/(\mathrm{Manu} + \Delta\mathrm{MANU})$$

$$\mathrm{LIM} - P_{\mathrm{M}} = P_{\mathrm{M}}max/P_{M}$$

Appendix B

Table A1
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

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 C

Table A2
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	0.00007	0.0002
	(0.34)	(2.61)	(− 0.089)	(− 3.34)	(0.166)	(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)	(0.317)			
MACHINE-LABOUR					0.37	
					(2.58)	
IRRIGATION	− 0.54	4.48	2.534	− 0.21	0.26	
	(− 0.68)	(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)	(0.33)	(2.27)	(− 0.80)	(− 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

See Table A1.

Appendix D

Table A3
Distribution of gainers and losers from using Fertilizer and Manure with Substitution (Scenario 2 over Base)

Crop/State	Mean Gain in Returns	Return loss severe	Return loss moderate	Return gain moderate	Return gain large
	Rs/ha	% household	% household	% household	% 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
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

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

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