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Subsidising Food Crisis

Synthetic fertilisers lead to poor soil and less food

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Contents

Executive Summary

After years of indiscriminate use, synthetic fertilisers are currently hampering the increase of food production in the country

Intensive agriculture, with high use of synthetic fertilisers and chemical pesticides, was introduced in India in the 1960s as part of the Green Revolution. As a result, synthetic fertilisers' consumption increased from a mere 0.07 million tonnes (Mt) in 1950-51 to a staggering 23.15 Mt in the year 2008-09. This contributed to the growth of food production in the country, but nearly five decades down the line, indiscriminate use of these synthetics has degraded the natural resource base, especially the soil. As a consequence, food production is no longer increasing and is now affected by diminishing returns and falling dividends in agriculture intensive areas.

Synthetic fertiliser consumption in India is highly variable among regions, but in 78 districts fertiliser consumption is twice the national average

The synthetic fertiliser usage in the country shows significant variation from region to region. However, in the most agriculture intensive districts (78 districts out of 528 major districts in India), synthetic N-P-K (nitrogen, phosphorus and potassium) fertiliser consumption is more than 200 kg/ha, a rate that is twice the country average. Six crops (rice, wheat, cotton, sugar cane, rapeseed and mustard) consume about two-thirds of the synthetic fertiliser applied. The irrigated area, accounting for 40 per cent of the total agricultural area, receives 60 per cent of the total fertiliser applied.

The huge Central Government fertiliser subsidy is one of the main reasons behind imbalance and overuse of synthetic nitrogen fertilisers in India

Synthetic fertilisers are released into the agrarian system at highly subsidised rates. The amount of subsidy outgo on synthetic N-P-K fertilisers (domestic and imported) in India during the last three decades has grown exponentially from a mere Rs. 60 crore during 1976-77 to an astronomical Rs. 40,338 crore during 2007-08. According to government sources (Ministry of Chemicals and Fertiliser, 2008) the subsidy estimate for 2008-09 was Rs.119,772 crores. At present, the subsidy structure is skewed towards synthetic nitrogen fertilisers and this has been phenomenal in promoting its overuse. Urea accounts for 82 per cent of the total consumption of nitrogen fertilisers in the country.

700 farmer interviews conducted in field surveys by the Principal Investigators in seven states across the country point to the fact that the huge fertiliser subsidy is one of the main reasons behind imbalance and overuse of synthetic nitrogen fertilisers in India. 84 percent of surveyed farmers reported that they used higher doses of nitrogen to replace other nutrients, since as a result of government subsidies, synthetic nitrogen is relatively cheaper to procure. 82 percent of farmers also expressed their willingness to use more ecological fertilisers if they were easily available and subsidised.

Overuse of synthetic nitrogen fertilisers, catalysed by skewed subsidy policies, is causing long-term damage to soil health locally and to the environment at a larger scale (e.g. climate gases and dead zones in the oceans). Soil degradation problems such as soil acidification and alkalisation, as well as deterioration of the soil's physical properties, such as infiltration, soil aeration, soil structure and bulk density, have all been linked to over emphasis on synthetic fertilisers and neglect of organic fertilisation. Several long-term fertiliser trial experiments by the Indian Council of Agricultural Research (ICAR) indicate that the continuous use of synthetic nitrogen alone has resulted in declining yield and has deleterious effects on long-term soil fertility and the sustainability of agricultural systems.

More subsidies, poor soil health and less food

Introspection on results from the multiple long-term fertiliser trials in rice-wheat systems have revealed gradual deterioration of soil health and thus long-term productivity due to overuse and imbalance use of synthetic fertilisers. In Punjab, the state with highest use of synthetic fertilisers in India, data on the relationship between food grain production and fertiliser consumption from 1960 to 2003 show that in spite of consistent increment in N-P-K fertiliser consumption, grain yield has not only practically stagnated but also showed a declining trend with fertiliser application during the later period, 1992 to 2003. Soil degradation, mainly the decline in soil organic matter both in quality and quantity, is one of the major reasons linked to stagnation and decline in yields in most intensive agriculture areas in India.

The response of additional fertiliser application to food grain production has shown a distinct declining trend in recent years: the increased use of synthetic fertilisers no longer contributes to higher soil productivity. The average crop response to fertiliser use was around 25 kg of grain per kg of fertiliser during 1960s, the said value has reduced drastically to eight kg/kg only during late 1990s. High use of chemical fertilisers is mostly associated with high level of water consumption and micro-nutrient deficiency in soil leading to decline in water table and further deterioration of the soil.

Subsidies: fertilising climate change

Manufacture and use of synthetic nitrogen fertilisers also contributes significantly to emissions of greenhouse gases, and thus climate change. The total emissions from the manufacture and use of synthetic nitrogen fertilisers represent six per cent of India's total anthropogenic emissions, comparable to sectors like cement or iron and steel industries, and to emissions from the entire road transport system. There is a significant potential to mitigate these emissions. Savings from the efficient use of nitrogen fertilisers and a shift from synthetic to ecological fertilisation could reduce total emissions from fertilisers in India to 36 Mt of CO_2-eq from the current 100 Mt of CO_2-eq, and the contribution of fertilisers to the country's emissions would drop from six to two per cent.

Who benefits: farmers, industry or petroleum companies?

Overall, from 1981 to 2008, the average share of the farmers in the synthetic fertiliser subsidy was 64 per cent, while the industry gets about 36 per cent (31 per cent domestic fertiliser industry and five per cent foreign producers/suppliers). However the share of petroleum companies, who supply the massive raw materials essential for fertiliser industry, is yet to be identified. The benefit of fertiliser subsidies also goes very disproportionately in favour of relatively richer irrigated regions than the poorer, mostly rain-fed regions.

The potential for a shift from synthetic to organic nitrogen fertilisers is real: India can save a substantial amount of taxpayers' money along the way

Studies in multiple locations have clearly shown that the deleterious effects of synthetic fertilisers on soil health can be improved by adopting ecological methods of farming and by using low-cost organic alternatives. Application of organic manure appears to be the most important option of sustainable nutrient management programmes under the prevailing Indian conditions, where low organic matter content of soils is a major threat to the maintenance of soil health. Organic matter can improve physical, chemical and biological properties of the soil, while synthetic fertilisers cannot perform any of these roles, apart form supplying a few major plant nutrients.

The amount of nitrogen that could be potentially recovered in organic residues is similar to the total amount of synthetic nitrogen applied to Indian soils every year, ~14 Mt. This highlights the potential feasibility of a complete shift from synthetic to organic nitrogen fertilisation. In addition, recent global meta-analysis have also shown that cover crops such as legumes can provide enough nitrogen to substitute the amount of synthetic nitrogen used worldwide while maintaining the same food production.

Vermicompost provides an excellent, profitable alternative for recycling organic residues in the country, and thus a substitute to synthetic nitrogen fertilisers. If India adopts a five-year plan to withdraw the synthetic fertiliser subsidy, it will be possible to save Rs. 12,000 billion as withdrawal of subsidy. Shifting 40 per cent of that savings from subsides (Rs. 4,900 billions only) to investment for vermicomposting units would make possible a shift from synthetic to organic nitrogen fertilisation.

The Government needs to:

1. Create an alternate subsidy system that promotes ecological farming and use of organic soil amendments.

2. Shift the irrational subsidy policy for synthetic fertilisers to sustainable ecological practices in agriculture.

3. Re-focus scientific research on ecological alternatives, to identify agro-ecological practices that ensure future food security under a changing climate.

Introduction

Since the introduction of the Green Revolution, synthetic fertiliser consumption has increased from a mere 70,000 tonnes in 1950-51 to a staggering 23,150,000 tonnes in the year 2008-09, a 300-fold increase! The introduction of synthetic fertilisers and fertiliser responsive varieties along with irrigation did help in a jump in production initially. But in recent decades, there has been an increasing debate on the adverse impacts that synthetic fertilisers have on both the environment and food production. Food productivity is no longer increasing and it is now affected by diminishing returns and falling dividends, especially in the agriculture intensive areas in the country.

In this report we present scientific evidence linking synthetic fertiliser overuse and imbalanced use in Indian agriculture to the current system of government subsidies on fertilisers (section I), showing how this system is leading to soil degradation and stagnant food production (section II). Synthetic fertilisers cause also further damage in the environment: in section III we show how synthetic fertilisers contribute largely to emission of greenhouse gases in India, a serious fact since climate change will greatly impact food production in the country. On the positive side, this failing system needing urgent action has alternative solutions that are available right now, feasible and real. In section IV we present a general overview on alternative solutions that can move the Indian farming towards ecological farming and food security.

1

Patterns of synthetic fertiliser subsidies and their impact on overuse and imbalance use

Trends in synthetic fertiliser use

In India, the consumption of synthetic fertilisers is very high in some regions (Punjab, Andhra Pradesh, Tamil Nadu, Haryana) while lower in others, the country average being about half of that in the synthetic intensive states (113 kg/ha vs. 210 kg/ha in Punjab, for example, see Table 1.1 & 1.2). But the variability is even more pronounced at the local level; it varies from as little as 10 kg/ha Gross Cropped Area (GCA) in most of the districts of the Northeastern states to over 500 kg/ha in Tiruchirapalli, Renga Reddy and Bangalore (Table 1.3 & 1.7). Out of 528 major districts in India, fertiliser consumption in 78 districts is over 200 kg/ha and in 15 districts, it is less than five kg/ha (Table 1.3). Six crops (rice, wheat, cotton, sugar cane, rapeseed and mustard) consume about two-thirds of the fertiliser applied. The irrigated area, which accounts for 40 per cent of the total agricultural area, receives 60 per cent of the fertiliser applied.

Table 1.1 Major fertiliser-consuming states of the country ($N+P_2O_5+K_2O$) in kg/ha of Gross Cropped Area (GCA)

States	2005-2006	2006-2007
Punjab	209	210
Andhra Pradesh	204	198
Tamil Nadu	187	191
Haryana	176	175
Uttar Pradesh	141	152
West Bengal	132	145
Bihar	118	137
Gujarat	116	127
Karnataka	119	116
India	**107**	**113**

Source: Fertiliser Statistics (Several Volumes)

Table 1. 2 State-wise fertiliser consumption (kg/ha GCA)

	Triennium Ending with			Growth rate (%)
State	1983	1994	2006	1983 to 2006
Andhra Pradesh	37	112	203	4.37
Assam	3	10	53	12.54
Bihar	22	69	120	7.34
Gujarat	40	105	113	3.21
Haryana	62	158	175	6.42
Himachal Pradesh	27	49	52	3.17
Jammu & Kashmir	33	70	78	3.41
Karnataka	34	59	116	5.25
Kerala	38	79	82	2.33
Madhya Pradesh	10	28	60	5.55
Maharashtra	24	65	96	4.92
Orissa	11	38	45	4.59
Punjab	126	174	206	2.87
Rajasthan	9	27	44	6.09
Tamil Nadu	72	126	190	3.76
Uttar Pradesh	51	70	151	4.27
West Bengal	42	94	141	6.21
North East State	6	17	26	6.40
All India	37	72	110	4.57
C.V. (%)	96	77	71	—

Data Source: Fertiliser Statistics (Several volumes)

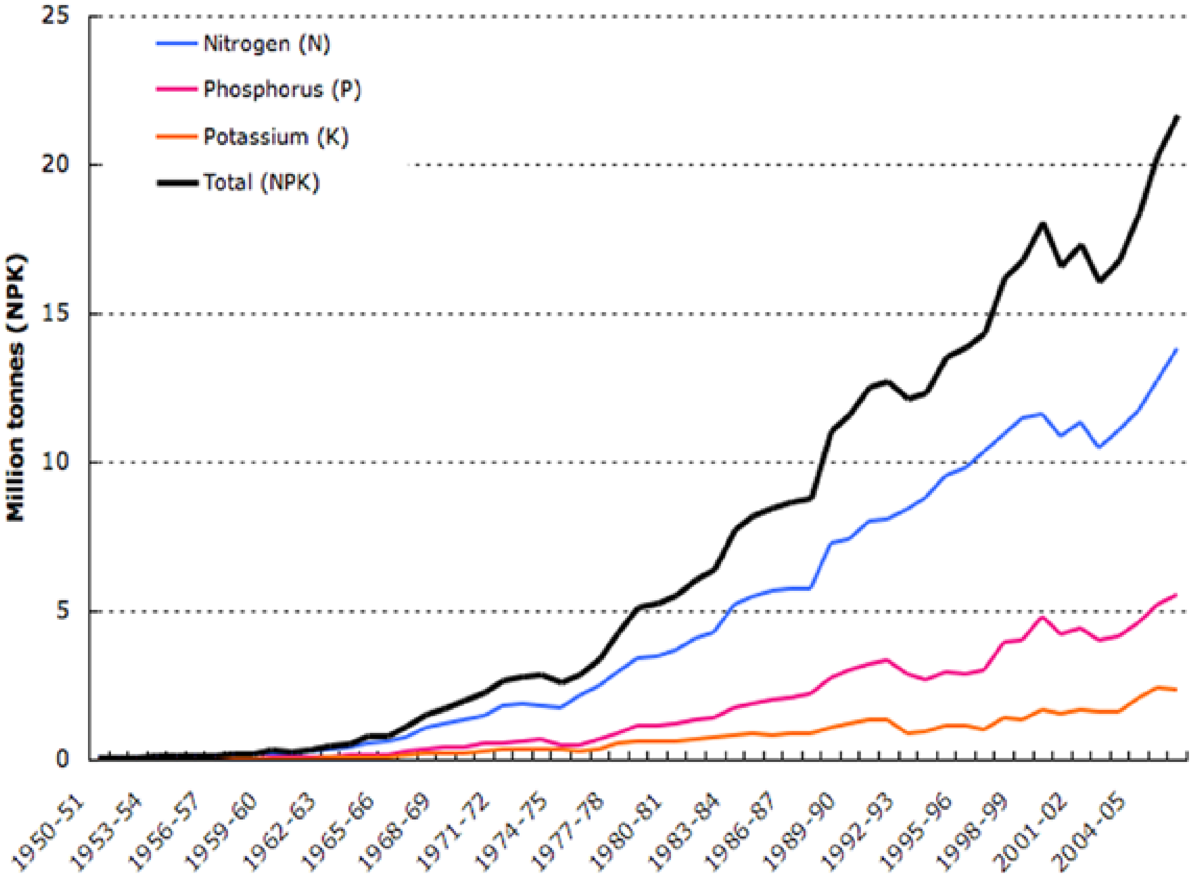

Figure 1. 1 Trends in synthetic fertiliser use in India. Data source: Fertiliser Association of India, 2008

While India consumes a wide variety of fertilisers, urea accounts for 82 per cent of the consumption of synthetic nitrogen (N) fertiliser and Di-ammonium Phosphate (DAP) for most of that of Phosphorous (P_2O_5). Other straight N fertilisers, such as Ammonium Sulphate, Calcium Ammonium Nitrate (CAN) and Ammonium Chloride account for only two per cent. The share of N through DAP and other complex fertilisers is about 16 per cent. DAP accounts for 63 per cent of total P_2O_5 consumption and other complex fertilisers for 27 per cent.

Table 1.3 Magnitude of fertiliser use in India (2006-07)

Fertiliser use (kg/ha of GCA)	No. of districts	Percent distribution
Above 200 kg/ha	78	14.8
150-200	63	11.9
100-150	105	19.9
75-100	75	14.2
50-75	74	14.0
25-50	79	15.0
10-25	31	5.9
5-10	8	1.5
Up to 5	15	2.8
Total	**528**	**100**

Source: Fertiliser Statistics (Several Volumes)

Trends and patterns of synthetic fertiliser subsidy in India

The amount of subsidy outgo on domestic and imported synthetic fertilisers in India during the last three decades has grown exponentially from a mere Rs.60 crores during 1976-77 to a whopping Rs. 40,338 crores during 2007-08. According to government sources, (Ministry of Chemicals and Fertilisers, 2008) it is expected to skyrocket to Rs.119,772 crores in 2008-09 (Fig. 1.2).

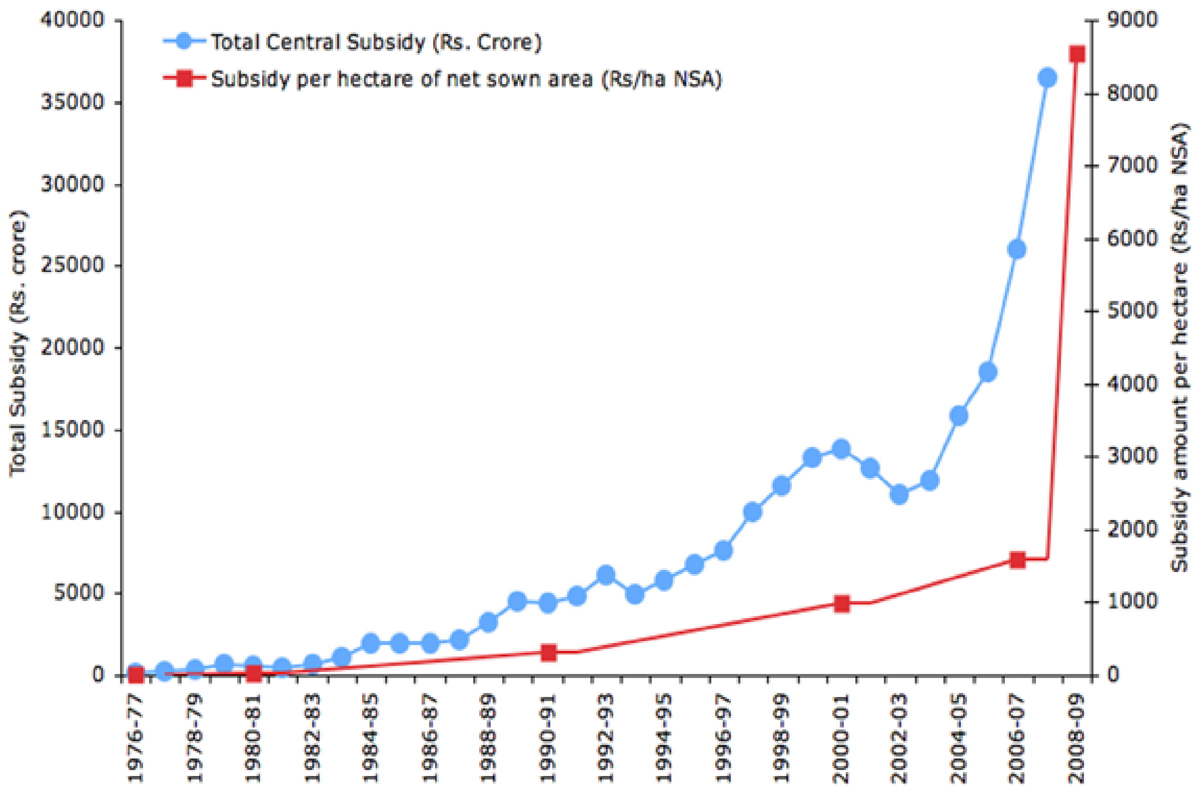

Figure 1. 2 Trend on fertiliser subsidies from the Central Government, total amount (blue) and amount per hectare of net sown area (red), from 1976 to 2008. Data source: Fertiliser Association of India, 2008.

Though a major part of the subsidy increase is on account of inflation, even in real terms subsidy on fertiliser has been increasing in leaps and bounds. The increase has resulted from both a rise in fertiliser use as well as a simultaneous increase in subsidy content per unit of fertiliser. Until the late 1990s, both total subsidy and subsidy per unit of synthetic fertiliser as well as per unit of cropped area was not too high. But in the recent years, the growth in subsidy per kilogramme of synthetic fertiliser and thus subsidy per hectare of Gross Cropped Area (GCA) and Net Sown Area (NSA) has grown exponentially (Fig 1.2 and Table 1.4).

Table 1.4 Growth in synthetic fertiliser use and magnitude of synthetic fertiliser subsidy in India

Year	1967 -77	1980-81	1990-91	2000-01	2006-07	2008-09
Gross cropped area (million hectare)	167.33	172.63	185.74	185.70	191.20	193.06
Net Sown Area (million hectare)	139.48	140.00	143.00	141.16	141.31	140.34
Total synthetic fertiliser use (million tonnes)	3.41	5.52	12.55	16.70	21.65	23.15
Total synthetic fertiliser subsidy (billion rupee)	0.60	5.05	43.89	138.00	224.52	1197.72
Subsidy per kg of NPK (Rs)	0.2	1	3	8	10	52
Subsidy per ha of GCA (Rs)	3.6	29	236	743	1174	6204
Subsidy per ha of NSA (Rs)	4.3	36	307	978	1589	8534

Source: Fertiliser Statistics (Several Volumes)

Although it is a fact that fertiliser subsidy exits because fertilisers are sold to the farmers at a price lower than its economic cost, it is not true that the benefits of the subsidy are enjoyed by farmers alone. The relative benefit-incidence of the fertiliser subsidy on the farmers, the fertiliser industry and foreign firms has been a matter of some research. However, the share of petroleum companies, who supply the massive raw materials essential for fertiliser industry, is yet to be identified. According to Gulati and Sharma (1997) and further studies at National Institute of Public Finance and Planning, New Delhi, for the period, 1981-82 to 2007-08, the average share of the farmers in the synthetic fertiliser subsidy was 64 per cent, share of the domestic fertiliser industry was 31 per cent, and the residual five per cent accruing to foreign producers/suppliers. As far as the share of domestic industries are concerned, around 75-80 per cent of total subsidies on urea are absorbed by them (Annexure IV) while the entire subsidy on potassium (K) fertilisers is absorbed by the foreign firms (Table 1.5). Table 1.5 also shows that subsidy as a percentage of real price of different types of synthetic fertilisers (based on domestic production cost and import price) ranges from 70 per cent in the case of urea to as high as 88 per cent in case of Muriate of Potash (MOP).

Table 1.5 Magnitude of subsidy on various types of synthetic fertilisers during 2008 (Rs./tonnes)

Type of Fertiliser	Domestic Production Cost	Import Price (CIF Price)	Farm Gate Price (MRP)	Average Subsidy	Subsidy (as % of cost)
Urea	13,017	31,166	4,830	11,200	69.87
DAP	58,584	58,584	9,350	49,234	84.04
MOP	Not Produced	35,563	4,455	31,108	87.47
Complex Fertilisers	43,274	No Import	6,552	36,722	84.86
Single Super Phosphate	9,277	14,919	3,400	8,134	70.52

Source: Ministry of Chemicals and Fertilisers

Further, the benefit of fertiliser subsidies also goes very disproportionately in favour of relatively richer (and irrigated) states like Punjab and Haryana than the poorer (mostly rain-fed) states like Orissa, Jharkhand, Assam and other Northeastern states. Among states, fertiliser subsidy per hectare of Net Cultivated Area (NCA) varies in the range of Rs. 393 in Rajasthan to Rs. 3,167 in Punjab. The level is close to five per cent of value of the crop output (Chand and Pandey, 2008).

Six crops viz. rice, wheat, cotton, sugar cane, rapeseed-mustard, and potato consume more than two-thirds of the fertiliser applied (FAI 2008) Similarly, the irrigated area, which accounts for 40 per cent of the total agricultural area, receives 60 per cent of the fertiliser applied thereby indicating a higher share in the fertiliser subsidy. (FAI 2008)

Imbalance and overuse of fertiliser

In the case of fertilisers, one of the critical issues related to subsidies has been the imbalance and overuse of fertilisers (N-P-K) brought about by distortions in price ratio in favour of N fertiliser. This has already caused widespread soil degradation and reduced productivity, which is becoming more acute with the passage of time (Planning Commission, 2007). A composite index of imbalance in use of N- P-K indicates that Punjab and Haryana topped the imbalance list in fertiliser use followed by Bihar, Kerala and Rajasthan (See Table 1.6). The problem is more acute at the district level (Table 1.7). It is to be noted here that a close perusal of Table 1.6 clearly shows that the overuse of synthetic fertilisers (particularly N fertilisers) is the main reason behind imbalanced use of synthetic fertilisers.

Discrepancy and overuse of fertilisers is highly problematic especially since it causes extreme levels of soil degradation and associated losses in yields. These issues are analysed in detail in section II of this report.

Table 1. 6 Imbalance in fertiliser use in various states during Triennium Ending 2006-07

States	Percent share of N, P and K in total synthetic fertiliser consumption N-P-K			Ratios of N, P and K $N: P_2O_5: K_2O$			Imbalance Index
Andhra Pradesh	61.1	26.3	13.6	4.5	2.0	1	0.03
Assam	47.1	28.5	24.4	2.1	1.0	1	0.09
Bihar	77.5	14.8	6.7	10.8	2.1	1	0.17
Gujarat	65.6	25.6	8.8	7.8	3.1	1	0.06
Haryana	79.1	18.8	2.0	47.1	12.4	1	0.18
Himachal Pradesh	64.2	19.6	16.2	4.0	1.2	1	0.08
Jammu & Kashmir	67.0	28.4	4.6	12.8	3.5	1	0.09
Karnataka	50.3	27.9	21.7	2.5	1.5	1	0.06
Kerala	42.9	20.9	36.2	1.2	0.6	1	0.16
Madhya Pradesh	63.6	31.4	5.5	11.3	6.2	1	0.09
Maharashtra	55.2	29.9	14.8	3.6	2.0	1	0.02
Orissa	62.9	21.9	15.2	4.1	1.4	1	0.05
Punjab	79.4	19.8	2.7	33.7	9.2	1	0.18
Rajasthan	77.8	20.2	1.9	51.2	19.9	1	0.15
Tamil Nadu	51.4	22.6	26.0	2.0	1.0	1	0.08
Uttar Pradesh	74.6	20.0	4.4	16.2	5.1	1	0.12
West Bengal	50.5	27.7	21.9	2.3	1.3	1	0.06
North East State	73.0	19.0	8.0	8.2	2.1	1	0.12
Others	53.4	25.7	20.8	2.7	1.3	1	0.07
All India	64.9	24.1	10.9	5.9	2.4	1	0.06

Data Source: Fertiliser Association of India 2008

Table 1.7 High fertiliser consuming districts of the country ($N+P_2O_5+K_2O$ in kg/ha) for the year 2006-07

Districts	Consumption (kg/ha)	$N : P_2O_5 : K_2O$	Imbalance Index
Tiruchirapalli (TN)	539	1.2: 0.7:1	0.26
Bangalore Urban (Kar)	508	1.8: 0.8:1	0.22
Renga Reddy (AP)	503	1.1:0.6:1	0.25
Varanasi (UP)	440	10.2: 4.1: 1	0.24
Podukkotal (TN)	401	1.9: 1.2: 1	0.15
US Nagar (Uttara)	376	10.6:2.3:1	0.16
Kamal (Haryana)	328	42.6:9.7:1	0.25
W. Godavari (AP)	316	3.8:1.8:1	0.13
Surat (Guj)	312	2.5:12:1	0.20
Nellore (TN)	309	1.8:1.2:1	0.11
Nizamabad (AP)	308	6.2:1.9:1	0.17
Meerut (UP)	306	19:5:1	0.21
Kurukshetra (Har)	292	28.4:7.1:1	0.25
Guntur (AP)	289	3.7:1.5:1	0.22
Mandya (Kar)	282	2.1:0.7:1	0.14
Krisna (AP)	277	3.7:1.7:1	0.09
Hooghly (WB)	275	1.2:1.1:1	0.15
Burdwan (WB)	272	2.2:1.4:1	0.11

Source: Fertiliser Statistics (Several Volumes)

Is price a major factor for an imbalanced use of synthetic fertilisers?

From 1980-81 to 1990-91, prices of all the N-P-K fertilisers increased almost in the same way (Annexure I). However, serious distortions were caused in the relative prices of N, P and K in 1990-91 when P and K fertilisers were decontrolled. It caused the price of P to nearly double the price of N, which was only marginally higher in the 1980s. After this gaping difference in price ratio during 1992-93, the price of P and K increased at lower rates than that of N, but the prices of N relative to P and K were far lower than those that prevailed during 1980s. Thus, 1991 was a turning point in fertiliser prices in favour of N. This is an important factor in shifting the balance of fertiliser use in favour of N and against P and K (Chand and Pandey, 2008).

Today, farmers are applying more of those fertilisers that are being subsidised by the government; the industry is also producing fertilisers, which are covered under the subsidy. The government is yet to give a serious thought to the health status of Indian soils, which are being degraded due to imbalance and overuse of fertilisers. Healthy soils need a whole range of nutrients (micro-nutrients and secondary nutrients along with nitrogen, phosphate and potash) plus proper organic matter to achieve better yield results (Tandon,1992, Nambiar,1993).

In the year 2006-07, out of a total consumption of 21.7 Mt of N-P-K nutrients, N alone comprised 13.8 Mt, which is roughly two-thirds of the total fertiliser consumption. For instance, while the recommended ratio between N, P and K is 4:2:1, the actual ratio in 2005-06 in Punjab was 20:6:1 and in Haryana 30:9:1, indicating a huge inefficiency in the use of fertilisers. It is believed that a high subsidy on N fertiliser (urea) is leading to overuse of N fertilisers and thus resulting into imbalanced use of N- P-K (Gulati, 2007). Results of several field surveys conducted by one of the Principal Investigators representing seven states across the country (viz., Haryana, Orissa, West Bengal, Andhra Pradesh, Tamil Nadu and Gujarat) particularly in irrigated rice-wheat based production systems (Ludhiana, Karnal, Kaithal, Burdwan and Hoogly); rain-fed groundnut based production systems (Anantapur and Junagarh), and in eastern coastal regions (Midnapore, Kendrapara, Khurda, Guntur, West Godavari and Salem) under two different research projects, support the hypotheses that an enormous fertiliser subsidy is said to be one of the main reasons resulting in an imbalanced and overuse (in selected regions) of synthetic fertilisers in India (See Table 1.8). In all the states, an average 84 percent of the respondents used higher doses of N to replace other fertilisers since it is relatively cheaper. When asked, 82 percent of respondents were also more willing to use higher doses of bio-fertilisers if easily available and subsidised.

Table 1.8 Farmers response towards use of fertilisers and prices

States	Districts	Number of sample respondent farmers	Do you use more urea/N-fertiliser since it is cheaper/subsidised?		Will you use more bio-fertilisers if it is subsidised?	
			Yes (%)	No(%)	Yes (%)	No (%)
Andhra Pradesh	Anantapur, Guntur and West Godavari	100	84	16	76	24
Gujarat	Junagarh	100	77	23	88	12
Punjab	Ludhiana	100	97	03	86	14
Haryana	Karnal and Kaithal	100	94	06	91	09
Orissa	Kendrapara, Khurda	100	68	32	66	34
Tamil Nadu	Salem	100	89	11	87	13
West bengal	Burdwan, Hooghly and Midnapore	100	81	19	77	23
Total	**13**	**700**	**84**	**16**	**82**	**18**

Source: Field survey (household survey; FGD & RRA) conducted by the principal investigator in two different research projects conducted during 1999-2004.

2 Impacts of Long-Term Synthetic Fertiliser Use on Food Productivity and Soil Degradation

Nearly five decades after the Green Revolution the sustainability of Indian agriculture, and thereby the country's food security, are both facing a serious challenge. Widespread yield stagnation and yield decline in the rice-wheat cropping system have been reported in recent years. Many long-term experiments conducted at several locations in India show signs of yield fatigue i.e. lack of yield growth: either stagnation or decline (Ladha et al., 2003, Singh et al., 2005, Yadav et al., 1998). Many authors have related this yield fatigue to a number of factors – the loss of soil fertility and/or problems of soil degradation linked to the overuse or inappropriate use of synthetic fertilisers being significant determinants (Dawe et al., 2003, Dwivedi et al., 2003, Ladha et al., 2003, Masto et al., 2008, Singh et al., 2005, Yadav et al., 1998). But, in a vicious circle, farmers are at the same time being compelled to apply higher fertiliser rates to obtain the same yield they achieved with lower fertiliser inputs (Singh et al., 2005).

Subsidies are often criticised given that they lead to irrational and overuse of fertilisers. Overuse of nitrogen synthetic fertilisers has been directly linked to their cheap availability under the highly subsidised system (See table 1.8). Excess use of fertilisers seems to be becoming common in the most intensive farming areas in India. For example, in some rice-wheat cropping systems in north India, researchers have shown that one-third of the farmers applied 50 per cent more fertilisers than recommended (Singh et al 2005).

In this section, we review scientific data pointing to the link between inappropriate use of synthetic fertilisers, soil infertility and the decline in food productivity.

Intensive synthetic fertiliser use and food productivity

On analysing data from several long-term experiments on intensive rice-wheat systems, it was found that there has been a significant decline or stagnation in yields, especially for rice. For example, rice yields in the highest yielding treatments in eight out of 11 long-term (over eight years) rice-wheat experiments in India and Nepal declined, and in three cases wheat yields declined (Duxbury et al., 2000).

Multiple such observations of yield fatigue have raised concerns about the long-term sustainability of the intensive rice-based cropping systems. Researchers were able to track a decline in rice yield at an average rate of 23 kg/ha each year using data from 33 long-term experiments in South Asia, most of which were conducted in India (Ladha et al. 2003) (See table 1.8). This yield decline was attributed to the loss of organic matter, the decrease of nutrient supply, and climate fluctuations. Based on a 14-year study in Punjab, it has been noted that rice yields declined even when the recommended rates of nutrients (N-P-K) is applied. This decline is attributed to the total loss of soil nitrogen and organic matter (Bhandari et al., 2002). Constant cultivation without the adequate addition of organic matter adversely affected crop yields and fertility status of soil (Saha et al., 2000).

In Punjab, the state with highest use of synthetic fertilisers in India, data on the relationship between food grain production and fertiliser consumption from 1960 to 2003 clearly shows that in spite of consistent increment in N-P-K fertiliser consumption, grain yield not only remained practically stagnant but also showed a declining trend with increasing fertiliser application during the later period 1992 to 2003 (Figure 2.1, Source: Banga, 2005).

The ratio of increase in grain production to the additional synthetic fertiliser applied is rapidly declining. Data shows that in the 1960s, the addition of one kilogramme of N-P-K fertilisers in recommended ratio corresponded with an increase in 25 kg of grain production. In the early 1990s, this yield response to fertiliser dropped to 17 kg of grain per kg of fertiliser applied, and more recently in the late 1990s, the gain plumbed to eight kg of grain per additional kg of fertiliser added (Shankaram, 1995; Aulakh and Bahl, 2001). Current data suggests that the response to fertiliser application is detrimental not only for the yield but also for soil fertility and quality (Masto et al., 2008).

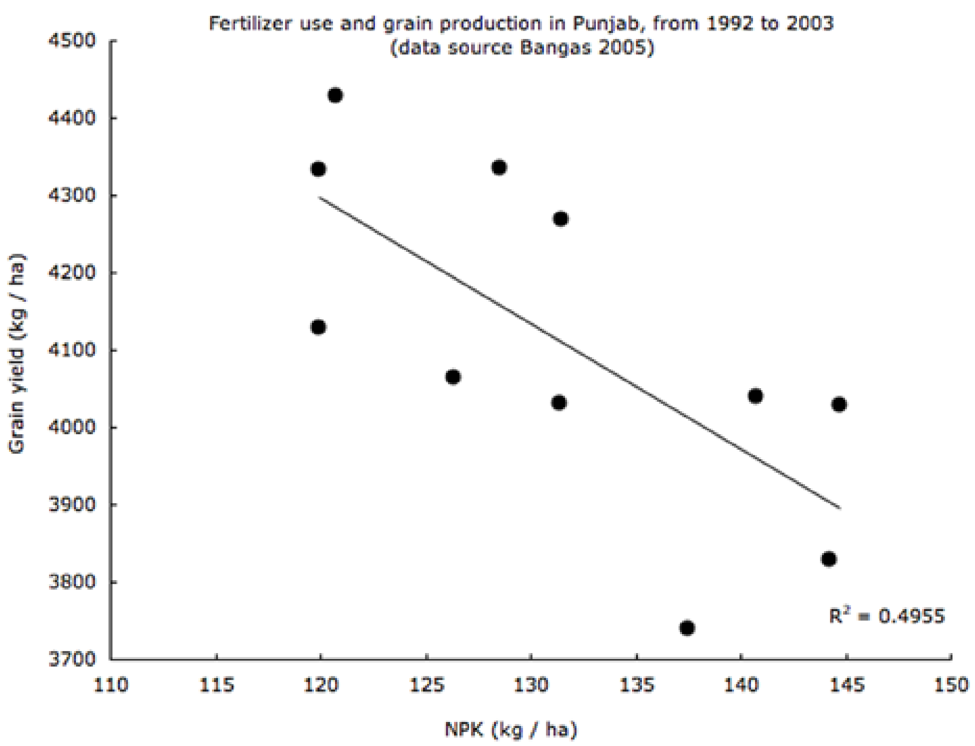

Figure 2.1 Relationship between fertiliser use (N-P-K) and grain yield between 1992-93 and 2002-03 in some localities in Punjab (Source: Banga, 2005)

Generally, an imbalance and overuse of three major nutrients (N-P-K), specially nitrogen, has not only affected the balanced availability of these three nutrients in the soils but has also resulted in large-scale deficiencies of several other micro-nutrients such as sulphur, magnesium, zinc, and boron, and degradation of the soil in different parts of the country (Tiwari, 2002; Tandon, 1992, Masto et al., 2008). As a result, decline in crop productivity and soil fertility have been reported, particularly from intensively cultivated areas (Abrol et al, 2000). Findings from long-term fertiliser experiments have clearly shown how the high productivity of an N-driven system is short-lived and counter-productive. For many of the Indian farmers, the use of N alone (only urea) is a common fertilising practice; the soil degradation associated with this N alone practice gives an early warning about the unsustainability of the current system (Masto et al., 2008).

The maximum level to which fertiliser use can rise in any crop/region is a theoretical estimate, which assumes that the total production will either diminish or remain unchanged if we increase the fertiliser application beyond that level i.e., marginal product becomes zero. An 'optimum' (economic) level of fertiliser recommendation also depends on the input-output price ratio, type of crops and their varieties, types of farming practices, production season and the environment; nature of soils and on many other agro-ecological factors. All of these factors are so heterogeneous across regions and crops in India that any meaningful generalisation is almost impossible even at the district level. In spite of all these limitations, there are studies that estimated the optimum and maximum level of fertiliser used in experimental plots in various regions of the country (Mandal, 2006). The following points emerge from the review of such studies:

1.Fertiliser use in most of the locations is at sub-optimal level under rain-fed environments but in few locations (in high fertiliser-use districts) in irrigated areas it is over used.

2.The optimal level changes significantly if the true value of fertilisers is considered i.e. hypothetical fertiliser price with no subsidy. The optima changes over time.

3.Since the cost of fertilisers is a small percentage of the total cost of production, farmers want to ensure good yields by using more than the recommended amounts of fertilisers. They do not generally know that they are in the process wasting money or even reducing yields. Thus, it appears that fertilisers are overused primarily because it may be over subsidised.

Intensive synthetic fertiliser use and soil degradation

According to a review by the Food and Agricultural Organisation (FAO) in the 1990s, about half of the cultivable soils in India were degraded, which is the highest percentage in the Asian-Pacific region (Scherr, 1999). Moreover, soil degradation in India continues to be a major problem, especially for food production and food security. Since World War II, soil degradation in Asia had led to a cumulative loss of productivity in cropland of 12.8 per cent (Oldeman, 1999). Improper management of soil fertility, including overuse and an imbalanced use of synthetic fertilisers, is one of the causes behind soil degradation in general, and is thus linked to food insecurity worldwide, and particularly in India (Scherr, 1999).

Soil degradation, mainly the decline in soil organic matter both in quality and quantity, is one of the major reasons linked to stagnation and decline in yields in the most intensive agriculture areas in India (Dawe et al., 2000; Yadav et al., 2000; Ladha et al., 2003). The decline in soil organic matter is related to the improper use of synthetic fertilisers and lack of organic fertilisation (e.g. addition of fertilisers rich in organic matter, like compost, manure or green manure), practices that are now widespread in the most intensive agriculture areas in India (Masto et al., 2008, Singh et al., 2005).

An emerging concern in rice-wheat systems is the reduction in soil organic matter content and the associated reduction in nutrient supplying capacity. Nambiar (1995) reported soil organic matter declines in soils not receiving farmyard manure in some long-term experiments (LTEs) in India, and that applications of manure were effective in building up soil organic matter and boosting crop yields. In the present rice-based cropping systems, crop residues are either burnt or removed from the field for stock feed and bedding, roofing and fencing. The traditional practice in many places of the Indo Gangetic Plains of burning rice straw after harvest is causing large losses of major nutrients and micronutrients (Muhammed, 2007).

Another component of soil degradation impacting Indian agriculture productivity is a negative nutrient balance, both for macro and micro-nutrients. In general, soil nutrient balances in the region are negative, due to inappropriate fertiliser applications (Yadav et al., 1998; Regmi et al., 2002; Ladha et al., 2003). Integrated nutrient management, including application of organic amendments is a practice to improve the nitrogen status of soils (Dwivedi et al., 2003, Masto et al., 2008, Yadav et al., 2000).

The common practice of applying mostly nitrogen fertilisers (usually only urea) that is influenced by the government's subsidy system on nitrogen is not only causing nutrient imbalances, but it is also negatively affecting the physical and biological properties of the soils. For example, indicators of good soil fertility like microbial biomass, enzymatic activity and water-holding capacity are all drastically reduced under common nitrogen fertiliser practices (Masto et al., 2008).

Another common detrimental effect of the excess use of nitrogen fertiliser on soil health is acidification, and the impact it has on soil living organisms, crucial also for natural nutrient cycling (Darilek et al., 2009, Kibblewhite et al., 2008).

Many Indian scientists are calling for a revision of the current unsustainable farming practices, that provoke soil degradation and are compromising the future of the country's food security (Eyhorn, 2007, Gupta and Seth, 2007, Mandal et al., 2007, Masto et al., 2008, Prasad, 2006, Ranganathan et al., 2008).

3

Greenhouse gas emissions and mitigation potential from fertiliser manufacture and application in India

In addition to economic losses that arise from high subsidies and lower outputs, there are extremely tall environmental costs, which are a result of both the manufacture and use of synthetic nitrogen (N) fertilisers. Nitrogen fertiliser manufacture and application to the soil contribute significantly to greenhouse gases (GHG) emissions and thus, climate change. India consumes ~14 Mt of synthetic N every year, of which about 80 per cent is produced within the country, making it the second largest consumer and producer of synthetic N fertiliser in the world, after China (Figure 3.1).

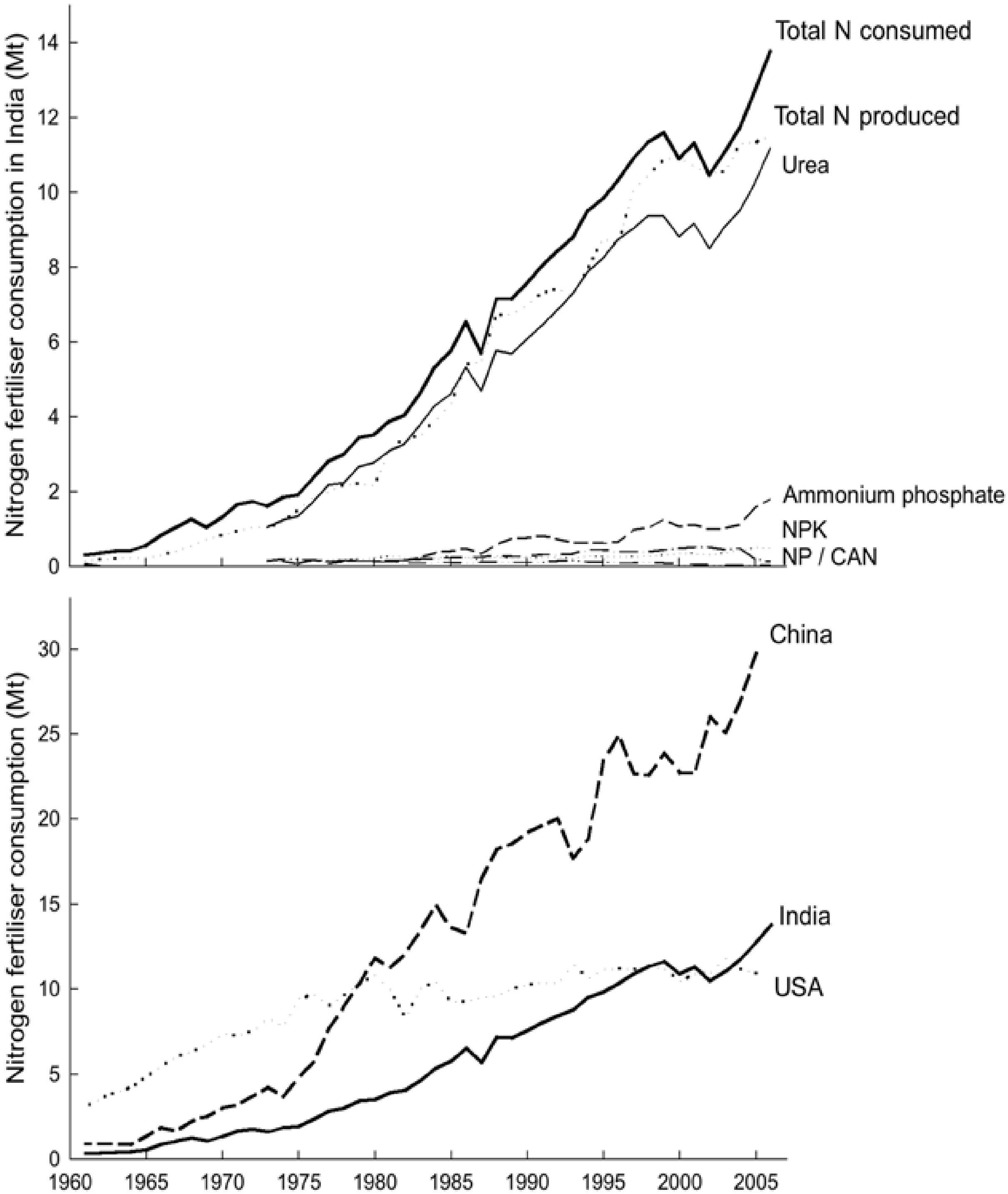

Figure 3.1 Consumption of N fertilisers in India from 1960 to 2006 (top) and consumption of total nitrogen in China, India, and USA (bottom). Sources: Fertiliser Association of India 2007 and International Fertiliser Industry Association 2008.

Currently, close to 100 Mt of synthetic N fertiliser are consumed globally every year, a 10-fold increase since the 1960s. However, since much of this N is used inefficiently, significant amounts escape into the air, or seep into the soil and underground water, which in turn result in a host of environmental and human health problems, from climate change and dead zones in the oceans to cancer and reproductive risks (Galloway et al., 2008), making it essential to estimate the mitigation potential of these emissions employing practices that work toward a sustainable farming system.

India is the second largest producer and consumer of N fertiliser in the world with close to a 15 per cent share of the global total (International Fertiliser Industry Association (IFA), 2008). The fact that N fertilisers attracts all Government subsidies on plant nutrients, has provoked a large increase in national N fertiliser – production and consumption, and the creation of many industrial fertiliser plants in the last few decades alone (Fertiliser Association of India (FAI) 2007). Between 2002 and 2006 alone, for instance, consumption rose by over 32 per cent, and in order to meet this growing demand, India had to import about 20 per cent of its N fertilisers (FAI 2007). This is despite the fact that production itself has grown at an average rate of six per cent annually since 1981, slowing down only slightly in the last years, in part limited by fossil fuel availability and the cost of energy.

An estimate of emissions from the manufacture of synthetic N fertilisers

Manufacture of synthetic nitrogen fertiliser is a very energy intensive process, and currently requires large amounts of fossil fuel energy. Natural gas is the main fuel and feedstock, which accounts for 62 per cent of the energy used in synthetic N fertiliser production. Less efficient and more polluting fuels such as naphtha and fuel oil also represent a high share, 15 and 9 per cent respectively, of the energy used in fertiliser manufacture (values as of 2006/07, FAI 2007).

Of the various forms in which synthetic N fertilisers are available, urea accounts for a chunk of the total N fertiliser produced and consumed (81 per cent in 2006). The synthesis of urea is based on the combination of ammonia and CO_2 and its emissions are dominated by CO_2. While other synthetic N fertilisers comprise a smaller percentage of the fertiliser market, they make notable emissions to the atmosphere both during production and consumption. We calculated emissions from the manufacture of synthetic N fertiliser following the Intergovernmental Panel on Climate Change (IPCC) methodology (see details in Tirado et al. in press).

An estimate of emissions from the application of synthetic N fertilisers

In addition to emissions from manufacture, N fertilisers when applied to farm soils result in emissions of N_2O. The concern over N_2O emissions arises from its long atmospheric life (166 ± 16 years) and its higher global warming potential (296 times that of CO_2) (IPCC 2007).

The amount of N_2O emitted from N fertilisers in soils depends largely on the amount of fertiliser applied, and to a lesser extent on temperatures, soil or crop type (Dobbie et al., 1999; Dobbie and Smith, 2003). Despite the number of variables, the IPCC recommends the use of a default emission factor – 1.25 kg of N_2O emitted per 100 kg of N applied to soils, to calculate the direct emissions from N inputs in managed agricultural soils of (IPCC tier 1 methodology, IPCC 2007). Going by this, and also with the lower emission factor recommended for India – 0.70 kg N_2O per 100 kg N (Garg et al. 2006 based on Pathak et al. 2004, 2002) and the higher one modeled by Crutzen – 4.00 kg N_2O per 100 kg N (Crutzen et al., 2008), we calculated emissions from the application of synthetic nitrogen fertiliser following the IPCC methodology (see details in Tirado et al. in press).

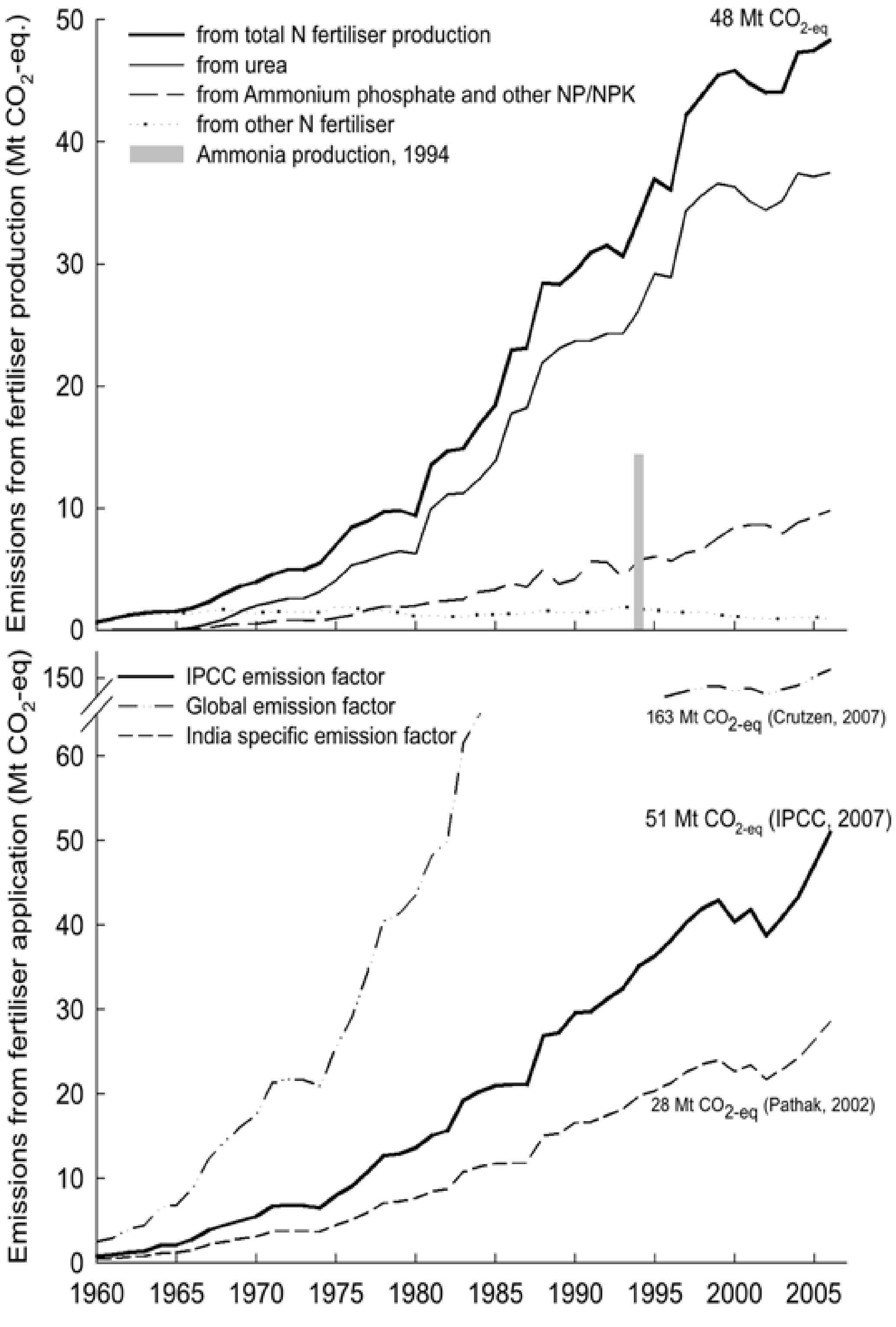

Figure 3.2 Greenhouse gas emissions from the manufacture of nationally produced synthetic N fertilisers (top) and from synthetic N application to soils (bottom) in India from 1960 to 2006. Total values given are for year 2006. Top: the grey bar indicates emissions from the manufacture of ammonia sector in 1994, the most recent data available from the official GHG inventory in India in 1994. Bottom: emissions calculated with three emissions factors: IPCC (1.25 kg. N_2O/ 100 kg. N), Indian specific (0.70 kg. N_2O/ 100 kg. N), global top-down model emission factor (4.00 kg. N_2O/ 100 kg. N),

Results

Going by conservative estimates, greenhouse gas emissions (GHGs) from synthetic N fertiliser for India reached ~100 Mt of CO_2-eq. in 2006-07 (Figure 2). Together, both the manufacture and application of synthetic N are responsible for six per cent of India's total greenhouse gas emissions, comparable to sectors like cement or iron and steel industries, and to emissions from the entire road transport system (Figure 3.3).

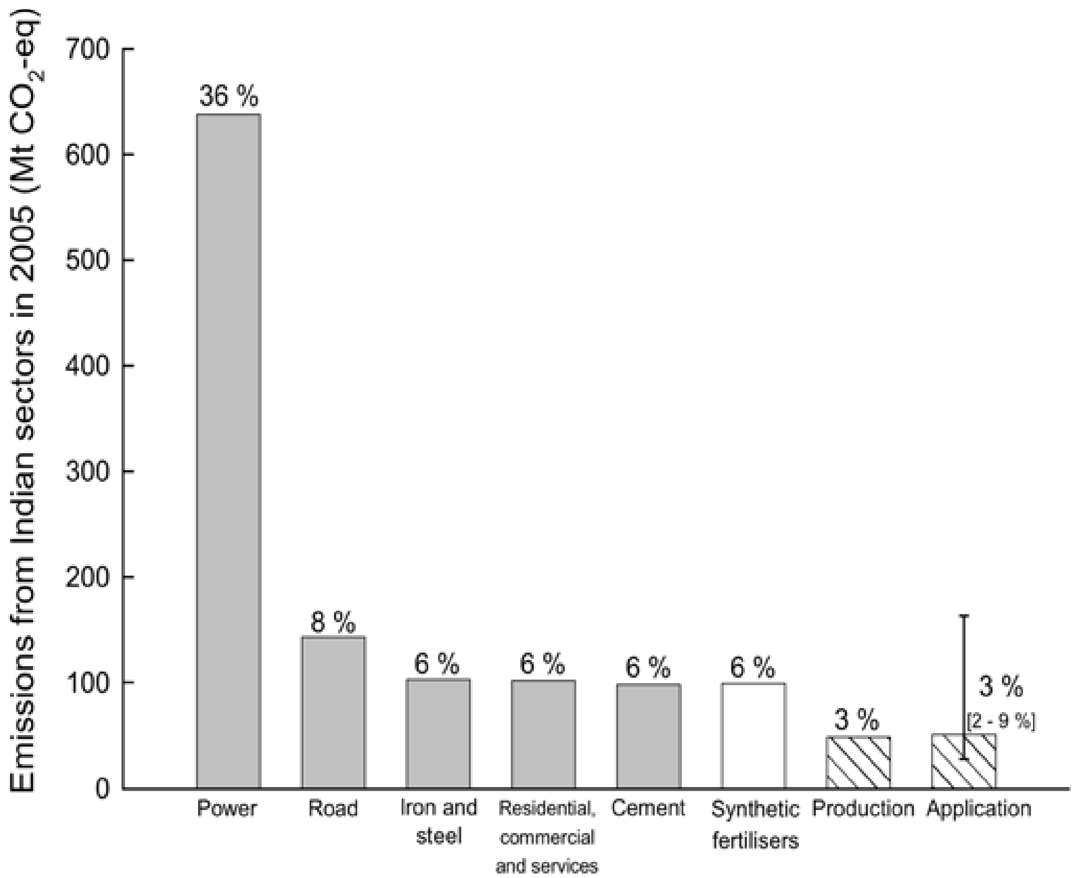

Figure 3.3 Emissions from different sectors in India in year 2005 (grey bars, data from Garg et al. 2006) and from calculations in this study (white and hashed bars). Percentages show the contribution of each sector to the country's global GHG emissions in 2005, which totalled 1751 million tonnes of CO_2-eq (Garg et al. 2006).

Mitigation measures

By increasing the efficient use of N and shifting from synthetic to ecological fertilisation, there is a great potential to mitigate India's emissions from 100 Mt of CO_2-eq to 36 Mt of CO_2-eq., and thereby the contribution of fertilisers to the country's emissions would drop from 6 to 2 per cent.

Ecological fertilisation Nitrogen-fixing legumes used as green manure can provide an alternative to all the synthetic fertiliser currently in use worldwide, without compromising food production (Badgley et al., 2007). Additionally, recycled organic residues, like manure or compost, prove to be good substitutes to synthetic N. Doing away with the production itself, which accounts for high carbon emissions (48 Mt of CO_2-eq. in 2006/07), we can halve the emissions to ~50 Mt of CO_2-eq., and the contribution of fertilisers to the country's emissions would drop from 6 to 3 per cent (Figure 4).

Efficient use of N By using N appropriately i.e. keeping in mind optimum weather conditions, proximity to crop growth etc, we will not only reduce the amount of N required but also thereby the loss of N to air, soil and water from the current 60 per cent (possibly as high as 80 per cent) to an average of 30 per cent as in much of Europe and North America (Ju et al., 2009). With reductions of about 30 per cent emissions, the contribution of fertilisers to the country's emissions would drop from 6 to 4 per cent.

Total emissions, could potentially be reduced to 37 per cent and save 66 Mt of CO_2-eq per year (Figure 3.4) from the efficient use and ecological fertilisation.

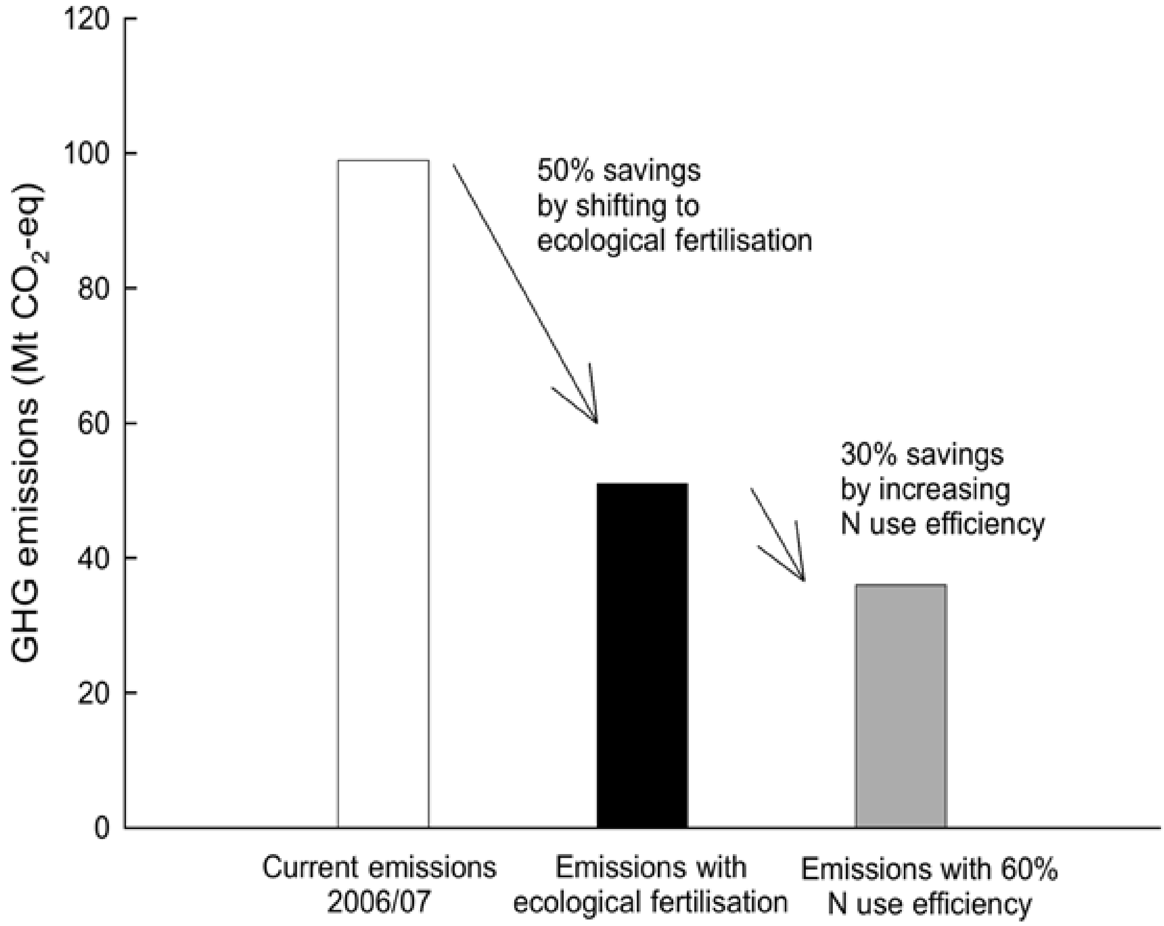

Figure 3.4 Potential mitigation potential (Mt CO_2-eq yr-1) for emissions from N fertiliser production and application in India, relative to current emissions in 2006/07, from a shift to ecological fertilisation and an increase in N use efficiency from 30 to 60 per cent.

4

Solutions to the soil degradation and stagnation of food productivity

Results of long-term fertilisation trials summarised in the section II clearly indicate that increasing food production by continuing to rely on synthetic nitrogen fertilisers is not a sustainable option.

In addition to widespread environmental damage, studies carried out under different cropping systems have categorically shown that stretching of synthetic fertiliser application to 150 per cent of recommended rate does not result in significant increments in crop yields (Mandal 2006).

More importantly, most of those long-term experiments in India also show what is one of crucial elements as a solution to these problems: an ecological fertilisation system based on practices relying on organic sources (manure, compost, legumes, etc.). Adding organic matter, commonly in the form of farm-yard manure, is very effective in improving soil quality and yields (Dwivedi et al., 2003, Mandal et al., 2006, Mandal et al., 2007, Masto et al., 2008, Singh et al., 2005, Yadav et al., 2000a, Yadav et al., 2000b). Fertilising with organic matter improves yields, while overuse of synthetic fertilisers is often detrimental (See an example in Figure 4.1., with data from Singh et al. 2004).

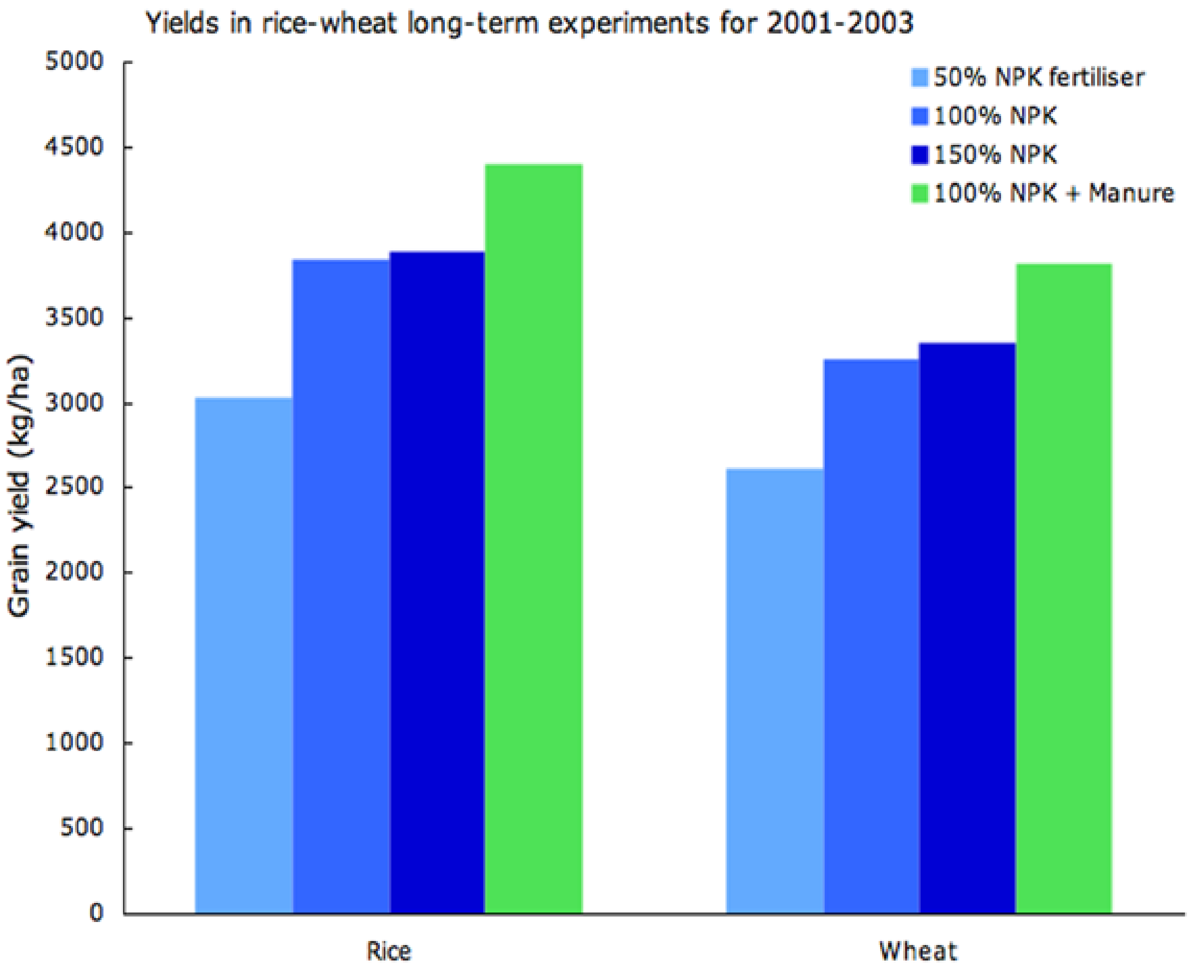

Figure 4.1 Yields of rice and wheat in rice-wheat cropping systems under long-term experiments for 2001-2003, under different amounts of synthetic fertilisers (N-P-K) and when adding farm-yard manure (Singh et al, 2004)

Although most long-term agronomic experiments in India show the benefits of adding farm-yard manure to synthetic fertilised soils, they have failed to explore the benefits of a shift from synthetic inputs to organic inputs for nitrogen fertilisation. Many experiments worldwide have shown that reliance on agro-ecological fertilisation with organic matter (e.g. manure, compost) or cover crops (e.g. legumes) helps improve soil quality and reduce dependence on synthetic fertilisers, while maintaining or even increasing food production. For example, in a 21-year-long study on European farms, soils that were fertilised organically showed better soil stability, enhanced soil fertility and higher biodiversity, including activity of microbes and earthworms, than soils fertilised synthetically (Mäder et al., 2002). Another recent meta-analysis of data from 77 published studies suggests that nitrogen-fixing legumes used as green manure can provide enough biologically fixed nitrogen to replace the entire amount of synthetic nitrogen fertiliser currently in use, without losses in food production (Badgley et al., 2007). The long-term sustainability of the Indian food production system needs the inclusion of the potential reliance on organic inputs for fertilisation into ongoing long-term research programmes in the country.

Strong scientific evidence from Indian studies presented in this report clearly reflects that ecological fertilisation based on organic material is crucial for soil health and future food production. But further analysis, including experiments that shift away from synthetic fertilisation are badly needed to establish the environmental, economic and social feasibility of organic fertilisation, and to determine, which are the specific ecological fertilisation practices that will work best in the Indian scenario. Besides the critical positive effect ecological fertilisation has on soil health and food security, additional potential benefits are multiple and worth analysing: Economic savings for farmers, reduce pollution on unused organic waste (e.g. livestock manure), and mitigation of climate change gases, both through savings in synthetic fertiliser manufacture and reduced emissions from fertilised soils (discussed in the previous chapter) (Bellarby et al., 2008, Byerlee and Murgai, 2005, Naylor et al., 2005, Pan et al., 2009).

However, in spite of relative lack of research focus on ecological fertilisation, many studies in India have started to show examples of the benefits of focusing on ecological fertilisation. For instance, recycling of crop residues, which are otherwise removed or burned at present, can improve the soil environment into a sustainable production system (Narang and Virmani, 2001; Samra et al., 2003). Crop residues, when incorporated, become an important source of carbon and nutrients (including micro-nutrients) to soil, enhancing microbial activity and soil aggregation (Verma and Bhagat, 1992; Yadvinder et al., 2000).

In another example, including legume crops for nitrogen fertilisation, and thus diversifying the rice-wheat rotation, resulted in higher nutrient use efficiency, lower soil compactation and higher organic carbon in soils while sustaining wheat productivity and restoring soil health (Dwivedi et al., 2003, Singh et al., 2005).

The carbon sequestration in farm soils with these practices also largely benefits the long-term mitigation of climate change gases from the agriculture sector (Bellarby et al., 2008, Lal, 2004, Lal, 2008).

Benefits of organic fertilisers on soil health in Indian farms

Results from the 33-year-old long-term fertiliser trial at the Central Research Institute for Jute and Allied Fabrics (Indian Council of Agricultural Research) in rice-wheat-jute system illustrate how the impacts of lack of organic fertilisation on soil health are evident, especially on soil compactation and losses of organic content and nitrogen (Table 4.1, Ghoshal, 2004). These studies, in other locations too, have clearly shown that the deleterious effects of synthetic fertilisers on soil health can be overcome substantially through use of organic materials. This is primarily due to the fact that, apart from supplying some major plant nutrients, the synthetic fertilisers have practically no role in sustaining various soil health attributes, and can have negative effects. On the other hand, most of such soil qualities can be improved substantially through the use of organic materials.

Table 4.1 Effect of long-term application of synthetic fertilisers and organic manure on physico-chemical properties of soils in India. (Ghoshal, 2004)

Fertiliser treatment	pH	Bulk density (mg m^{-3})	Organic carbon (%)	Total org. carbon (%)	Total N (%)
Control, no fertiliser	8.37	1.19	0.69	2.31	0.087
N synthetic fertiliser (r.d.)	8.33	1.21	0.69	2.76	0.87
NP synthetic fertiliser (r.d.)	8.13	1.22	0.75	2.77	0.105
NPK synthetic fertiliser (r.d.)	8.13	1.24	0..71	2.79	0.094
NPK synthetic fertiliser (r.d.) plus manure (10t/ha)	8.07	1.18	0.89	2.90	0.102

Organic matter supplies soil with essential properties of a healthy and productive soil, including its physical (e.g. compactation, water holding capacity), synthetic (e.g. pH, nutrient availability) and biological (e.g. microbial diversity, nutrient cycling) properties. On the contrary, synthetic fertilisers cannot perform any of these beneficial roles for soil quality, apart from supplying the major plant nutrients. Sustaining the soil health through sole dependence on synthetic fertilisers cannot, therefore, be considered as a tangible proposition for future food production and food security. It is under this perspective that a question may be raised about whether the enormous amount of subsidy being given on synthetic fertilisers for increasing the uses of such plant nutrients are ethical or the funds could have been spent in better way by encouraging the use of various organic inputs on a large scale.

Economic alternatives to subsidies on synthetic nitrogen fertilisers

Considering the huge magnitude of the hidden cost (economic, environmental and social) associated with synthetic fertiliser application in the country, as has been discussed earlier, it is quite clear that synthetic fertiliser driven agriculture system is not sustainable. But while considering alternatives, attention also needs to be paid on the fact that with the expected population of 1,400 million by the year 2025, India will have to produce about 300 Mt of food grain from gradually shrinking land resources. Hence, technologies adopted need to enhance sustainability while maintaining productivity in ways that protect the natural resource base and ecological provisioning of agricultural systems. Policies are needed that promote sustainable agricultural practices that stimulate more technology innovation, such as agro-ecological approaches and organic farming to alleviate poverty and improve food security, (IAASTD, 2009 Global Summary for decision makers).

A plethora of alternative agro-ecological practices are available. Systematic research on the best nutrient management practices applicable to Indian farming is needed for reducing over-dependence on synthetic fertilisers and ensuring future food security. As a preliminary example, we discuss in this section, the feasibility of shifting from synthetic to bio-fertilisers as an alternative for soil health and food security.

Field trials carried out by the National Centre of Organic Farming have shown that using bio-fertilisers instead of synthetics in rice, wheat and maize cultivation, yield increases of approximately 10 per cent can be obtained (Table 4.2). Apart from increasing the crop yield, bio-fertilisers can reduce the dependence on synthetic fertilisers, thereby, making a huge savings in fertiliser subsidy as well as improving the soil health and reducing environmental damage of synthetic fertilisers.

Table 4.2 Analytical summaries of field data on the effects of bio-fertilisers on field crops.

Crop	No. of trials	Mean Yield (tonnes/ha)		Additional Yield (tonnes/hectare)
		Synthetic Fertiliser	Bio fertiliser	
Rice	238	4.24	4.72	0.47
Wheat	304	3.96	4.30	0.34
Maize	19	2.15	2.34	0.19

Source: Motsara & Bisoyi, 2001

A recent study on organic farming in seven districts of Meghalaya (Mohanty, 2008) reveals that organic farming in spices (turmeric and ginger) and fruit crops (pineapple, cashew and mandarin) are more profitable (between eight to 11 per cent) as well as productive (between 0.7 to 3.6 per cent) than farming with synthetic fertilisers, both in the short as well as in the long run.

Another study on organic sugarcane farming in Maharashtra (Table 4.3) reveals that organic cultivation of sugarcane is labour intensive, water saving and more economical than farming with synthetic fertilisers. The study also finds that indiscriminate use of synthetic fertilisers and pesticides are destroying the vital soil microorganisms and increasing micronutrient deficiencies.

Table 4.3 Comparative advantages of organic sugarcane cultivation in Maharashtra

Particulars	Organic Sugarcane	Synthetic sugarcane	Percent advantage in organic
Human labour employment (days/ha)	251	215	17
No. of irrigation required	21	26	-18
Cost of Production (Rs/tonne)	383	417	-8
Gross profit (Rs/ha)	79694	68924	16
Water productivity	4.54	4.01	13

Source: Kshirsagar, 2008

If we analyse the cost of synthetic fertilisers vis-à-vis organic sources of N-P-K, it can be seen that synthetic fertilisers are no longer economic, as their real cost (Rs. 64.54/kg.) is now higher than organic sources of N-P-K (Rs. 58.25/kg.) (Table 4.4). Therefore, meeting the N-P-K requirement through organic sources will not only reduce the fiscal burden on subsidy but also that will generate huge employment opportunities in rural areas. Such a move will also help improving soil health.

Table 4.4 Comparative costs: synthetic fertiliser vs organic fertiliser (based on N-P-K content)

Items	2006-07	2007-08	2008-09
Total synthetic fertiliser use (Mt)	21.65	22.25	23.15
Total synthetic fertiliser subsidy (Rs Billion)	259.52	403.38	1197.72
Subsidy per kg of NPK (Rs/kg)	11.99	18.13	51.74
MRP of synthetic fertiliser per kg. of NPK (Rs./kg.)*	12.75	12.89	12.80
Economic cost of synthetic fertiliser per kg of NPK (Rs/kg)	24.74	31.02	64.54
Cost of organic N-P-K through vermicomposting (Rs./kg.)**		**58.25**	

* Adjusted for N, P_2O_5 and K_2O content in Urea; DAP; MOP, SSP and NPK fertilisers and their use
** Based on recurring costs for vermicomposting
Data source: fertiliser statistics, several volumes

Although the benefits of applying organic matter to soils seems clear, there are concerns about the large-scale availability of traditional organic manures, since in most of the Asian countries there are other uses of organic materials (Gupta et al., 1998). Under this context, attention is now being paid to increase the utilisation of different kinds of organic waste of varying natures.

Tandon (1995) emphasised the importance of re-using organic waste in agriculture in establishing the natural link not only between land, plants, animals and humans but also with the activity of those industries dependent on agriculture for raw materials. Large quantities of organic wastes are produced from different agro-industries of the country, which may be utilised effectively for sustaining food, fuel and fibre production. There is an enormous scope of providing large amounts of plant nutrition from different kinds of organic wastes, which are being generated in huge quantities in a country like India with a population of over a billion people.

The practice of recycling organic wastes into compost deserves attention for sustaining productivity of agricultural soils of the country as well as for curtailing the indiscriminate uses of synthetic fertilisers.

The availability of major nutrients from different kinds of organic wastes generated in the country every year has recently been calculated (Bisoyi, 2003). The amount of nitrogen that could be potentially recovered in organic residues is similar to the total amount of synthetic nitrogen applied to Indian soils every year, 14 Mt (Table 4.5). This highlights the potential feasibility of a complete shift from synthetic to organic nitrogen fertilisation. In addition, recent global meta-analysis has also shown that cover crops such as legumes can provide enough nitrogen to substitute the amount of synthetic nitrogen used worldwide while maintaining the same food production (Badgley et al., 2007). It is clear that the potential for a shift from synthetic to organic nitrogen fertilisers is real, a concrete analysis of its applicability to the Indian scenario is needed.

Table 4.5 Potential sources of nitrogen from different organic wastes in India

Source of Organic Residues	Million tonnes of organic nitrogen
Cattle	2.997
Buffalo	0.745
Goat and Sheep	0.214
Pig	0.044
Poultry	0.027
Other livestock	0.079
Human beings	3.228
Farm crop wastes	5.600
Forest litter	0.075
Water hyacinth compost	0.060
Rural compost	1.130
Urban compost	0.024
Sewage sludge	0.012
Total	**14.215**

Source: Bisoyi, 2003

Vermicompost as an example of economic profitability of organic fertilisation

In recent years, vermicomposting has emerged as a simple and easily adoptable biotechnology for decomposing a wide range of organic waste into good quality compost in a short period of time. Vermicompost prepared with the help of some surface dwelling earthworms are nutritionally rich and also contain several antibiotics and beneficial micro-organisms for improving the quality of the soil and hence, the crops. Studies carried out on effects of vermicompost on performances of agriculture crops revealed the use of vermicompost to be highly efficient in reducing the dependence on fossil fuel-based plant nutrition through synthetic fertilisers.

Further, our own experiences show that investment in vermicomposting is not only financially viable but can also generate employment opportunities in rural areas on a large scale. Table 4.6 shows that the return to investment i.e. rate of capital turnover, in a small scale vermicompost unit (capacity 100 tonnes/year) is as high as 27.89 per cent/annum even the unit lasts for just 10 years. In addition, incorporation of these organic materials will help rejuvenate the soil health, encouraging the sustainability in terms of soil productivity.

Table 4.6 Economics of small scale vermicompost production

Function	Quantity	Denomination
1. Capacity	100	persons
2. Employment capacity	5 to 10	rupee
3. Cost of Production	2,44,750	rupee
a) Non recurring expenses	70,000	rupee
Cost of chamber with shed	50,000	rupee
Cost of worms	15,000	rupee
Cost of sieves etc	5,000	rupee
b) Recurring expenses	1,74,750	rupee/year
Wastes (20 tonnes)	20,000	rupee/year
11 Packaging and marketing expenses	4,000	rupee/year
Labour cost (5 permanent labour @ Rs 70 daily)	1,27,750	rupee/year
Labour cost (5 part-time labour for 60 days/year)	21,000	rupee/year
Annual maintenance/repair cost	2,000	rupee/year
4. Returns from sale of Vermicompost	2,50,000	rupee/year
5. Net Income		
1st year (cost include investment on infrastructure)	5,250	rupee/year
2nd year onwards	75,250	rupee/year
Average for 10 years	68,250	rupee/year
6. rate of Capital turnover (average for 10 years)	27.89	percent/year

Data source: Soil Testing Laboratory, Institute of Agriculture, Visva-Bharati.

A plan of gradually phasing out the use of synthetic fertilisers through vermicomposting has been proposed. (See table-4.7)

Table 4.7 Alternative strategies for phasing out synthetic fertiliser subsidies with vermicomposting

	1st year	2nd year	3rd year	4th year	5th year
Replacement of synthetic fertiliser (Mt of NPK)	3	6	9	15	21
Requirement of vermicompost (Mt)	100	200	300	500	700
Reduction in subsidy (billion rupees)	1714	3429	5243	8572	12000
Investment (billion rupees) towards bank loan for Vermicompost (Rs 70,000 per unit of 100 ty)	700	1400	2100	3500	4900

As per the Fertiliser Control Order of Government of India, total $N+P_2O_5+K_2O$ content of vermicompost should be at least 30 kg. per tonne. From a 100 tonne-capacity vermicomposting unit, therefore, 3000 kg. or three tonnes of $N+P_2O_5+K_2O$ may be produced per annum. A generalised economics of vermicompost production on such small-scale units has been shown in table 4.7.

Table 4.7 also shows that if we adopt a five-year-plan to withdraw the synthetic fertiliser subsidy, then it is possible to save Rs. 12,000 billion as withdrawal of subsidy. And with 40 per cent of that saving (Rs. 4,900 billions only) all the investment for vermicomposting units can be financed. Table 4.6 clearly indicates that such investments are highly productive with an annual rate of capital turnover as high as 14.92 per cent. Establishment of large numbers of such village-based small-scale units will not only help recycle various kinds of organic wastes for providing good amounts of plant nutrients but will also generate huge rural employment opportunities.

Conclusion:

Findings of this study clearly indicate that the present model of synthetic fertiliser subsidy is irrational and unsustainable. The study also points to the fact that a shift to agro-ecological modes of farming is possible and this shift is critical to ensure food security in the coming days. Hence,

1. The Government needs to look into an alternate subsidy system that promotes ecological farming and use of organic soil amendments.

2. The Government needs to shift the irrational subsidy policy for synthetic fertilisers to sustainable ecological practices in agriculture.

3. Scientific research needs to re-focus on ecological alternatives, to identify agro-ecological practices that ensure future food security under a changing climate.

5

annexures

Annexure- I Maximum retail prices of fertilisers in terms of nutrients (50 kg pack) exclusive of central VAT,/ state sales tax and local taxes

Year	Urea (46% N)	Single Super Phosphate (16% P2O5)	Muriate of Potash (60% K2O)
1980-81	4.35	5.27	1.83
1981-82	5.11	5.85	2.17
1982-83	5.11	5.85	2.17
1983-84	4.67	5.31	2.00
1984-85	4.67	5.31	2.00
1985-86	5.11	5.94	2.17
1986-87	5.11	5.94	2.17
1987-88	5.11	5.94	2.17
1988-89	5.11	5.94	2.17
1989-90	5.11	5.94	2.17
1990-91	5.11	5.94	2.17
1991-92	6.91	8.07	2.93
1992-93	6.00	16.25	7.50
1993-94	6.00	14.25	6.34
1994-95	6.81	14.13	6.26
1995-96	7.22	16.60	7.15
1996-97	7.46	17.36	6.73
1997-98	7.96	17.19	6.17
1998-99	8.33	17.19	6.17
1999-00	9.35	17.19	6.63
2000-01	10.00	18.75	7.09
2001-02	10.50	18.75	7.43
2002-03	10.76	19.06	7.59
2003-04	10.50	20.09	7.43
2004-05	10.50	19.81	7.43
2005-06	10.50	21.56	7.43
2006-07	10.50	21.81	7.43
Annual growth rate %	3.94	6.95	6.97

Source: Chand and Pandey, 2008 & Fertiliser Statistics, The Fertiliser Association of India, New Delhi, various issues.

Annexure II India's fertiliser imports between 1990-91 and 2007-08 (Million Tonnes)

Year	Urea	DAP	MoP
1990-91	Nil	2.155	2.120
1991-92	0.319	2.077	2.040
1992-93	1.857	1.533	1.761
1993-94	2.840	1.569	1.428
1994-95	2.884	0.792	2.120
1995-96	3.782	1.476	2.356
1996-97	2.328	0.475	1.101
1997-98	2.389	1.536	2.380
1998-99	0.556	2.091	2.580
1999-00	0.533	3.268	2.946
2000-01	Nil	0.861	2.646
2001-02	0.220	0.933	2.810
2002-03	0.119	0.383	2.603
2003-04	0.143	0.734	2.579
2004-05	0.641	0.644	3.310
2005-06	2.057	2.438	4.578
2006-07	4.719	2.875	3.448
2007-08	6.928	2.724	4.421

Source: Department of Fertilisers, Ministry of Chemicals & Fertilisers, G.O.I., New Delhi

Annexure III Domestic production and import of fertiliser (000 tons)

Year	N		P		K	NPK		Import share (%) in total consumption
	Production	Import	Production	Import	Import	Production	Import	
1990-91	6993	412	2051	1016	1326	9044	2754	23.3
1991-92	7302	566	2562	968	1236	9863	2770	21.9
1992-93	7431	1152	2321	727	1081	9751	2961	23.3
1993-94	7231	1589	1874	722	863	9106	3173	25.8
1994-95	7944	1473	2557	376	1282	10501	3131	23.0
1995-96	8769	2008	2594	686	1424	11362	4119	26.6
1996-97	8593	1156	2579	219	667	11172	2041	15.4
1997-98	10083	1377	3076	716	1437	13159	3531	21.2
1998-99	10477	657	3205	985	1558	13682	3200	19.0
1999-00	10873	856	3448	1534	1774	14321	4164	22.5
2000-01	10943	164	3734	437	1594	14677	2194	13.0
2001-02	10690	283	3837	494	1697	14527	2474	14.6
2002-03	10508	135	3908	228	1568	14415	1932	11.8
2003-04	10557	205	3627	372	1553	14183	2129	13.1
2004-05	11305	413	4038	307	2058	15343	2779	15.3
2005-06	11333	1390	4203	1145	2764	15536	5299	25.4
2006-07	11525	2704	4440	1373	2076	15965	6153	27.8

Source: Fertiliser Statistics, The Fertiliser Association of India, New Delhi, various issues.

Annexure IV Comparison of cost of domestic and imported urea

Year	Domestic production 000 tonne	Subsidy on indigenous fertiliser Rs. crore	Maximum retail price Rs/tonne	Price paid to indigenous producer (MRP + subsidy)	Import 000 tonne	Subsidy on Imported urea Rs. crore	Price paid for import Cif Rs./tonne
2004-05	20239	10243	4830	9891	641	494	10693
2005-06	20085	10653	4830	10134	2057	1211	11422
2006-07	20271	11400	4830	10454	4719	2704	10770

Annexure V Fertiliser use on important crops, 2003/04

Crop	Gross cropped area (million ha)	Share in fertiliser consumption (%)	Fertiliser consumption (kg/ha)			
			N	P_2O_5	K_2O	Total
Cotton	8.5	6	89.5	22.6	4.8	116.8
Irrigated	2.9	2.7	115.7	30.9	7	153.5
Rainfed	5.6	3.3	75.8	18.2	3.6	97.7
Groundnut	6.6	2.9	24.4	39.3	12.9	76.6
Irrigated	1.2	0.8	35.3	53.8	28.9	118
Rainfed	5.4	2.1	21.9	36	9.2	67.2
Jute	0.8	0.2	38	11.5	5	54.4
Irrigated	0.3	0.1	55.9	22.4	10.2	88.6
Rainfed	0.5	0.1	28.9	6	2.3	37.1
Maize	6.6	2.3	41.7	14.7	3.8	60.2
Irrigated	1.5	0.8	59.6	27.7	4.8	92.1
Rainfed	5.1	1.5	36.6	11	3.6	51.1
Paddy	44.7	31.8	81.7	24.3	13.1	119.1
Irrigated	24	22.2	103.4	32.8	18.8	155
Rainfed	20.7	9.6	56.6	14.5	6.5	77.6
Pearl millet	9.8	1.7	21.9	5.5	0.8	28.2
Irrigated	0.8	0.4	62.2	13.9	3.4	79.5
Rainfed	9	1.3	18.4	4.8	0.6	23.8
Pigeon pea	3.6	0.8	20.9	13.3	2	36.2
Irrigated	0.2	0.1	36.9	20.9	2.2	60
Rainfed	3.5	0.7	19.6	12.6	2	34.2
Rapeseed & mustard	6	3.4	69.1	25	2.9	97
Irrigated	3.8	2.6	81.7	30.4	4.3	116.5
Rainfed	2.2	0.8	45.9	15	0.4	61.3
Sorghum	9.9	2.9	29.2	14.2	4.1	47.5
Irrigated	0.8	0.5	58.5	29.1	10.7	98.3
Rainfed	9.1	2.4	26.9	13	3.6	43.6
Sugar cane	4.3	5.4	124.8	44	38.3	207.1
Irrigated	4.2	5.3	126.4	45	40.6	212
Rainfed	0.1	0.1	106	32	12.4	150.4
Wheat	25.7	21	99.6	30.2	6.9	136.7
Irrigated	22.8	19.7	105.6	32.1	7.3	144.9
Rainfed	2.9	1.3	55.7	15.9	4.3	75.9
Other crops	60.4	21.6	34.5	18.5	7.1	60.1
Irrigated	12.6	13.3	113.5	46.8	16.5	176.7
Rainfed	47.8	8.3	13.6	11	4.7	29.3
All crops	187	100	59.2	22.1	8.5	89.8
Irrigated	75.1	68.5	103.2	35.3	14.5	153.1
Rainfed	111.9	31.5	29.7	13.1	4.5	47.3

Annexure VI Methodology used for calculation of chemical fertiliser imbalanced use index and the assessment of benefit sharing of chemical fertiliser subsidy by different stakeholders

Fertiliser imbalanced use index

The imbalanced use of fertiliser was estimated by using an indicator of imbalance adopted in earlier studies (Mehta 2007) as under:

I = √[{(Na- Nn)2+(Pa- Pn)2+(Ka- Kn)2}/3]

Where I is the measure of deviation in proportion of actual use of N, P and K from the recommended norm and subscript `a' indicates actual and subscript `n' indicates norm. Value of I away from zero measures the magnitude of imbalance. When N, P and K are used in the recommended ratio then I is 0. If entire amount of fertiliser is in the form of K, which is the lowest digit in the norm, then I reach the value of 0.49. Thus I would lie between 0 and 0.49 representing perfect balance and extreme imbalance (Source: Chand and Pandey, 2008).

Assessment of benefit sharing of fertiliser subsidy by different stakeholders

The relative benefit-incidence of the substantial fertiliser subsidy on the farmers and the fertiliser industry has been a matter of some research. The difference between the hypothetical farm-gate price of imported fertilisers and the actual price paid by the farmers on fertiliser under the RPS, multiplied by the quantity consumed, may be taken as the fertiliser subsidy accruing to the farmers. The balance of the total subsidy on fertiliser after deducting the portion of subsidy accruing to farmers may be taken as the share of subsidy to the fertiliser industry, when the hypothetical farm gate price of imported fertiliser is lower than the domestic producers retention price. When the price of imported fertiliser is higher than the domestic producers retention price, the gap between the two may be accruing to the foreign supplies/producers.

Annexure VII List of abbreviations

AgGDP = Agricultural Gross Domestic Product

BD = Bulk Density (soil property)

C.I.F. = Cost insurance freight (Import price including insurance and transport cost)

C.V. = Co-efficient of Variation (a measure of variability)

CAN = Calcium Ammonium Nitrate (N fertiliser)

DAP = Di-ammonium Phosphate (P & N fertiliser)

ERC = Expenditure Reforms Commission

FAI = Fertiliser Association of India

FYM = Farm Yard Manure

GCA = Gross Cropped Area

ICAR = Indian Council of Agricultural Research

KUE = Potash Use Efficiency

MOP = Muriate of Potash (K- fertiliser)

MRP = Maximum Retail Price

NRP = Normative Referral Price

NSA = Net Sown Area

PDCSR = Project Directorate of Cropping Systems Research (one ICAR institute)

PUE = Phosphorus Use Efficiency

RPS = Retention Price Scheme (a scheme of determining fertiliser subsidy for domestic industries)

SSP = Single Super Phosphate (P fertiliser)

TOC = Total Organic Carbon (in soil)

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