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Fertilizer Use and its Determinants : A Review with Special Reference to Semi-Arid Tropical India

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FERTILIZER USE AND ITS DETERMINANTS : A REVIEW WITH SPECIAL REFERENCE TO SEMI-ARID TROPICAL INDIA

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The semi-arid tropics covering nearly two-thirds of the country's arable area, are spread over the states of Andhra Pradesh, Maharashtra, Gujarat, Karnataka, Madhya Pradesh, Tamil Nadu and parts of Uttar Pradesh, Punjab, Haryana and Rajasthan (Bapna et al. 1979). While the advent of irrigation in states like Punjab, Tamil Nadu, Haryana, Uttar Pradesh and others has helped in transformation of the irrigated SAT[1] areas, bulk of SAT India continues to be characterized by low output, highly unstable agricultural system supporting fairly high population densities (Ryan 1974). Till recently, these were looked upon more as problem areas requiring famine relief and protection rather than areas capable of making positive contributions to a country's agricultural growth.

Earnest efforts are now being made to rectify the imbalance. The share of dryland areas in development allocations is increasing; attempts to improve the technological base of agriculture in these areas have been intensified. The realization that irrigation will never reach a vast majority of SAT areas, has focused attention on development of high-output technologies and farming systems capable of performing well under constrained and uncertain moisture situations.

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1. The abbreviation SAT has been used for semi-arid tropics in this text.

Efficient soil fertility and water management have been identified as the key factors in this context and fertilizer use plays an important role in the new dryland agriculture technology. This paper focuses attention on fertilizer use in SAT India in terms of consumption levels, growth, farmers' practices and factors affecting farmers' demand for fertilizers. Information on these aspects is lacking; economists, like everyone else, were too preoccupied with the exciting changes taking place in irrigated agricultural regions of the country. As early as 1969, Desai emphasized the importance of rainfed regions as potential sources of future growth in fertilizer demand (Desai 1969). A decade later, he had to reiterate the call (Desai 1978); apart from the work he followed up through these years (Desai et al. 1973; Desai and Mellor 1969, Desai and Singh 1973), no systematic study was conducted on this problem.

Agrobiological scientists, on the other hand, have been more responsible. A large number and variety of experiments have been conducted under the All-India Coordinated Agronomic Experiments Scheme, the All-India Coordinated Research Project for Dryland Agriculture (AICRPDA), and the Sorghum and Millets Research Programmes of the Indian Council of Agricultural Research (ICAR), agricultural universities in different states and at the International Crops Research Institute for the Semi-Arid Tropics. These have established that most of the crops grown under dryland conditions do respond to fertilizers (Kanwar 1972). While there is need to further study the interactions of response with moisture (rainfall) variability, methods of application and other agronomic realities of dryland agriculture, successful diffusion of fertilizers requires an understanding of the status of fertilizer use, the pattern of its use and the factors inhibiting rapid growth in consumption at farmers' level.

This paper attempts to piece together information on various aspects of fertilizer use from different sources. A brief macro picture is first given covering consumption of fertilizers in India. The growth pattern of fertilizer use is then discussed in aggregate terms. The second section deals with micro-evidence on fertilizer use practices of farmers. Finally, factors affecting adoption and use of fertilizers have been identified.

I. CONSUMPTION LEVELS AND GROWTH IN FERTILIZER USE

Table 1 provides a synoptic view of current consumption levels of fertilizers (total plant nutrients) in India. It shows that more than 50% of the total fertilizers was consumed in only four states (Punjab, Uttar Pradesh, Andhra Pradesh and Tamil Nadu) which accounted for less than 30% of the gross cropped area of the country. The eastern states (Assam, Bihar, Orissa and West Bengal) account for about 18% of the area but consume only 10% of the fertilizers used. This clearly indicates concentration of fertilizer consumption in a few states (Desai 1978; Desai and Singh 1973).

The states of Madhya Pradesh, Andhra Pradesh, Maharashtra, Gujarat, Karnataka and Tamil Nadu fall predominantly under the semi-arid tropics.[2] If we leave out Andhra Pradesh (where fertilizer use is concentrated in 5-6 coastal districts) and Tamil Nadu (where very high irrigation levels obtain), a crude idea regarding fertilizer consumption in predominantly SAT areas can be had. Madhya Pradesh, Maharashtra, Gujarat and Karnataka account for about 36% of the country's cropped area but their contribution in total fertilizer consumption is less than one-fourth. This suggests

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2. Parts of Uttar Pradesh, Haryana, Rajasthan and Punjab are also included but state level data would not reveal the SAT position.

Table 1. Fertilizer use in Indian agriculture : 1978-79

	State	Fertilizer (N+P+K) consumption in 1978-79		Share in all India gross cropped area	% net irrigated area 1976-1977	Fertilizer (N+P+K) use per ha of cropped area (kg)	% of farmers using fertilizers	% crop area fertilized	Average rate of application of N+P+K per fertilized ha (kg)
		Thousand tonnes	Share in India total						
I	Assam	8	0.2	2.0	21.4	2.4	6	5	49
	Bihar	195	3.8	6.8	34.5	17.2	42	35	50
	Orissa	72	1.4	4.3	17.8	9.9	21	21	91
	West Bengal	243	4.8	4.6	23.3	31.9	66	50	89
II	Punjab	594	11.6	3.8	76.6	94.5	92	76	91
	Haryana	204	4.0	3.2	49.3	38.7	69	49	77
	Uttar Pradesh	1058	20.7	13.9	47.5	45.6	44	37	65
III	Rajasthan	134	2.6	10.1	17.3	7.8	31	20	55
	Gujarat	321	6.3	6.1	12.8	31.4	62	43	46
IV	Madhya Pradesh	193	3.8	12.5	10.7	9.2	15	11	46
	Andhra Pradesh	605	11.8	7.1	32.4	50.9	62	42	112
	Maharashtra	380	7.4	11.8	8.3	19.1	42	27	77
	Karnataka	361	7.1	5.9	13.2	36.6	50	33	105
	Tamil Nadu	493	9.6	4.3	38.8	68.9	70	55	128
V	Kerala	100	2.0	1.8	10.0	34.1	65	73	92
	H. Pradesh	12	0.2	0.6	16.3	12.8	34	28	28
	Jammu & Kashmir	18	0.3	0.6	43.0	18.8	40	28	47
	All India	5117	100.0	100.0	24.6	na	na	nr	nr

na. Not applicable

nr. Not reported

Source: For columns 1 thru 5; Fertilizer Association of India. 1979. Fertilizer Statistics, 1978-79. New Delhi, India. Various tables.
For columns 6 thru 8 see NCAER 1978.

that fertilizer use in SAT areas is comparatively lower. It is also low in Rajasthan and the eastern states.

Figures for average fertilizer consumption intensity also suggest a similar pattern. In Punjab, Uttar Pradesh, Andhra Pradesh and Tamil Nadu (all having well-developed irrigation resources), consumption levels exceed 40 kg of plant nutrients per hectare of gross cropped area; none of the four SAT states (Madhya Pradesh, Maharashtra, Karnataka and Gujarat) reach this level. The average consumption per hectare of cropped area is below the national average in the eastern states (West Bengal apart), the northern hill states of Jammu and Kashmir and Himachal Pradesh and in Rajasthan, Maharashtra and Madhya Pradesh.

The table also provides estimates on three fertilizer use parameters -- adoption, extent of coverage and actual rates of fertilizer (NPK) application per hectare. It shows wide inter-state variability in all the three parameters. In seven states more than 60% of the farmers used fertilizers. All these (with the exception of Gujarat) were predominantly rice and wheat growing areas. The percentage area fertilized in these states was above 40% and the rate of application was also high -- 76 to 128 kg/ha. On the other extreme, five states had less than 35% adoption, relatively lower rates of application (Orissa being an exception) and very low percentage of fertilized area. So far as the four states mentioned above are concerned, Madhya Pradesh had very low values for all the three parameters: Maharashtra and Karnataka had 42-50% adoption, 27-33% crop area fertilized and rather high rates of application. Gujarat had relatively higher figures for adoption and percentage area fertilized, but the rate of application was lower. Thus, even within these states

considerable variability exists and it is not possible to draw a concrete inference based on state level data.

Table 2 gives the distribution of 385 districts in India over different consumption level intervals. Only 7% of the districts had consumption levels above 40 000 tonnes, but these 27 districts consumed 29% of the total fertilizers. On the other extreme, over 42% districts had very low consumption levels (less than 5 000 tonnes) and accounted for only about 8% of the total. This underscores the point mentioned earlier regarding concentration of fertilizer use on small areas.

The pattern in typically SAT regions is highlighted by an analysis (Saolapurkar 1979) pertaining to two SAT states -- Maharashtra and Andhra Pradesh, based on district level data on fertilizer consumption in 1977-78. Table 3 summarizes the essential features of this analysis. It shows that in both the states fertilizer use was concentrated in districts with high irrigation intensities. The situation in Maharashtra appears somewhat less skewed probably because of fairly widespread use of fertilizers (at very low rates) on groundnut, cotton and some foodgrain crops.

The aggregative analysis on consumption pattern reveals continued concentration tendencies, led mainly by irrigation and to some extent by the area under high value (or high response) unirrigated crops (Jayaraman 1979).

Growth in Fertilizer Use

Growth of fertilizer use in Indian agriculture during the sixties was studied in depth by Desai (Desai 1969; Desai 1978; Desai and Singh 1973). Historical evidence indicates that though the use of fertilizers for field crops started in the late thirties, it was only during

Table 2. Distribution of districts by consumption level of fertilizers (total plant nutrients), 1978-79

Consumption range (thousand tonnes)	Number of districts	Percent share of total consumption
Above 60	9	12.3
41 - 60	17	16.7
21 - 40	64	34.2
11 - 20	68	19.9
5 - 10	63	9.1
Below 5	164	7.8
Total	385	100.0

Source: Fertilizer Association of India. 1979. Fertilizer Statistics 1978-79, New Delhi, India.

Table 3. Fertilizer consumption in Andhra Pradesh and Maharashtra districts: 1977-78

State/ Category	No. of distts.	Share in State totals			(NPK) consumption (kg/ha) of cultivated area
		Cultivated area	Irrig. area	Total fertilizer (NPK) consumption	
Andhra Pradesh					
Irrigated	11	38	75	78	93
Unirrigated	10	62	25	22	16
Maharashtra					
Irrigated	8	26	52	58	44
Unirrigated	17	74	48	42	11

Source: Saolapurkar 1979.

the First Five Year Plan that it really got a strong push. Consumption of the three types of fertilizers rose from about 81 000 tonnes in 1952-53 to about 300 000 tonnes in 1960-61 and 5 100 000 tonnes in 1978-79. The growth, however, has not been monotonic and wide inter-year fluctuations were witnessed. There was a sharp deceleration in 1972-73 and 1973-74 and a substantial decline in 1974-75. The last four years (1975-76 to 1978-79) have been very impressive but Desai cautions that this should not be interpreted as a definite acceleration, it most likely implies a recovery along the pre-1972 trend (Desai 1978). He also pointed out that the statewise base of growth in fertilizer consumption continued to be narrow and states like Uttar Pradesh, Punjab, Tamil Nadu, Andhra Pradesh and Gujarat still accounted for bulk of the post-1975 growth in fertilizer consumption. This continuing concentration raises fears about future growth in fertilizer consumption in India.

The districtwise study on growth in fertilizer use (Desai and Singh 1973) focused attention on the concentration problem. It examined data on fertilizer consumption for 286 districts over the period 1960-61 to 1968-69 and found wide inter-district variability in fertilizer consumption. More than 80% of nitrogen (N), and phosphorus (P) was consumed in less than one-third of the districts all though this period. On the other extreme, more than 50% of the districts accounted for only 10% of the total fertilizer consumption.

Extending the analysis to 1975-76 and 1976-77, the pattern was found to be persisting -- 87% of the growth in nitrogen consumption between these two years was accounted for by only 81 (30%) districts, most of

these were important in the sixties also (Desai 1978). Desai concluded that while there was some broadening of the districtwise base generating growth in fertilizer consumption, it was still quite narrow and dominated by the traditional growth generating districts throughout the last 15 years or so. Results obtained by Maharaja for Gujarat (Maharaja 1975) and Saolapurkar for Maharashtra and Karnataka (1974-75 to 1977-78) (Saolapurkar 1979), supported most of these findings. However, Maharaja found evidence of a district widening of the spatial base of fertilizer consumption over the period 1960-61 to 1969-70. He found that the growth in consumption of nitrogenous and phosphatic fertilizers was higher in districts which had low initial consumption levels as compared to that in districts where the initial consumption levels were higher.

It was also shown (Desai and Singh 1973) that the performance of the southern region (Andhra, Kerala, Karnataka and Tamil Nadu) was very good with respect to growth in both nitrogen and phosphorus use while that of the central (Madhya Pradesh, Rajasthan, Uttar Pradesh) and eastern (Assam, Bihar, West Bengal, Orissa) regions was very poor. The western region (Gujarat, Maharashtra) performed relatively better with respect to growth in phosphorus consumption and the northern region (Punjab, Haryana) did better with respect to nitrogen growth. The study also investigated the factors behind varying growth patterns. These shall be discussed later.

The SAT Regions

We have attempted to interpret the results of the study by Desai and Singh in terms of SAT regions (Desai and Singh 1973). The study gives growth rates (1960-61 to 1968-69) of fertilizer consumption for districts falling

in different annual rainfall classes -- less than 500 mm, 501-750 mm, 751-1150 mm, and more than 1150 mm. The last class is treated by the authors as assured rainfall category. We have interpreted the districts falling in 501 mm to 1150 mm class as belonging to semi-arid tropics.[3] Table 4 shows the distribution of districts by rainfall and irrigation classes.

The top half of the table reveals that 46 districts had high to very high growth rates of nitrogen use. Of these, 36 were located in the semi-arid region, the arid and assured rainfall areas had 5 each. Bulk of the medium growth districts were also located in the semi-arid region. Considering the distribution within each category, the arid region showed maximum contrast, 10 district in the low to very low and 5 districts in the high to very high growth category. In the semi-arid and assured rainfall areas, these figures were 77 (46%) and 26 (22%), and 77 (75%) and 5 (5%), respectively. These figures clearly brought out the poor performance of the high rainfall districts. These belonged mostly to the eastern region. The semi-arid regions (and even the arid region) performed relatively better during the sixties.

With respect to growth in phosphorus use, performance of the semi-arid arid areas was distinctly superior. Once again the assured rainfall regions were found to be lagging behind.

Classification by irrigation levels within each type of area provides a more realistic assessment. This reveals that all the districts

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3. The limitations of this classification are recognized. It was attempted in the hope that this will enable some broad judgements.

Table 4. Distribution of districts according to normal rainfall-cum-levels of irrigation and growth rates of fertilizer (nutrient) use

Normal rainfall category	Irrigation level	Number of districts according to different growth rate categories					Total number of districts
		Very high	High	Medium	Low	Very low	
	Nitrogen (N)	>1500	751-1500	301-750	101-300	<101	
I Arid (<500 mm)	<20%	nil	nil	nil	2	8	10
	>20%	1	4	1	nil	nil	6
	Total	1	4	1	2	8	16
II Semi-arid (501-1150 mm)	<20%	1	9	30	25	31	96
	>20%	10	16	23	13	8	70
	Total	11	25	53	38	39	166
III Assured rainfall (>1150 mm)	<20%	nil	2	15	11	40	68
	>20%	nil	3	6	12	15	36
	Total	nil	5	21	23	55	104
	Grand total	12	34	75	63	102	286
	Phosphorus (P)	>500	301-500	101-300	51-100	<50	
I Arid	<20%	nil	nil	1	nil	9	10
	>20%	nil	1	3	1	1	6
	Total	nil	1	4	1	10	16
II Semi-arid	<20%	5	8	29	19	35	96
	>20%	6	13	28	11	12	70
	Total	11	21	57	30	47	166
III Assured rainfall	<20%	3	nil	12	11	42	68
	>20%	1	3	7	6	19	36
	Total	4	3	19	17	61	104
	Grand total	15	25	80	48	118	286

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in the high nitrogen growth class in arid regions had higher irrigation, all the 10 low growth districts had low irrigation. This held for the semi-arid regions also -- 26 out of the 36 high to very high growth districts had high irrigation, 56 out of the 77 low to very low growth districts had low irrigation. In fact, growth in nitrogen consumption was high in only 10 (out of 96) low irrigation SAT districts. In the assured rainfall areas, irrigation did not seem to have made much impact. With respect to phosphorus use also, a similar trend was observed.

Taking an overall view, and considering low irrigation situation, the semi-arid districts seem to have performed better than the arid and assured rainfall districts. Only 58% of the (96) districts in this class had low or very low growth of nitrogen use (57% for phosphorus use). In the arid and assured rainfall districts, the proportions were 100% and 75% respectively (90% and 78% for phosphorus use). Ten percent of the districts had high to very high growth rate of nitrogen use (13% for phosphorus use) in the unirrigated semi-arid areas. The corresponding figures for arid and assured rainfall areas were nil and 3%, respectively (nil and 4% for phosphorus use).

The above analysis provides some useful insights into the relative position of SAT regions vis-a-vis others. (1) The semi-arid (and also the arid) regions had higher growth of fertilizer use during the sixties as compared to the assured rainfall regions, more distinctly so with respect to phosphorus use; (2) Availability of irrigation seemed to bring about a much greater impact on fertilizer use in the semi-arid (and also arid areas; (3) With low levels of irrigation, growth rates fell substantially in the semi-arid regions but they still out-performed the assured

rainfall areas; (4) High nitrogen growth districts were concentrated in the high irrigation areas. For phosphorus use, particularly in the semi-arid areas, the correlation was not so strong. It may be noted that both Maharaja and Jayaraman found area under commercial crops to be more important than irrigation in explaining phosphorus consumption pattern in Gujarat (Maharaja 1975; Jayaraman 1979).

II. FERTILIZER USE PATTERN ON SAT CROPS AND FARMS

In order to understand the forces which lead to the macro patterns discussed earlier, it is necessary to know the fertilization practices in greater detail. An attempt has been made in this section to provide information on the rates of fertilization of different crops, the extent of coverage, cropwise allocation of fertilizers etc. with special focus on the semi-arid regions of the country. The overall picture presented in the following section is based on three comprehensive studies. The first (NCAER 1974) provides estimates of fertilizer use on selected crops for the country as a whole. The second (NCAER 1978) gives the position statewise and the third (Raheja et al. 1979) focuses attention on fertilizer use for high yielding varieties of selected crops.

Fertilizer Use on Selected Crops : All-India Estimates

Table 5 presents country-level estimates of cropwise fertilizer use based on a sample of over 4 000 households spread over the whole country.[4] The

4. The sampling design gave a higher weightage to Intensive Agricultural Development Districts (IADP) and though the estimates have been adjusted, we feel that this has biased the estimates upwards.

Table 5. Cropwise allocation, extent and rates of fertilizer application on selected crops in India, 1970-71

Crop	% of total (NPK) used	% crop area fertilized	Rate of application per fertilized hectare (kg)		
			N	P	K
Rice	31	47	39	8	2
Wheat	19	50	51	4	2
Sorghum	5	17	27	10	4
Maize	4	25	54	3	1
Other cereals	5	16	33	11	1
Pulses	1	5	25	5	1
Sugarcane	18	83	199	30	24
Cotton	8	40	37	7	3
Oilseeds	4	30	15	12	1
Other crops	5	nr	nr	nr	nr
Total	100	nr	nr	nr	nr

Source: NCAER 1974.

nr. Not reported

table shows that foodgrains accounted for nearly two-third of the total fertilizer used in the country. This is in significant contrast to the position till the fifties when commercial crops were the major claimants (Desai 1969). One also notes that crops like sorghum, pulses, other cereals, cotton and oilseeds, which are the dominant crops of SAT India, accounted for a small (23%) share. In fact, only three crops -- rice, wheat and sugarcane, claimed more than two-third of the total fertilizer consumed. The extent of fertilization, measured as the extent of crop area fertilized, was also high for these three crops; the major SAT crops (with the exception of cotton) fared poorly in this regard. The rate of fertilizer application also followed the same trend. One should note that these are average figures over irrigated and unirrigated, local and high yielding varieties. Table 6 provides the estimates for extent and rates of application under irrigated and unirrigated conditions.

The table shows the irrigation-fertilizer complementarity quite clearly. Under unirrigated conditions, the extent of fertilization dropped, only for rice, cotton and oilseeds it extended to nearly one-third of the cropped area. For wheat, maize, sorghum, other cereals and pulses, the extent of unirrigated crop area fertilized ranged between 3 to 16% only. The rate of application of nitrogen also fell drastically under unirrigated condition and did not exceed 30 kg per hectare in any case. If we leave out rice, wheat and maize, we get a more relevant picture for SAT; for crops like sorghum, cotton and groundnut, the values lay between 15 to 25 kg N per fertilized hectare only. It is also interesting to note that the rates for phosphorus did not fall so significantly,

Table 6. Extent of area fertilized and rates of fertilizer application for selected crops under irrigated and unirrigated conditions, 1970-71 (All India)

Crop	% crop area fertilized		Rate per fertilized hectare (kg)					
			Irrigated			Unirrigated		
	Irrig.	Unirrig.	N	P	K	N	P	K
Rice	65	36	48	10	1	30	6	2
Wheat	69	16	54	3	1	28	8	5
Sorghum	39	13	44	13	8	17	9	1
Maize	47	5	57	2	1	31	10	1
Other cereals	39	11	50	4	1	24	17	n
Pulses	15	3	36	5	1	9	4	n
Sugarcane	83	nil	199	30	24	nil	nil	nil
Cotton	70	31	61	12	7	22	3	1
Oilseeds	35	29	14	19	2	15	10	1

Source: NCAER 1974.

n. Negligible -- less than 0.5

indeed for some crops, the unirrigated rates were higher. This reinforces the conclusion drawn earlier regarding relatively smaller impact of irrigation on phosphorus use.

Table 7 provides yet another stratification of the data in terms of extent of area fertilized and rates of application for high yielding and traditional varieties under unirrigated conditions for rice, wheat, maize and sorghum. The irrigated crop parameters (data not presented here) were significantly higher in all cases. Once again it was noted that phosphorus rates did not record as large declines under unirrigated conditions as nitrogen. For some crops (HYV) the unirrigated phosphorus rates were higher.

The table shows that even under unirrigated conditions, the HYV were fertilized more extensively and at higher rates. It was also noted that the percentage area fertilized was higher for sorghum as compared to maize or wheat. These data demonstrate that fertilizer use under unirrigated conditions was not an uncommon practice for HYV. The local varieties (with the exception of paddy) were fertilized to a very limited extent.

State Level Estimates

The All-India estimates presented above conceal a very large element of variability. We have used data from the latest NCAER Survey (NCAER 1978) conducted in 1975-76 covering more than 21 000 households to provide a statewise picture.[5] In the tables that follow, estimates have been presented for 10 states -- Punjab, Haryana, Uttar Pradesh, Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu.

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5. It may be noted that 1975-76 was the first year of the post-1974 recovery in fertilizer consumption. Growth in fertilizer consumption in subsequent years suggests that the estimates for this year would be biased downwards and that current estimates should be significantly higher.

Table 7. Extent of area fertilized and rates of fertilizer application for high yielding and traditional varieties of rice, wheat, maize and sorghum under unirrig. conditions, 1970-71 (All-India estimates)

Fertilizer use variables	Variety	Rice	Wheat	Maize	Sorghum
% area fertilized	HYV	94	56	39	80
	Local	31	11	5	10
Rate of nitrogen per fertilized ha (kg)	HYV	44	43	37	26
	Local	26	18	31	15
Rate of phosphorus per fertilized ha (kg)	HYV	6	16	nil	16
	Local	9	3	2	11
Rate of potash per fertilized ha (kg)	HYV	2	12	nil	3
	Local	1	2	1	6

Source: NCAER 1974.

The first table (Table 8) provides information on some broad fertilizer use and other indicators. As can be seen, the survey covered nearly 15 000 households in these ten states. On the basis of availability of irrigation, the state can be grouped into three categories -- Punjab, Haryana, Uttar Pradesh, Andhra Pradesh and Tamil Nadu in the high irrigation, Gujarat and Rajasthan in the medium and Madhya Pradesh, Maharashtra and Karnataka, in the low irrigation category.

The adoption level of fertilizer was high in the highly irrigated states (Uttar Pradesh being an exception). In the largely unirrigated states, it was significantly lower (except in Gujarat). The same trend obtained with respect to percentage area fertilized and rate of fertilizer application also. Among unirrigated states, Karnataka had high rates of application particularly of phosphatic and potassic fertilizers.

In the irrigated states, more than 80% of the fertilized area was irrigated; in the unirrigated states, a significant fraction of the fertilized area was unirrigated. In Rajasthan, an arid state, practically no fertilizer was used under rainfed conditions. In most of the other low-irrigation, semi-arid states this was not the case. A similar pattern was indicated when allocation of different fertilizers among irrigated and unirrigated crops was considered. These data suggested that in SAT states where irrigation had made a significant headway, or where agroclimatic conditions did not favor fertilizer use on drylands (as in Rajasthan), almost the entire fertilizer was used on irrigated crops. In other states like Gujarat, Maharashtra, Madhya Pradesh and Karnataka, fertilizer use under rainfed conditions was observed though in these states too irrigated crops claimed a dominant share. One would also like to recall that the

Table 8. Summary statistics on sample characteristics and fertilizer use in ten states : NCAER Fertilizer Demand Survey, 1975-76

Particulars		Punjab	Haryana	Uttar Pradesh	Andhra Pradesh	Tamil Nadu	Guja-rat	Mahara-shtra	Madhya Pradesh	Karna-taka	Rajas-than
1. No. of sample households		821	721	2587	1796	1828	1193	1085	2144	1321	1268
2. Average size of holding[a]		4.0	4.0	1.5	2.7	1.3	4.4	3.3	3.3	2.9	4.6
3. % area irrigated[b]		87	80	71	46	57	31	16	13	16	34
4. % households using fertilizers		92	60	44	62	70	62	42	15	50	31
5. % crop area fertilized		76	49	37	42	55	43	27	11	33	20
6. Rate per fertilized hectare (kg)	N	72	65	53	82	77	34	55	34	57	43
	P	17	10	9	24	25	10	14	12	26	12
	K	1	1	2	5	26	2	8	1	21	c
	Total	90	76	64	111	128	46	77	47	104	55
7. % fertilized area irrigated[d]		97	98	92	83	94	51	43	57	43	91
8. % irrigated area fertilized[d]		83	59	49	76	90	63	67	40	87	46
9. % unirrigated area fertilized[d]		27	4	10	13	9	32	18	5	22	3
10. % of total fertilizers used for irrig. crops[d]	N	98	98	95	90	97	74	60	77	77	94
	P	99	100	99	88	96	70	60	78	74	100
	K	99	99	97	86	96	70	65	94	76	100

Source: NCAER 1978. Various tables, different volumes.

a. Cultivated area per farm in hectares

b. Net irrigated area as percent of net cultivated area

c. Less than 0.5

d. Derived from Appendix tables

unirrigated states had significantly lower adoption levels and also lower extent of fertilization.

The table also indicated that in most of the states (Punjab, Tamil Nadu and Karnataka being exceptions), a significant fraction of irrigated land was unfertilized. This tendency prevailed even in the low irrigation states where one would, a priori, expect a greater effort to fully exploit the irrigation-fertilizer complementarity. This is an important finding and has significant implications for growth in fertilizer consumption. It would be useful to investigate forces which lead to this kind of sub-optimal pattern.

In Table 9, we have shown the allocation pattern of nitrogenous fertilizers among crops in these ten states. For phosphorus the information is given in Appendix I. The table reveals that foodgrains accounted for over 70% of the total nitrogen used in Punjab, Harvana, Uttar Pradesh, Tamil Nadu, Madhya Pradesh and Rajasthan. In fact, wheat and paddy together accounted for more than two-third of the total nitrogen used in these states. In other states too (Gujarat being an exception) food crops were found to dominate. It was also noted that in all states fertilizer use on wheat was almost entirely confined to the irrigated crop, but in Gujarat, Maharashtra and Madhya Pradesh, a significant proportion of fertilizer used for paddy went to the unirrigated crops also.

In Andhra Pradesh, Gujarat, Maharashtra and Karnataka, more than 40% of the nitrogen was used by the non-food crops. Cotton, groundnut, sugarcane, tobacco and chillies were the important fertilized crops in this category. It was also noted that in most states (except Maharashtra), bulk of the nitrogen used for cotton went to the irrigated crop. For

Table 9. Allocation of total nitrogen among crops in ten states : NCAER Fertilizer Demand Survey: 1975-76

Crop	Punjab		Haryana		Uttar Pradesh		Andhra Pradesh		Tamil Nadu	
	% gross cropped area	% of total N used	% GCA	% of total N used	% GCA	% of total N used	% GCA	% of total N used	% GCA	% of total N used
1. Paddy	12.2 (100.0)	16.5 (100.0)	7.4 (98.0)	19.2 (99.7)	20.4 (51.7)	35.5 (95.4)	34.5 (92.2)	60.7 (98.3)	42.5 (92.2)	69.0 (98.7)
2. Maize	11.8 (89.0)	9.6 (94.0)	3.9 (84.0)	3.4 (79.0)	6.0 (73.3)	4.9 (98.5)	nr	nr	nr	nr
3. Kharif sorghum	nr	nr	2.3	nr	4.0 (43.6)	0.3 (100.0)	12.5	nr	5.8 (22.0)	1.8 (90.9)
4. Rabi sorghum	nr	nr	nr	nr	nr	nr	3.0	nr	5.4 (39.0)	1.7 (91.9)
5. Pearl millet	nr	nr	18.7 (67.0)	1.4 (98.0)	5.1 (38.4)	1.6 (14.2)	nr	nr	6.0	nr
6. Ragi	nr	nr	nr	nr	nr	nr	1.6	nr	5.9 (50.0)[a]	2.2[a] (95.7)
7. Cotton	11.2 (98.0)	12.0 (100.0)	4.6 (97.0)	3.0 (100.0)	nr	nr	3.4 (38.0)	7.6 (63.4)	4.5 (59.0)	5.4 (99.0)
8. Groundnut	nr	nr	nr	nr	nr	nr	14.9 (10.0)	1.3 (52.3)	15.0 (26.0)	2.3 (87.6)
9. Tobacco	nr	nr	nr	nr	nr	nr	1.5 (48.0)	1.9 (63.5)	nr	nr
10. Chillies	nr	nr	nr	nr	nr	nr	3.1 (67.0)	10.2 (75.9)	nr	nr
11. Wheat	42.0 (92.0)	51.1 (99.1)	34.3 (98.0)	56.3 (99.0)	32.9 (87.2)	53.3 (97.9)	nr	nr	nr	nr
12. Sugarcane	3.0 (94.0)	3.4 (98.6)	4.7 (98.0)	13.4 (99.0)	7.4 (89.1)	19.4 (95.8)	2.3 (98.0)	9.2 (100.0)	2.8 (100.0)	9.0 (100.0)
13. Others	**19.8**	**7.4**	**24.1**	**3.3**	**24.2**	**5.0**	**23.2**	**9.1**	**12.1**	**8.6**

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Table 9 continued

Crop	Gujarat		Maharashtra		Madhya Pradesh		Karnataka		Rajasthan	
	% gross cropped area	% of total N used	% GCA	% of total N used	% GCA	% of total N used	% GCA	% of total N used	% GCA	% of total N used
1. Paddy	6.6 (44.3)	14.4 (69.3)	10.5 (36.2)	17.9 (57.5)	25.2 (11.0)	24.1 (43.3)	11.8 (62.7)	39.7 (82.3)	1.2 (49.4)	2.4 (95.2)
2. Maize	nr	nr	nr	nr	3.9 (14.7)	3.4 (80.6)	nr	0.8[c] (97.9)	9.0 (59.2)	4.9 (66.1)
3. Kharif sorghum	7.3 (19.8)	2.1 (33.4)	17.8 (8.8)	14.0 (32.1)	9.5 (nr)	nr	20.9 (7.0)	7.6 (38.0)	3.1 (nr)	nr
4. Rabi sorghum	3.2	nr	15.8 (10.9)	4.0 (69.9)	nr	nr	8.1 (7.0)	2.4 (39.8)	nr	nr
5. Pearl millet	15.2 (38.7)	9.5 (54.4)	7.5 (nr)	1.8 (nr)	1.2 (nr)	nr	nr	nr	37.2 (15.3)	7.1 (53.3)
6. Ragi	nr	nr	1.1	nr	nr	nr	9.1 (4.0)	4.6 (13.5)	nr	nr
7. Cotton	17.3 (31.1)	25.3 (83.3)	7.1 (10.5)	12.2 (26.4)	nr	nr	8.8 (7.0)	3.0 (66.1)	1.6 (87.5)	7.1 (97.5)
8. Groundnut	16.4 (19.6)	7.0 (26.9)	4.4 (9.0)	3.1 (29.1)	nr	nr	6.9 (7.0)	2.4 (25.0)	nr	nr
9. Wheat	11.2 (54.4)	15.2 (94.2)	8.3 (65.7)	16.6 (94.2)	19.3 (32.3)	58.2 (92.4)	2.8 (42.0)	4.1 (98.1)	22.2 (84.2)	70.2 (99.8)
10. Sugarcane	0.2 (100.0)	1.0 (100.0)	1.5 (99.7)	18.6 (99.7)	0.4 (99.9)	3.5 (100.0)	3.1 (95.0)	29.8 (99.3)	0.1 (nr)	0.6 (nr)
11. Others	24.6	25.5	26.0[b]	11.8	41.5	11.8	29.5	5.6	25.6	7.7

Source: NCAER 1978. Figures in parentheses indicate percentage devoted to irrigated crop.

nr. Not reported.

a. Fertilizer use confined to rabi ragi only which occupies 3.4% of the gross cropped area. Irrigated area pertains to this crop.

b. Includes 5.7% and 5.4% area under sorghum and cotton mixtures respectively.

c. Rabi maize.

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roundnut, except in Tamil Nadu, the position was reverse. Another important point to note was the fact that fertilizer use was more diversified in the southern and western states as compared to Punjab and Haryana where only a few crops dominated.

Sorghum, pearl millet and groundnut crops are of special interest for ICRISAT. For sorghum, information on fertilizer use was available for Maharashtra, Karnataka, Gujarat, Uttar Pradesh and Tamil Nadu. There is sizeable area under sorghum in Madhya Pradesh and Andhra Pradesh also, but fertilizer use on this crop is presumably uncommon in these states. In Uttar Pradesh and Tamil Nadu, a very small proportion of nitrogen was allocated to sorghum -- mainly to the irrigated crop. In Maharashtra and Karnataka, this crop occupied about 34% and 29% of the gross cropped area respectively, and a fair amount of fertilizer was allocated to this crop. In these states and also in Gujarat, most of the fertilizer used for sorghum went to the unirrigated crop.

Rajasthan, Gujarat, Haryana and Maharashtra are important pearl millet producing states. In the first three states, fertilizer use on this crop was noted. More than 50% of the nitrogen used for this crop went to the irrigated crop in Gujarat and Rajasthan; in Haryana the proportion going to irrigated crop was almost 100%. This was in significant contrast to the position for sorghum. Thus, fertilizer use under unirrigated conditions was more common for sorghum.

Groundnut is important in Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu and Maharashtra. Table 9 indicated that this crop was fertilized in all these states and, except in Tamil Nadu and Andhra Pradesh, more than 70% of the nitrogen used for this crop went to the unirrigated

crop. Reference to Appendix I shows that the share of this crop was higher for phosphatic fertilizers, particularly in Gujarat.

Appendix I showed a similar cropwise allocation picture for phosphatic fertilizers. There was also some indication that phosphorus use was more concentrated than nitrogen and crops like wheat, paddy, sugarcane, cotton and groundnut accounted for 72 to 97% of the total phosphatic fertilizers consumed in different states. This clearly implied that, unlike nitrogen, phosphorus use has not spread to many crops. It was also noted that states like Andhra Pradesh, Karnataka, Gujarat and Maharashtra were somewhat better in this respect as compared to Punjab, Haryana, Uttar Pradesh, Tamil Nadu, Madhya Pradesh and Rajasthan.

These findings suggested that the crop base for fertilizer consumption in the irrigated states was narrow, particularly so for phosphorus. In the unirrigated states the number of crops fertilized was larger. One wonders whether this difference between irrigated and unirrigated SAT areas represents an evolutionary pattern through which the (presently) unirrigated areas will pass as more and more irrigation becomes available. The results also showed that irrigation and availability of high response crops (commercial as well as HYV of cereals) have dominated the fertilizer use scene in the Indian SAT.

In view of the special focus on unirrigated SAT agriculture, we have derived some additional information on fertilizer use under irrigated conditions in four states -- Gujarat, Maharashtra, Karnataka and Madhya Pradesh, the states where the share of unirrigated crops in total fertilizer consumption was significant. Table 10 provides data on cropwise

Table 10. Fertilizer use under unirrigated conditions in selected states : NCAER, 1975-76

Crop	Variables	Gujarat: % of fertilizer used under unirrig. conditions N	Gujarat: % of fertilizer used under unirrig. conditions P	Gujarat: % unirrig. crop area fertilized	Gujarat: Rate per fertilized ha (kg) N	Gujarat: Rate per fertilized ha (kg) P	Gujarat: Rate per fertilized ha (kg) K	Maharashtra: % of fertilizer used under unirrig. conditions N	Maharashtra: % of fertilizer used under unirrig. conditions P	Maharashtra: % unirrig. crop area fertilized	Maharashtra: Rate per fertilized ha (kg) N	Maharashtra: Rate per fertilized ha (kg) P	Maharashtra: Rate per fertilized ha (kg) K
1. Paddy	HYV	3	3	91	41	12	nil	5	5	71	51	14	12
	TRV	14	2	65	35	2	a	14	13	38	38	9	5
2. Maize	HYV	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
	TRV	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
3. Kharif sorghum	HYV	1	nil	70	106	nil	nil	21	20	68	43	10	4
	TRV	4	1	11	28	2	3	3	3	8	30	4	1
4. Pearl millet	HYV	9	14	40	21	11	a	nr	nr	nr	nr	nr	nr
	TRV	7	2	36	16	1	nil	nr	nr	nr		nr	nr
5. Cotton	HYV	8	3	50	41	5	a	17	17	71	58	15	7
	TRV	7	2	16	18	2	a	6	10	25	36	15	7
6. Groundnut[b]		20	62	63	3	10	2	5	10	29	30	13	3
7. Kharif ragi		nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr
8. Other kharif		22	7	nr	nr	nr	nr	33	21	nr	nr	nr	nr
9. Wheat	HYV	a	1	3	84	95	nil	a	a	15	82	9	8
	TRV	3	1	24	10	1	nil	2	1	6	73	5	5
10. Rabi sorghum	HYV	nr	nr	nr	nr	nr	nr	1	a	32	75	6	nil
	TRV	nr	nr	nr	nr	nr	nr	2	1	3	29	4	3
11. Other rabi		2	2	nr	nr	nr	nr	1	a	nr	nr	nr	nr
		100	100					100	100				

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Table 10 continued

Crop	Variables	Karnataka: % of fertilizer used under unirrig. conditions N	Karnataka: % of fertilizer used under unirrig. conditions P	Karnataka: % unirrig. crop area fertilized	Karnataka: Rate per fertilized ha (kg) N	Karnataka: Rate per fertilized ha (kg) P	Karnataka: Rate per fertilized ha (kg) K	Madhya Pradesh: % of fertilizer used under unirrig. conditions N	Madhya Pradesh: % of fertilizer used under unirrig. conditions P	Madhya Pradesh: % unirrig. crop area fertilized	Madhya Pradesh: Rate per fertilized ha (kg) N	Madhya Pradesh: Rate per fertilized ha (kg) P	Madhya Pradesh: Rate per fertilized ha (kg) K
1. Paddy	HYV	9	10	58	75c	38c	33c	2	nil	49	50	nil	nil
	TRV	21	12	62	48c	17c	11c	57	31	11	19	3	a
2. Maize	HYV	nil	nil	nil	nil	nil	nil	nr	nr	nr	nr	nr	nr
	TRV	a	nil	22	14	nil	nil	3	1	4	19	2	nil
3. Kharif sorghum	HYV	5	5	46	23	12	8	nr	nr	nr	nr	nr	nr
	TRV	15	16	18	22	11	9	nr	nr	nr	nr	nr	nr
4. Pearl millet	HYV	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil
	TRV	nil	nil	nil	nil	nil	nil	nr	nr	nr	nr	nr	nr
5. Cotton	HYV	1	a	33	18	5	5	nil	nil	nil	nil	nil	nil
	TRV	3	3	8	26	10	9	nil	nil	nil	nil	nil	nil
6. Groundnut[b]		8	7	30	18	8	6	nil	nil	nil	nil	nil	nil
7. Kharif ragi		17	22	38	20b	14	8	nil	nil	nil	nil	nil	nil
8. Other kharif		12	9	nr	nr	nr	nr	9	13	nr	nr	nr	nr
9. Wheat	HYV	a	a	48	19	5	5	7	13	28	42	24	nil
	TRV	a	a	3	22	21	21	13	25	5	16	10	a
10. Rabi sorghum	HYV	a	1	71	14	13	11	nil	nil	nil	nil	nil	nil
	TRV	6	10	36	10	8	6	nil	nil	nil	nil	nil	nil
11. Other rabi		2	5	nr	nr	nr	nr	9	17	nr	nr	nr	nr
		100	100					100	100				

Source: NCAER 1978. Various tables.

nr. Not reported
a. Negligible
b. For traditional varieties
c. For the dominant autumn paddy crop

(and varietywise) allocation of total fertilizer (nitrogen and phosphorus separately) used under unirrigated conditions, extent of fertilizer use and rates of application. There are gaps in the data and it was not possible to fully account for all the fertilizer used. Accordingly, we have sizeable fraction shown under the "other crops" category.[6]

In Karnataka, paddy, sorghum and ragi accounted for 73 and 76% of the total nitrogen and phosphorus used under rainfed conditions. In Madhya Pradesh also, food crops accounted for more than 70% of the fertilizer so used. In Gujarat and Maharashtra, on the other hand, the share of non-food crops was significantly higher: food crops accounted for only 41% and 48% respectively of the total nitrogen used in Gujarat and Maharashtra. For phosphorus, the share of the non-food crops was even higher. Cotton and groundnut were the major claimants in this category. It was also found that pearl millet accounted for nearly 16% of the total nitrogen used in Gujarat. In both Maharashtra and Karnataka, the share of sorghum was more than one-fourth.

The allocation data suggests that the HYV do not always claim a larger share in total fertilizer used on the crop concerned. In Karnataka and Madhya Pradesh, for example, most of the fertilizer was used by the traditional varieties; but in Gujarat (pearl millet) and Maharashtra (sorghum and cotton) there was some evidence that the HYV figured more prominently in this regard. The importance of HYV is more clearly brought out by the data on percentage area fertilized and rates of application

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6. The NCAER has classified varieties of all crops as traditional or high yielding, the latter including both the fertilizer-responsive, dwarf types and other improved varieties. In Table 10, we have maintained this classification for rice, wheat, pearl millet, sorghum, maize and cotton only (NCAER 1978).

and on both these scores (exceptions apart) the HYV fared much better as compared to traditional varieties. Their share in total fertilizer used was low only because the coverage under such varieties was poor.

Scrutiny of data on rates of application for important fertilizer using crops indicated that except for paddy and wheat, the unirrigated rates were generally around 20 kg to 40 kg per fertilized hectare for nitrogen and 5 kg to 15 kg per hectare for phosphorus in Gujarat, Karnataka and Madhya Pradesh. In Maharashtra, cotton and rabi sorghum had significantly higher rates of application of nitrogen.

The state level analysis presented above suggests that irrigation has been the most crucial determinant of fertilizer use in SAT India. One also notes that with high irrigation intensities fertilizer use tends to become more and more concentrated. The use pattern is clearly more diversified in the unirrigated SAT states. A disturbing feature was the evidence that not all the irrigated land is fertilized -- in highly irrigated and high fertilizer consuming and also in low irrigation states. This needs careful investigation.

Among unirrigated crops, in some states, paddy and wheat receive a greater share of fertilizers. In several others, major share is claimed by crops like cotton and groundnut. In all cases, the HYV receive greater attention in terms of extent of fertilization and also rates of application. It is clear that the pattern of fertilizer use under rainfed conditions in SAT India is governed by availability of high-response options.

One also notices considerable inter-state variation in fertilizer use parameters for crops like sorghum, pearl millet and groundnut. In some states, fertilizer use on a particular crop was non-existent; in

others it was confined to the irrigated crop only, and in yet others, unirrigated crop was also fertilized. One needs to take a critical look at regional adaptation and variations in response of these crops to fertilizer application for a full understanding of the pattern of fertilizer consumption in difeerent areas.

Finally, there was evidence to indicate that even for the low value crops like sorghum and millets, fertilizer use on traditional varieties was not uncommon, though the extent of area fertilized was very low.

Fertilizer Use on High Yielding Varieties

Several studies indicate that high yielding varieties of major cereals introduced in the mid-sixties, played an important catalytic role in adoption and diffusion of fertilizer use (Desai and Singh 1973; Desai 1978). We have looked at the data on fertilizer use for HYV of sorghum, pearl millet, cotton and groundnut -- the most important cereal and cash crops grown on drylands in SAT India. The data come from a survey (Raheja et al. 1979) conducted by the Indian Agricultural Statistics Research Institute (ICAR), New Delhi in selected districts in different states and pertain to 1975-76 -- the latest year for which the report is available.[7]

Table 11 provides data on adoption of HYV and different fertilizer use parameters in different districts. Sorghum crop was studied in five districts, four in the kharif and one in the rabi season. The data show that the spread of HYV was highly variable. It was high in Karnataka districts -- high rainfall and irrigation led to almost full coverage

7. As can be seen from Table 11, most of the districts belong to the semi-arid tropics. Selection of the districts was on the basis of highest targetted area (among districts in the state) under HYV of the crop concerned. While the data do not always reveal high adoption in the districts, the selection procedure does inject an element of upward bias in various estimates.

Table 11. Fertilizer use on HYV of sorghum, pearl millet, groundnut and cotton in selected districts : IASRI, 1975-76

Crop/ State	District	No. of sample farmers	% area under HYV	% HYV area irrigated	Av. rate of NPK per ha of HYV area (kg)	% area fertilized		Rate fertilized ha (kg)	
						N	P	N	P
Sorghum									
Maharashtra	Akola	253	15	nil	51	67	46	51	21
Karnataka	Dharwar	271	54	6	41	81	60	30	15
	Shimoga	272	85	2	85	98	97	50	22
	Shimoga[a]	263	94	100	149	100	100	85	36
M. Pradesh	Mandsaur	189	17	nil	9	26	25	19	14
Pearl Millet									
Gujarat	Kaira	264	95	24	45	91	3	47	63
	Sabarkanta	278	95	6	41	94	18	40	21
	Mehsana	282	95	nil	6	26	2	22	26
Haryana	Hissar	284	50	79	9	30	nil	31	nil
Rajasthan	Jaipur	168	14	7	9	23	8	36	12
Maharashtra	Aurangabad	146	17	nil	4	18	1	19	19
M. Pradesh	Morena	229	37	nil	35	64	15	49	24
Tamil Nadu	Madurai	286	66	100	23	51	21	35	13
	S. Arcot	137	4	50	61	66	48	52	24
Groundnut									
A. Pradesh	Chittoor	281	100	3	20	25	48	17	26
	Karimnagar	283	100	nil	4	7	8	35	16
Karnataka	Kolar	187	24	2	2	4	3	17	23
	Dharwar	272	17	100	33	72	68	17	23
Maharashtra	Aurangabad	146	57	nil	7	17	2	39	25
Punjab	Jullunder	226	nr	32	4	b	18	b	23
	Patiala	226	75	69	35	21	68	46	38
Tamil Nadu	S. Arcot	137	71	21	11	22	22	17	17
	S. Arcot[a]	235	95	92	74	61	60	18	68
U. Pradesh	Moradabad	22[illegible]	50	48	27	67	nil	40	nil
Cotton									
Gujarat	Kaira	264	74	72	51	87	11	56	20
	Sabarkanta	278	94	96	58	95	30	50	34
	Mehsana	282	31	93	58	85	17	54	46
Haryana	Hissar	284	67	100	18	52	nil	34	nil
Rajasthan	Chitorgarh	208	27	62	8	18	9	29	32
Maharahstra	Jalgaon	195	23	75	121	98	72	92	29
Tamil Nadu	Coimbatore	281	66	97	210	97	85	116	49
	Coimbatore[a]	251	94	99	116	94	46	85	39
Karnataka	Dharwar[a]	253	45	9	33	49	43	35	21

Source: Raheja 1979.

nr. Not reported

a. Rabi crop

b. Estimate not given

Important HYV for different crops were: Sorghum - CSH-1, CSH-2, Vidisha; Pearl millet - HB-2, HB-3, HB-5; Groundnut - TMV-2, SB-11, MG-8, M-13, M-145, T-28, Spanish Improved; Cotton - H-4, 320-F, C-Indore-1, MCU-5, Varalaxmi

in Shimoga district.[8] In other districts, coverage under HYV was very poor. One also notes that almost the entire area under HYV in the kharif season was unirrigated. Similar inter-district variability existed in the fertilizer use parameters. Shimoga was clearly an area where the HYV were well-adapted and almost the entire area in both seasons received both nitrogen and phosphorus at fairly high rates. In other districts, both area fertilized and rates of application were markedly lower -- Mandsaur (Madhya Pradesh) having the lowest values.

Similar variability existed in adoption of pearl millet hybrids also. High coverage was noted in Gujarat districts and in Madurai, in others the spread of HYV was much lower. It was also noted that in the Tamil Nadu districts and in Hissar (Haryana), a high proportion of the area under hybrids was irrigated. Data for percent area fertilized and rates of fertilizer application revealed some interesting features. In Mehsana, Jaipur and Aurangabad, the extent of HYV area fertilized with nitrogen was below 26%, that for phosphorus was even smaller. But in Sabarkanta and Morena where also bulk of the pearl millet hybrid area was unirrigated, the spread of fertilizer use was much higher and the rates of application were more than twice as high. In fact, values of fertilizer use indicators in these two districts were higher than those observed in Hissar and Madurai where most of the pearl millet hybrids were grown under irrigated conditions. Thus, high and low levels of fertilizer use were observed in both irrigated and unirrigated districts.

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8. Note that this was the only non-SAT district in the sample.

There is not enough evidence to compare the two crops -- sorghum and pearl millet. One does, however, note that under unirrigated conditions the sorghum HYV had higher fertilizer use parameters as compared to the pearl millet hybrids. This showed up more strongly for percentage area fertilized and rates of phosphorus application. Ignoring extreme values, the rates of application under unirrigated conditions for these crops appeared to range between 30 kg to 50 kg per ha for nitrogen and 15 kg to 24 kg per ha for phosphorus. These are not too far out of line with the state level estimates presented in Table 10 earlier.

The data for groundnut indicated that the improved varieties of this crop had fairly high spread in all but the two Karnataka districts. The districts also varied widely in terms of percentage groundnut area irrigated. In six out of 10 districts for nitrogen and four districts for phosphorus, less than 25% of the crop area was fertilized. The importance of phosphatic fertilization for this crop was also evident -- the N:P ratio was lower than or equal to unity in almost all districts for either fertilized area or rate of application or both. Indeed, with respect to this nutrient, this crop performed better than any other crop considered. Moradabad (Uttar Pradesh) was the only district where no phosphorus was used on this crop.

Cotton fared relatively better with generally high spread of HYV. In almost all districts, bulk of the area under superior varieties was irrigated. In Jalgaon (Maharashtra) and Coimbatore (Tamil Nadu), fertilizer use on this crop was very high. In the three Gujarat districts, a high percentage of crop area fertilized at moderate (50 kg to 56 kg per hectare) rates of nitrogen application. In the northern districts

(Hissar and Chitorgarh), fertilizer use was markedly lower in terms of both the parameters. Thus, for this crop, three distinct situations were noted -- high spread and high level of application, high spread and moderate levels and low spread and low level, in different districts.

This analysis thus reveals that: (a) on an average, the HYV of sorghum, pearl millet and groundnut are fertilized at lower levels as compared to cotton but for these crops fertilizer use under unirrigated conditions was quite common, (b) between sorghum and pearl millet, the former appeared to have higher fertilizer use indicators for the rainfed crop, (c) considerable inter-district variation in fertilizer use existed for all the crops studied; while availability of irrigation was an important determinant of this variability, it did not explain fully the observed pattern, particularly for the pearl millet hybrids, (d) the IASRI survey also revealed (data not reported here) that the local varieties of sorghum and pearl millet were also fertilized in some districts. The extent of crop area fertilized was very low and the rates ranged (ignoring extreme values) from 15 kg to 30 kg of nitrogen per hectare.

Fertilizer Use on SAT Farms

Evidence from micro-level studies suggests (Desai 1969; Desai and Singh 1973; Maharaja 1975) that farmers' fertilizer use allocations are based on the size and certainty of returns from fertilizer use for different crops. Roy also found that profits from fertilization (determined by physical response and prices) was the main factor explaining inter-farm differences in fertilizer use (Roy 1970).

However, very few empirical studies are available on fertilizer use on farmers' fields under dryland conditions. In view of the fact that

very little fertilizer has been traditionally used in these areas, this lack of interest is understandable. The cropping pattern was dominated by low-value crops and, apart from cotton and perhaps groundnut, hardly any other unirrigated crop was fertilized. It has been argued that farmers used most of their fertilizers on the small parcels of wet lands where returns from its application were relatively assured (Desai 1969). An attempt has been made here to review the findings of some important studies in this area.

(a) Bellary-Panchmahals Study

Krishnaswamy and Patel provide some information of the fertilizer use practices of 240 farmers from 24 villages in Bellary (Karnataka) and Panchmahals (Gujarat) districts for 1970-71. Both the districts reflect the characteristics of traditional semi-arid agriculture. Table 12 provides the available information on cropping pattern, fertilizer use levels, etc. on the sample holdings in each district.

Sorghum and pearl millet were the important cereals in Bellary and groundnut and cotton were the main cash crops. These four crops accounted for about 72% of the gross cropped area on the sample farms. In Panchmahals, paddy and maize were the most important cereals; wheat, sorghum and pearl millet were also grown by the sample cultivators. Groundnut and cotton were the cash crops but the area under these crops was lower as compared to Bellary.

Fertilizer use was generally low in both the districts though the Panchmahals sample had relatively higher rates. In Bellary, some fertilizer was used for almost all the crops including inferior millet. Only for paddy and hybrid sorghum the farmers used more than 35 kg of plant

Table 12. Levels of fertilizer application on farms in Bellary (Karnataka) and Panchmahal (Gujarat) districts : 1970-71

Crop	Bellary Sample					Panchmahal Sample				
	% area under crop	Fertilizer used kg/ha				% area under crop	Fertilizer used kg/ha			
		N	P	K	Total		N	P	K	Total
Paddy	0.2	39	nil	nil	39 (53)	21.9	15	a	nil	15 (29)
Wheat	0.2	nil	nil	nil	nil	5.6	69	19	19	107 (22)
Sorghum (Local)	34.0[b]	1	7	5	13 (25)	2.1[b]	nil	nil	nil	nil
Sorghum (HYV)	nr	13	15	7	35 (74)	nr	nr	nr	nr	nr
P. Millet (Local)	4.2[b]	nil	12	nil	12 (16)	4.5[b]	18	nil	nil	18 (29)
P. Millet (HYV)	nr	nil	12	nil	12 (100)	nr	18	1	nil	19 (33)
Navane	nr	2	7	2	11 (24)	nil	na	na	na	na
Maize	0.1	nil	nil	nil	nil	16.4	20	4	a	24 (16)
Gram	a	nil	12	nil	12 (6)	nil	na	na	na	na
Groundnut	21.0	2	8	2	12 (48)	13.2	23	11	a	34 (24)
Cotton	12.5	3	6	2	11 (34)	11.1	19	8	nil	27 (54)
	72.2					74.8				
Other crops	27.8					25.2				
% of farmers using fertilizers					58.0					41.0
Area fertilized as % of gross cropped area					31.5					20.5
Nutrients used per fertilized ha (kg)					14.0					24.0
Year when fertilizer was first used					1967					1961

Source: Krishnaswamy and Patel 1973. Compiled from tables 5.2, 5.16, 5.17 and 5.20 of Vol.I.

nr. Not reported
na. Not applicable
a. Negligible
b. Total of HYV and local. Figures in parentheses indicate percent area under the crop for which fertilizer was used.

nutrients. For all other crops, the rate was around 10 to 13 kg per ha. Another striking feature was the relatively high level of phosphorus use in this area. The spread of fertilizer use was 100% for hybrid pearl millet, 74% for hybrid sorghum, 53% for paddy and 48% for groundnut. Only a small fraction of the area under other crops was fertilized.

The Panchmahals farmers generally used higher rates of application, nitrogen playing a dominant role in almost all cases. The extent of area fertilized was, however, generally lower. Except for wheat, the rates were less than 35 kg per ha for all crops.

This table shows that fertilizer use was a recent practice on the sample farms, the Panchmahal farmers leading by 6 years. One gets the impression that the Bellary farmers being relatively recent adopters of fertilizers, were still experimenting. They tried to use fertilizer for the hybrids, as they were doubtless advised by the extension agencies but exercised caution regarding fertilization rates. They seemed to be relatively sure about paddy. As regards other crops, they appeared to be assessing the responses by applying low dosages to all the important crops. This pattern of behavior appears consistent with the risk and poverty dominated environment of the SAT. The Panchmahals farmers, having some more experience, seemed to have formed their judgements regarding profitable levels of fertilizer application and applied fairly high levels to wheat crop. The proportion of area fertilized was lower but more or less evenly spread over all crops. Capital rationing and risk adjustment, both seem to operate through limiting fertilized area in Panchmahals; in Bellary, the level of application also seemed to be so influenced.

The data show two more important trends. Firstly, crops which occupied a sizeable proportion of the cropped area were generally fertilized at lower rates and to a small extent, perhaps because the farmers did not have enough liquid resources to cover the entire area. Higher fertilization rates were tried for crops which occupied smaller area. Secondly, the view that cash crops are always fertilized at higher rates does not appear to be true. In both the samples, highest rates were observed for cereals.

(b) Gujarat Studies

Two farm level studies from Gujarat are important. Desai used data from Surat and Kaira districts for 1964-65 (Desai 1969). Maharaja's study pertained to 1968-69 and the sample farmers came from Surat, Baroda and Junagarh districts.

The first study (Desai 1969) showed that fertilizer use was concentrated on a few crops like sugarcane, tobacco and banana. The share of food crops in total fertilizer used was small but not insignificant. In general, crops like sugarcane, banana, tobacco, paddy and wheat had a higher level of fertilizer use (in terms of both area fertilized and rates) and unirrigated crops were meagrely fertilized. This study indicated that even in 1964-65, Gujarat farmers had high level of fertilizer use -- adoption varied from 32 to 80% in different areas, for some crops very high rates of fertilizer application (more than 100 kg nitrogen per hectare) was used. Crops like sorghum and pearl millet were fertilized at low levels -- the rate of application of nitrogen per fertilized hectare varied from 16 kg to 26 kg. Desai concluded that the observed pattern (dominance of irrigated and commercial crops) was consistent with relative responses (and profitabilities) of different crops to fertilizer

application.

Most of these observations were borne out by Maharaja's analysis also (Maharaja 1975). Paddy, wheat, sugarcane, tobacco and groundnut were fertilized more extensively and at higher rates as compared to crops like sorghum and pearl millet. The pearl millet hybrids were fertilized at higher levels as compared to the traditional varieties -- the rate of application of nitrogen per fertilized hectare varied from 25 kg to 28 kg per ha for local varieties and from 54 kg to 142 kg per ha for the hybrids in different areas.

These two studies suggest that fertilizer use is not a recent introduction in Gujarat; even before the new varieties came, farmers in the study areas were using significant quantities of fertilizers. Their decisions were influenced by the magnitude of additional returns obtainable from fertilizer application and this was reflected in higher fertilizer use for irrigated crops, high value commercial crops and high yielding varieties.

(c) AICRPDA Agro-Economic Studies

Agro-economic studies conducted at different locations under the All-India Coordinated Research Project on Dryland Agriculture also provide some useful information (AICRPDA 1978). Analysis of data on fertilizer from different locations indicated wide inter-crop and inter-regional variability in fertilizer use on dryland crops. Relatively stable dryland areas like Indore (Madhya Pradesh), reported relatively high levels of fertilizer use while in areas like Sholapur and Ahmadnagar (Maharashtra), fertilizer use was very low. One also found evidence of a fair amount of experimentation by farmers who fertilized (at low rates and on small areas) a fairly large number of crops including pulses. However, there were areas like Ahmadnagar where fertilizer use was practically non-existent.

All these studies suggest that farmers in the unirrigated SAT areas of the country are now generally aware of the importance of fertilizers and have started using fertilizers on crops which yield significant responses. While the area covered with fertilizers is generally low, rates of application are often moderately high. There is also some evidence to show that farmers are trying out fertilizers for crops like gram, greengram, and other pulses which have witnessed sharp price increases. This suggested that if the returns were attractice enough, farmers would be willing to use fertilizers even under unirrigated conditions.

It must also be pointed out that fertilizer use in SAT agriculture is characterized by very high interregional and inter-farm variability. Also, adoption levels are poor and discontinuous. A much deeper probe is needed to identify the underlying causes.

III. FACTORS AFFECTING FERTILIZER USE

The evidence on wide variability in the levels of adoption, nature and number of crops fertilized, the extent of area fertilized and rates of fertilizer application, over farms, crops as well as time (Desai and Bandhopadhyay 1973) underscores the need for understanding the need for understanding the underlying reasons. Drawing basically from microeconomic factor demand theory, several workers (Desai 1969; Desai and Bandhopadhyay 1973; Desai and Mellor 1969; Roy 1970) postulate that the size and certainty of returns from fertilizer use is the main determinant of fertilizer demand. Thus, prices (of inputs as well as output) play an important role as also the physical response from fertilizer application. Aggregative analysis usually considers price as the main determinant while

micro studies, emphasize, apart from prices, factors which influence the response function and also factors which influence the adoption and diffusion of an innovation. The following sections discuss the analytical approaches used in and the findings of macro and micro studies on fertilizer demand.

A. Macro-Level Analysis

(i) Price Factors

Two approaches have generally been used to measure the impact of price changes on fertilizer use. The normative approach uses fertilizer response functions and optimizing behavior assumptions to obtain demand for fertilizers using production functions or programming tools (Dhillon and Sidhu 1977; Dhillon and Sankhayan 1977; Ogunfowora and Norman 1973; Pal 1974). Usually (Dhillon and Sidhu 1977; Pal 1974) they show highly inelastic demand with respect to both fertilizer and output prices. However, in view of the fact that this approach does not (usually) consider factors like risk and also the wide diversity in response functions across locations, varieties and other factors, its usefulness in understanding the impact of price changes on fertilizer demand is rather limited (Timmer 1974).

Direct estimation of fertilizer demand functions from time series data on fertilizer consumption, prices and the prices of farm products, is the other approach. Both static and Nerlovian adjustment lag models have been used to derive aggregate fertilizer demand functions. A few such studies are available for India (Desai 1969; Parikh 1965; Parikh 1966; Patil 1978; Rao 1973).

Desai used a static regression model relating fertilizer consumption per hectare with real price of fertilizer (fertilizer price/index of output prices) and irrigated area for each year from 1957-58 to 1964-65 with 12 states as observation points (Desai 1969). Irrigated area turned out to be the dominant determinant of fertilizer use. Fertilizer price had negative coefficients and these were significant in five out of eight years. The price elasticity was not calculated. We worked back on the data and found the elasticities ranging from -1.84 to -3.60.

We also pooled Desai's data for 12 states and eight years and using appropriate estimation procedure, obtained the following aggregate demand functions:

$$F_t = 4.46 + \underset{(0.017)}{0.090I_t} - \underset{(0.311)}{1.253P_t}$$

where F = fertilizer (total plant nutrients) consumed in kg per ha,

I = percentage irrigated area, and

P = price of fertilizer/price of output.

Both the coefficients were highly significant and an elasticity value of -2.0 was obtained.

Parikh attempted to derive a similar static demand function using state level data from 1951 to 1961. Apart from fertilizer/output price ratio, irrigated area and trend were used as explanatory variables. The price coefficient did not turn out to be significant in any case. In a subsequent paper (Parikh 1966) has used data from 1958-59 to 1963-64 and employed covariance analysis technique to come up with a short run elasticity estimate of -1.2 and long run elasticity of -2.5. Rao's study, however, revealed smaller short run elasticity estimates (Rao 1973).

All these studies have shown the importance of irrigation as the major determinant.

It has been argued (Timmer 1973) that the influence of prices on fertilizer demand operates through two mechanisms -- it directly affects the equilibrium demand level and also has an indirect effect through its impact on the rate of diffusion. Timmer holds:

> "In arguing the role of price policy in speeding the rate of growth of fertilizer demand, it is essential to keep these mechanisms separate. For the direct impact, there is no substitute for the price role. For the indirect impact several substitutes are possible, including greater extension effort, fertilizer trials and demonstrations, an active private fertilizer marketing system, and so on. Whether they are better social investments than an incentive price policy is obviously an empirical issue to be resolved in specific contents" (Timmer 1973).

Desai pleads strongly for the second option in context of rapid growth of fertilizer use in Indian agriculture and argues that (Desai 1978):

> "...it is these efforts (growth in irrigated areas, diffusion of HYV on rainfed areas and diffusion of fertilizer use under unirrigated conditions), more than marginal manipulations of (fertilizer) prices which will determine the limits and pace of further growth in cultivators' demand for fertilizers" (Desai 1978, parentheses added).

This obviously implies that the positive impact of such measures will offset the negative impact of a price rise. The evidence on the impact of irrigation lends strong support to this view. Results obtained by Maharaja for determinants of fertilizer consumption in Gujarat over the period 1960-61 to 1969-70 obtained by pooling cross-section (districts) and time series data, are interesting in this context (Maharaja 1975). He found that during a period characterized by rapid

technological change (post-1965), the effect of price did not become overt -- the technology variable swamped it. However, when the effect of technological change was netted out, the normal price effect became discernible. He argued:

> "...during a particular year, though fertilizer consumption may decline on account of unfavorable price ratios, the decline in consumption may be more than compensated to the extent to which technological change is injected in the region" (Maharaja 1975).

(ii) Other Factors

Some other variables which influence fertilizer consumption at the macro level are aggregate availability of fertilizers (domestic as well as import supplies), the efficiency and spread of the distribution system (Desai 1978), the parameters of aggregate demand for agricultural products (Timmer 1974), technological change in both fertilizer production and agriculture, the status of fertilizer promotion and extension activities and, perhaps, the nature of distribution of productive resources in agriculture. Not much empirical work has been done on comprehensive macro models encompassing all these variables. Capital constraints (usually proxied by income) and education have been used in some studies using static models (Colmenares 1975; Heady and Tweeten 1963; Heady and Yeh 1959) and were found to affect fertilizer use.

The dynamic adjustment lag model assumes that variables like capital constraint and education affect fertilizer consumption through their impact on the rate of adjustment and some empirical testing of this proposition has been done (reported in Timmer 1974), with respect to the effect of education on the speed of adjustment. The results indicate that education leads to a speeding up of the rate of adjustment.

The study by David on fertilizer demand of Asian rice farmers attempts to integrate micro and macro approaches (David 1974). It uses cross-sectional farm level data from several countries and specifies a demand model which includes variable measuring differences in fertilizer response functions across locations in addition to fertilizer/product price ratio and liquidity position of the farmers. The results indicate that differences in response functions and prices play an important role in explaining fertilizer use on farms.

B. Micro-Studies on Fertilizer Demand

Most of the studies in India have looked at fertilizer use from the micro angle. A large number of variables -- technological, economic, socio-psychological and environmental, have been hypothesized to influence farmers' decisions to use fertilizers. It has been postulated that the farmer has to make three related decisions (i) whether to use fertilizers, (ii) which crop(s) to fertilize and (iii) at what rates (Desai 1969; Desai et al. 1973). The first is basically a function of the state of awareness and knowledge of the farmer regarding fertilizer use on crops he commonly grows. The factor relevant here are the socio-psychological attributes influencing adoption and the level of extension activities. The other two decisions are primarily governed by profitability of fertilizer use at the farmers' level. Two factors are crucial here -- the response to fertilizer application and fertilizer and prices. Desai's work has shown that (Desai 1969; Desai et al. 1973; Desai and Mellor 1969; Desai and Singh 1973): (i) the returns from fertilizer use must be quite substantial before farmers are induced to use fertilizers,

(ii) the allocation of fertilizers between crops is a function of relative profitability of fertilizer use and so long as capital constraints restrict the size of the fertilizer stock of the farmer, some crops and some proportion of the area will be left unfertilized, and (iii) the rate of fertilizer application is influenced by the nature of the response function, the discounting yardsticks used by farmers and the ability of the farmers to buy fertilizers.

The response function plays a crucial role in this process. Since it is affected by a large number of factors, the latter also became relevant determinants of fertilizer demand. This is how factors like variety (HYV or local), irrigation, soil type and fertility status, use of organic manures, rotation, rainfall, etc. enter the picture. Variables which influence the technical efficiency of fertilizer use like method of application, time of application, choice of the fertilizer material, etc. also assume importance in this context.

Factors like tenancy, farmer's asset or liquidity position, credit, markets etc. affect farmers' decisions to use fertilizers through their impact on profitability (tenancy) or his ability to buy and use fertilizers. Alongwith cropping pattern these are usually included to explain inter-farm differences in fertilizer use. Then we have variables influencing adoption like age, education, socioeconomic status, extension contacts, farmers' attitude towards risk and subsistence, etc. (Jones 1964).

The following paragraphs indicate the hypothesized effect of some important variables and also the results obtained in earlier studies.

1. Response to Fertilizer

Response to fertilizer determines the rate of application and also the

crops to be fertilized. It has been shown that farmers' allocation of fertilizers among crops is determined by relative responses or relative profitability of fertilizer use (Aklilu 1978; Desai 1969; Desai and Mellor 1969; Maharaja 1975). Similarly, differences in response functions have also been found to explain variability in fertilizer application rates (David 1974; Roy 1970). It is not always possible to measure differences in response and several workers use factors which influence response to explain inter-farm or inter-crop differences in fertilizer use. For example, a number of studies (Desai and Singh 1973; NCAER 1974; NCAER 1978) show that both area fertilized and rates of application are higher for HYV than for local. Irrigation is one of the most important factors affecting response, not only in terms of shifting the response curve upwards, but also by imparting stability. Hence almost all studies show the positive influence of irrigation (Desai and Sharma 1966; Desai 1969; Desai et al. 1973; Desai and Singh 1973; Jayaraman 1979; Maharaja 1975; NCAER 1974; NCAER 1978; Panse and Singh 1966; Shetty 1969). Several have indicated concentration of fertilizer use on irrigated lands (Desai and Singh 1973; Griliches 1958; Maharaja 1975; NCAER 1974; NCAER 1978). Rainfall during the pre-sowing and growth periods of the crop also exercises a similar influence (Jayaraman 1979; Maharaja 1975) and its effect is likely to be much more important under rainfed conditions. Use of organic manures affects fertilizer use in two ways. Some empirical studies (Krishnaswamy and Patel 1973) have shown negative association between use of organic manures and fertilizers as farm size increases and have infered that small farmers substituted organic manures for fertilizers. But others (AICRPDA 1978; NCAER 1974) have generally reported complementarity between

the two. Soil type and quality is another important variable affecting response but very few studies have used it to explain fertilizer use differences between farmers. There is so much heterogeneity in soil quality even within a small area that it is difficult to obtain data on plotwise soil characteristics and capture this effect. Desai and Singh attempted to examine growth of fertilizer use by broad soil types and found high growth of nitrogen use in districts having deltaic alluvium and calcareous seirozenic soil types. With respect to growth in phosphorus use, deltaic alluvium again ranked first followed by black or black plus others (mixed red and black, red and yellow, coastal alluvium) soil types (Desai and Singh 1973). The latter are important in SAT India. Shetty found fragmentation -- another quality aspect of the farmer's land, to be an important factor influencing fertilizer use. The cropping history and fertilization practices followed on the plot in the preceding seasons also affects fertilizer use. It is hypothesized that crops following legumes are fertilized at lower nitrogen levels and that if heavy rates of fertilization (particularly phosphorus) were used in the preceding season, fertilizer use in the following crop would be lower. While we have no evidence on the former, it has been reported (Desai et al. 1973) that crops following heavily fertilized chilli or tobacco crop in Guntur district were either not fertilized or fertilized at very low rates. On factors affecting technical efficiency of fertilizer use like time and method of application, choice of fertilizer material, etc. we have very little evidence from farmer's fields. The Guntur study (Desai et al. 1973) showed that farmers initially started with nitrogen use (as they seem to be invariably doing) on groundnut crop but quickly switched over to

phosphorus. There was also clear evidence on a move towards more balanced use of fertilizers by farmers in the Guntur area. This study also showed that farmers used nitrogen mostly in the form of straight fertilizers and phosphorus in the form of complex fertilizers. It was infered that complex fertilizers have played an important role in promoting phosphorus use. These changes have come about gradually.

2. Farm Characteristics

Cropping patterns have been found to be an important factor explaining inter-farm and interregional differences in fertilizer use (Desai 1969; Desai et al. 1973; Desai and Singh 1973; Jayaraman 1979; Maharaja 1975; NCAER 1978). Fertilizer use varied directly with the proportion of irrigated crops and the proportion of market crops (not necessarily commercial crops). The NCAER study suggested that the fertilization rates on a crop declined as the proportion of area occupied by the crop increased and also as the intensity of cropping increased (NCAER 1974). The effect of farm size on fertilizer use is rather ambiguous because it exerts two (opposing) kinds of influence. Since small farmers generally cultivate their holdings with greater intensity and fertilizer is a land augmenting factor (Akilu 1978), they tend to use more fertilizer per unit area as compared to the larger farmers. This implies a negative association between farm size and fertilizer use. On the other hand internal capital rationing and also poor access to the credit markets for small farmers often results in a positive association. Not surprisingly therefore, studies which use farm size as a factor explaining inter-farm differences in fertilizer use, come up with conflicting results. Most of them find negative association (Desai and Sharma 1966; Krishnaswamy and Pa l 1973; NCAER 1978) some report positive association (Colmenares 1975; David 1974)

and some report inconclusive results for different crops (NCAER 1974). Almost all studies, however, show that adoption of fertilizers and the extent of area fertilized are positively correlated with farm size -- at least in the initial phases (Akilu 1978; Colmenares 1975; Mukherjee 1970; NCAER 1974; NCAER 1978; Panse and Singh 1966).

Farmer's ability to buy fertilizers (liquidity) has been measured in terms of assets or income of the farmer and its effect on fertilizer use has been studied hypothesizing a positive association. The NCAER study shows a positive influence for some crops but others find inconclusive results with respect to rates of application (NCAER 1974; David 1974). Once again, this variable was found to have a more powerful influence the acceptance, adoption and extent of area fertilized (Choudhary and Maharaja 1966; Savale 1966; Shetty 1969). Credit is another variable which has been considered important. In the regression analysis attempted by NCAER this variable emerged significant for only one crop though tabular analysis showed that this factor was quite important (NCAER 1974). The more comprehensive recent study (NCAER 1978) does not give a clear picture in this regard though in terms of reasons on non-adoption, this was frequently indicated to be very important (AICRPDA 1978; NCAER 1974; NCAER 1978). The Guntur study (Desai et al. 1973) showed that capital was not a constraint in this area. However, a normative analysis for another high fertilizing area -- Punjab, showed very significant impact of credit on fertilizer use (Cancian 1977).

It has been hypothesized that tenant farmers apply lower rates of fertilizers. Some studies (NCAER 1974) support this hypothesis and others do not (Desai 1969; Desai et al. 1973; Mukherjee 1970). Most of the studies which investigated the impact of this variable on adoption, found the hypothesized negative association (Shetty 1966; Shetty 1969). Some (Choudhary and Maharaja 1966; Desai 1969; Desai et al. 1973) found no systematic association. It needs to be mentioned here that tenancy would affect profitability of fertilizers and hence its adoption and use depending upon the terms of tenancy (Colmenares 1975; Perrin et al. 1976). For example, if the tenant bears the cost of all inputs and then has to part with some proportion of his output as rent, the profitability of fertilizer use for the tenant goes down and hence this form of tenancy will affect fertilizer use adversely. If however, the inputs and output are equally shared, or if the landlord pays for the cash inputs or if a fixed rent tenancy exists, the profitability does not alter because of tenancy. None of the studies have looked into this aspect and hence we do not get a clear picture.

Access to markets has also been considered as a factor affecting adoption and levels of use because of its impact on transportation costs of fertilizers. The study by Savale showed negative association between adoption level of fertilizer and distance from the market (Savale 1966). This variable has not been considered in most of the studies.

3. Sociological Factors

Age of the farmer was found to influence the adoption of fertilizers (Shetty 1969). As regards level of fertilizer use, the NCAER study found negative relationship in most of the cases suggesting higher conser-

vatism of older farmers. Education level of the farmer exerts a positive influence on fertilizer use. The two studies which have examined its effect on the rate of application (Desai and Sharma 1966; NCAER 1974) did not find a significant association. However, this variable was found to influence adoption and diffusion of fertilizer use in the hypothesized manner (Choudhary and Maharaja 1966; Colmenares 1975; Desai et al. 1973; Shetty 1969).

The socioeconomic status of the farmer is assumed to be positively associated with fertilizer use. However, its effect is also captured by variables like farm size, assets, income, education, etc., and in a functional relationship it rarely shows up. It has been argued that (Cancian 1977) in the early stage of adoption, the relationship between adoption and economic status (measured as asset, etc.) is not a linearly rising one. This has important methodological implications in terms of specifying the nature of the adoption curve. The experience which farmers have about fertilizers is believed to be important in determining rates of fertilization (Desai 1969). The NCAER study showed that farmers who had been using fertilizers for longer periods generally used higher levels.

The subsistence needs of the farmer measured usually by family size or consumption units in the family may prompt farmers with higher family consumption obligations to use more fertilizers. The results obtained (NCAER 1974) are inconclusive.

Some variables like extension or urban contact (Aklilu 1978; Shetty 1969) and certainty of returns (Colmenares 1975; Desai 1969; Savale 1966) have also been argued to be important but not much work has been done to test these. The latter (uncertainty and risk) has received

quite a bit of attention recently at the theoretical level. The fact that this could be an extremely important factor under unirrigated conditions is suggested by the result obtained on variability of profits from fertilizer use on maize, sorghum and pearl millet (Kanwar et al. 1973). We have collaborative evidence from the semi-arid areas (AICRPDA 1978) which shows that uncertainty regarding yield and fear of heavy loss due to crop failure is the major reason behind non-adoption of fertilizers by farmers in dryland areas. It has been argued (Colmenares 1975; Gerhart 1974) that in restricted environments, risk aversion may be an important determinant of adoption. Some evidence from Colombia (Colmenares 1975) suggests that farmers' attitudes towards risk (aversion) and perception riskiness have significant impact on fertilizer adoption and use.

Two methodological points need to be made in this context. It has been shown that the commonly used method of studying the characteristics of adopters and non-adopters with a view to identifying their influence, could lead to misleading conclusions. Classification of farmers as adopters and non-adopters at a point in time, does not really make sense because the same farmer often moves from one category to the other (Desai et al. 1973).

Secondly, it has been pointed out (Gaikwad et al. 1969) that some of the factors are more relevant for acceptance and adoption (like education, experience, extension contact, etc.) than for levels of application. In other words, the relative importance of various factors varies at different stages of the adoption process (awareness, trial, adoption, diffusion) (Aklilu 1978). Viwed in this light, the conflicting results obtained by various workers can be explained. Except for one study

(Desai et al. 1973), this aspect has been ignored in others.

C. Analytical Approaches

Some workers have used parametric programming procedures to examine the impact of factors like price changes, capital constraint and irrigation on fertilizer use (Dhillon and Sidhu 1977; Dhillon and Sankhayan 1977; Ogunfowora and Norman 1973; Sankhayan and Sirohi 1972) and have found the hypothesized effects to hold. Such studies always pertain to some kind of an average farm situation. A large number of factors cancel out during this averaging and it is not an easy task to parameterize all of them. Thus, this approach can provide only a restricted understanding of farmer's fertilizer use decisions.

Multiple regression analysis appears to offer a better alternative and has been attempted in several studies (Colmenares 1975; David 1974; Jayaraman 1979; Maharaja 1975; NCAER 1974) with varying degrees of success. The main problems here are the very large number of variables and high inter-correlations between them. The data requirement itself poses the most serious problem. Empirical work in this area has, therefore, been scanty and inadequate.

The choice and specification of variables requires considerable care, not only from multicollinearity angle but also from simultaneity point of view. Inclusion of factors like organic manures, variety, etc. (decisions on which are jointly made with fertilizer use decisions) in the demand function creates simultaneity bias. Again some variables included in the model could represent more than one effect, for example, farm size could depict economic status as well as land-fertilizer substitution.

It is not easy to interpret the coefficient. The definition of the dependent variable itself matters a lot in choice and specification of causal variables. All the variables which are used to explain differences in fertilizer use per hectare of gross cropped area cannot be used as such when cropwise analysis is attempted. Finally, one needs to sort out factors which are important for adoption and factors which are useful for explaining differences in levels of fertilizer use. Both are influenced by the same set of variables but their relative importance differs. No one has attempted this and hence the results are often blurred.

Irrigation, cropping pattern, capital rationing and size and certainty of returns from fertilizer use are perhaps the major determinants of farmers' demand for fertilizers in SAT areas. As has been shown, no empirical study exists which looks at fertilizer use problems in this environment. In view of the fact that fertilizers form one of the important elements of the technologies being evolved for dryland agriculture, the need for an intensive study on this aspect cannot be over emphasized. Absence of knowledge regarding forces motivating farmers to use fertilizers and the magnitude of these forces could pose a major constraint when these technologies are finally offered to the farmers.

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Appendix I. Allocation of phosphorus among crops in ten states : NCAER 1975-76

Crop	Punjab	Haryana	Uttar Pradesh	Andhra Pradesh	Tamil Nadu	Guja-rat	Mahara-shtra	Madhya Pradesh	Karna-taka	Rajas-than
1. Paddy	11.0	14.[illegible]	3.1	22.6	72.7	4.7	18.7	13.7	40.4	0.1
2. Maize	4.0	1.4	0.1	nr	nr	nr	nr	1.5	0.6	0.1
3. Kharif sorghum	nr	nr	nil	nr	1.5	1.1	13.5	nr	8.5	nr
4. Rabi sorghum	nr	nr	nr	nr	1.1	nr	1.3	nr	2.5	nr
5. Pearl millet	nr	8	0.8	nr	nr	10.3	2.1	nr	nr	nil
6. Ragi	nr	nr	nr	nr	1.0	nr	nr	nr	5.9	nr
7. Cotton	5.4	0.7	nr	3.7	5.5	23.9	14.8	nr	2.8	13.9
8. Groundnut	nr	nr	nr	4.0	2.0	27.7	5.4	nr	3.3	nr
9. Chillies	nr	nr	nr	12.5	nr	nr	nr	nr	nr	nr
10. Tobacco	nr	nr	nr	3.8	nr	nr	nr	nr	nr	nr
11. Wheat	74.9	57.1	77.5	nr	nr	15.9	17.0	70.0	5.4	79.6
12. Sugarcane	0.2	21.2	11.1	8.6	8.4	1.2	16.1	2.4	23.6	3.2
13. Others	14.0	5.0	8.0	21.1	11.4	26.6	28.1	16.3	24.5	3.2

nr. Not reported
n. Negligible

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