RESEARCH REPORT

SUSTAINING RAPID GROWTH IN INDIA'S FERTILIZER CONSUMPTION: A PERSPECTIVE BASED ON COMPOSITION OF USE

Gunvant M. Desai

August 1982

INTERNATIONAL
FOOD
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Research Report 31
International Food Policy Research Institute
August 1982

Library of Congress Cataloging in Publication Data

Desai, Gunvant M.
Sustaining rapid growth in India's fertilizer consumption.

(Research report ; 31)
Includes bibliographical references.
1. Fertilizers–India. 2. Fertilizer industry–India. I. Title. II. Series: Research report (International Food Policy Research Institute) ; 31.

S633.5.I4D473 1982 338.1'62 82-15521
ISBN 0-89629-032-8

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FOREWORD

The International Food Policy Research Institute, as part of the Consultative Group on International Agricultural Research, is profoundly concerned about the new agricultural technology and the policies needed to encourage its adoption and increase its effectiveness in meeting major societal objectives. The spread of high-yielding varieties depends greatly on increases in fertilizer availability to farmers. Likewise, continued rapid growth in fertilizer use depends on new crop varieties that can provide greater yields in response to larger doses of fertilizer. It is clear that during the next few decades the food supplies necessary to meet even minimum expected rates of population growth and growth in per capita income cannot be realized without the development of this symbiotic fertilizer-research relationship.

In this research report, Gunvant M. Desai demonstrates that growth in fertilizer use is a complex function of many variables that must be seen in relation to each other if an effective expansionary policy is to be developed. He notes that in the past there has been a lack of understanding of the importance of ample, assured supplies of fertilizer. Without increased fertilizer supplies, expanded fertilizer use will not be possible, and fertilizers will be confined to the crops and places where they have been most profitable in the past. He suggests that growth in fertilizer use has been constrained by the role of foreign assistance in financing fertilizer imports for developing countries, the large fluctuations in the size and timing of such foreign assistance allocations, and fluctuations in foreign exchange availability due to changes in export demands and prices. This has been exacerbated by deficiencies in administration of fertilizer supplies.

Desai analyzes these and other issues through the Indian experience. He provides a basis for understanding that experience and developing policies to continue fertilizer growth in India in the face of the more difficult economic environment for fertilizer use. Perhaps most valuable, this research provides a model for similar in-depth analyses in other countries.

Desai has spent almost 20 years exploring the complex factors of fertilizer use, which his study reflects in its thorough and highly integrated approach. This analysis will be followed by another research report that will include a comparison of other countries and provide the basis for other intensive analyses at the country level.

John W. Mellor

Washington, D.C.
August 1982

ACKNOWLEDGMENTS

The author is especially indebted to John Mellor for his encouragement and counsel during every stage of his research on fertilizers. He is also grateful to Per Pinstrup-Andersen, Mohinder Mudahar, A. J. S. Sodhi, Marc Nerlove, Yair Mundlak, J. S. Sarma, Ammar Siamwalla, and Alberto Valdés. Although they have all read an earlier version of this report and the present version has benefited greatly from their comments, the author alone remains responsible for any errors or deficiencies that may still be present. Tom Quinlivan provided competent research assistance and Tricia Klosky was most helpful in locating relevant materials.

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SUMMARY

It is well known that fertilizer consumption in the developing countries is low and needs to be raised; what is not so commonly recognized is that in some of them fertilizer use has grown enormously. The complexities of generating sustained rapid growth in fertilizer use are also not understood fully.

India's fertilizer consumption rose to about 5.5 million metric tons of nutrients in 1980/81 from less than 100,000 tons in the early 1950s. It now ranks fourth after the United States, the U.S.S.R, and China. But consumption per unit of land is still considerably less than in these and many other countries. The future requirements of agricultural production also point out the need for sustaining rapid growth in fertilizer consumption.

This study attempts to identify key policy areas that can sustain rapid growth in India's fertilizer consumption by developing a perspective on the major forces behind the past growth. The perspective is based on changes in the composition of total fertilizer use. Consumption profiles by crop are developed using the findings of the surveys conducted by the National Sample Survey Organisation (NSS) and the National Council of Applied Economic Research (NCAER) between the early 1950s and the mid-1970s. Three aspects are examined: shares of crops in total fertilizer consumption, diffusion of fertilizer use by crop, and average rates of use on fertilized areas by crop. Wherever possible, separate profiles are also developed for irrigated and unirrigated areas and areas sown with traditional varieties as compared with those sown with improved and high-yielding varieties. These findings are then used with available research on other aspects of fertilizer use to discuss the major forces behind the past growth and the policies required to sustain rapid growth in fertilizer consumption in the 1980s.

Forces behind growth in fertilizer consumption are commonly identified by estimating one aggregate fertilizer demand function from time-series data. This implies that changes in total fertilizer consumption are due to changes in the variables behind farmers' demand for fertilizer. In developing countries like India, however, such an interpretation of the time series would be logically incorrect. There are possibilities of growth in fertilizer demand without changes in demand-governing variables such as prices because of the sizable untapped economic potential of fertilizer use. Similarly, the pace and pattern of growth in fertilizer consumption depend not just on growth in farmers' demand for fertilizer. Growth of fertilizer supplies, expansion of distribution networks, and development of the supporting systems of agricultural research, extension, and credit, as well as how these processes interact, are also important. Examining the changes in the composition of total consumption in the course of growth in fertilizer use provides a meaningful basis to pursue such inquiry.

Until the mid-1940s fertilizer use was confined to the plantations, and to sugarcane, rice, and tobacco in the nonplantation sector. It spread to many food and nonfood crops after the government launched the Grow-More-Food Campaign. By 1955/56 food crops had a share of about 70 percent in total consumption of about 125,000 tons of nutrients. Tea, coffee, and rubber plantations consumed about 25 percent, and the remaining 5 percent went to nonfood crops like cotton, jute, groundnuts, and tobacco. The 70 percent share of food crops included about a 45 percent share of foodgrains and a 25 percent share of other food crops like sugarcane, spices, and potatoes. Among foodgrains, rice dominated with a share of about 37 percent whereas all other foodgrains had a combined share of only about 8 percent.

In the subsequent two decades total fertilizer consumption increased to 3.4 million tons of nutrients. The composition of consumption also changed substantially in certain respects. By 1976/77 the share of food crops had increased to more than 80 percent whereas that of the plantations had dropped to about 6 percent. More importantly, the share of foodgrains had increased to about 70 percent. This was mainly due to

the rise in the share of wheat from only 3 percent in 1955/56 to about 22 percent in 1976/77. The share of rice had remained virtually unchanged, and that of foodgrains other than rice and wheat had increased from 5 percent to only 10 percent. The share of nonfood crops had risen to about 11 percent mainly because of growth in consumption of cotton and groundnuts after the late 1960s.

The above changes were primarily an outcome of the varied pace of diffusion of fertilizer use (measured as changes in percentage of crop area fertilized) on different crops. By 1976/77 fertilizer use had spread to 55 percent of wheat area and 45 percent of rice area as opposed to 12 percent of bajra area and less than 5 percent of area sown with minor cereals and pulses. Among nongrain crops, it had spread to more than 70 percent of area sown with sugarcane, potatoes, chillies, and tobacco as compared to about 40 percent of area sown with cotton, jute, and groundnuts. On many crops, notably wheat, jowar, bajra, cotton, and groundnuts, diffusion of fertilizer use was much faster in the 1970s than in the previous two decades.

Average rates of application on fertilized area were quite low for all crops in the mid-1950s. In the following 20 years they increased on all crops. By 1976/77 average rates in terms of nutrients per fertilized hectare reached about 300 kilograms on potatoes, 150-170 kilograms on sugarcane and chillies, 70-85 kilograms on rice, wheat, and cotton, and 40-60 kilograms on most other crops. Between 1970/71 and 1976/77 the rates on many crops increased by 40-50 percent. Throughout the period covered by the findings, there was more cross-sectional variation among crops with respect to percentages of area fertilized than average rates on fertilized area.

Irrigated area, accounting for less than one fourth of the total area sown, had a share of 70 percent or more in total fertilizer consumption between the mid-1950s and the mid-1970s. For each crop the share of irrigated area in fertilizer consumption was also higher than the percent of crop area irrigated. This was so because both diffusion and rates of fertilizer use were higher on irrigated areas than on unirrigated areas. But for each crop the difference in diffusion between the two types of areas was considerably greater than in rates of application.

Despite greater diffusion, only about two thirds of total irrigated area was fertilized by 1976/77. Even for sugarcane, wheat, and rice, fertilizer use had not spread to 25-30 percent of irrigated area under them. For other crops this percentage was higher.

Fertilizer use had spread to about 18 percent of total unirrigated area by 1976/77. Crops more commonly fertilized under unirrigated conditions were the same as those more commonly fertilized under irrigated conditions. After 1970/71 there was an acceleration in the diffusion of fertilizer use on cotton, groundnuts, and jowar under unirrigated conditions.

Larger percentages of areas sown with high-yielding and improved varieties were fertilized, and at higher rates, than those sown with the traditional varieties. But there was less than complete diffusion of fertilizer use even on the former. This was particularly true under unirrigated conditions. In 1976/77 the share of high-yielding and improved varieties in fertilizer consumption on eight major crops was about 60 percent. It ranged from about 10 percent on groundnuts to about 80 percent on cotton and wheat. On rice it was 55 percent.

The study confirms what many microstudies have revealed about the dominant influence of certain crops, irrigation- and fertilizer-responsive varieties, on the pace and pattern of growth of fertilizer consumption. This implies a greater relative importance of physical productivity of fertilizer than of prices in influencing growth of farmers' fertilizer demand, particularly until total consumption reaches its economic potential. However, the findings based on nationwide surveys also suggest that past growth could have been faster. This is evident from less than complete diffusion of fertilizer use on each and every crop, even under irrigated conditions, by the mid-1970s. The slow but steady growth in fertilizer use under unirrigated conditions, even on the traditional varieties, also indicates farmers' willingness to tap the economic potential of fertilizer use under such conditions.

Past growth in fertilizer consumption was adversely affected by: inadequate efforts to promote fertilizer use on foodgrains other than rice and wheat, oilseeds other than groundnuts, and unirrigated areas in general; slow expansion of and inefficiencies in the distribution system; repeated shortfalls in domestic fertilizer production; and wide

year-to-year fluctuations in fertilizer imports. Often these deficiencies in the fertilizer system were mutually reinforcing.

India's Sixth Five-Year Plan aims at raising fertilizer consumption to 9.7 million tons of nutrients in 1984/85. To achieve anything like this, it will be crucial to achieve the Sixth Plan's irrigation target and also to accelerate growth in fertilizer use under unirrigated conditions. The latter calls for sustained efforts to expand distribution networks in districts with low irrigation and to promote fertilizer use in such districts. It is necessary to recognize that the extent and vigor of these efforts will critically depend on total fertilizer supply staying ahead of growth in the market for fertilizer under irrigated conditions.

2

INTRODUCTION

The economic potential of fertilizer use in a country is determined by fertilizer response functions, cost of fertilizer, and prices of crops. Actual fertilizer use is an outcome of the conversion of the economic potential into farmers' demand for fertilizer, and this demand being met by fertilizer supply and distribution systems.

Since it was invented in the mid-nineteenth century,[1] the use of chemical fertilizer in any country has begun with a few farmers at selected locations.[2] This implies that the beginnings of fertilizer use were below economic potential.[3] The existence of untapped potential implies possibilities of growth in fertilizer use through interactions between fertilizer demand, supply, and distribution even without changes in the agro-economic variables determining the economic potential of fertilizer use. Biological breakthroughs in crop production and changes in prices influence not only the potential but also the pace of growth in fertilizer consumption. However, so long as there is untapped potential, it would be incorrect to attribute all changes in levels of fertilizer consumption to changes in response functions and prices,[4] or to put undue emphasis on prices as policy instruments for generating growth in fertilizer use. Under such circumstances policies that generate and spread knowledge about the response functions, promote geographical expansion of fertilizer distribution systems, and increase fertilizer supplies in a coordinated manner may be more effective in accelerating growth in fertilizer consumption.

Appreciable fertilizer use in many developing countries is relatively recent.[5] Their low levels of consumption per unit of arable

[1] The use of water-soluble inorganic compounds such as saltpeter and sodium nitrate was not unknown before the 1840s. The production and consumption of chemically manufactured fertilizer began in the 1840s after the chemistry of soils and plants began to be understood as a result of the research of De Saussure, Boussingout, Liebig, and Lawes and after commercial production of sulfuric acid began. For the evolution of the concept of fertilizer and the early development of the fertilizer industry, see Mirko Lamer, *The World Fertilizer Economy* (Stanford, Cal.: Stanford University Press, 1957); Theodore J. Krepps, *The Economics of the Sulfuric Acid Industry* (Stanford, Cal.: Stanford University Press, 1938); Vincent Sauchelli, *Manual on Fertilizer Manufacture*, 3rd ed. (Caldwell, N.J.: Industry Publications, Inc., 1963); and International Fertilizer Development Center, *Fertilizer Manual* (Muscle Shoals, Alabama: IFDC, 1979).

[2] Information is readily available for only a few countries, but it is not difficult to surmise that this is a typical beginning for fertilizer use, which requires that farmers be aware of it in order to adopt it. Supply and distribution systems must be in place for fertilizer use to spread. Thus it would be unrealistic to assume that fertilizer use begins simultaneously with all farmers for whom it is potentially profitable.

[3] Empirically, the existence of the untapped viable potential of fertilizer use is manifested as less than complete diffusion of fertilizer use and suboptimal rates of application, even on fertilized land under a given set of fertilizer-response functions and prices. The reasons for untapped potential range from farmers' lack of knowledge about potential returns from fertilizer use to various inadequacies in the fertilizer distribution and supply systems. For further discussion, see Gunvant M. Desai, "Understanding the Process of Growth in Fertilizer Consumption: A Conceptualization," International Food Policy Research Institute, forthcoming research report.

[4] This is the very essence of the methodology that determines the factors governing growth in fertilizer consumption of a country by estimating a fertilizer demand function from time series on total fertilizer consumption, prices of crops and fertilizers, and variables behind fertilizer response functions (such as crops, crop varieties, irrigation). This specification implies that the nonstochastic changes in time series of fertilizer consumption are due only to the changes in the explanatory variables, which cannot be correct so long as there is untapped viable potential for fertilizer use. For other limitations of this methodology, see Desai, "Understanding the Process."

[5] During the first century of its use, more than 85 percent of the world fertilizer consumption was concentrated in about a dozen countries of Western Europe, the U.S.S.R., the United States, and Japan. Even in the early 1950s, the share of developing countries (the developing market economies and the Asian centrally planned economies) in the world fertilizer consumption of about 20 million tons of nutrients was only 7 percent. For an historical perspective on fertilizer consumption in different countries, see Lamer, *World Fertilizer Economy*. Also see K. G. Clark and Mildred S. Sherman, *Pre-War World Production and Consumption of Plant Foods in Fertilizers*, Miscellaneous Publication No. 593 (Washington, D.C.: U.S. Department of Agriculture, 1946).

land suggest that much of the cropland is not yet fertilized.[6] Trials conducted under field conditions in many countries indicate substantial untapped potential.[7] There is also growing evidence of deficiencies in agricultural research and extension as well as in fertilizer distribution and supply systems. This indicates the relevance of distinguishing between agroeconomic variables and fertilizer demand, distribution, and supply systems. These considerations are particularly important in developing policies related to growth in fertilizer use.

A crop-by-crop perspective is useful for understanding growth in a country's fertilizer consumption because returns on its use vary among crops due to differences in the responses to fertilizer use and in crop prices.

When fertilizer use begins in a country, many farmers are unaware of its advantages. Those who are aware do not know the fertilizer responses of all the crops they grow. Fertilizer use, therefore, begins not only with a small number of farmers at a limited number of locations but also with the exclusion of some crops that could potentially profit from it. Fertilized crops receive suboptimal rates of application because of a lack of knowledge about response functions and because of farmers' attitudes toward risks and uncertainties.

Such beginnings imply that the time series on growth in total fertilizer consumption includes changes in consumption by crop. It also implies that growth in fertilizer consumption on an individual crop is an outcome of the changes in the area sown with the crop, diffusion of fertilizer use on the crop, and rate of application on fertilized area sown with the crop. The net effect of these changes determines the growth in aggregate fertilizer consumption for a crop.[8]

The above changes would be governed by the spread of an awareness of fertilizer among farmers, their fertilizer adoption behavior, and growth in their knowledge about the responses of different crops to fertilizer use under their own farm conditions. In addition to changes in farmers' demand at microlevels, growth in aggregate fertilizer consumption would also be affected by the factors governing fertilizer distribution and supply systems. Thus the pace and pattern of growth in fertilizer consumption is an outcome of interactions among all these elements.

Using the framework described, this study attempts to understand the major forces behind the past growth in India's fertilizer consumption. The understanding is then used to identify key areas of public policy that would sustain rapid growth of fertilizer use in the 1980s. Through empirical analysis of the Indian experience, the study also aims at demonstrating the usefulness of the approach adopted here in asking pertinent questions about growth in fertilizer use in developing countries.

The study develops fertilizer consumption profiles by crop for India at a few points in time between the early 1950s and the mid-1970s. During the period total fertilizer consumption increased from less than 100,000 metric tons to about 3.5 million tons in terms of nutrients.[9] Consumption per hectare of gross sown area increased from less than 1 kilogram to about 20 kilograms.

India has a multicrop agriculture. Rice has about 22 percent of the gross sown area and wheat and jowar about 10 percent each. The remaining area is sown with more than 30 crops, both food and nonfood. Virtually all nonplantation crops are grown on farms

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[6] For all developing countries taken together, the consumption per hectare of arable land was 43.9 kilograms of nutrients in 1979/80. For a large majority, it was lower than 15 kilograms per hectare. For details see Food and Agriculture Organization of the United Nations, *Fertilizer Yearbook, 1980* (Rome: FAO, 1981).

[7] For evidence, see Food and Agriculture Organization of the United Nations, *FAO Fertilizer Programme: 20 Years of Increasing Crop Yields, 1961-1981* (Rome: FAO, 1981). Also see Saleem Ahmed and Nazir Ahmed, "Calculating the Potential Annual Global Fertilizer Requirement Using the Recommended Rate Method: Some Tentative Results," Resource Systems Institute, East-West Center, Hawaii. (Mimeographed.) Current consumption as a percentage of estimated potential, according to the study, is 4-7 percent for Africa, 10-20 percent for Asia, and 20-30 percent for Latin America. Continuous rapid growth in fertilizer consumption of the developing countries in the post-1973/74 price environment also demonstrates the existence of untapped potential for fertilizer use in these countries. See Gunvant M. Desai, "Commentary: The Fertilizer Question," *IFPRI Report,* September 1980.

[8] For empirical evidence on this aspect for the United States and a number of other developed and developing countries, see Gunvant M. Desai, "Understanding Growth of Fertilizer Consumption: Anatomy of the Dependent Variable," International Food Policy Research Institute, Washington, D.C., 1981. (Mimeographed.)

[9] All tons in this report are metric tons.

of all sizes in different parts of India. Therefore, changes in fertilizer consumption by crop provide a meaningful basis for identifying major variables and processes behind the past growth in fertilizer use.

Appreciable fertilizer use began in India in the 1920s on tea plantations. During the 1930s use spread to sugarcane and rice in certain areas. Although the low fertility of Indian soils has been recognized since the 1890s, fertilizer consumption grew little outside the plantation sector, and the government did nothing to push it. This changed in 1943 when the Grow-More-Food Campaign was launched in the wake of the Japanese occupation of Burma (from which India was importing rice) and the Bengal Famine. The measures taken marked the beginning of efforts to promote fertilizer use in the nonplantation sector in order to raise food production rapidly. These efforts gathered momentum after India became independent in 1947.[10]

Since then, evidence from experiment stations and fertilizer trials on cultivators' fields have consistently shown that fertilizer use is potentially profitable on a number of crops, though to a varying extent.[11] Similarly, the potential of fertilizer use on different crops has increased over time but at different paces.[12]

The importance of crop considerations also comes through in the findings of many microstudies conducted in different parts of India during the last three decades. They show the dominant influences of irrigation, cropping patterns, and crop varieties on adoption of fertilizer by farmers. They also indicate that many farmers begin fertilizer use at low rates and on only some crops. Use then spreads to other crops, and rates of application are increased. These changes vary by crop, indicating the need to distinguish between diffusion of fertilizer use and rates of application on different crops in studying the growth in consumption.[13]

The findings of microstudies are insufficient to develop profiles by crop of total fertilizer consumption because of India's size and diversity. It is now possible to fill in a part of this lacuna with findings recently made available from the 26th round of the NSS and the surveys conducted by the NCAER. These findings and those of the 8th, 11th, and 22nd rounds of the NSS are used to develop fertilizer consumption profiles by crop. The profiles are then used with research on other aspects of fertilizer use to discuss the major forces behind its past growth and the policies required to sustain rapid growth in the 1980s.

Findings of the above surveys differ in scope (Table 1). For instance, the 8th round of NSS findings for 1953/54 covers only percentages of area sown with seven cereals receiving manure and fertilizer. The 11th round findings of the NSS relate to the average rates of fertilizer use on the entire

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[10] For an historical perspective, see Gunvant M. Desai, *Growth of Fertilizer Use in Indian Agriculture, Past Trends and Future Demands*, International Agricultural Development Bulletin No. 18 (Ithaca, N.Y.: Cornell University Press, 1969), chapter 2; and Gunvant M. Desai, "Fertiliser in India's Agricultural Development" in *Agricultural Development of India—Policy and Problems*, ed. C. H. Shah (Bombay: Orient Longman Ltd., 1979), pp. 377-426.

[11] Major studies based on these data that examine the profitable scope of fertilizer use in India and estimate fertilizer requirements include V. G. Panse, *Technical and Economic Possibilities of the Use of Nitrogen Fertiliser in India* (New Delhi: Institute of Agricultural Research Statistics, 1964); T. P. Abraham, "Optimal Fertiliser Dressings and Economics of Manuring," *Indian Journal of Agricultural Economics* 20 (April-June 1965): 1-20; Kirit S. Parikh and T. N. Srinivasan, *Optimum Requirement of Fertilisers for the Fifth Plan Period* (New Delhi: Indian Statistical Institute, 1974). For a discussion of variation in the returns to fertilizer use on different crops under the price environment of the mid-1960s and its relationship with the prevailing fertilizer practices of farmers, see Gunvant M. Desai and Gurdev Singh, *Growth of Fertiliser Use in Districts of India, Performance and Policy Implications* (Ahmedabad: Centre for Management in Agriculture, Indian Institute of Management, 1973), chapter 4.

[12] The two most important factors behind this were differences among crops in growth in irrigated area and the spread of fertilizer-responsive varieties.

[13] For a summary of these findings, see Desai, "Fertiliser in India's Agricultural Development," pp. 410-421. For details, among others see Indian Council of Agricultural Research, Institute of Agricultural Research Statistics, *Fertiliser Practices Followed by Farmers* (New Delhi: ICAR, 1964); various reports of the Expert Committee on Assessment and Evaluation of the Intensive Agricultural District Programme; V. G. Panse and D. Singh, "Promotion and Assessment of Technological Change in Indian Agriculture," *Indian Journal of Agricultural Economics* (January-March 1966): 121-131; Gunvant M. Desai, P. N. Chary, and S. C. Bandyopadhyay, *Dynamics of Growth in Fertiliser Use at the Micro Level* (Ahmedabad: Centre for Management in Agriculture, Indian Institute of Management, 1973); Dayanath Jha and Rakesh Sarin, "Fertilizer Use in Semi-Arid Tropical India," International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India, 1980. (Mimeographed.)

Table 1—Sample size of selected national surveys and total fertilizer consumption, 1953/54-1976/77

Survey	Year	Sample Size	Total Fertilizer Consumption
		(households)	(1,000 tons of nutrients)
8th Round, NSS[a]	1953/54	10,000	Less than 100
11th Round, NSS	1955/56	7,275	About 120
22nd Round, NSS	1966/67	4,201	1,100
26th Round, NSS	1970/71	35,793	2,256
NCAER[b]	1975/76	21,495	2,894
NCAER	1976/77	21,566	3,411

Sources: For details, see India, Department of Statistics, National Sample Survey Organisation, *The National Sample Survey; Tables with Notes on Farming Conditions and Practices in Rural Areas: 1953/54,* Eighth Round, No. 60 (Delhi: Manager of Publications, 1962); *The National Sample Survey: Tables with Notes on Some Aspects of Agriculture in India,* Eleventh Round, No. 140 (Delhi: Manager of Publications, 1969); *The National Sample Survey: Tables with Notes on Farm Practices,* Twenty-second Round, No. 202 (New Delhi: Controller of Publications, 1975); "Fertiliser Use in Agricultural Holdings, NSS 26th Round," *Sarvekshana* (October 1978): 85-89; National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978 (mimeographed); and Fertiliser Association of India, *Fertiliser Statistics, 1978/79* (New Delhi: FAI, 1979).

[a] National Sample Survey.

[b] National Council of Applied Economic Research.

(as distinguished from fertilized) area under many crops in 1955/56. The 22nd round of the NSS provides estimates by crop of the percentages of households using fertilizer with or without irrigation in 1966/67. Against this, the 26th round of the NSS provides crop estimates of fertilizers used on irrigated and unirrigated area, the number of households using fertilizer, as well as the amount of area fertilized under both conditions in 1970/71. The NCAER surveys provide data for 1975/76 and 1976/77 on the percent of area fertilized and the average rates on four categories of area under major crops: (1) irrigated area sown with high-yielding and improved varieties, (2) irrigated area sown with traditional varieties, (3) unirrigated area sown with high-yielding and improved varieties, and (4) unirrigated area sown with traditional varieties.

There are also problems in interpreting the findings of each survey. For instance, the report of the 22nd round of the NSS provides estimates of the percentages of households fertilizing each of the different crops in four seasons. The seasonal findings relate to fertilizer use on a crop by cultivators growing it at different times in the year and not to use on the same crop in different seasons. It is not possible to consolidate the seasonal findings for each crop for the entire agricultural year (in this case 1966/67) because the report does not provide the number of cultivators to whom the findings for each season relate. Furthermore, the fourfold classification of seasons in the report does not correspond to the classification of seasons as kharif, rabi, and summer that is standard in Indian agricultural statistics.

Similarly, there are too many problems in interpreting the estimates of the 26th round of the NSS of the number of households using fertilizers and the amount of area under various crops receiving fertilizer application to examine diffusion of fertilizer use by crop. Separate estimates are given for five different fertilizers: urea, ammonium sulfate, superphosphate, mixed fertilizers, and other (remaining) fertilizers. Since more than one of these could be used on the same area under the same crop by a household, clearly one cannot add the available estimates to get the percentage of households fertilizing different crops or the percentages of area under different crops receiving fertilizer.

There are several major difficulties in using the survey results of NCAER for the four categories of land under each major

crop to develop national profiles. First, no data on the distribution of India's total area sown with any crop are available by the fourfold classification according to irrigation and varieties. The official area statistics by crop distinguish between irrigated and unirrigated areas. Data on further classification by varieties are not available. Also, the definition of irrigated area in NCAER surveys is quite different from the one in the official statistics. Whereas the official statistics relate to area actually irrigated, the NCAER surveys define irrigated area as "area which a farmer expects to irrigate during the year with reasonable assurance from a known source, which might differ from the area he actually irrigates."

Finally, there are problems of consistency between statistics of total fertilizer consumption and estimates of total consumption based on findings of fertilizer consumption by crop. For instance, the estimates of total consumption in 1955/56 and 1970/71 based on the 11th and 26th rounds of the NSS respectively are considerably lower than the available statistics on total fertilizer consumption during those two years. On the other hand, the estimates of total consumption in 1975/76 and 1976/77 based on the results of the NCAER surveys are considerably higher than actual total consumption during those years. Clearly, these discrepancies need attention before the survey findings can be taken as profiles of total fertilizer consumption by crop.

Even though they are based on national surveys, various findings used in this study are not ideal to study growth in India's fertilizer consumption from a crop perspective. Interpretation must be based on findings of microstudies and personal judgment. Procedures used and assumptions made are discussed where appropriate.

Despite these limitations, the NSS and NCAER surveys are the most important sources of information on changes in consumption by crop during a quarter of a century when India's annual fertilizer use grew tremendously. This information raises pertinent questions about the processes and factors that have governed growth in the past and what needs to be done to sustain it in the future. It also raises doubts about whether one can determine the causal factors governing growth in fertilizer consumption of a country from the time series of aggregate fertilizer consumption by assuming growth to be a phenomenon driven only by farmers' demand for fertilizer.

3

FERTILIZER CONSUMPTION PROFILES BASED ON THE NATIONAL SAMPLE SURVEYS IN THE 1950S AND 1960S

Three aspects of consumption profiles by crop are examined; shares of crops in total fertilizer consumption, diffusion of fertilizer use by crop, and average rates on fertilized area by crop. Consumption profiles for the reference years of the surveys are built after examining the consistency between statistics of total fertilizer consumption and the estimates of total consumption implied by the findings of the sample surveys. Changes in the consumption profiles over time are discussed in Chapter 5.

As shown in Table 2, the report of the 8th round of the NSS (sample size 10,423 households) provides estimates of the percentages of area for each of seven cereals that received one, two, three, or no applications of any "manure" (which in this case includes farmyard manure, town compost, and inorganic fertilizers) in 1953/54. The report also gives the percentage of area receiving one dose of manure that was treated with inorganic fertilizers. From this information, percentages of area under seven cereals using fertilizers are estimated.

Three conclusions emerge from Table 2. First, more than 60 percent of the total area sown with the seven cereals (which accounted for about 55 percent of total cultivated area) did not receive any manure or fertilizer. The percentage was about 50 for rice, maize, and ragi, and between 70 and 80 percent for wheat, jowar, bajra, and barley. These figures are consistent with observations of many investigators about the low levels of manurial applications, the fertility of Indian soils, and low average yields.[14] Second, only about 5 percent of the total area under the seven cereals received inorganic fertilizer. This is not surprising since total fertilizer consumption was barely 0.5 kilogram per hectare. Third, among the seven cereals, the percentage of area receiving fertilizer application varied between 8 percent for rice and less than 2 percent for bajra. In the case of wheat, it was 3 percent. Greater fertilizer use on rice than on other cereals is consistent with the history of fertilizer use on this crop.[15]

The report of the 11th round of the NSS for 1955/56 (sample size 7,275 households) gives rates of fertilizer application on total area under crops, accounting for about 93 percent of total cultivated area. Using this information, it is possible to estimate crop shares in total fertilizer consumption during the mid-1950s (Table 3).

The NSS findings on rates of fertilizer application are not available for (1) vegetables other than potatoes and fruits ("other food crops" in Table 3); (2) tea, coffee, and rubber, the three plantation crops, (3) fibers other than cotton and jute; (4) fodder crops; and (5) nonfood crops not specified in Table 3. Fertilizer use is assumed for categories (1) and (2) at an average rate of 10 kilograms and 250 kilograms of fertilizer materials per hectare respectively. These rates amount to 2 kilograms and 50 kilograms of nutrients respectively. Nearly half of the area under other food crops was sown with such crops as bananas, fresh vegetables, and tapioca

[14] The observations of the Famine Enquiry Commission are relevant: ". . . the fertility of the soils of India has thus become stabilized at a low level. If, therefore, the yield of crops is to be increased and in particular if the full benefit is to be derived from improved varieties, plant food must be added to the soil in considerable quantities. Hitherto the use of manures has been confined largely to the more profitable among crops, such as tobacco, sugarcane and vegetables, . . ." (India, Famine Enquiry Commission, *Final Report of the Famine Enquiry Commission* [Madras, 1945], p. 1944). The First Five-Year Plan (1951-56) also recognized the widespread deficiencies of nitrogen and phosphorus in Indian soils (India, Planning Commission, *First Five-Year Plan* [Delhi: Publications Division, 1953], pp. 254-259).

[15] For a discussion of the beginnings of fertilizer use on plantations, the gradual spread to sugarcane and rice in certain areas, and the factors behind this, see Sir Henry Knight, *Food Administration in India, 1939-47* (Stanford, Cal.: Stanford University Press, 1954), pp. 133-135.

Table 2—Share of area sown with major cereals using manures and fertilizers, 1953/54

Cereal	Distribution of Area Treated by Manure					Share of Area with One Dose of Manure Using Fertilizers	Share of Total Area Using Fertilizers
	No Dose	One Dose	Two Doses	Three Doses	Total		
					(percent)		
Rice	48.0	42.0	6.0	4.0	100	11.0	8.0
Wheat	71.0	28.0	1.0	0.0	100	10.0	3.1
Jowar	76.0	22.0	0.0	2.0	100	8.0	2.4
Bajra	81.0	18.0	0.0	1.0	100	8.0	1.8
Maize	48.0	51.0	1.0	0.0	100	13.0	7.0
Ragi	50.0	48.0	2.0	0.0	100	5.0	3.1
Barley	70.0	27.0	2.0	1.0	100	11.0	4.0
Total	63.0	32.2	2.6	2.2	100	10.1	4.9

Source: India, Department of Statistics, National Sample Survey Organisation, *The National Sample Survey, Tables with Notes on Farming Conditions and Practices in Rural Areas: 1953/54,* Eighth Round, No. 60 (Delhi, Manager of Publications, 1962).

Note: These findings are based on the National Sample Survey, Eighth Round (sample size 3,294 villages, 10,423 households). The survey results are available for the percent of area sown with each of the seven cereals receiving one, two, three, or no doses of manures, which include farmyard manure, town compost, and inorganic fertilizers. They are also available for the percent of area treated by inorganic fertilizers receiving one dose of manure. The estimates of the percentage of total area under each cereal treated with inorganic fertilizers are made by assuming that one third of the area sown with each cereal receiving more than one dose of manure was treated with inorganic fertilizers. Although arbitrary, this assumption appears realistic as can be seen from the discussion of the findings for 1955/56. The estimates for the seven cereals taken together are made by taking an average weighted by the area sown with each cereal.

on which microstudies conducted in the 1950s show widespread diffusion of fertilizer use at selected locations. Thus, the assumption of an average rate of 2 kilograms of nutrients for the entire area under other food crops appears reasonable. On tea, coffee, and rubber, an average rate of 50 kilograms of nutrients is assumed because, according to data in official dispatches, in the mid-1950s these crops received annually about 90,000 tons of nitrogenous fertilizers and unknown quantities of phosphatic and potash fertilizers and fertilizer mixtures. Some fertilizers officially allocated to the nonplantation sector were probably also used on the plantations because of the strong demand pull. The average rate of 50 kilograms of nutrients per hectare in the mid-1950s also seems consistent with an average rate of about 90 kilograms per hectare in 1960/61. No fertilizer use is assumed on categories (3), (4), and (5) in the mid-1950s.

How good is the profile of fertilizer consumption by crop shown in Table 3? Since a firm estimate of total fertilizer consumption in 1955/56 is not available, it is difficult to answer this question.[16] Available information on dispatches and carryover stocks of nitrogenous fertilizers in some states indicates that the estimate of total consumption on all crops made in Table 3 could be less than 10 percent lower than the actual total. In the following discussion, this discrepancy is ignored because it is impossible to say whether it is due to the underestimation of the average rates in the survey conducted by the NSS organization or to downward bias in the assumptions made concerning fertilizer use on crops not covered by the NSS.

Until the mid-1940s, fertilizer use outside the plantation sector was confined to a few crops (notably sugarcane, rice, and tobacco). Against this, fertilizer use had begun on many crops by the mid-1950s even though average consumption was still less than 1 kilogram of nutrients per hectare. This was mainly due to the efforts of the government to promote fertilizer use in the nonplantation

[16] Data on fertilizer consumption in India up to 1960/61 relate to fertilizer dispatches or allocations.

Table 3—Area, rates of application, and consumption of fertilizers by crop, 1955/56

Crop	Area	Rate (in Fertilizer Materials)	Total Consumption of Fertilizer Materials	Share of Crop in	
				Total Area	Fertilizer Consumption
	(1,000 hectares)	(kilograms/ hectare)	(1,000 metric tons)	(percent)	
Foodgrains					
Rice	31,633	6.064	191,823	21.47	36.63
Wheat	13,704	1.314	16,693	8.62	3.19
Jowar	17,447	0.461	8,043	11.84	1.54
Bajra	10,972	0.300	3,292	7.45	0.63
Maize	3,811	0.830	3,163	2.59	0.60
Ragi	2,333	1.337	3,119	1.58	0.60
Barley	3,405	0.576	1,961	2.31	0.37
Other cereals and millets	5,412	0.115	622	3.67	0.12
Total cereals and millets	87,717	2.607	228,716	59.53	43.68
Gram	9,844	0.069	679	6.68	0.13
Arhar	2,336	0.207	484	1.59	0.09
Other pulses	11,428	0.161	1,840	7.76	0.35
Total pulses	23,608	0.127	3,003	16.03	0.57
Total foodgrains	111,325	2.081	231,719	75.56	44.25
Nongrain food crops					
Sugarcane	1,896	34.122	64,695	1.29	12.35
Potatoes	280	41.983	11,755	0.19	2.24
Condiments and spices	1,438	18.629	26,789	0.98	5.12
Other food crops[a]	(3,188)	(10)	(31,880)	(2.16)	(6.09)
Total nonfoodgrain food crops	3,614	28.566	103,239	2.45	19.71
	(6,802)	(19.865)	(135,119)	(4.62)	(25.80)
Nonfood crops					
Cotton	8,372	1.199	10,038	5.68	1.92
Jute	700	2.674	1,872	0.48	0.36
Other fibers[a]	(589)	(0.000)	(0)	(0.40)	(0.00)
Groundnuts	5,238	1.245	6,521	3.56	1.25
Rape and mustard	1,242	0.231	287	0.84	0.05
Other oilseeds	5,449	0.000	0	3.70	0.00
Tobacco	415	9.291	3,856	0.28	0.74
Tea, coffee, and rubber[a]	(537)	(250)	(134,250)	(0.36)	(25.64)
Fodder crops[a]	(5,959)	(0.000)	(0)	(4.05)	(0.00)
Other nonfood crops[a]	(682)	(0.000)	(0)	(0.46)	(0.00)
Total nonfood crops	21,416	1.054	22,574	14.54	4.32
	(29,183)	(5.374)	(156,824)	(19.81)	(21.96)
All crops	136,355	2.622	357,532	92.56	68.28
	(147,310)	(3.555)	(523,662)	(100)	(100)

Sources: India, Department of Statistics, National Sample Survey Organisation, *The National Sample Survey, Tables with Notes on Some Aspects of Agriculture in India,* Eleventh Round, No. 140 (Delhi: Manager of Publications, 1969); India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agricultural Statistics* (New Delhi: Controller of Publications, various years).

Notes: This table is developed using findings of the National Sample Survey, Eleventh Round, on average rates of application of chemical fertilizers and official statistics on area under different crops. The National Sample Survey gives rates of application for all crops except the ones marked with an *a*. The average rates on these excluded crops are based on circumstantial evidence. The "other food crops" category consists mainly of vegetables and fruits.

[a] Rates of application not given by the National Sample Survey.

sector under the Grow-More-Food Campaign launched in 1943.

Food crops accounted for about 80 percent of the total sown area and about 70 percent of total fertilizer consumption. The relatively low share of foodgrains (44 percent) in total consumption was mainly due to the low share of all foodgrains other than rice. These crops accounted for only 8 percent of total fertilizer use even though they made up 54 percent of the sown area. This contrasts sharply with rice, which had 21 percent of total area and 37 percent of total consumption. Incidentally, rice occupied only 28 percent of the area under all foodgrains but had an 83 percent share of total fertilizer consumed by all foodgrains.

The three plantation crops (tea, coffee, and rubber) were next in total consumption with a 26 percent share. They had less than 1 percent of total sown area. Sugarcane was third with 12 percent of total consumption and 1 percent of total area. Three fourths of the total consumption was on rice, tea, coffee, rubber, and sugarcane.

The important nonfood commercial crops such as cotton, jute, and oilseeds had much smaller shares of total fertilizer consumption than crops like sugarcane, condiments and spices, and potatoes, despite having four times more area.

Table 4 presents estimates of the percentage of area fertilized and average rates of application on the seven cereals covered by the 8th round of the NSS. Similar information is not available for other crops from nationwide surveys. However, available evidence from a few microstudies in the 1950s plus the estimates of fertilizer consumption in Table 3 suggest that diffusion of fertilizer use on some nonplantation crops (for example, sugarcane, potatoes, condiments and spices, vegetables, and tobacco) could have been higher than on rice but must have been quite low on most other crops. Because crops like sugarcane and potatoes did not account for a high proportion of total sown area, it seems safe to say that by the mid-1950s fertilizer use had not spread to more than 5 percent of India's 147 million hectares of gross cultivated area.

The report of the 22nd round of the NSS for 1966/67 (sample size 4,201 households) provided data on the percentage of households fertilizing crops with and without irrigation, whether households not using fertilizer on particular crops were growing them with irrigation, what proportions of farms of different sizes were fertilizing crops, and whether they were using fertilizer on their entire crop area. The usefulness of the findings is diminished because the crop data are reported by autumn, winter, spring, and summer. It is not possible to consolidate the seasonal findings for each crop for the entire agricultural year because the report does not give the number of cultivators to whom the seasonal data relate.

However, when the findings cover more than one season an attempt is made to identify the seasons accounting for most of the hectarage sown with the crop. This was done by taking into account the sowing seasons in various states and their relative importance in the total hectarage sown with the crop. Such findings are identified by an *a* in Tables 5, 6, and 7.

The percentage of households using fertilizer on different crops varied widely (Table 5). For a majority of crops, however, fertilizer use was much less in seasons accounting for most of the aggregate crop hectarage. In a large majority of the cases, 25-50 percent of the households using fertilizer were not fertilizing their entire area

Table 4—Percentage of area sown with major cereals fertilized and average rates of application, mid-1950s

Cereal	Area Receiving Fertilizer[a]	Average Rates	
		Fertilizer Materials[b]	Nutrients[c]
	(percent)	(kilograms/hectare)	
Rice	8.0	75.8	15.2
Wheat	3.1	42.4	8.5
Jowar	2.4	19.2	3.8
Bajra	1.8	16.7	3.3
Maize	7.0	11.9	2.4
Ragi	3.1	43.1	8.6
Barley	4.0	14.4	2.9
Seven cereals	4.9	56.6	11.3

[a] Relates to 1953/54. For details see Table 2.

[b] This is estimated by dividing total fertilizer consumption of the crop in Table 3 by total fertilized area sown with the crop.

[c] This is based on 20 percent nutrient content in fertilizer materials.

Table 5—Household distribution of fertilizer use and nonuse, with and without irrigation, by crop and season, 1966/67

Crop/Season	Distribution of Households Growing the Crop						Share of Households Using Fertilizer on Entire Crop Area
	Fertilizer Used			No Fertilizer Used			
	With Irrigation	Without Irrigation	Total	With Irrigation	Without Irrigation	Total	
	(percent)						
Rice (paddy)							
Autumn[a]	15.37	8.69	24.06	19.09	56.85	75.94	16.88
Winter[a]	17.83	7.50	25.33	21.47	53.20	74.67	15.50
Spring	62.46	2.52	64.98	27.13	7.89	35.02	45.31
Summer	52.30	0.00	52.30	38.89	8.81	47.70	48.40
Wheat							
Winter[a]	18.44	0.00	18.44	26.49	57.07	83.56	7.83
Spring[a]	22.41	2.39	24.80	42.26	32.94	75.20	14.17
Summer	0.00	9.50	9.50	30.92	59.58	30.50	4.75
Jowar							
Autumn[a]	2.78	5.26	8.04	12.60	79.36	91.96	4.82
Winter	1.34	3.22	4.56	5.26	90.18	95.44	2.55
Spring	11.78	8.37	20.15	12.36	67.49	79.85	13.11
Summer	24.08	12.74	36.82	47.40	15.78	63.18	31.56
Bajra							
Autumn[a]	5.34	8.27	13.61	11.74	74.65	86.39	6.84
Winter	3.98	7.69	11.67	10.05	78.28	88.33	6.05
Maize							
Autumn[a]	7.98	8.54	16.52	12.62	70.86	83.48	7.98
Winter	24.45	12.22	36.67	24.25	39.08	63.33	24.45
Spring	33.61	0.00	33.61	31.90	34.49	66.39	25.73
Ragi							
Autumn[a]	9.23	0.00	9.23	5.92	84.85	90.77	5.55
Winter	7.28	10.04	17.32	7.66	75.02	82.68	9.54
Barley							
Winter[a]	5.72	0.00	5.72	11.96	82.32	94.28	2.86
Spring	11.80	1.58	13.38	50.20	36.42	86.62	6.72
Gram							
Spring	8.63	2.50	11.13	24.63	54.24	78.87	6.29
Tur							
Winter[a]	0.67	6.38	7.05	2.35	90.60	92.95	6.46
Spring	5.26	4.88	10.14	3.39	86.47	89.86	5.16
Masur							
Spring	3.94	1.29	5.23	12.71	82.06	94.77	2.63
Moong							
Winter	0.00	4.22	4.22	0.80	94.98	95.78	1.32
Potatoes							
Winter	30.49	1.49	31.94	45.42	22.64	68.06	26.56
Spring[a]	36.13	1.15	37.28	53.49	9.23	62.72	36.13
Sugarcane							
Winter[a]	29.89	1.68	31.57	53.85	14.58	68.43	26.20
Spring[a]	41.93	0.00	41.93	49.51	8.56	58.07	34.95
Tapioca							
Winter	2.50	25.00	27.50	5.00	67.50	72.50	20.00
Tobacco							
Spring	10.96	10.17	21.13	47.31	31.56	78.37	18.29
Groundnuts							
Autumn[a]	2.39	14.33	16.72	3.39	79.89	83.28	12.19
Winter	0.00	5.92	5.92	6.09	87.99	94.08	5.31
Spring	12.51	5.09	17.60	37.68	44.72	82.40	12.51
Rapeseed and mustard							
Winter[a]	6.68	0.00	6.68	12.42	80.90	93.32	3.34
Spring	12.80	0.30	13.10	42.02	44.88	86.90	5.19
Cotton							
Autumn	15.21	0.00	15.21	68.54	16.25	84.79	12.35
Winter	8.34	7.41	15.75	15.48	68.77	84.25	12.14
Spring	14.50	16.18	30.68	7.29	62.03	69.32	20.79
Jute							
Autumn	0.75	18.71	17.46	1.50	81.04	82.54	9.85

Source: India, Department of Statistics, National Sample Survey Organisation, *The National Sample Survey, Tables with Notes on Farm Practices,* Twenty-second Round, No. 202 (New Delhi: Controller of Publications, 1975).

Note: The seasons in this table are the seasons when the crops are grown. They are not the different seasons in which fertilizer is used on same standing crop.

[a] Most of the land sown with this crop was being cultivated in this season.

Table 6—Percentage of households using fertilizer by farm size, crop, and season, 1966/67

Crop/Season	Farm Size: Less than 0.4 Hectares	0.4-1.0 Hectares	1-2 Hectares	2-4 Hectares	4-6 Hectares	More than 6 Hectares	All Farms
Rice (paddy)				(percent)			
Autumn[a]	15.5	21.0	23.3	23.5	36.4	30.2	24.1
Winter[a]	32.7	19.2	23.8	25.4	37.3	36.8	25.3
Spring	59.2	60.4	75.0	65.0	43.7	81.0	65.0
Summer	39.4	0.0	54.1	78.7	84.2	0.0	52.3
Wheat							
Winter[a]	n.a.	0.0	9.4	17.0	15.2	40.2	18.4
Spring[a]	8.8	11.8	24.6	28.1	32.8	34.8	24.8
Summer	n.a.	11.1	2.9	21.2	0.0	n.a.	9.5
Jowar							
Autumn[a]	0.0	4.7	9.7	7.5	11.4	6.2	8.0
Winter	0.0	0.7	2.1	4.7	8.4	7.1	4.6
Spring	0.0	24.9	24.0	20.9	25.5	15.0	20.2
Summer	0.0	33.3	20.0	33.3	n.a.	75.0	36.8
Bajra							
Autumn[a]	0.0	3.9	18.1	11.5	17.0	14.6	13.6
Winter	0.0	0.0	17.6	11.7	28.4	0.0	11.6
Maize							
Autumn[a]	8.4	6.0	17.1	16.8	24.2	25.7	16.5
Winter	n.a.	0.0	25.1	33.2	n.a.	n.a.	36.7
Spring	0.0	0.0	25.4	61.7	0.0	73.1	33.6
Ragi							
Autumn[a]	5.9	7.8	7.1	9.4	11.7	73.1	9.2
Winter	38.1	25.0	15.0	15.7	16.0	19.6	17.3
Barley							
Winter[a]	n.a.	0.0	0.0	7.7	13.7	8.7	5.7
Spring	14.4	9.3	20.0	13.7	7.8	19.8	13.4
Gram							
Spring	0.0	6.0	9.1	14.4	13.7	12.0	11.1
Tur							
Winter[a]	0.0	0.0	3.1	11.7	9.0	5.7	7.1
Spring	0.0	2.3	14.0	11.3	14.9	13.7	10.1
Masur							
Spring	0.0	12.8	0.0	4.7	18.0	0.0	5.2
Moong							
Winter	0.0	0.0	5.1	5.0	17.7	0.0	4.2
Potatoes							
Winter	0.0	32.1	27.3	45.0	61.6	39.5	31.9
Spring[a]	66.4	33.1	43.0	26.4	67.5	37.9	37.3
Sugarcane							
Winter[a]	36.1	27.6	18.6	36.0	62.0	34.5	31.6
Spring[a]	0.0	57.2	32.0	39.5	56.0	44.1	41.9
Tapioca							
Winter	12.5	25.0	45.6	25.0	0.0	n.a.	27.5
Tobacco							
Spring	0.0	0.0	32.9	12.4	0.0	48.9	21.1
Groundnuts							
Autumn[a]	0.0	8.6	7.5	11.0	32.2	20.7	16.7
Winter	0.0	0.0	3.5	2.8	4.7	14.3	5.9
Spring	0.0	0.0	0.0	33.3	100.0	13.6	17.6
Rapeseed and mustard							
Winter[a]	n.a.	0.0	10.9	0.0	0.0	25.3	6.7
Spring	5.8	1.9	13.5	17.5	32.3	28.3	13.1
Cotton							
Autumn[a]	0.0	0.0	0.0	6.4	17.3	24.6	15.2
Winter	0.0	15.5	5.7	13.6	5.1	25.4	15.8
Spring	0.0	15.7	14.9	18.4	33.0	41.1	30.7
Jute							
Autumn	25.0	25.3	18.5	10.1	0.0	50.5	17.5

Source: India, Department of Statistics, National Sample Survey Organisation, *The National Sample Survey: Tables with Notes on Farm Practices*, Twenty-second Round, No. 202 (Delhi: Controller of Publications, 1975).

Notes: The seasons in this table are the seasons when the crops are grown. They are not the different seasons in which fertilizer is used on the same standing crop. n.a. means not applicable because the crop was not grown on farms of that size.

[a] Most of the land sown with this crop was being cultivated in this season.

Table 7—Percentage of households using fertilizer on entire crop area by farm size, crop, and season, 1966/67

Crop/Season	Farm Size: Less than 0.4 Hectares	0.4-1.0 Hectares	1-2 Hectares	2-4 Hectares	4-6 Hectares	More than 6 Hectares	All Farms
				(percent)			
Rice (paddy)							
Autumn[a]	90	80	66	64	72	69	70
Winter[a]	95	58	56	64	56	70	61
Spring	69	84	77	53	17	100	71
Summer	0	n.a.	100	83	73	n.a.	83
Wheat							
Winter[a]	n.a.	n.a.	0	0	100	57	43
Spring[a]	65	55	58	60	52	57	57
Summer	n.a.	100	100	25	n.a.	n.a.	50
Jowar							
Autumn[a]	n.a.	100	82	31	83	36	60
Winter	n.a.	0	21	100	69	24	57
Spring	n.a.	49	100	76	29	66	65
Summer	n.a.	50	100	100	n.a.	100	86
Bajra							
Autumn[a]	n.a.	41	54	41	71	42	50
Winter	n.a.	n.a.	24	100	43	n.a.	53
Maize							
Autumn[a]	72	45	49	40	47	58	48
Winter	n.a.	n.a.	100	0	n.a.	n.a.	67
Spring	n.a.	n.a.	100	62	n.a.	73	77
Ragi							
Autumn[a]	100	53	45	100	0	58	60
Winter	100	47	53	62	36	65	55
Barley							
Winter[a]	n.a.	n.a.	n.a.	100	0	0	50
Spring	84	59	30	61	48	32	50
Gram							
Spring	n.a.	100	45	59	53	51	57
Tur							
Winter[a]	n.a.	n.a.	100	100	53	100	92
Spring	n.a.	0	89	17	100	0	51
Masur							
Spring	n.a.	100	n.a.	0	0	0	50
Moong							
Winter	n.a.	n.a.	0	100	0	0	81
Potatoes							
Winter	n.a.	100	100	66	100	50	83
Spring[a]	100	100	90	100	100	100	97
Sugarcane							
Winter[a]	100	100	73	84	84	75	83
Spring[a]	n.a.	77	74	82	82	100	83
Tapioca							
Winter	0	75	80	100	n.a.	n.a.	73
Tobacco							
Spring	n.a.	n.a.	75	100	n.a.	100	87
Groundnuts							
Autumn[a]	n.a.	100	62	4	93	70	73
Winter	n.a.	n.a.	100	100	100	84	90
Spring	n.a.	n.a.	n.a.	100	36	14	71
Rapeseed and mustard							
Winter[a]	n.a.	n.a.	0	n.a.	n.a.	100	50
Spring	100	100	18	38	28	47	40
Cotton							
Autumn[a]	n.a.	n.a.	n.a.	100	100	67	81
Winter	n.a.	100	63	100	0	74	77
Spring	n.a.	100	75	66	80	61	68
Jute							
Autumn[a]	100	50	77	25	n.a.	0	56

Source: India, Department of Statistics, National Sample Survey Organisation, *The National Sample Survey: Tables with Notes on Farm Practices,* Twenty-second Round, No. 202 (New Delhi: Controller of Publications, 1975).

Notes: The seasons in this table are the seasons when the crops are grown. They are not the different seasons in which fertilizer is used on the same standing crop. n.a. means not applicable because the crop was not grown on farms of that size.

[a] Most of the land sown with this crop was being cultivated in this season.

under the crops. Notable exceptions were sugarcane, potatoes, tobacco, and cotton. Also it is clear that the proportion of area sown with crops receiving fertilizer was lower than the proportion of households fertilizing that area. This is indicated by the finding that small farms used fertilizer (Table 6) and that the percentage fertilizing their entire crop area was higher than for bigger farms (Table 7).

Table 5 shows that a higher proportion of crops grown with irrigation were fertilized than crops grown without irrigation. Nevertheless, more than half of the households growing a crop with irrigation did not fertilize it. This indicates that the diffusion of fertilizer use on any crop, even under irrigated conditions, was far from complete by 1966/67. At the same time, there was some fertilizer use on all unirrigated crops. This is significant because 1966/67 was a year of severe drought in many parts of India.[17] It also indicates that the diffusion of fertilizer use was proceeding simultaneously and not sequentially on irrigated and unirrigated areas.

Table 6 shows that except for households with holdings of less than half a hectare, there was not much difference in diffusion of fertilizer use by crop according to farm size. And even among the smallest holdings, the crops commonly fertilized (such as rice, sugarcane, and potatoes) were the same as for larger farms.

In the 26th round of the NSS, information on fertilizer use by crop was collected from 35,793 households in 4,529 villages in different parts of India. Unlike 1966/67, 1970/71 was a year of normal weather. The total fertilizer consumption was about 2.26 million tons of nutrients—nearly twice that of 1966/67 and about 20 times that of 1955/56.

Table 8 shows the 26th round's estimates of urea, ammonium sulfate, superphosphate, mixed fertilizers, and other fertilizers used on all crops in 1970/71. In terms of nutrients, the estimate of total fertilizer consumption amounts to only 1.38 million tons, about 39 percent lower than the actual total consumption. The estimates of nitrogen (N), phosphate (P_2O_5), and potash (K_2O) consumption are 32, 54, and 48 percent below actual consumption. Because the three nutrients are used in varying proportions on different crops, it is clear that the survey did not underestimate fertilizer consumption on all crops uniformly. This is taken into account later.

The discrepancy between the 26th round's estimates and actual consumption is too large to be due to the nutrient conversion ratios of mixed and other fertilizers. Nor can it be due to any inaccuracy in official estimates of total fertilizer consumption based on domestic production, imports, and changes in stocks. The discrepancy seems to be mainly due to underestimation of cultivated area; exclusion of fertilizer consumption on tea, coffee, and rubber plantations in the NSS estimates of fertilizer consumpton on "all crops;" and underestimation of fertilizer consumption on certain crops.

The NSS estimate of total fertilizer consumption is arrived at by adding consumption of different fertilizer materials on irrigated and unirrigated areas under different crops. These estimates are based on data on fertilizer practices as well as the survey estimates of irrigated and unirrigated area under different crops. A comparison of the estimates of area shown in Table 9 with the official statistics of irrigated and unirrigated area under various crops in 1970/71 shows wide differences.[18] For instance the 26th round's estimate of area under all crops is 132 million hectares against 166 million hectares in *Indian Agricultural Statistics*.[19] Similarly, the survey estimates of irrigated and unirrigated area under a number of crops (for example, rice, bajra, sugarcane, cotton, tobacco, and spices and condiments) differ substantially from the official statistics. This is one source of discrepancy between the 26th round estimate and actual consumption.

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[17] The fact that 1966/67 was the second consecutive year of a severe drought enhances the value of these findings. Clearly, until fertilizer use is widespread, the role of weather fluctuations in causing setbacks to growth in farmers' total demand for fertilizer should not be exaggerated. The decrease in demand when some farmers give up or reduce fertilizer use can be made up by an increase in use in areas not affected by drought.

[18] For a discussion of this aspect, see India, Department of Statistics, National Sample Survey Organisation, *The National Sample Survey: Tables on Land Holdings, All-India,* Twenty-sixth Round, No. 215 (New Delhi: Controller of Publications, 1976), pp. 5-8.

[19] India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agricultural Statistics* (New Delhi: Controller of Publications, various years).

Table 8—Total fertilizer consumption by kind of fertilizer, from the National Sample Survey's Twenty-sixth Round, 1970/71

Fertilizer	Total Materials	Nutrients[a]			
		N	P_2O_5	K_2O	Total
		(1,000 metric tons)			
Urea	1,535.9	706.5	...	...	706.5
Ammonium sulfate	544.6	112.2	...	...	112.2
Superphosphate	410.1	...	...	...	65.6
Mixed fertilizers	658.0	118.4	184.2	32.9	335.5
Other fertilizers	448.0	75.0	...	88.7	163.7
All fertilizers	3,596.6	1,012.1	249.8	121.6	1,383.5
Actual consumption	5.861[b]	1,479.0	541.0	236.0	2,256.0

Sources: India, Department of Statistics, National Sample Survey Organisation, "Fertiliser Use in Agricultural Holdings, NSS 26th Round," *Sarvekshana* (October 1978): 85-89, S165-S234; and Fertiliser Association of India, *Fertiliser Statistics, 1976/77* (New Delhi: FAI, 1977).

[a] The nutrients are urea, 46 percent nitrogen (N); ammonium sulfate, 20.6 percent N; superphosphate, 16 percent phosphate (P_2O_5); mixed fertilizers, 18 percent N, 28 percent P_2O_5, and 5 percent potash (K_2O); other fertilizers = 16.75 percent N and 19.8 percent K_2O. For urea, ammonium sulfate, and superphosphate standard ratios are used. The nutrient content of mixed fertilizer (that is, fertilizer containing two or more nutrients) is based on the nutrient content of dominant NP and NPK fertilizers used during 1970/71 (see Fertiliser Association of India, *Fertiliser Statistics, 1970/71* [New Delhi: FAI, 1971]). Similarly, on the basis of fertilizer materials used in that year, it is assumed that "other fertilizers" refer to single nutrient fertilizers (mainly calcium ammonium nitrate, ammonium sulfate nitrate, and muriate of potash). It is also assumed that two thirds of other fertilizers were nitrogenous with an average nitrogen content of 25 percent; the remaining one third were potassic with 60 percent K_2O.

[b] Estimated by the author from data on consumption of different nutrients.

Table 9—Irrigated and unirrigated area and fertilizer consumption by crop, from the National Sample Survey's Twenty-sixth Round, 1970/71

Crop	With Irrigation		Without Irrigation		Total	
	Area	Consumption	Area	Consumption	Area	Consumption
	(1,000 hectares)	(metric tons)	(1,000 hectares)	(metric tons)	(1,000 hectares)	(metric tons)
Rice	11,314	1,006,200	19,809	266,700	31,123	1,272,900
Jowar	1,032	39,200	15,019	59,000	16,051	98,200
Bajra	1,004	30,300	8,448	49,900	9,452	80,200
Maize	1,559	94,200	4,140	56,700	5,699	150,900
Ragi	248	11,600	2,426	19,000	2,674	30,600
Wheat	10,583	844,600	4,954	51,600	15,537	896,200
Barley	1,243	22,400	754	5,500	1,997	27,900
Other cereals	411	3,600	3,428	3,900	3,839	7,500
Gram	1,059	8,800	3,138	3,500	4,197	12,300
Tur	101	1,000	1,809	6,200	1,910	7,200
Other pulses	1,395	6,400	7,160	9,800	8,555	16,200
Sugarcane	1,298	208,100	375	14,100	1,673	222,200
Rapeseed and mustard	342	15,800	596	1,700	938	17,500
Groundnuts	573	47,100	5,298	161,100	5,871	208,200
Sesamum	40	20[c]	782	1,400	822	1,600
Cotton	1,121	96,300	5,234	61,600	6,355	157,900
Jute	82	5,800	630	4,700	712	10,500
Tobacco	20	5,400	167	31,000	187	36,400
Spices and condiments	255	27,900	397	19,700	652	47,600
Remaining crops	2,888	189,800	104,800	13,788	13,788	294,600
All crops	36,568	2,664,700	95,464	931,900	132,032	3,596,600

Source: India, Department of Statistics, National Sample Survey Organisation, "Fertiliser Use in Agricultural Holdings, NSS 26th Round," *Sarvekshana* (October 1978): 85-89, S165-S234.

The estimates of fertilizer consumption on irrigated and unirrigated area under different crops in Table 10 are based on the official area statistics. They are derived from the ones in Table 9 by multiplying them by the ratios of actual irrigated and unirrigated areas under different crops to the estimates of these areas made in the 26th round. When adjusted in this manner, the estimate of total consumption of fertilizer materials rises from 3.60 to 4.24 million tons. In terms of nutrients, it goes up from 1.38 to 1.63 million tons, but is still substantially below total actual consumption of 2.26 million tons. This seems to be due to the exclusion of fertilizer consumption on tea, coffee, and rubber plantations in the NSS estimate of total consumption and underestimation of fertilizer consumption on certain crops.

The 26th round did not cover fertilizer use on tea, coffee, and rubber plantations. Though these plantations had only 0.5 percent of total cultivated area, their share in total fertilizer consumption has been substantial. In the early 1950s, for instance, the plantation crops accounted for more than one fifth of total fertilizer consumption. By 1970/71, area under tea, coffee, and rubber had increased by 11, 50, and 90 percent respectively.[20] Similarly, per hectare yield of these crops went up 28, 70, and 22 percent. This indicates that there must have been substantial growth in fertilizer consumption on plantations between 1955/56 and 1970/71, considering that overall consumption increased about 20 times. If consumption on plantations increased 10 times during the period, it would have amounted to 268,000 tons of nutrients in 1970/71. This would still imply a decline from 26 to 12 percent in the plantations' share of total fertilizer consumption. Alternatively, a rate of 300 kilograms per hectare in 1970/71 against 50 kilograms of nutrients in 1955/56 would make the total for the plantation sector 217,000 tons of nutrients. (This implies a 9.5 percent share in total fertilizer consumption.) In the absence of data, it is difficult to say what the total consumption of fertilizers on plantations was. But taking plantation consumption into account substantially reduces the gap between the estimate of the total based on the 26th round and the actual level in 1970/71.

Finally, it seems that the 26th round severely underestimated fertilizer consumption on certain crops in the "remaining crops" category. This category had a sown area of about 16 million hectares and included vegetables, potatoes, tapioca, fruits, oilseeds other than groundnuts, sesamum, rapeseed and mustard, fibers other than cotton and jute, fodder crops, and miscellaneous crops. Several microstudies in the 1950s and 1960s show that fertilizer use was more common on potatoes, bananas, tapioca, and vegetables grown for market than on most other crops. Even on the acreage under these crops in the 1950s there was vast scope for growth in fertilizer use through further diffusion and increased rates of application. Since then area and per hectare yield of these crops have increased substantially. For instance, area under potatoes, bananas, and tapioca increased by 72, 43, and 42 percent respectively between 1955/56 and 1970/71. During the same period, per hectare yields of potatoes and tapioca increased by 50 and 102 percent respectively. Also, urban demand for crops like potatoes, fruits, and vegetables grew substantially by 1970/71, and bananas became one of the leading nonplantation export crops. Therefore, it seems reasonable to say that fertilizer consumption on these crops must have grown rapidly. Nor can one rule out some growth in use on other remaining crops. The 26th round's estimate of only 7 kilograms of nutrients per hectare on remaining crops seems low compared with the 1970/71 average rate of 13 kilograms for the entire gross sown area and the growth in total consumption during the preceding 15 years.

Another reason why fertilizer consumption on remaining crops could have been substantially underestimated is that the survey did not cover the urban sector. Although this sector accounts for only 4 percent of the total operational holdings in the country, its share is much larger for crops like potatoes, vegetables, and bananas, which are intensively cultivated near towns and cities. Similarly, the sample of households surveyed may have been too small to accurately reflect fertilizer practices on

[20] A time series of index numbers of area, production, and yield of different crops is given in India, Ministry of Agriculture and Irrigation, *Agricultural Situation in India*, February 1981, pp. 866-871. The arguments in the text are based on these statistics.

Table 10—Adjusted estimates of fertilizer consumption on irrigated and unirrigated area by crop, 1970/71

Crop	Fertilizer Consumption		
	Irrigated Area	Unirrigated Area	Total
		(metric tons)	
Rice	1,275,225	310,228	1,585,453
Jowar	23,322	63,863	87,185
Bajra	16,086	75,949	92,035
Maize	56,133	67,478	123,611
Ragi	14,921	16,878	31,799
Wheat	792,007	87,170	879,177
Barley	23,932	8,958	32,890
Other cereals	937	5,523	6,460
Gram	10,154	7,359	17,513
Tur	69	9,021	9,090
Other pulses	3,647	16,249	19,896
Sugarcane	300,447	26,884	327,331
Rapeseed and mustard	16,447	3,021	19,468
Groundnuts	46,853	212,306	259,159
Sesamum	240	3,231	3,471
Cotton	116,659	76,170	192,829
Jute	5,800	5,006	10,806
Tobacco	27,540	61,072	88,612
Spices and condiments	72,102	59,795	131,897
Remaining crops	200,593	123,664	324,257
All crops	3,003,114	1,239,825	4,242,939

Source: These estimates are derived from the estimates of the Twenty-sixth Round of the National Sample Survey shown in Table 9 using the official statistics on irrigated and unirrigated area by crop from India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agricultural Statistics* (New Delhi: Controller of Publications, various years).

market-oriented crops like grapes, apples, onions, garlic, and tapioca, which are intensively cultivated in compact blocks in a relatively small number of districts.

If it is assumed that 2 million hectares of remaining crops were grown in this way and were fertilized at 100 kilograms of nutrients per hectare, total consumption for the group would be increased by 200,000 tons of nutrients. This would imply an average rate of about 20 kilograms of nutrients per hectare of land under all remaining crops. This seems more realistic than the survey estimate of 7 kilograms of nutrients per hectare. Also, as will be shown later, adding 2 million hectares to the survey estimate of fertilized area under remaining crops makes diffusion of fertilizer use on these crops consistent with the findings of the survey for other crops.

Consumption of at least 220,000 tons of nutrients on plantations and an additional 200,000 tons on remaining crops substantially reduces the gap between the adjusted survey estimate and the actual total. The consumption of P_2O_5 and K_2O is more common on the plantations and on intensively fertilized crops like potatoes, vegetables, and bananas grown near urban areas than on most other crops. This also explains why the survey underestimated the consumption of these two nutrients much more than that of nitrogen.

These adjustments reconcile the gap between the survey estimate and actual total fertilizer consumption to a large extent without touching the survey findings. However, no attempt is made to explain the remaining discrepancy of about 9 percent.

Crop Shares in Total Fertilizer Consumption

Table 11 shows five alternatives for estimating the relative shares of crops in total fertilizer consumption in 1970/71.

Alternative A is based on the 26th round's estimates shown in Table 9. The survey

Table 11—Alternative estimates of total fertilizer consumption by crop, 1970/71

Crop	Share in Total Consumption				
	Alternative A[a]	Alternative B[b]	Alternative C[c]	Alternative D[d]	Alternative E[e]
			(percent)		
Foodgrains					
Rice	35.39	37.37	29.72	27.05	30.70
Wheat	24.92	20.72	16.48	15.00	17.02
Jowar	2.73	2.05	1.63	1.49	1.70
Bajra	2.23	2.17	1.73	1.57	1.78
Maize	4.20	2.91	2.32	2.11	2.39
Ragi	0.85	0.75	0.60	0.54	0.61
Barley	0.78	0.78	0.62	0.56	0.64
Other cereals and millets	0.21	0.15	0.12	0.11	0.12
All cereals and millets	71.31	66.90	53.22	48.43	54.96
Gram	0.34	0.41	0.33	0.30	0.34
Tur	0.20	0.21	0.17	0.16	0.18
Other pulses	0.45	0.47	0.37	0.34	0.38
All pulses	0.99	1.09	0.87	0.80	0.90
All foodgrains	72.30	67.99	54.09	49.23	55.86
Nongrain food crops					
Sugarcane	6.18	7.71	6.14	5.58	6.33
Condiments and spices	1.32	3.11	2.47	2.25	2.55
Above nongrain food crops	7.50	10.82	8.61	7.83	8.88
Nonfood crops					
Cotton	4.39	4.54	3.62	3.28	3.73
Jute	0.29	0.25	0.20	0.18	0.20
Groundnuts	5.79	6.11	4.86	4.42	5.02
Rapeseed and mustard	0.49	0.46	0.36	0.33	0.37
Sesamum	0.04	0.08	0.07	0.06	0.07
Tobacco	1.01	2.09	1.66	1.51	1.71
Above nonfood crops	12.01	13.53	10.77	9.78	11.10
Remaining nonplantation crops	8.19	7.66	15.83	14.40	14.40
Plantation crops (tea, coffee, rubber)	n.c.	n.c.	10.70	9.75	9.75
All crops	100.00	100.00	100.00	90.99	100.00
			(million tons)		
Total consumption					
Materials	3,597	4.243	5.334	5.861	5.861
Nutrients	(1.384)	(1.633)	(2.053)	(2.256)	(2.256)

Note: n.c. means "not considered."

[a] This column is based on the Twenty-sixth Round estimates of the National Sample Survey shown in Table 9. It does not include fertilizer consumption on tea, coffee, and rubber plantations or urban operational holdings.

[b] This column is based on the adjusted irrigation area in Table 10. It also excludes use on plantation and urban holdings.

[c] These figures are the same as Alternative B with the addition of 220,000 tons of nutrients used on tea, coffee, and rubber plantations and 200,000 tons used on remaining nonplantation crops.

[d] These figures are based on actual total consumption of 2.26 million tons of nutrients.

[e] The estimates in Alternative D are raised to offset a 9 percent underestimation in the figures for 1970/71.

estimates of irrigated and unirrigated area under different crops differ substantially from the official area statistics. Total fertilizer consumption in this case is 39 percent lower than the actual and does not include consumption on tea, coffee, and rubber plantations or on operational holdings in the urban sector. The Alternative B estimates are based on the crop estimates of consumption shown in Table 10. They also do not take into account consumption on the plantations and on urban operational holdings. Total consumption in this case is 28 percent lower than the actual.

Alternative C includes consumption on tea, coffee, and rubber plantations. In addition to this, the estimate of fertilizer consumption on remaining nonplantation crops is raised to take into account the intensive fertilizer practices on such crops as potatoes, vegetables, and bananas. Total estimated fertilizer consumption in Alternative C is about 9 percent lower than the actual consumption in 1970/71.

In Alternative C the percentages of crop shares are arrived at by dividing estimated consumption on each crop by estimated total consumption, namely 2.05 million tons of nutrients. In Alternative D crop shares are estimated by taking the denominator as 2.26 million tons of nutrients, which was the actual total consumption in 1970/71. That is why the Alternative D total of crop shares adds up to 91 percent and not 100.

Alternative E is arrived at by adjusting the estimates in Alternative D for all crops except plantation crops and the remaining nonplantation crops to account for the 9 percent underestimation of total consumption in Alternative D. This is done by apportioning the discrepancy among crops according to their relative share in total consumption in Alternative B.

The most important conclusion suggested by Table 11 is that use of fertilizer on foodgrains is lower than had been assumed. So long as one does not take into account fertilizer consumption on tea, coffee, and rubber, and underestimation on certain crops in the remaining nonplantation crops category, the share of foodgrains in total fertilizer consumption is about 70 percent (Alternatives A and B). But this implies that total fertilizer consumption was 28-39 percent lower than the actual level in 1970/71. When plantation use and underestimation are taken into consideration, the share of foodgrains in total fertilizer consumption drops to 53 percent. However, the estimated total is then 9 percent lower than actual consumption (Alternative C). Bridging this gap, as is done in Alternative E, raises the share of foodgrains to 56 percent.

The 56 percent share of foodgrains in total fertilizer consumption, even in 1970/71, seems quite low because it has been generally assumed to be 70 percent throughout the last three decades. It deserves some scrutiny. A 70 percent share of fertilizer consumption for foodgrains can be supported only by assuming that the entire gap between the estimate based on the 26th round's findings and the actual total was solely due to underestimation on foodgrains. However, this implies no consumption on tea, coffee, and rubber plantations or on crops like fruits and vegetables on urban operational holdings. Obviously, such an assumption would be incorrect.

The share of total fertilizer consumption attributed to foodgrains in Alternative E seems reasonable on the following grounds. First, the experiences of virtually every country show that the relative shares of crops change as total consumption grows. In India one would expect the share of fertilizer used on foodgrains to rise because of its importance in the cropping pattern, the relatively little use on foodgrains other than rice in the 1950s, the replacement of traditional varieties by fertilizer-responsive varieties, and public policies. The 56 percent share of foodgrains in total consumption in 1970/71 was 12 percentage points more than in 1955/56. In the absolute increase of more than 2 million tons of consumption of total nutrients by 1970/71, the 12 percentage points increase in the share of foodgrains cannot be considered inconsequential, particularly since the bulk of the fertilizer was used on only two foodgrain crops. The consistency between the 26th round's estimates by crop of proportions of area fertilized and rates of application and the findings of many microstudies on fertilizer use patterns lends support to the above estimate.

As shown in Table 12, based on Alternative E and official area statistics, some crops had larger shares of total fertilizer consumption than of total sown area in 1970/71. These crops were rice, wheat, sugarcane, condiments and spices, groundnuts, tobacco, the plantation crops, and crops like vegetables, bananas, and potatoes. Together

Table 12—Shares of crops in total sown area and in fertilizer consumption, 1970/71

Crop	Share of Crop in Total Sown Area	Share of Crop in Total Fertilizer Consumption
	(percent)	
Foodgrains		
Rice	22.55	30.70
Wheat	11.03	17.02
Jowar	10.18	1.70
Bajra	8.08	1.78
Maize	3.53	2.39
Ragi	1.49	0.61
Barley	1.54	0.64
Other cereals	2.99	0.12
All cereals	61.39	54.96
Gram	4.72	0.34
Tur	1.59	0.18
Other pulses	7.64	0.38
All pulses	13.95	0.90
All foodgrains	75.34	55.86
Nongrain food crops		
Sugarcane	1.56	6.33
Condiments and spices	1.12	2.55
Above nongrain food crops	2.68	8.88
Nonfood crops		
Cotton	4.72	3.73
Jute	0.45	0.20
Groundnuts	4.56	5.02
Rapeseed and mustard	0.85	0.37
Sesamum	1.12	0.07
Tobacco	0.26	1.71
Above nonfood crops	11.96	11.10
Remaining nonplantation crops	9.58	14.40
Plantation crops (tea, coffee, and rubber)	0.44	9.75
All crops	100.00[a]	100.00[b]

Sources: Area based on India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agricultural Statistics* (New Delhi: Controller of Publications, various years). Consumption estimates from Table 11, Alternative E.

[a] The total sown area for all crops is 165.791 million hectares.

[b] Total fertilizer consumption was 5.861 million tons of fertilizer materials.

these crops accounted for 45 percent of the sown area and about 85 percent of total fertilizer consumption. Thus, remaining crops, taking up more than half of the total sown area, used only 15 percent of the fertilizers. Foodgrains other than rice and wheat accounted for 42 percent of the total sown area but only 8 percent of total fertilizer consumption. Within the foodgrain category, they accounted for 55 percent of area but only 15 percent of consumption. This again shows how misleading it is to assume a 70 percent share for foodgrains in total fertilizer consumption on the grounds that they have a 75 percent share of total sown area.

Shares of Irrigated and Unirrigated Area

Table 13 shows the percentages of irrigated sown area for each crop and the relative shares of irrigated and unirrigated area in the total fertilizer consumption for that crop. In the case of remaining nonplantation crops, 75 percent of the additional consumption discussed earlier is assumed to be on irrigated areas and 25 percent on unirrigated areas.

In 1970/71 a little less than one fourth of India's total sown land was irrigated and its share in total fertilizer consumption was about 70 percent. In all cases the shares of irrigated area in total fertilizer consumption were higher than the percentage of sown area irrigated. This pattern is consistent with the findings of numerous microstudies. Two findings of the 26th round must be stressed. First, for all crops except tobacco with 10 percent or more sown area under irrigation, more than 40 percent of fertilizer consumption on the crop was on irrigated areas. Second, 80-90 percent of fertilizer consumption on rice and wheat was on irrigated areas despite substantially lower percentages of area being irrigated.

Despite the dominant share of irrigated area in total fertilizer consumption, diffusion of fertilizer use on irrigated areas was far from complete by 1970/71, as the findings below show.

Diffusion of Fertilizer Use

Estimates of the total number of holdings growing crops with and without irrigation and of those using each of the five fertilizers on crops in the two situations are available

Table 13—Percent of crop area irrigated and share of irrigated area in total fertilizer consumption, 1970/71

Crop	Percent of Crop Area Irrigated	Share in Fertilizer Consumption	
		Irrigated Area	Unirrigated Area
Foodgrains			
Rice	38.5	80.4	19.6
Wheat	54.3	90.1	9.9
Jowar	3.6	26.8	73.2
Bajra	4.0	17.5	82.5
Maize	15.9	45.4	54.6
Ragi	13.1	46.9	53.1
Barley	52.0	72.8	27.2
Other cereals and millets	2.2	14.5	85.5
All cereals and millets	27.6	77.6	22.4
Gram	15.6	58.0	42.0
Tur	0.3	0.8	99.2
Other pulses	6.3	18.3	81.7
All pulses	8.8	29.8	70.2
All foodgrains	24.1	76.9	23.1
Nongrain food crops			
Sugarcane	72.4	91.8	8.2
Condiments and spices	35.4	54.7	45.3
Above nongrain food crops	56.9	81.5	18.5
Nonfood crops			
Cotton	17.3	60.5	39.5
Jute	10.9	53.7	46.3
Groundnuts	7.5	18.1	81.9
Rapeseed and mustard	25.2	84.5	15.5
Sesamum	2.6	6.9	93.1
Tobacco	23.7	31.1	68.9
Above nonfood crops	12.7	38.2	67.8
Remaining nonplantation crops	22.3	70.0	30.0
All crops	23.0	71.2	28.8

Source: These figures are based on Table 10 and India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agricultural Statistics* (New Delhi: Controller of Publications, various years).

from the 26th round of the NSS. Similar estimates by crop are also available for total area and area receiving the application of each fertilizer. Using these NSS estimates, percentages of holdings fertilizing their crops and the area fertilized by crop are derived to study diffusion of fertilizer use on different crops. Table 14 presents estimates of gross percentages. They are called gross because they are calculated by adding the estimates of holdings (area) using each of the five fertilizers on a crop and dividing the sums by total holdings (area) growing that crop. Because more than one of the five fertilizers could be used by a holding on the same crop, diffusion of fertilizer use is overestimated in Table 14. This is evident for tobacco and may have occurred for other crops. Virtually all microstudies have shown that superphosphate and muriate of potash are used along with a nitrogenous fertilizer.

Overestimation of the diffusion of fertilizer use on irrigated areas is also indicated by the NSS estimates for 17 states of total irrigated area, irrigated area not fertilized, net irrigated area fertilized (estimated by subtracting irrigated area not fertilized from total irrigated area), and gross area fertilized under irrigated conditions (estimated by adding area fertilized by each of the five types of fertilizers). For the 17 states, gross area fertilized under irrigated conditions was 64.6 percent and the net area 49.9 percent (Table 15).

For unirrigated area under all crops, the above estimates are available for only 6 states, which account for about one third of India's total sown area. For all crops, gross

Table 14—Diffusion of fertilizer use, based on gross percentages, by crop, 1970/71

Crop	Gross Percent of Holdings Using Fertilizer			Gross Percent of Area Fertilized			
	Irrigated Holdings	Unirrigated Holdings	All Holdings[a]	Irrigated Area	Unirrigated Area	All Area[a]	All Area[b]
Foodgrains							
Rice	75.6	21.7	42.8	88.8	20.0	45.0	46.4
Wheat	63.2	10.8	44.7	73.6	13.0	54.2	45.6
Jowar	25.7	6.1	8.4	28.6	6.1	7.5	6.9
Bajra	30.7	8.6	12.4	32.9	7.6	10.3	8.6
Maize	38.8	12.7	18.8	47.3	17.3	25.5	22.1
Ragi	34.8	8.9	12.9	53.6	13.0	16.8	18.2
Barley	26.4	2.5	17.6	29.4	6.5	20.8	18.4
Other cereals and millets	10.8	2.2	3.4	9.0	1.7	2.5	1.9
Gram	12.9	1.2	5.4	10.8	0.8	3.3	2.4
Tur	7.2	5.5	5.6	18.8	4.2	5.0	4.2
Other pulses	10.7	2.6	4.7	7.4	2.1	3.0	2.4
Nonfoodgrains							
Sugarcane	48.4	21.6	43.1	74.0	25.9	63.2	60.7
Condiments and spices	48.6	19.5	31.6	66.7	27.5	42.8	41.3
Cotton	49.0	13.6	23.7	66.9	12.6	23.1	22.9
Jute	86.8	14.2	23.6	95.1	10.3	20.1	19.5
Groundnuts	53.0	14.4	19.8	70.3	30.6	34.5	33.5
Rapeseed and mustard	46.9	7.7	25.0	46.2	3.9	19.3	14.6
Sesamum	8.3	1.9	2.4	7.5	2.9	3.2	3.0
Tobacco	54.9	24.4	32.6	90.0	101.7	100.5	98.8
Remaining nonplantation crops	n.a.	n.a.	n.a.	37.0	4.8	11.5	10.9
All crops	n.a.	n.a.	n.a.	64.6	11.4	26.1	24.4

Sources: India, Department of Statistics, National Sample Survey Organisation, "Fertiliser Use in Agricultural Holdings, NSS 26th Round," *Sarvekshana* (October 1978): 85-89, S165-S234; and India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agricultural Statistics* (New Delhi: Controller of Publications, various years).

Notes: The gross percentages for crops are calculated by adding the estimates of holdings using each of the five fertilizers on a crop and dividing the sums by estimates of the total number of holdings growing that crop. The percentages of area fertilized are also calculated in this way.

The five fertilizers are ammonium sulfate, urea, superphosphate, mixed fertilizer, and other. n.a. means "not available."

[a] Based on the Twenty-sixth Round's estimates of irrigated and unirrigated area by crops.

[b] Based on the official statistics of irrigated and unirrigated area under different crops and the Twenty-sixth Round's estimates of gross percent of area fertilized under irrigated and unirrigated conditions.

unirrigated area fertilized was 14.8 percent of total unirrigated area and net area fertilized was 13.0 percent.

Two significant conclusions emerge from Table 15. First, there is a considerable difference in percentages of gross and net irrigated areas fertilized in a majority of the states. Differences are smaller for unirrigated areas. This is not surprising because use of more than one fertilizer on the same unit of land would be more common on irrigated than on unirrigated land. Second, diffusion of fertilizer use was far from complete even on irrigated areas in such states as Punjab, Tamil Nadu, and Andhra Pradesh. There was considerable variation among states. This indicates that even under irrigated conditions, diffusion of fertilizer use was proceeding at vastly different paces in the different states.

No information by crop is available from the NSS report on area not receiving fertilizer. Therefore, diffusion of fertilizer use by crop, based on net percentages, is estimate in Table 16 using the following assumptions.

For irrigated conditions, it is assumed that superphosphate and other fertilizers

Table 15—Gross and net area fertilized under irrigated and unirrigated conditions by state, from the National Sample Survey's Twenty-sixth Round, 1970/71

State	Irrigated Area Fertilized		Unirrigated Area Fertilized		Total Area Fertilized	
	Gross	Net	Gross	Net	Gross	Net
			(percent)			
Punjab	97.3	72.2	30.9	23.4	83.2	61.8
Kerala	142.0	71.0	31.9	26.0	65.6	37.6
Tamil Nadu	109.5	67.5	9.0	n.a.	60.4	n.a.
Gujarat	80.8	62.6	31.1	n.a.	38.9	n.a.
West Bengal	84.4	57.7	16.5	14.9	33.9	25.9
Andhra Pradesh	90.8	74.9	11.8	n.a.	33.4	n.a.
Uttar Pradesh	50.5	44.4	13.6	13.5	33.1	29.8
Haryana	47.0	42.1	6.5	n.a.	27.5	n.a.
Jammu and Kashmir	65.3	50.0	3.0	n.a.	25.7	n.a.
Bihar	52.0	42.1	13.8	11.6	24.8	20.4
Karnataka	90.2	46.3	12.6	10.3	20.9	14.2
Himachal Pradesh	18.6	18.6	17.3	n.a.	17.4	n.a.
Maharashtra	52.0	40.9	10.1	n.a.	15.7	n.a.
Orissa	66.7	40.2	5.4	n.a.	12.6	n.a.
Madhya Pradesh	41.4	31.4	5.8	n.a.	10.9	n.a.
Rajasthan	33.9	31.9	1.3	n.a.	6.8	n.a.
Assam	0.0	0.0	1.1	n.a.	1.1	n.a.
Total	64.6	49.9	11.3	n.a.	26.1	n.a.

Source: India, Department of Statistics, National Sample Survey Organisation, "Fertiliser Use in Agricultural Holdings, NSS 26th Round," *Sarvekshana* (October 1978): 85-89, S165-S234.

Notes: States are arranged in descending order according to gross percent of total area fertilized. n.a. means not available.

were used by the same holdings using urea or ammonium sulfate or mixed fertilizer. Thus, the net percentage of holdings fertilizing a crop is calculated by adding holdings using urea, ammonium sulfate, and mixed fertilizer on the crop and dividing the sum by the total number of holdings growing the crop with irrigation. For unirrigated conditions, the net percentage of holdings fertilizing a crop is calculated by adding holdings using the same three fertilizers plus two thirds of those using other fertilizer on the crop and dividing the sum by the total number of holdings growing the crop without irrigation. The same procedures are used to calculate net percentages of irrigated and unirrigated area fertilized under different crops. These procedures imply use of straight phosphate and potassic fertilizers only with nitrogenous fertilizers (either straight or mixed). The procedure for irrigated conditions also allows for the use of more than one fertilizer containing nitrogen on the same crop, inasmuch as other fertilizers include straight nitrogenous fertilizers (for example, calcium ammonium nitrate, ammonium sulfate nitrate) as well as potassic fertilizers. For the country as a whole, the assumptions underlying these procedures seem consistent with the fertilizer practices of cultivators.

The net percentage of irrigated area under all crops receiving fertilizer works out to 51.6 percent. This compares well with the estimate of 49.9 percent irrigated area fertilized in Table 15, which is based on the survey data of irrigated area not receiving any fertilizer. No such comparison is possible for unirrigated areas, but, as Table 15 shows, double counting was more serious in the case of irrigated area.

Table 16 concludes that about one fifth of the total sown area was fertilized in 1970/71. Fertilizer use varied between 35 and 75 percent on area sown with rice, wheat, sugarcane, tobacco, and condiments and spices. For virtually all other crops, less than one fifth of the area was fertilized. Among foodgrains, diffusion of fertilizer use on rice and wheat contrasts sharply with that on jowar, bajra, and pulses. Less than 10 percent of the area sown with the latter was fertilized, though they accounted for

Table 16—Diffusion of fertilizer use, based on net percentages, by crop, 1970/71

Crop	Net Percent of Holdings Using Fertilizer			Net Percent of Area Fertilized			
	Irrigated Holdings	Unirrigated Holdings	All Holdings[a]	Irrigated Area	Unirrigated Area	All Area[a]	All Area[b]
Foodgrains							
Rice	63.0	20.1	36.8	71.0	17.7	37.1	38.1
Wheat	53.6	9.6	38.0	58.9	11.5	43.8	37.2
Jowar	22.3	4.7	6.8	24.1	4.7	6.0	5.4
Bajra	25.1	7.1	10.2	26.0	6.1	8.3	6.9
Maize	32.0	11.5	16.3	36.7	15.5	21.3	18.9
Ragi	29.7	6.8	10.4	45.4	10.0	13.4	14.7
Barley	24.2	2.1	16.1	26.0	4.7	18.0	15.8
Other cereals and millets	9.9	1.9	2.9	8.0	1.2	1.9	1.3
Gram	11.3	1.0	4.7	9.2	0.6	2.8	1.9
Tur	5.6	4.8	4.9	16.8	3.5	4.2	3.6
Other pulses	9.6	1.9	4.0	5.3	1.4	2.1	1.7
Nonfoodgrains							
Sugarcane	41.2	20.7	32.2	62.2	24.3	53.7	51.7
Condiments and spices	38.0	18.0	26.3	54.1	24.3	35.9	34.8
Cotton	35.2	12.3	18.8	53.8	11.0	18.5	18.4
Jute	71.9	12.9	20.6	75.6	9.2	16.8	16.4
Groundnuts	38.1	9.5	13.5	48.0	18.7	21.5	20.9
Rapeseed and mustard	41.5	6.4	21.9	39.2	3.7	16.7	12.7
Sesamum	7.4	1.6	2.0	7.5	2.6	2.8	2.7
Tobacco	41.3	20.1	25.9	65.0	76.3	75.1	73.6
Remaining non-plantation crops	n.a.	n.a.	n.a.	27.9	3.9	8.9	8.5
All crops	n.a.	n.a.	n.a.	51.6	9.3	21.0	19.6

Sources: Based on India, Department of Statistics, National Sample Survey Organisation, "Fertiliser Use in Agricultural Holdings, NSS 26th Round," *Sarvekshana* (October 1978): 85-89, S165-S234; and India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Indian Agricultural Statistics* (New Delhi: Controller of Publications, various years).

[a] Based on the Twenty-sixth Round's estimates of irrigated and unirrigated area by crops and the derived estimate of net percent of area fertilized under irrigated and unirrigated conditions made from the findings of the Twenty-sixth Round.

[b] Based on the official statistics of irrigated and unirrigated area by crops and the derived estimates of net percent of area fertilized under irrigated and unirrigated conditions made from the findings of the Twenty-sixth Round.

about one third of the total sown area and about 45 percent of total area sown with foodgrains.

As expected, fertilizer use was far more common under irrigated conditions. What is surprising, however, is that on none of the crops was diffusion of fertilizer anywhere near complete, even under irrigated conditions. About half of the country's irrigated land was not fertilized. Even for rice, wheat, sugarcane, tobacco, condiments and spices, crops on which fertilizer use was more common, fertilizer use had not spread to 30-45 percent of the irrigated area by 1970/71. Incredible though this seems, these findings are consistent with the geographical concentration of fertilizer use. Throughout the 1960s more than 70 percent of India's total fertilizer consumption was concentrated in less than one third of the districts, which suggests low diffusion of fertilizer use on irrigated areas of the remaining districts.

Finally, the estimate of net fertilized area under the remaining nonplantation crops in Table 16 supports the arguments for the underestimation of fertilizer consumption on these crops. According to Table 16, only 9 percent of the total area sown with these crops was fertilized. This seems low compared with the percentages

for other crops, particularly because this category includes potatoes, onions, vegetables, tapioca, and bananas on which fertilizer use was quite common. As argued earlier, much of the fertilized area sown with these crops could not have been captured by the 26th round. When 2 million hectares are added to the estimate of net fertilized area sown with these crops based on the survey, the net fertilized area sown with the remaining nonplantation crops goes up from 9 to 21 percent. This degree of diffusion seems quite consistent with the percentages for other crops. With this adjustment, the estimate of total net fertilized area as a percentage of total sown area rises from 19.6 to 20.8 percent.

Rates of Fertilizer Application

Table 17 shows the average rates of application of fertilizer materials on gross and net fertilized area by crop. These rates are calculated by dividing estimates of fertilizer consumption on each crop shown in Table 9 by gross and net fertilized area under each crop. The rates are calculated from the estimates of consumption shown in Table 11.

Rates of application of nutrients are shown in Table 18. For all nonplantation crops taken together, the average rate of application is 40 kilograms of nutrients per hectare on gross fertilized area and 50 kilo-

Table 17—Rates of application of fertilizer materials on gross and net fertilized area by crop, 1970/71

Crop	Gross Fertilized Area				Net Fertilized Area			
	Irrigated Area	Unirrigated Area	All Area[a]	All Area[b]	Irrigated Area	Unirrigated Area	All Area[a]	All Area[b]
	(kilograms/hectare)							
Foodgrains								
Rice	101	67	91	92	126	76	111	112
Wheat	109	80	106	104	135	91	132	129
Jowar	133	64	81	75	157	83	103	95
Bajra	92	78	83	80	116	96	103	99
Maize	128	79	104	94	165	88	124	112
Ragi	87	60	68	70	101	78	86	88
Barley	61	112	67	70	69	154	78	82
Other cereals and millets	97	66	78	75	109	97	102	98
Gram	77	135	88	95	91	184	106	115
Tur	53	82	76	82	59	97	89	96
Other pulses	62	64	64	65	86	96	92	94
Nonfoodgrains								
Sugarcane	223	145	216	213	266	155	255	252
Condiments and spices	164	181	171	171	202	204	203	203
Cotton	131	93	114	113	175	107	142	141
Jute	74	72	73	73	94	81	88	88
Groundnuts	117	101	104	104	171	165	166	166
Rapeseed and mustard	100	74	97	94	118	76	112	109
Sesamum	67	61	62	62	67	70	70	70
Tobacco	300	182	194	209	415	243	259	279
Remaining nonplantation crops	163	196	174	175	216	242	225	226
All crops	113	86	105	106	142	105	130	131

Sources: Derived from Tables 9, 10, 14, and 16.

[a] Based on the National Sample Survey's Twenty-sixth Round estimates of total area sown with each crop.

[b] Based on the official statistics of total irrigated and unirrigated area under each crop.

Table 18—Rates of application of nutrients on gross and net fertilized area by crop, 1970/71

Crop	Gross Fertilized Area				Net Fertilized Area			
	Irrigated Area	Unirrigated Area	All Area[a]	All Area[b]	Irrigated Area	Unirrigated Area	All Area[a]	All Area[b]
	(kilograms/fertilized hectare)							
Foodgrains								
Rice	37	26	34	34	47	29	42	42
Wheat	45	31	43	42	55	35	54	52
Jowar	61	21	29	27	72	27	37	34
Bajra	37	28	35	34	47	34	44	42
Maize	51	31	41	37	65	34	49	44
Ragi	36	22	26	27	42	29	33	34
Barley	26	41	27	28	30	58	32	34
Other cereals and millets	42	23	28	27	48	33	37	35
Gram	32	45	34	36	38	61	41	44
Tur	20	32	30	32	23	38	35	38
Other pulses	24	23	23	23	33	34	33	34
Nonfoodgrains								
Sugarcane	92	57	88	87	110	61	104	103
Condiments and spices	64	75	68	68	79	83	81	81
Cotton	53	36	45	45	71	41	56	56
Jute	29	30	29	29	37	34	35	35
Groundnuts	40	32	33	33	59	52	53	53
Rapeseed and mustard	37	34	37	36	44	35	43	42
Sesamum	22	18	19	19	22	21	21	21
Tobacco	111	56	64	69	153	75	85	92
Remaining nonplantation crops	62	82	69	69	83	101	89	89
All crops	44	31	40	40	55	38	50	50

Note: These estimates are derived by converting total consumption of urea, ammonium sulfate, superphosphate, mixed fertilizers, and other fertilizers on each crop into N, P_2O_5, and K_2O using the ratios shown in the footnote of Table 8, and dividing the total nutrient consumption on each crop thus obtained by gross/net fertilized area under each crop.

[a] Based on the National Sample Survey's Twenty-sixth Round estimates of total area sown with each crop.

[b] Based on the official statistics on total irrigated and unirrigated area under each crop.

grams of nutrients per hectare on net fertilized area. (Allowing for an underestimation of consumption of 200,000 tons of nutrients and of area by 2 million hectares, the average rate of application on net fertilized area under all nonplantation crops becomes 53 kilograms of $N + P_2O_5 + K_2O$ per hectare.)

The per hectare rate of application of nutrients on net fertilized area varied between 21 kilograms on sesamum and 103 kilograms on sugarcane. On a majority of crops (including all foodgrains) it varied between 34 and 56 kilograms per hectare. The average rate per hectare on net fertilized area under sugarcane, tobacco, condiments and spices, and probably some of the crops included in the category of the remaining nonplantation crops was more than 80 kilograms. Among foodgrains, it was highest on wheat—52 kilograms per hectare. On rice it was 42 kilograms per hectare. This difference seems reasonable for the country as a whole, in view of the greater success of high-yielding varieties of wheat by 1970/71 and the longer history of fertilizer use on rice.

The average rate of application on the net fertilized area under irrigated conditions was about 1.6-2.0 times higher than under

unirrigated conditions for rice, wheat, maize, sugarcane, cotton, and tobacco. There was little difference for groundnuts, sesamum, jute, and condiments and spices. For barley and the pulses gram and tur, however, the average rate was higher on unirrigated area.

For all crops, the average rate of application under irrigated conditions was about 1.5 times higher than under unirrigated. This contrasts sharply with about five times greater diffusion of fertilizer use on irrigated than on unirrigated areas.

4

FERTILIZER CONSUMPTION PROFILES BASED ON NCAER SURVEYS IN THE 1970S

The surveys conducted by NCAER to collect data on fertilizer use on selected crops in 1975/76 and 1976/77 were based on a sample of about 22,000 households. According to the official statistics, India's total fertilizer consumption of nutrients was 2.89 million tons in 1975/76 and 3.41 million tons in 1976/77.

The surveys provided data by state on percent of cropped area fertilized and average rates of application on fertilized area, for both total area and area under selected crops. When used with the official area statistics, however, they substantially overestimate India's total fertilizer consumption (Tables 19 and 20).

For all states taken together, the estimates based on the survey findings are higher than the actuals by 60 percent in 1975/76 and 31 percent in 1976/77. The estimates also do not reflect the substantial increase in actual total fertilizer consumption between 1975/76 and 1976/77. In 12 out of the 17 states, the direction of change of the survey estimates differs from the actuals. This indicates the limitations of the NCAER survey findings for estimating gross sown area fertilized and average rates of application on fertilized area by state.

Table 21 shows the coverage of the NCAER surveys for selected crops. Using these findings with official statistics on area

Table 19—Percentage of total sown area fertilized and average rates of application by state, 1975/76 and 1976/77

State	1975/76		1976/77	
	Sown Area Fertilized	Rate of Application	Sown Area Fertilized	Rate of Application
	(percent)	(kilograms/ fertilized hectare)	(percent)	(kilograms/ fertilized hectare)
Andhra Pradesh	41.7	111.7	45.4	104.8
Karnataka	33.4	104.6	24.3	159.3
Kerala	72.6	92.0	89.3	88.7
Tamil Nadu	55.4	128.1	58.9	127.6
Assam[a]	4.9	49.4	3.6	42.2
Bihar	35.3	49.7	39.3	42.5
Orissa	20.7	90.8	15.9	64.3
West Bengal	49.8	89.5	49.3	78.7
Madhya Pradesh	10.8	46.5	11.0	46.0
Uttar Pradesh	37.1	64.6	40.8	61.7
Rajasthan	20.1	355.5	17.8	47.6
Haryana	48.7	76.6	48.8	74.1
Himachal Pradesh	27.6	28.5	24.6	27.8
Jammu and Kashmir	28.5	47.0	26.3	44.1
Punjab	76.3	90.8	76.1	92.6
Gujarat	43.1	45.8	41.1	44.7
Maharashtra	27.3	77.3	28.3	71.9
All states above	33.5	79.5	34.0	77.1

Source: National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, 1978. (Mimeographed.)

[a] Assam includes Assam, Manipur, Meghalaya, and Tripura.

Table 20—Total fertilizer consumption derived from NCAER survey findings on percentage of total sown area fertilized and average rate of application, and their relation to actual total consumption by state, 1975/76 and 1976/77

State	Estimates of Total Consumption Based on NCAER Surveys		Actual Total Consumption		Estimated Consumption as Share of Actual Consumption	
	1975/76	1976/77	1975/76	1976/77	1975/76	1976/77
	(1,000 metric tons of nutrients)				(percent)	
Andhra Pradesh	604	564	412	402	146	140
Karnataka	390	382	219	206	178	185
Kerala	199	232	65	69	306	336
Tamil Nadu	513	537	300	278	171	193
Assam[a]	10	6	9	9	111	67
Bihar	198	189	135	156	147	121
Orissa	145	74	48	62	302	119
West Bengal	355	296	130	153	273	193
Madhya Pradesh	107	106	109	137	98	77
Uttar Pradesh	554	583	485	729	114	80
Rajasthan	191	143	78	99	245	144
Haryana	203	191	97	137	209	139
Himachal Pradesh	7	6	9	9	78	67
Jammu and Kashmir	12	11	10	12	120	92
Punjab	433	443	311	371	139	119
Gujarat	201	187	149	202	135	93
Maharashtra	415	403	265	290	157	139
All states above	4,537	4,353	2,831[b]	3,321[b]	160	131

Sources: Derived by multiplying findings of the National Council of Applied Economic Research given in Table 19 by official area statistics from India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Estimates of Area and Production of Principal Crops in India* (New Delhi: Controller of Publications, 1980). Actual fertilizer consumption statistics are from Fertiliser Association of India, *Fertiliser Statistics, 1978/79* (New Delhi, FAI, 1979).

[a] Assam includes Assam, Manipur, Meghalaya, and Tripura.

[b] Actual total consumption in the country was 2,894,000 tons in 1975/76 and 3,411,000 tons in 1976/77. Union territories are not included in the table.

under crops in various states, an attempt is made to estimate total fertilizer consumption.

Crops for which the above findings are not available are referred to as "remaining crops." Crops included in this category differ by state. To estimate total fertilizer consumption by crop in each state, the percentage of area under remaining crops fertilized and average rates of application on the fertilized area under them were estimated using the survey findings on cropping patterns of the sample households in each state, their total fertilizer consumption, total fertilized area, and their fertilizer consumption on the selected crops.

The estimates of fertilizer consumption in Tables 22 and 23 were made by multiplying the official statistics on area sown with different crops by the survey findings on percent of area fertilized and rates of application. Table 24 brings these state estimates together for the entire country. The terms "selected crops" and "remaining crops" differ by state as explained above. For all states taken together, the estimates of total consumption in Table 24 are closer to actual levels in both years than those in Table 20. But they are still weak in capturing the direction of change from 1975/76 to 1976/77. Also, there are wide discrepancies between the state estimates and actual figures even in 1976/77. In six states estimated consumption is 27-94 percent higher than actual; in seven other states, it is about 20 percent higher than actual; and in the remaining four, it is 28-44 percent below actual consumption.

This discussion leads to the following

Table 21—States covered in the NCAER survey findings on percentage of crop area fertilized and average rate of application and percentage of crop area covered, 1975/76 and 1976/77

Crop	States	Percentage of Total Crop Area Fertilized in the States Covered	
		1975/76	1976/77
Foodgrains			
Rice	All states	99.3	99.1
Wheat	All states except Andhra Pradesh, Kerala, Tamil Nadu, Orissa	99.3	99.3
Jowar	Karnataka, Tamil Nadu, Uttar Pradesh, Gujarat, Maharashtra	67.0	67.9
Bajra	Uttar Pradesh, Rajasthan, Haryana, Gujarat	66.1	66.4
Maize	Bihar, Madhya Pradesh, Uttar Pradesh, Rajasthan, Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab	81.7	83.2
Ragi	Karnataka, Tamil Nadu, Orissa	61.0	58.5
Barley	Uttar Pradesh, Rajasthan	71.6	74.3
Nongrain food			
Sugarcane	All except Kerala, West Bengal, Orissa, Himachal Pradesh, Jammu and Kashmir	96.7	96.7
Potatoes	Assam, West Bengal	26.3	26.9
Tapioca	Kerala	83.4	83.8
Chillies	Andhra Pradesh	20.4	17.5
Nonfood			
Cotton	Andhra Pradesh, Karnataka, Tamil Nadu, Rajasthan, Haryana, Punjab, Gujarat, Maharashtra	90.6	90.5
Jute	Assam, West Bengal	75.2	75.7
Groundnuts	Andhra Pradesh, Karnataka, Tamil Nadu, Gujarat, Maharashtra	79.0	79.4
Tobacco	Andhra Pradesh	42.4	43.6
All crops above[a]		60.33[a]	60.59[a]
Remaining crops[b]		39.67[b]	39.41[b]

Sources: Estimated from information available in National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978 (mimeographed); and India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Estimates of Area and Production of Principal Crops in India* (New Delhi: Controller of Publications, 1980).

Note: The states listed are those for which the survey findings on the two parameters (crop area fertilized and average rate of application) are available from the NCAER study.

[a] This is area under crops included as a percentage of total cropped area in the states covered by the survey.

[b] This is area sown with crops for which separate parameters are not available as a percentage of total cropped area in the states covered by the survey.

conclusions: First, the survey findings overestimate fertilizer consumption to a lesser extent in 1976/77 than in 1975/76. Second, they are more dependable for studying the consumption profile for the country as a whole than for individual states. Finally, the pattern of discrepancies by state indicates that the survey findings on percentages of rice area fertilized and average rates of application on fertilized rice area are high. In most of the states for which estimates of fertilizer consumption were 27-94 percent higher than actual in 1976/77, rice is an important crop.

Crop Shares in Total Fertilizer Consumption

The shares of different crops in total fertilizer consumption in 1975/76 and 1976/77 shown in Table 25 are derived from Tables 22 and 23 rather than from the actual

Table 22—Consumption of nutrients by crop and state, 1975/76

State	Rice	Wheat	Jowar	Bajra	Maize	Ragi	Barley
	(1,000 metric tons of nutrients)						
Andhra Pradesh	318	...	...	...	...	...	...
Karnataka	151	22	26	...	...	20	...
Kerala	67	...	...	...	...	...	...
Tamil Nadu	275	...	17	...	...	12	...
Assam[a]	5	...	...	...	...	...	...
Bihar	78	68	...	...	8	...	...
West Bengal	190	46	...	...	...	...	...
Orissa	83	...	...	...	...	2	...
Madhya Pradesh	20	53	...	...	2	...	...
Uttar Pradesh	73	263	1	7	22	...	5
Rajasthan	3	64	...	6	3	...	10
Haryana	29	75	...	2	4	...	...
Himachal Pradesh	1	2	...	...	2	...	...
Jammu and Kashmir	10	1	...	...	1	...	...
Punjab	51	223	...	...	30	...	...
Gujarat	17	18	6	23	...	...	...
Maharashtra	48	51	59	...	...	...	...
All states above	1,424	887	109	38	72	34	15

State	Sugarcane	Cotton	Ground-nuts	Other Crops[b]	Remaining Crops	All Crops
	(1,000 metric tons of nutrients)					
Andhra Pradesh	27	24	8	38	63	478
Karnataka	39	11	13	...	38	320
Kerala	...	...	...	5	78	150
Tamil Nadu	29	18	11	...	50	412
Assam[a]	c	...	...	1	3	10
Bihar	7	...	...	...	13	174
West Bengal	...	...	...	35	101	372
Orissa	4	...	...	...	56	150
Madhya Pradesh	3	...	...	...	15	93
Uttar Pradesh	83	...	...	...	40	494
Rajasthan	...	18	...	...	13	117
Haryana	18	6	...	...	12	146
Himachal Pradesh	...	...	...	...	c	5
Jammu and Kashmir	...	...	...	...	c	12
Punjab	8	38	...	...	46	396
Gujarat	6	51	25	...	47	193
Maharashtra	54	87	14	...	63	376
All states above	278	253	71	79	638	3,898

Sources: Developed from the survey estimates by the National Council of Applied Economic Research of the percentage of area fertilized and the average rates of application on fertilized area and from official statistics of area sown with different crops. National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978. (Mimeographed.)

[a] Includes Assam, Manipur, Meghalaya, and Tripura.

[b] The figure for Andhra Pradesh includes 24,000 metric tons of nutrients on chillies and 14,000 tons on tobacco. The figure for Kerala includes 5,000 tons on tapioca. The figure for Assam includes 1,000 tons on potatoes and less than 500 tons on jute. The figure for West Bengal includes 27,000 tons on potatoes and 8,000 tons on jute.

[c] Less than 500 tons was consumed.

total consumption. The latter, which includes consumption on tea, coffee, and rubber plantations, was lower than the estimated total consumption based on the survey findings and official area statistics.

There was little difference between 1975/76 and 1976/77 in the shares of crops in total consumption. Rice and wheat dominated with 37 and 23 percent, followed by sugarcane and cotton. The share of crops other

Table 23—Consumption of nutrients by crop and state, 1976/77

State	Rice	Wheat	Jowar	Bajra	Maize	Ragi	Barley
	(1,000 metric tons of nutrients)						
Andhra Pradesh	301	...	...	...	...	...	...
Karnataka	119	7	15	...	...	16	...
Kerala	75	...	...	...	...	...	...
Tamil Nadu	273	...	13	...	...	14	...
Assam[a]	3	[c]	...	...	...	...	...
Bihar	89	62	...	...	12	...	...
West Bengal	145	43	...	...	...	...	...
Orissa	55	...	...	...	...	1	...
Madhya Pradesh	16	53	...	...	4	...	...
Uttar Pradesh	99	229	[c]	9	22	...	3
Rajasthan	3	43	...	7	5	...	2
Haryana	29	77	...	1	3	...	...
Himachal Pradesh	1	1	...	...	3	...	...
Jammu and Kashmir	8	1	...	...	1	...	...
Punjab	54	253	...	...	29	...	...
Gujarat	16	19	8	14	...	...	...
Maharashtra	52	43	69	...	...	...	...
All states above	1,338	831	105	31	79	31	5

State	Sugarcane	Cotton	Ground-nuts	Other Crops[b]	Remaining Crops	All Crops
	(1,000 metric tons of nutrients)					
Andhra Pradesh	27	26	5	41	49	449
Karnataka	45	16	17	...	30	265
Kerala	...	...	...	4	55	134
Tamil Nadu	30	21	18	...	86	455
Assam[a]	...	...	...	1	1	5
Bihar	3	...	...	43	12	221
West Bengal	...	...	...	...	45	233
Orissa	1	...	...	...	16	73
Madhya Pradesh	3	...	...	...	22	98
Uttar Pradesh	92	...	...	...	39	493
Rajasthan	...	13	...	...	30	103
Haryana	17	5	...	...	6	138
Himachal Pradesh	...	...	...	...	[c]	5
Jammu and Kashmir	...	...	...	...	[c]	10
Punjab	8	34	...	...	39	417
Gujarat	4	35	31	...	46	173
Maharashtra	51	75	16	...	62	368
All states above	281	225	87	89	538	3,640

Sources: Developed from the survey estimates by the National Council of Applied Economic Research of the percentage of area fertilized and the average rates of application on fertilized area and from official statistics of area sown with different crops. National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978. (Mimeographed.)

[a] Includes Assam, Manipur, Meghalaya, and Tripura.

[b] The figure for Andhra Pradesh includes 21,000 tons of nutrients on tobacco and 20,000 tons on chillies. The figure for Kerala includes 4,000 tons on tapioca. The figure for Assam includes 1,000 tons of nutrients on potatoes and less than 500 tons on jute. The West Bengal figure includes 35,000 tons on potatoes and 8,000 tons on jute.

[c] Less than 500 tons was consumed.

than the 15 covered by the table was about 5 percent. If potatoes and chillies are included, the share of this category would be about 11 percent.

By the mid-1970s the share of foodgrains (the seven cereals shown separately and others included in the remaining crops) was about 70 percent. This was due to high shares of rice and wheat. All other foodgrains combined accounted for more cultivated

Table 24—Total fertilizer consumption derived from NCAER findings on percentage of area fertilized and average rate of application by crop and state, 1975/76 and 1976/77

State	Estimated Total Consumption, 1975/76			Estimated Total Consumption, 1976/77			Estimated Consumption of All Crops as Percent of Actual Total Consumption[b]	
	Selected Crops[a]	Remaining Crops	All Crops	Selected Crops	Remaining Crops	All Crops	1975/76	1976/77
	(1,000 metric tons of nutrients)							
Andhra Pradesh	415	63	478	400	49	449	116	112
Karnataka	282	38	320	235	30	265	145	129
Kerala	72	78	150	79	55	134	131	194
Tamil Nadu	362	50	412	369	86	455	137	164
Assam[c]	7	3	10	4	1	5	111	56
Bihar	161	13	174	219	12	221	129	142
Orissa	94	56	150	57	16	73	313	118
West Bengal	271	101	372	188	45	233	286	187
Madhya Pradesh	78	15	93	76	22	98	85	72
Uttar Pradesh	454	40	494	454	39	493	102	68
Rajasthan	104	13	117	73	30	103	150	104
Haryana	134	12	146	132	6	138	151	99
Himachal Pradesh	5	[d]	5	5	[d]	5	56	56
Jammu and Kashmir	12	[d]	12	10	[d]	10	100	120
Punjab	350	46	396	378	39	417	127	112
Gujarat	146	47	193	127	46	173	130	86
Maharashtra	313	63	376	302	62	368	142	127
All states above	3,260	638	3,898	3,102	538	3,640	137	110

Source: National Council of Applied Economic Research, "Fertilizer Demand Study, Survey Data on Pattern of Fertilizer Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978. (Mimeographed.)

[a] The crops selected are those given in Table 23.

[b] Actual total consumption is given in Table 20.

[c] These figures include Assam, Manipur, Meghalaya, and Tripura.

[d] Less than 500 tons.

area than rice and wheat. But they had only about 10 percent of total fertilizer consumption.

The shares of the four nongrain food crops (sugarcane, potatoes, tapioca, and chillies) exceeded the total consumption of the four nonfood crops (cotton, jute, groundnuts, and tobacco) despite a smaller share of total cropped area. Sugarcane and potatoes had more than 10 percent of consumption but only 2 percent of total cropped area.

Diffusion and Rates of Application on Different Crops

Table 26 shows estimates by crop of the percent of area fertilized and the average rates of application on these areas in 1975/76 and 1976/77 for the country as a whole.

For nonplantation crops as a group, about 29 percent of the country's total cropped area was fertilized at an average rate of 78 kilograms of nutrients per fertilized hectare in 1975/76 and 76 kilograms in 1976/77. These estimates imply higher than actual levels of total consumption. Thus, values must have been lower than those in the table, and much lower in 1975/76 than in 1976/77. For instance, if it is assumed that 250,000 tons (7 percent) of the total actual consumption of 3.4 million tons in 1976/77 were used on plantations, the estimate of 29 percent of total cropped area being fertilized would require an average rate of about 66 kilograms per fertilized hectare, instead of 76 kilograms. At 76

Table 25—Shares of crops in estimated total fertilizer consumption and in total sown area, 1975/76 and 1976/77

Crop	Share of Covered Crop Area in Total Consumption[a]		Share of Entire Crop Area in Total Consumption[b]		Share of Crop in Total Sown Area Under All Crops	
	1975/76	1976/77	1975/76	1976/77	1975/76	1976/77
	(percent)					
Foodgrains						
Rice	36.53	36.76	36.79	37.09	23.1	23.0
Wheat	22.76	22.83	22.92	22.99	12.0	12.5
Jowar	2.80	2.88	4.18	4.24	9.4	9.4
Bajra	0.97	0.85	1.47	1.28	6.8	6.4
Maize	1.85	2.17	2.26	2.61	3.5	3.6
Ragi	0.87	0.85	1.43	1.45	1.5	1.5
Barley	0.38	0.14	0.53	0.19	1.6	1.3
Total	66.16	66.48	69.58	69.85	57.9	57.7
Nongrain food						
Sugarcane	7.13	7.72	7.37	7.98	1.6	1.7
Potatoes	0.72	0.99	2.74	3.68	0.4	0.4
Tapioca	0.13	0.11	0.16	0.13	0.2	0.2
Chillies	0.62	0.55	3.04	3.14	0.4	0.5
Total	8.60	9.37	13.31	14.93	2.6	2.8
Nonfood						
Cotton	6.49	6.18	7.16	6.83	4.2	4.1
Jute	0.21	0.22	0.28	0.29	0.3	0.4
Groundnuts	1.82	2.39	2.30	3.01	4.2	4.2
Tobacco	0.36	0.58	0.85	1.33	0.2	0.3
Total	8.89	9.37	10.59	11.46	8.9	9.0
Above crops	83.64	85.22	93.48	96.24	69.4	69.5
Remaining crops	16.36[c]	14.78[c]	6.52	3.76	30.6	30.5
All crops	100.00	100.00	100.00	100.00	100.0	100.0

Sources: These figures are derived from Tables 22 and 23. The area statistics are from India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Estimates of Area and Production of Principal Crops in India* (New Delhi: Controller of Publications, 1980).

[a] These shares in total fertilizer consumption are derived from Tables 22 and 23. Thus they relate to the parts of crop area explicitly covered by the survey. Table 21 shows the percentages of crop area thus covered.

[b] These estimates relate to the entire area sown with the crop in the country. They are arrived at by assuming that the parts of crop area excluded from explicit coverage by the survey were fertilized to the same extent and at the same rates as the parts explicitly covered by the survey.

[c] Includes consumption on nonplantation crops other than the ones mentioned in the table. Also includes consumption on the parts of area sown with crops mentioned in the table that were excluded from explicit coverage in the survey.

kilograms per fertilized hectare, about 25 percent of the total cropped area would be fertilized, instead of 29 percent.

Because the survey overestimates total fertilizer consumption less in 1976/77, the following discussion is based on the estimates for that year even though estimates for most crops differ little in the two years.

For the 15 crops covered by the table, the crop area fertilized is more than 50 percent for wheat, sugarcane, potatoes, chillies, and tobacco; 20-50 percent for rice, maize, ragi, tapioca, cotton, jute, and groundnuts; and less than 20 percent for jowar, bajra, barley, and remaining crops. However, among the remaining crops, vegetables and fruits such as bananas would be more than 50 percent whereas most of the others would be less than 20 percent.

Average rates of application were more than 100 kilograms per hectare on fertilized area sown with potatoes, chillies, sugarcane, and tobacco, which are more commonly fertilized than other crops, though each accounts for less than 2 percent of the country's total cropped area. Next were cotton, rice, wheat, and ragi with average rates of 70-80 kilograms per hectare. Average

Table 26—Percentage of area fertilized and average rates of application by crop, 1975/76 and 1976/77

Crop	Crop Area Fertilized		Average Rate of Fertilizer Application on Fertilized Area	
	1975/76	1976/77	1975/76	1976/77
	(percent)		(kilograms/fertilized hectare)	
Foodgrains				
Rice	44.91	44.92	81	78
Wheat	55.85	55.09	78	73
Jowar	19.38	17.32	52	57
Bajra	16.35	11.46	31	39
Maize	33.21	36.51	45	43
Ragi	39.01	30.10	53	71
Barley	32.62	19.11	23	17
Nongrain food				
Sugarcane	65.14	69.70	159	146
Potatoes	56.85	73.32	302	294
Tapioca	28.60	38.20	49	33
Chillies	69.39	87.44	227	169
Nonfood				
Cotton	44.46	42.39	85	85
Jute	39.56	38.55	50	40
Groundnuts	34.10	38.48	37	40
Tobacco	94.43	96.80	92	117
Above crops	41.33	40.85	77	75
Remaining crops	11.40	9.97	82	82
All crops	29.39	28.68	78	76

Source: These figures were derived from data in National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978. (Mimeographed.)

Note: The average rates of application on fertilized area are for the percentages of total crop area fertilized given in Table 21.

rates varied between 33 and 43 kilograms for the other seven crops except for jowar (57 kilograms) and barley (17 kilograms).

In both survey years wheat area was fertilized to a greater extent than rice area, but the average rate on rice was higher. The pattern for rice seems surprising. This suggests the possibility that rates on fertilized area and fertilizer consumption under rice were overestimated in the survey.

Fertilizer Use by Categories of Crop Area

The NCAER surveys provide findings on percentages of area fertilized and average rates on fertilized area under selected crops for four categories: irrigated area sown with high-yielding and improved varieties (denoted in Tables 27-30 as IA-HY&IV), irrigated area sown with traditional varieties (IA-TV), unirrigated area sown with high-yielding and improved varieties (UA-HY&IV) and unirrigated area sown with traditional varieties (UA-TV).

Official statistics on crop area sown in the four categories are not available. Consequently, NCAER survey findings are used with the official statistics on total area sown with eight crops to estimate area sown in each of the four categories by state. These estimates are subject to the limitations of the survey findings. It is important to note this because the survey was not designed to estimate the distribution of crop area under the above categories. The estimates of total area sown with each crop in the four categories by state are then used with the survey findings by state on the percentage of crop area fertilized and average rates in each category to construct a fertilizer consumption profile by category for the country

Table 27—Distribution of total area sown, according to irrigation availability and type of variety, selected crops, 1975/76 and 1976/77

Crop	Year	IA-HY&IV	IA-TV	UA-HY&IV	UA-TV	IA	UA	HY&IV	TV
					(percent)				
Rice	1975/76	20.8	25.6	2.1	51.5	46.4	53.6	22.9	77.1
	1976/77	21.8	25.2	1.9	51.1	47.0	53.0	23.7	76.3
Wheat	1975/76	47.6	23.7	2.6	26.1	71.3	28.7	50.2	49.8
	1976/77	48.6	26.0	3.4	22.0	74.6	25.4	52.0	48.0
Jowar	1975/76	3.0	10.7	7.8	78.5	13.7	86.3	10.8	89.2
	1976/77	3.6	10.9	8.4	77.1	14.5	85.5	12.0	88.0
Bajra	1975/76	9.9	21.1	7.8	61.2	31.0	69.0	17.7	82.3
	1976/77	10.3	23.0	6.3	60.4	33.3	66.7	16.6	83.4
Maize	1975/76	10.2	37.8	4.9	47.1	48.0	52.0	15.1	84.9
	1976/77	10.9	39.7	5.3	44.1	50.6	49.4	16.2	83.8
Sugarcane	1975/76	38.3	51.1	5.1	5.5	89.3	10.7	43.4	56.6
	1976/77	44.2	44.6	5.3	5.9	88.8	11.2	49.5	50.5
Cotton	1975/76	21.7	11.0	15.9	51.4	32.7	67.3	37.6	62.4
	1976/77	21.7	11.3	14.3	52.7	33.0	67.0	36.0	64.0
Groundnuts	1975/76	2.0	12.8	3.0	82.2	14.8	85.2	5.0	95.0
	1976/77	0.9	16.4	1.7	81.0	17.3	82.7	2.6	97.4
All crops above	1975/76	22.5	22.8	4.5	50.2	45.3	54.7	27.0	73.0
	1976/77	23.6	23.5	4.4	48.5	47.2	52.8	28.0	72.0

Sources: Derived from data in National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978 (mimeographed); and India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Estimates of Area and Production of Principal Crops in India* (New Delhi: Controller of Publications, 1980).

Notes: IA = irrigated area; UA = unirrigated area; HY&IV = high-yielding and improved varieties; TV = traditional varieties.

Official statistics on the area sown with different crops in the four categories are not available. Consequently, NCAER survey findings on distribution of crop area among the four categories in different states are used with the official crop area statistics by state to estimate the all-India distribution of total area sown with each crop by the four categories.

as a whole. The eight crops are rice, wheat, jowar, bajra, maize, sugarcane, cotton, and groundnuts. They accounted for about 65 percent of the country's total cropped area and more than 80 percent of the estimated fertilizer consumption. Tables 27 - 30 show the results of the calculations.

Neither the distribution of total crop area among the four categories nor the percentages of crop area fertilized in each category differ much in the two years covered by the surveys. But the average rates on fertilized area in virtually all important situations were lower in 1976/77 than in 1975/76. Therefore, the larger discrepancy between the estimated and actual total fertilizer consumption in 1975/76 was probably due to overestimation of rates of application. This could be the main reason why the survey findings do not reflect growth in total fertilizer consumption from 1975/76 to 1976/77.

The percentages of crop area irrigated in Table 27 are consistently higher than those shown in the official statistics. This could be due to the difference in definition. The official statistics relate to area actually irrigated, whereas the NCAER surveys define irrigated areas as "area which a farmer expects to irrigate during the year with reasonable assurance from a known source, but which might differ from the area he actually irrigates."[21] On the other hand, the official statistics of area covered only by high-yielding varieties are consistently higher than the survey estimates of area covered by

[21] National Council of Applied Economic Research, *Fertiliser Demand Study, Final Report*, vol. 1 (New Delhi: NCAER, 1978), p. 123.

Table 28—Percentage of area fertilized, according to irrigation availability and type of variety, selected crops, 1975/76 and 1976/77

Crop	Year	IA-HY&IV	IA-TV	UA-HY&IV	UA-TV	IA	UA	HY&IV	TV	All
						(percent)				
Rice	1975/76	85.7	58.1	71.6	20.7	70.5	22.8	84.5	33.1	44.9
	1976/77	84.9	61.6	63.1	19.0	72.4	20.6	83.1	33.1	44.9
Wheat	1975/76	83.0	56.8	19.4	8.8	74.3	9.7	79.8	31.7	55.8
	1976/77	81.4	49.4	19.4	9.1	70.2	10.5	77.3	30.9	55.1
Jowar	1975/76	82.9	36.8	62.1	10.3	46.9	15.0	67.9	13.5	19.4
	1976/77	71.4	33.2	61.8	7.6	42.7	13.0	64.5	10.8	17.3
Bajra	1975/76	45.1	10.5	35.3	11.2	21.6	14.0	40.8	11.1	16.4
	1976/77	30.2	13.6	21.5	6.4	18.7	7.3	26.9	7.7	11.5
Maize	1975/76	72.5	49.6	45.5	10.2	54.5	13.6	63.7	27.8	33.2
	1976/77	86.1	45.9	61.5	12.8	54.6	18.0	78.1	28.5	36.5
Sugarcane	1975/76	82.3	60.6	34.5	16.4	69.9	25.0	76.7	56.3	65.1
	1976/77	82.4	65.9	52.0	18.8	74.1	34.5	79.1	60.4	69.7
Cotton	1975/76	88.7	52.3	66.0	17.4	76.4	28.4	79.1	23.5	44.5
	1976/77	85.2	51.1	76.9	13.5	73.6	27.0	81.9	20.0	42.4
Groundnuts	1975/76	78.2	54.1	51.7	29.3	57.4	30.1	62.3	32.7	34.1
	1976/77	52.8	53.1	68.4	34.7	53.0	35.4	63.0	37.8	38.6
All crops above	1975/76	82.7	52.4	54.0	16.8	67.4	19.9	77.9	27.9	41.4
	1976/77	81.2	51.9	53.3	15.7	66.6	18.8	76.8	27.6	41.3

Source: Derived from Table 27 and data in National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978. (Mimeographed.)

Notes: IA = irrigated area; UA = unirrigated area; HY&IV = high-yielding and improved varieties; TV = traditional varieties.

The estimates of total area sown with each crop in the four categories by state made for Table 27 are used with NCAER survey findings by state on the percentage of crop area fertilized in each category to estimate the percentage of total area sown with each crop that was fertilized in the four categories.

both high-yielding and improved varieties. This is true for both survey years and for each cereal shown in the tables. For instance, according to the official statistics, 31-35 percent of area under rice was covered by high-yielding varieties alone, but the survey shows that only 23-24 percent of the area was under high-yielding and improved varieties. This suggests that the impact of the possible overestimation of irrigated area in the surveys on the estimate of fertilizer consumption was offset by the underestimation of the area covered by high-yielding and improved varieties.

Table 28 generally confirms what one would expect. The highest percentage of crop area fertilized was in the category IA-HY&IV and the lowest in UA-TV. Similarly, a much higher percentage of crop area was fertilized in irrigated area (irrespective of varieties) than in unirrigated area. For each of the eight crops in both years, the percentage fertilized was higher in area under high-yielding and improved varieties than in area under traditional varieties, whether or not the area was irrigated. Finally, in none of the categories for any crop was the entire area fertilized. In fact, even by 1976/77 less than one fourth of the irrigated area under any of the eight crops was fertilized, and less than one third of the irrigated area under all eight crops was fertilized.

The average rates of application on fertilized area in the categories are also as expected (Table 29). For all crops except sugarcane, the highest rate was in the category IA-HY&IV and the lowest in UA-TV. On most of the crops, the rates on irrigated area were 50-100 percent higher than on unirrigated area if the varietal classification is disregarded. The differences between the two categories of varieties on irrigated area were smaller. For example, rates for rice, wheat, and cotton on IA-HY&IV were 35-66 percent higher than on IA-TV. On jowar they were only 20-25

Table 29—Average rates of application on fertilized area, according to irrigation availability and type of variety, selected crops, 1975/76 and 1976/77

Crop	Year	IA-HY&IV	IA-TV	UA-HY&IV	UA-TV	IA	UA	HY&IV	TV	All
		(kilograms of nutrients/fertilized hectare)								
Rice	1975/76	110	74	72	44	94	47	107	61	81
	1976/77	101	75	56	43	89	45	98	63	78
Wheat	1975/76	88	58	51	32	81	36	88	54	78
	1976/77	81	54	47	28	74	33	80	51	73
Jowar	1975/76	81	67	57	31	73	41	66	43	52
	1976/77	80	64	64	37	71	50	69	47	57
Bajra	1975/76	42	28	32	24	38	27	38	25	31
	1976/77	40	48	33	32	44	32	38	39	39
Maize	1975/76	50	48	31	30	49	30	46	44	45
	1976/77	44	50	30	29	48	30	40	45	43
Sugarcane	1975/76	152	174	63	95	163	74	148	171	159
	1976/77	142	164	47	67	152	53	135	160	146
Cotton	1975/76	111	67	79	49	101	65	100	56	85
	1976/77	99	71	87	56	92	75	95	63	85
Groundnuts	1975/76	80	53	41	29	58	30	61	34	37
	1976/77	163	59	53	32	64	32	85	38	40
All crops above	1975/76	99	73	63	38	89	44	95	59	77
	1976/77	92	73	64	39	84	45	89	60	75

Source: Derived from Table 27 and data in National Council of Applied Economic Research, "Fertiliser Demand Study, Survey Data on Pattern of Fertiliser Use on Selected Crops: 1975/76 and 1976/77," New Delhi, October 1978. (Mimeographed.)

Notes: IA = irrigated area; UA = unirrigated area; HY&IV = high-yielding and improved varieties; TV = traditional varieties.

The estimates of total area sown with each crop in the four categories by state made for Table 27 are used with NCAER survey findings by state on the percentage of crop area fertilized and average rates in each category to derive the all-India average rates of application on fertilized area in each category.

percent higher. And on bajra and maize in 1976/77 the rates on IA-TV were marginally higher than on IA-HY&IV.

Finally, Table 30 shows that for the eight crops, about 57 percent of total consumption was on IA-HY&IV. This category accounted for about 23 percent of the total area sown with the eight crops. Next in importance was IA-TV with about 28 percent of total fertilizer consumption and 23 percent of total area. The two categories had about 85 percent of total consumption and about 46 percent of total crop area under the eight crops. The remainder (UA) accounted for only about 14 percent of total consumption. Of this, about one third of consumption was on UA-HY&IV, which accounted for about 4 percent of total crop area. Thus, the share in fertilizer consumption of about half of the crop area in the UA-TV category was only 10 percent. Table 28 shows that this was primarily due to much lower diffusion of fertilizer use in this category (about 15-18 percent) compared to more than 50 percent for the other three categories.

Among individual crops, Table 30 shows that the share of IA-HY&IV was as high as 80 percent for wheat alone. About half of total fertilizer consumption for rice, cotton, and sugarcane was in this category. The share of the remaining four crops was much less. For all crops except wheat and cotton, more than 40 percent of consumption was on traditional varieties. On the other hand, the distribution of total fertilizer consumption on each crop between irrigated and unirrigated area was overwhelmingly in favor of the former. This is primarily due to the low relative share of unirrigated area in total fertilizer consumption on rice and wheat. More than half of the rice area and about one fourth of the wheat area were unirrigated, but their shares in total fertilizer consumption were only about 15 percent and 2 percent respectively.

Tables 28 and 29 show that this is mainly

Table 30—Distribution of total fertilizer consumption, according to irrigation availability and type of variety, selected crops, 1975/76 and 1976/77

Crop	Year	IA-HY&IV	IA-TV	UA-HY&IV	UA-TV	IA	UA	HY&IV	TV	Estimated Total Consumption
					(percent)					(1,000 tons of nutrients)
Rice	1975/76	54.1	30.1	2.9	12.9	84.2	15.8	57.0	43.0	1,424
	1976/77	53.0	33.2	1.9	11.9	86.2	13.8	54.9	45.1	1,338
Wheat	1975/76	79.9	17.8	0.6	1.7	97.8	2.3	80.5	19.5	887
	1976/77	80.3	17.5	0.8	1.4	97.8	2.2	81.1	18.9	837
Jowar	1975/76	20.3	26.4	27.9	25.4	46.7	53.3	48.2	51.8	109
	1976/77	21.0	23.4	33.6	22.0	44.4	55.6	54.6	45.4	105
Bajra	1975/76	37.1	12.4	17.7	32.8	49.5	50.5	54.8	45.2	38
	1976/77	28.2	33.7	10.0	28.1	61.9	38.1	38.2	61.8	31
Maize	1975/76	25.2	60.4	4.6	9.8	85.6	14.4	29.8	70.2	72
	1976/77	26.2	57.2	6.2	10.4	83.4	16.6	32.4	67.6	79
Sugarcane	1975/76	46.2	51.9	1.1	0.8	98.1	1.9	47.3	52.7	278
	1976/77	50.7	47.3	1.3	0.7	98.0	2.0	52.0	48.0	281
Cotton	1975/76	56.5	10.3	21.7	11.5	66.8	33.2	78.2	21.8	253
	1976/77	50.8	11.4	26.5	11.3	62.2	37.8	77.3	22.7	225
Groundnuts	1975/76	10.5	29.4	5.0	55.6	39.4	60.6	15.0	85.0	71
	1976/77	5.0	33.5	3.9	57.6	38.5	61.5	8.9	91.1	87
All crops above	1975/76	57.8	27.3	4.8	10.1	85.1	14.9	62.6	37.4	3,132
	1976/77	56.8	28.8	4.8	9.6	85.6	14.4	61.6	38.4	2,983

Sources: Derived from Tables 27-29 and India, Ministry of Agriculture and Irrigation, Directorate of Economics and Statistics, *Estimates of Area and Production of Principal Crops in India* (New Delhi: Controller of Publications, 1980).

Note: IA = irrigated area; UA = unirrigated area; HY&IV = high-yielding and improved varieties; TV = traditional varieties.

because of differences in the diffusion of fertilizer use on irrigated and unirrigated areas rather than because of differences in the rates of application. It is significant that diffusion of fertilizer use was substantially higher on UA-HY&IV than on UA-TV for each of the eight crops. The complementarity between irrigation and fertilizer as well as irrigation, fertilizer, and high-yielding varieties has long been recognized. However, the above pattern points to fertilizer use on high-yielding varieties grown on unirrigated areas. The significance of this cannot be overemphasized since unirrigated areas will continue to account for more than half of India's total cultivated land for many years to come.

5

CHANGES IN FERTILIZER CONSUMPTION PROFILES

Although fertilizer consumption profiles for different years cannot be compared with statistical precision, certain broad conclusions are inescapable. The estimates used in the following discussion are meant as orders of magnitude.

Shares of Crops in Growth of Fertilizer Use

Until the mid-1940s, fertilizer use was confined to plantation crops, rice, and sugarcane. By the mid-1950s, however, virtually all crops had some share in total fertilizer consumption. Since then, food crops such as foodgrains, sugarcane, condiments and spices, vegetables, and fruits have dominated consumption. Their share rose from about 70 percent in 1955/56 to more than 80 percent by 1976/77 and accounted for more than four fifths of the growth in the total from about 100,000 tons to 3.4 million tons.

Among food crops, in 1955/56 the share of foodgrains in total fertilizer consumption was about 45 percent and that of other food crops about 25 percent. By 1976/77 the share of the former rose to about 70 percent and that of the latter fell to about 12 percent. Foodgrains held a relatively low share in 1955/56 because fertilizer use on foodgrains other than rice had only recently begun. Their share in total consumption was less than 10 percent, although more than half of the country's area was sown with them. Throughout the period 1955/56 - 1976/77, about 85 percent of the fertilizer consumption on foodgrains was on rice and wheat, though they accounted for less than half of the total area sown with foodgrains.

Rice had the highest share of total fertilizer consumption among crops throughout the period (37 percent in 1955/56, 31 percent in 1970/71, and 35 percent in 1976/77). About one third of the increment in total fertilizer consumption between 1955/56 and 1976/77 was due to increased use on rice. On the other hand, wheat consumed only 3 percent of fertilizer in the mid-1950s. This increased to about 17 percent by 1970/71 and to 22 percent by 1976/77. By 1970/71 wheat ranked next to rice in fertilizer consumption. Between 1955/56 and 1976/77 it contributed about 22 percent to the increment in India's total use. Thus about 55 percent of the growth in total fertilizer consumption was due to increased use on rice and wheat.

More area was sown with other foodgrains than with rice and wheat but other foodgrains received less than 5 percent of the total fertilizer in 1955/56. Their share rose to about 10 percent by 1976/77 but was still less than one fifth the combined share of rice and wheat. Thus, even though fertilizer use on these crops had begun by the early 1950s, and they accounted for about 40 percent of India's gross sown area, they contributed only about 10 percent of the growth in total consumption between 1955/56 and 1976/77.

Since the early 1950s the time series of fertilizer consumption on all foodgrains taken together has risen more rapidly than that of total fertilizer consumption. Consumption on wheat rose far more rapidly than consumption on all foodgrains, and consumption on rice increased at about the same rate as the total. This implies that to estimate fertilizer's contribution to the growth in India's foodgrain production, it is crucial to distinguish between foodgrains, and to avoid the conventional assumption that the proportion of total fertilizer being used on foodgrains is fixed.

Fertilizer use in India began on the plantations but their share in total consumption dropped from about 25 percent in the early 1950s to about 6 percent in the mid-1970s. Thus they contributed only about 5 percent of the increment in total consumption. This is not surprising because these crops account for less than 1 percent of total cultivated area.

The share of nongrain food crops (for example, sugarcane, potatoes, chillies) in total fertilizer consumption was about 25 percent in 1955/56 despite a share of less than 5 percent in total sown area. This was

due to early fertilizer use on sugarcane in the 1930s, high responses of these crops to fertilizer application, and their being cash crops. By 1976/77 the share of these crops also declined to about 12 percent. Thus they contributed about 11 percent to the increment in total fertilizer consumption between 1955/56 and 1976/77.

Among the nonfood crops, cotton, jute, oilseeds, and tobacco had about a 12 percent share in total sown area, more than twice that of the nongrain food crops. Their share in total consumption in 1955/56 was less than 5 percent, but it increased to 11 percent by 1976/77. Most of the increase was due to growth in fertilizer consumption on cotton and groundnuts, particularly after the late 1960s.

The pattern of changes in fertilizer consumption by crops was due mainly to changes in the proportions of area fertilized, and rates of application on fertilized area. Changes in area sown were less important.

Diffusion of Fertilizer Use by Crop

The fertilized proportion of total area sown with cereals increased from 5 percent in 1953/54 to 26 percent by 1970/71 and to 37 percent by 1976/77.

Fertilizer use on rice began in the 1930s and in 1953/54 about 8 percent of the area was fertilized, highest among the cereals. Only 3 percent of wheat area was fertilized in 1953/54. By 1970/71 fertilizer use had spread to about 37 percent of area sown with both these cereals. In the next six years the diffusion of fertilizer use was faster on wheat than on rice. By 1976/77 about 55 percent of wheat area was fertilized compared to about 45 percent for rice.

Changes in the percentages of area fertilized for foodgrains can be grouped as follows: in 1953/54, rice and maize, 7-8 percent; wheat, barley, ragi, jowar, and bajra, 2-4 percent; and other cereals, millets, and pulses, less than 1 percent; in 1970/71, rice and wheat, 37-38 percent; maize, ragi, and barley, 15-19 percent; jowar and bajra, 5-7 percent; other cereals, millets, and pulses, less than 2 percent; and in 1976/77, rice and wheat, 45-55 percent; maize and ragi, 30-37 percent; jowar and barley, 17-19 percent; bajra, 12 percent; and other cereals, millets, and pulses, less than 5 percent.

For the country as a whole, no figures on the fertilized proportion of the area sown with nonfoodgrain crops are available for the early period. However, the share of these crops in total fertilizer consumption and microstudies indicate that during the 1950s, fertilizer use on crops such as sugarcane, potatoes, chillies, and tobacco was more common than on rice, but it was no more common on cotton, jute, groundnuts, and other oilseeds than on foodgrains other than rice. By 1976/77 more than 70 percent of the area sown with sugarcane, potatoes, chillies, and tobacco and about 40 percent of the area sown with cotton, jute, and groundnuts was fertilized. The spread of fertilizer use on oilseeds other than groundnuts was considerably smaller.

From these findings it is clear that for virtually all crops the percentage of area receiving fertilizer application increased over time, but the rate of increase among crops varied greatly.

Average Rates on Fertilized Area by Crop

Average rates of application on fertilized area were quite low for all crops in the mid-1950s. They were only about 15 kilograms of nutrients (about 75 kilograms of fertilizer materials) per hectare on rice and 2-4 kilograms of nutrients per hectare on the other foodgrains. The rates on sugarcane and potatoes were about 40 kilograms of nutrients if one assumes that about one fifth of the area was fertilized.

By 1970/71 there was a considerable increase in the rates on all crops. Among foodgrains, average rates per fertilized hectare ranged from 34 kilograms of nutrients on jowar, barley, and ragi to 42 on rice and 52 on wheat. Rates on sugarcane, tobacco, and condiments and spices were 80-100 kilograms. For other nonfoodgrain crops, the range was 35-55 kilograms. Variation by crop in the average rates on fertilized area was much less than in the percentages of area fertilized.

Between 1970/71 and 1976/77, the average rates on fertilized area sown with rice, wheat, jowar, ragi, sugarcane, and cotton increased by 40-50 percent. They reached

about 75 kilograms of nutrients per hectare on rice and wheat, about 85 kilograms on cotton, and about 146 kilograms on sugarcane. On the other hand, they declined by 50 percent on barley and by 20 percent on groundnuts. Rates also declined on maize and bajra, but marginally.

By 1970/71 diffusion of fertilizer use on crops like jowar, bajra, cotton, and groundnuts had proceeded slowly; but the rates of application on fertilized area had increased markedly. Similarly, between 1970/71 and 1976/77 percentages of fertilized area sown with bajra, maize, barley, and groundnuts increased, but the average rates on fertilized area declined. These findings suggest that diffusion and rates of fertilizer use for the country as a whole were governed by different factors.

Fertilizer Consumption on Irrigated and Unirrigated Areas

The percentage of India's gross cultivated area irrigated rose from about 17 percent in the early 1950s to 23 percent by 1970/71, and to 25 percent by 1976/77. This area accounted for 70 percent or more of total fertilizer consumption.

For each crop the share of irrigated area in total fertilizer consumption was higher than the percent of crop area irrigated. For example, 80-90 percent of total fertilizer consumption on rice and wheat in 1970/71 was on irrigated areas, although only 39 percent of rice area and 53 percent of wheat area were irrigated. For cotton, 61 percent of total fertilizer consumption was on irrigated area, which accounted for only 17 percent of the total cotton area. About 20-25 percent of fertilizer consumption on jowar and bajra was on irrigated area that was less than 5 percent of the total area.

Both diffusion and rates of consumption were higher on irrigated areas than on unirrigated areas, but for every crop, the difference in diffusion was greater than in rates. In general, diffusion on irrigated area was four to five times higher than on unirrigated area but rates on irrigated area were less than two times higher than on unirrigated area.

Despite greater diffusion, only about two thirds of total irrigated area was fertilized by 1976/77. This estimate, based on the definition of irrigated area in the NCAER survey, seems consistent with the estimate of 51 percent for 1970/71 based on the 26th round of the NSS. Even in the case of extensively fertilized crops such as sugarcane, wheat, and rice, 25-30 percent of irrigated areas under them were not fertilized by 1976/77. For many crops this was more than 40 percent.

More than three fourths of India's gross cultivated area was not irrigated from the early 1950s to the mid-1970s. The share of unirrigated area in total fertilizer consumption was less than 30 percent throughout the period. The share seems to have declined from about 28 percent in 1970/71 to 18 percent in 1976/77. Lack of data for the 1950s and 1960s makes it difficult to say whether the share of unirrigated area was constant or declining during this period.

In 1970/71 about 10 percent of India's unirrigated area was fertilized at an average rate of about 38 kilograms of nutrients per hectare. By 1976/77, the proportion of unirrigated area that was fertilized increased to about 18 percent and the average rate to about 45 kilograms per hectare.

Diffusion of fertilizer use by crop had virtually the same pattern under irrigated and unirrigated conditions. Crops more commonly fertilized under irrigated conditions were also more commonly fertilized under unirrigated conditions. Fertilizer use on cotton, groundnuts, and jowar under unirrigated conditions accelerated sharply after 1970/71.

Fertilizer Use on High-Yielding and Traditional Varieties

Findings on fertilizer use on high-yielding and traditional varieties are available only from the NCAER surveys. Therefore, it is not possible to study changes over time. However, the effects of varietal change on fertilizer consumption profiles is clearly evident from acceleration in the diffusion of fertilizer use and increase in the rates of application, particularly on wheat, rice, jowar, maize, and cotton. It is also evident from a comparison of the higher diffusion and rates on virtually all crops sown with high-yielding and improved varieties to the diffusion and rates on traditional varieties under either irrigated or unirrigated conditions.

At the same time, nearly 40 percent of total fertilizer consumption in the mid-1970s was on areas sown with traditional varieties. Of this, three fourths of the consumption was on irrigated areas and one fourth on unirrigated areas. A substantial proportion of total fertilizer consumption on many individual crops (including rice, jowar, and maize) was also on areas sown with traditional varieties. Two major exceptions to this pattern were wheat and cotton, where about 80 percent of the total consumption was on areas sown with high-yielding and improved varieties.

6

CONCLUSIONS AND QUESTIONS

> "In conclusion, it is maintained that water and manure constitute the cultivator's chief wants, and that supply of manure must go hand in hand with the water, and must, like the latter, be taken up by government, otherwise the soil will not be able to provide for the increasing millions of people."
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> John Augustus Voelcker
> *Report on the Improvement of Indian Agriculture*
> (London: Eyre and Spottiswoode, 1893)

This study suggests certain conclusions and questions about the forces behind the growth in India's fertilizer consumption from the early 1950s to the mid-1970s. It also indicates major changes in policies necessary to sustain rapid growth during the 1980s and areas of further research.

Composition of Total Fertilizer Demand

The pace of growth in fertilizer consumption varied greatly among crops and also on the same crop under irrigated and unirrigated conditions. This implies that the relative importance of the response function-cum-price environment for different crops was different in determining total fertilizer demand at various times. For instance, the environment for wheat must have exerted increasing influence on total fertilizer demand from the early 1950s onward. It must also have exerted considerably greater influence after the mid-1960s than before. Similarly, the response function-cum-price environment for crops like cotton and jowar must have played a greater role in influencing total fertilizer consumption during the 1970s than during the preceding two decades.

Although changes in the crop composition of total fertilizer demand are obviously important to understanding the forces behind the time series of fertilizer consumption, they are often ignored.[22] Instead, factors behind growth in total fertilizer consumption are identified by estimating one aggregate fertilizer demand function with such explanatory variables as index numbers of prices for all crops and fertilizers, total irrigated area, and area sown with high-yielding varieties.

An aggregate fertilizer demand function implies that the changes in total fertilizer consumption were "caused" by the changes in the explanatory variables. This study indicates that it is erroneous to attribute all of the changes in total fertilizer consumption to changes in the explanatory variables, particularly irrigation and prices. Even by the mid-1970s only about as much irrigated area was fertilized as total irrigated area in the mid-1950s.[23] Not only that, diffusion of fertilizer use, even on irrigated area under such crops as sugarcane, rice, and wheat, was not complete. Fertilizer use under unirrigated conditions also grew, even after

[22] This is not unique to India. For evidence on other countries, see Desai, "Understanding Growth." For instance, between 1927/28 and 1978/79, the share of corn in total U.S. fertilizer consumption increased from 22 to 40 percent and that of soybeans from 0.3 to 7.5 percent, but the share of cotton declined from 25 to 3 percent. Similarly, in a number of Western European countries, the share of hay and pastures in total fertilizer consumption steadily increased in the post-World War II period, reaching more than 40 percent by the 1970s. Even among the developing countries, scanty evidence clearly shows the composition of total fertilizer consumption changing over time.

[23] Between the mid-1950s and the mid-1970s gross irrigated area increased from 26 to 43 million hectares. The estimate of irrigated area fertilized based on the NSS 26th round findings for 1970/71 is 19 million hectares and the one based on the NCAER surveys for 1976/77 is about 29 million hectares. Undoubtedly, part of the growth in fertilizer consumption between the mid-1950s and the mid-1970s must have occurred on the additional area brought under irrigation during this period. But this is quite different from saying that a change in irrigated area was necessary for growth in fertilizer consumption on irrigated area, which is what the specification implies.

1973/74 when relative prices were less favorable to farmers than in the previous five to eight years.[24] All this, together with the estimates of the potential of fertilizer use made by several researchers, demonstrates that aggregate fertilizer consumption between the early 1950s and the mid-1970s was nowhere near the potential indicated by the prevailing response functions-cum-price environment.[25] Thus, it would be both illogical and misleading to relate the changes in total fertilizer consumption to the changes in irrigation and prices and to take the regression coefficients as estimates of their influence on farmers' demand for fertilizer. This cannot be overemphasized because such equations give results that are statistically significant and apparently convincing, as shown in the Appendix.

In India, actual total fertilizer consumption has been substantially less than the economic potential for it; and fertilizer prices have been administratively controlled. Under these circumstances, it would be incorrect to interpret the time series of total fertilizer consumption within a framework of demand analysis only, relating it to the agroeconomic variables behind farmers' demand for fertilizer in order to identify the forces governing it. The pace of growth in total fertilizer consumption would also be governed by the processes that convert the potential into actual farmers' demand. This would include development of an adequate and efficient distribution system, efforts to promote fertilizer use on different crops, and increased availability of fertilizer through domestic production and imports.[26] Thus viewed, incomplete diffusion of fertilizer use on all land where its use is potentially profitable should not be considered as resulting only from time lags in farmers' demand, caused by changes in agroeconomic variables.[27] It is equally important to determine whether the time series of total fertilizer consumption was influenced by the ways in which fertilizer distribution, promotion, and supply systems were developing. One gets more meaningful insights by pursuing this line of inquiry than by focusing only on agroeconomic variables.

The above discussion is not meant to downplay the importance of agroeconomic variables in the growth of fertilizer consumption. The variables behind fertilizer-response functions such as crops, varieties, and irrigation have exerted far greater influence than prices on past growth in fertilizer consumption. This is indicated by persistent variation in the growth of fertilizer use among crops despite comparable trends in prices.[28] In fact, between the early 1950s and mid-1970s, prices of several crops less commonly fertilized (cereals other than rice and wheat, pulses, groundnuts) often rose faster than those more commonly fertilized (rice and wheat). The importance of response functions is also revealed by much slower diffusion of fertilizer use under unirrigated conditions.

The impact of varietal change on fertilizer consumption is also clearly evident. Between

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[24] The ratio of the index numbers of prices of fertilizers and agricultural commodities (base 1961/62) was 55 in 1973/74. It rose to 78 in 1974/75 and to 93 in 1975/76. Then it fell to 81 in 1976/77 and 69 in 1977/79. Between 1965/66 and 1972/73 the ratio ranged from 62 to 70. See India, Ministry of Agriculture and Irrigation, *Bulletin on Food Statistics* (New Delhi: Controller of Publications, various years).

[25] For instance, under the fertilizer response functions-cum-prices environment prevailing in the early 1960s, Panse estimated that it was possible (in the technoeconomic sense) to use 3.57 million tons of nitrogen in India. Nitrogen consumption in the early 1960s was about one tenth of this. See V. G. Panse, *Technical and Economic Possibilities of Nitrogen.*

[26] This is elaborated in Desai, "Understanding the Process."

[27] There are two kinds of time lags in farmers' optimal demand for fertilizers. The first relates to farmers who already use fertilizer on all crops on which it is potentially profitable, but not enough. In their case, reduced demand could be due to lack of knowledge about response functions and optimal fertilizer practices, uncertainties associated with prices and weather, and capital constraints. The second kind is due to farmers not being aware of fertilizer, delays in adoption from lack of conviction about net returns, and initial fertilizer use on only some crops. Evidence shows the widespread prevalence of the second type in the growth of India's fertilizer consumption. More often than not, time lags were associated with factors such as crops, crop varieties, and irrigation, rather than farmers' characteristics (such as literacy status, owner or tenant, size of farm) or prices. This explains why fertilizer use spread more rapidly on certain crops and under irrigated conditions. It also explains why further diffusion of fertilizer use has not stopped even with unfavorable changes in the price environment after 1973/74.

[28] For data on prices, see India, Ministry of Agriculture and Irrigation, *Bulletin on Food Statistics;* India, Ministry of Agriculture and Irrigation, *Agricultural Situation in India;* and Fertiliser Associaton of India, *Fertiliser Statistics, 1979/80* (New Delhi: FAI, 1980).

1967/68 and 1976/77, total fertilizer consumption increased from 1.54 to 3.41 million tons in terms of nutrients. It is not possible to estimate how much of this was on the high-yielding varieties. However, the NCAER surveys and many microstudies clearly show that the spread of the fertilizer-responsive varieties accelerated diffusion of fertilizer use and raised application rates on a number of crops. The impact was greatest on irrigated areas but not confined to them. One could also argue that growth in fertilizer supply and expansion of distribution in the wake of the rapid spread of high-yielding varieties accelerated diffusion of fertilizer use even on traditional varieties.[29]

Although the overall impact of response functions on the pattern of fertilizer consumption was greater, prices have played an important role, particularly in certain periods. Available evidence suggests that the 9 percent decline in total fertilizer consumption during 1974/75, despite an increase of about 1.5 million hectares in irrigated area and 1.3 million hectares in high-yielding varieties of cereals, could be largely attributed to a sudden 80 percent increase in fertilizer prices.[30] Similarly, crop prices could have adversely affected the rate of growth in fertilizer consumption during the 1950s, particularly on wheat. But it is also clear that between 1967/68 and 1971/72 when fertilizer consumption increased from 1.54 to 2.66 million tons, there was little change in crop prices. On the other hand, in the next two years, fertilizer consumption grew from 2.64 to only 2.84 million tons despite higher crop prices. More significantly still, in the five years after 1974/75, when fertilizer consumption doubled, the relative prices of crops and fertilizer were roughly the same as in the early to mid-1960s.

It may be virtually impossible to sort out with statistical precision the influence of price and nonprice factors on the growth in fertilizer consumption for two reasons. First, the past growth represents movement toward a viable economic potential that was changing due to increases in irrigation, the spread of fertilizer-responsive varieties, and changes in relative prices. Second, the pace of growth in total fertilizer consumption was influenced by developments in the fertilizer distribution and supply systems.

A Question About Past Growth

This study confirms what many microstudies have repeatedly shown about the dominant influence of certain crops, irrigated areas, and fertilizer-responsive varieties on the pace and pattern of growth of fertilizer consumption. This is obviously explained by the larger size and greater certainty of returns in situations where fertilizer use was more common. But it would be erroneous to conclude that fertilizer use was not profitable in the situations where it was less common or totally absent. A question arises as to why fertilizer use did not expand faster than it actually did.

There was sufficient scope in India for a faster growth in fertilizer use than actually occurred. This is indicated by substantially less than complete diffusion of fertilizer use on all crops, even on irrigated areas by the mid-1970s. Similarly, slow but steady growth in fertilizer use under unirrigated conditions, even on traditional varieties, clearly suggests a viable potential and farmers' willingness to use it. Thus, it is just as necessary to ask why the past growth in fertilizer was not faster as to emphasize the importance of irrigation and high-yielding varieties in governing the past growth.

To answer the above question, it would be necessary to distinguish between such agroeconomic variables as crops, crop varieties, irrigation, and prices, which determine economic viability of fertilizer use, and behavioral factors and institutional arrangements that convert the potential into farmers' demand for fertilizer, affect development and operation of the fertilizer distribution system, and enlarge availability of fertilizer. Clearly, within the limits set by the agroeconomic variables, these three processes and the interplay between them determine the

[29] For a review of the evolution and growth of fertilizer distribution and supply systems in India up to the mid-1970s see Desai, "Fertiliser in India;" and Fertiliser Association of India, *Development of Fertiliser in India. FAI Silver Jubilee Commemorative Volume* (New Delhi: FAI, 1980).

[30] See various papers submitted to the 1976 Annual Conference of the Indian Society of Agricultural Economics in "Impact of Increase in Input Prices on Profitability and Production," *Indian Journal of Agricultural Economics* 21 (July-September 1976): 63-156.

growth and pattern of fertilizer consumption.

Among the factors that slowed past growth in India's fertilizer consumption, the following deserve particular mention: inadequate efforts to promote use, slow expansion of and inefficiencies in the distribution system, repeated shortfalls in domestic fertilizer production, and wide year-to-year fluctuations in imports.

Fertilizer promotion was particularly inadequate for foodgrains other than rice and wheat and for oilseeds. Even the massive fertilizer promotion program developed by the Fertiliser Corporation of India around 1970 did not include any foodgrain except rice in Madhya Pradesh. Similarly, it did not include bajra in Gujarat, Maharashtra, Mysore, Andhra Pradesh, or Tamil Nadu, which amounts to much of the area sown with bajra, nor traditional varieties of jowar in any state except Andhra Pradesh, Mysore, and Gujarat. Pulses were not included in any state. Among the nonfoodgrain crops, important omissions were cotton in Mysore and Tamil Nadu and oilseeds other than groundnuts in all states.[31]

The limitations of the distribution system are apparent in the lack of outlets in some areas. For instance, in 1974/75 the number of villages per outlet varied from 3 or fewer in Kerala, Tamil Nadu, Andhra Pradesh, Punjab, Haryana, and Gujarat to more than 10 in a majority of the states. In Assam, it was as high as 85. Even these figures are only indicative because distribution outlets within states also varied widely; outlets were concentrated at railheads in a few districts.[32]

Other shortcomings of the distribution system include: inadequacy and delays in supply at distribution points; insufficient credit both for farmers and distribution agencies; procedural delays in making even the limited credit available; transport bottlenecks and high transportation costs; inadequate storage facilities; and dilatory licensing procedures and other restrictions, such as a compulsory requirement to stock phosphatic and potassic fertilizers with nitrogenous fertilizers.

Fertilizer production shortfalls are evident from a comparison of the targets of fertilizer capacity proposed in different five-year plans and the actual levels achieved. In all plans except the first only 50-60 percent of the target for capacity was achieved. The performance in meeting production targets was still worse.[33]

In the 26 years between 1951/52 and 1976/77, imports accounted for 27-70 percent of total availability (domestic production plus imports) of fertilizer. In 12 years, it was 50 percent or more. Thus a substantial proportion of total availability was based on imports. In absolute terms, the volume of imports increased from less than 50,000 tons of nutrients in the early 1950s to more than 1 million tons by the mid-1970s. Growth, however, fluctuated widely throughout the period. For instance, imports increased by more than 50 percent in 6 years and declined 20-36 percent in 5 years.[34]

The experiences of the late 1960s and the mid-1970s clearly suggest that efforts to promote fertilizer use and to develop an efficient distribution system were influenced by the ways in which total fertilizer supply grew.[35] Between 1965/66 and 1967/68 total fertilizer production increased from 357,000 tons to 610,000 tons. During the same

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[31] See India, Ministry of Food and Agriculture, *Fertiliser Distribution Interim Report of the National Commission on Agriculture* (New Delhi: Controller of Publications, 1971), pp. 18-23. Sustained efforts to promote fertilizer use under irrigated conditions were also absent. See India, Ministry of Food and Agriculture, *Report of the Committee on Fertilisers* (Delhi: Manager of Publications, 1965), chapters 7 and 8, for the recognition of the problem and measures considered necessary to step up fertilizer promotion activities. Also see papers on fertilizer promotion in Fertiliser Association of India, *Strategy for Stimulating Fertiliser Consumption, Proceedings of FAI-FAO Seminar* (New Delhi: FAI, 1977), for articles on this subject during the mid-1970s.

[32] See Desai, "Fertilizer in India"; Bhag Israni and R. Kapoor, "Problems and Prospects of Expanding Retail Network" in *Strategy for Stimulating Fertiliser Consumption, Proceedings of FAI-FAO Seminar* (New Delhi: FAI, 1977).

[33] For details, see the documents on the five-year plans, and Fertiliser Association of India, *A Study on Fertiliser Demand and Marketing (Fertiliser Distribution and Marketing Fertiliser)* (New Delhi: FAI, 1973), and Desai, "Fertiliser in India," chapter 2, p. 394.

[34] Fertiliser Association of India, *Fertiliser Statistics, 1979/80*, p. I. 168.

[35] That constraints arising from aggregate availability of fertilizer could have adversely affected efforts to generate rapid growth in fertilizer consumption during the late 1940s, the late 1950s, and the early 1960s is also indicated by Tarlok Singh, "Planning for Agriculture" in *Agricultural Development of India—Policy and Problems*, ed. C. H. Shah (Bombay: Orient Longman Ltd., 1979); and India, Ministry of Food and Agriculture, *Report of the Fertiliser Distribution Enquiry Committee* (Delhi: Manager of Publications, 1960).

period, fertilizer imports increased from 413,000 tons to 1.5 million tons. Substantial inventories resulting from this sudden increase in availability of fertilizers created pressures to expand distribution networks and develop potential markets. These efforts lasted for only about three years because imports were reduced by more than 800,000 tons between 1967/68 and 1970/71, even though domestic production increased by half that amount. As a result of the dramatic spread of high-yielding varieties (particularly wheat), fertilizer consumption increased at an accelerated pace. This led to tight supplies of fertilizers in the early 1970s when there were worldwide shortages of fertilizer, causing the government to invoke its powers to regulate fertilizer distribution under the Essential Commodities Act. The period after 1974/75 was just the opposite. As a result of sustained growth in domestic production and an increase in imports from 629,000 tons in 1970/71 to 1.6 million tons in 1974/75 and again in 1975/76, pressure from the supply side developed. This led once again to accelerated efforts to expand the fertilizer distribution system and promote fertilizer use, illustrated by the Intensive Fertiliser Promotion Campaign launched by the government in collaboration with the fertilizer industry and the emphasis on promotion by fertilizer factories.

To answer why the past growth of fertilizer consumption was not faster, empirical research is required on the reasons for deficiencies in fertilizer promotion, distribution and supply systems and on how interactions between them affected growth in farmers' demand for fertilizer. Such integrative research on the total process would also help identify major policy instruments required to sustain rapid growth in fertilizer consumption during the 1980s by giving a sense of proportion about the relative importance of different issues and avoiding needless controversies.

Sustaining Rapid Growth

Although it could have been faster, the growth of India's fertilizer consumption has been impressive. By the late 1970s, India ranked fourth after the United States, the U.S.S.R., and China in total fertilizer consumption and production. Of course, all of these countries are large. But the United States and the U.S.S.R. ranked second and fourth even before World War II, whereas China and India were not even in the top 15 countries until the 1960s. India's consumption per unit of land is considerably less than that of these three and many other countries. But such a comparison is often misleading. One cannot judge a country's performance in raising its level of fertilizer use in this way simply because fertilizer consumption did not begin at the same time in all countries. Growth in India's fertilizer consumption per unit of land since the 1950s compares favorably with a number of developed and developing countries when based on the time taken to raise the average level of fertilizer consumption per unit of land from, say, less than 1 kilogram to 30 kilograms per hectare.[36]

The Sixth Five-Year Plan, 1980-85, aims at raising total fertilizer consumption from 5.3 million tons of nutrients in 1979/80 to 9.7 million tons in 1984/85.[37] This implies an annual growth rate of about 13 percent, which India has repeatedly attained. But in absolute terms it implies an annual increment of nearly 900,000 tons. Thus far, the annual increment has exceeded 500,000 tons only in 1976/77, 1977/78, and 1978/79, and the largest was 875,000 tons in 1977/78. Furthermore, fertilizer consumption increased by only 138,000 tons in 1979/80 and 260,000 tons in 1980/81. Achieving the Sixth Plan's agricultural production targets depends on attaining the fertilizer consumption target. That, in turn, depends on the policies adopted

[36] It must also be recognized that comparisons between countries based on the data available in FAO's *Fertilizer Statistics* on amount of fertilizer consumption per hectare on arable land exaggerates the differences between India and many other countries, notably those where a substantial proportion of total fertilizer consumption is on pasture land as in some European countries, Australia, and New Zealand and those with a high degree of multiple cropping as in some Asian countries, including China. There is hardly any fertilizer use on hay and pastures in India. The data for India in the FAO statistics relate to gross cropped area, which includes multiple cropped area, whereas those for many other countries relate to arable land, which excludes multiple cropped area.

[37] India, Planning Commission, *Sixth Five-Year Plan, 1980-85* (New Delhi: Controller of Publications, 1981), p. 105.

in certain key areas based on valid premises. Thus, for instance, relative prices will be relevant, but it also must be recognized that the required growth cannot be achieved by price manipulation alone. There should be no doubt about this.

Future possibilities for expansion of fertilizer use depend on past developments. This study shows that fertilizer use had spread to about two thirds of total irrigated area by 1976/77. Growth in consumption of about 2 million tons by 1979/80 and the past consumption suggests that by 1979/80 about 85 percent of India's total irrigated area was fertilized. Thus, there is much less scope for growth through further spread on unfertilized irrigated areas. Only about 8 million of India's 52.6 million hectares under irrigation are not being fertilized. A substantial proportion of this is probably affected by waterlogging and related problems, which indicates that little irrigated land is available for further diffusion of fertilizer use.

Similarly, the past pattern suggests that the average rate of fertilizer application on irrigated areas under all crops could have reached about 90 kilograms per hectare by 1979/80. At this rate, total fertilizer consumption on fertilized irrigated areas would be about 4 million tons of nutrients, about 76 percent of the total. Consequently, further growth in consumption on area now irrigated through increases in rates may not be as rapid in the short run as in the past, particularly since most of the irrigated areas with good water control probably were sown with high-yielding varieties by 1979/80.[38] An increase in agricultural production from raising rates on fertilized irrigated areas further would not be large. Therefore dependence on this strategy to generate rapid growth in fertilizer demand would enhance pressures for higher crop prices or fertilizer subsidies.

This underscores the importance of the irrigation development programs of the Sixth Plan, which aim at raising total irrigated area from 52.6 million hectares in 1979/80 to 66.2 million in 1984/85.[39] Given the complementarities among irrigation, high-yielding varieties, and fertilizer, the importance of achieving the Sixth Plan's target of irrigation cannot be overemphasized.

At an average rate of 100 kilograms per hectare on the entire 66.2 million hectares of irrigated area in 1984/85, total fertilizer consumption on irrigated areas would be 6.6 million tons of nutrients. (At the rate of 110 kilograms it would still be 7.3 million tons.) Thus the target of raising total fertilizer consumption to 9.65 million tons in 1984/85 and to substantially higher levels in the years beyond critically depends on accelerating growth in fertilizer use under unirrigated conditions.

Data generated through thousands of fertilizer trials indicate a viable economic potential for rapid growth in fertilizer use under unirrigated conditions. The national surveys and many microstudies also show that fertilizer use on virtually all crops under unirrigated conditions has been growing. Thus, a sustained vigorous effort is required to accelerate such growth.[40]

That these efforts should include fertilizer promotion activities to convince farmers about returns from fertilizer use and to expand fertilizer distribution systems in districts with little irrigation, needs no emphasis. It is also clear that the available high-yielding varieties have barely begun to spread under unirrigated conditions. Concerted efforts are required to accelerate this process now that their diffusion on the

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[38] By 1979/80 high-yielding varieties had spread to about 35 million hectares sown with rice, wheat, jowar, bajra, and corn according to the annual report of the Ministry of Agriculture for 1980/81. Assuming that 75 percent of the total irrigated area in 1979/80 was sown with these crops, total irrigated area under them would be about 39 million hectares. See India, Ministry of Agriculture and Irrigation, *Report, 1980-81* (New Delhi: Controller of Publications, 1981).

[39] This implies a sustained annual increase in irrigated areas of 2.7 million hectares, a rate achieved in only a few years in the recent past.

[40] Not all unirrigated areas in India have low and uncertain rainfall. In fact, unirrigated net sown area is equitably distributed among high, medium, and low rainfall regions. See India, Ministry of Agriculture and Irrigation, *Indian Agriculture in Brief, 1980* (New Delhi: Controller of Publications, 1980), pp. 22-23. Thus the problem of raising fertilizer consumption under unirrigated conditions should not be viewed as occurring only with low rainfall. In fact, a study based on the fertilizer growth performance of districts during the 1960s clearly showed that districts with low irrigation located in high rainfall regions, particularly in eastern India (including parts of Madhya Pradesh), performed the worst among all districts with little irrigation. See Desai and Singh, *Growth of Fertiliser Use*, chapter 4. Scrutiny of the trends in the 1970s indicates a similar pattern.

present irrigated areas is near completion. It is necessary to recognize that the extent and vigor of all these efforts will critically depend on the availability of fertilizer. Unless the growth in total supply stays ahead of growth in the market for fertilizer under irrigated conditions, there would be little motivation to develop markets in unirrigated areas.

This is clearly revealed by past experience. Therefore hasty reductions of fertilizer imports, either because of increased capacity of the domestic industry or to clear inventories, must be stopped. Fertilizer import policy should be based on an understanding of the role of supply in opening up potential markets through pressures on fertilizer promotion and distribution systems. This requires a realistic view of anticipated production from the domestic fertilizer industry, given its infrastructure constraints which lower capacity utilization. It also calls for a judicious assessment of the size and location of fertilizer stocks required to sustain rapid growth in fertilizer consumption in a country of India's size.

Achieving anything like the Sixth Five-Year Plan's target of fertilizer consumption would, therefore, require decisive policies and their vigorous implementation in four major directions: achieving the Sixth Plan's irrigation target; sustaining massive efforts to accelerate growth in fertilizer use under unirrigated conditions, both by increasing its use on traditional varieties and by spreading high-yielding varieties rapidly; enlarging aggregate supplies of fertilizer by increasing domestic production and also by increasing imports; and removing various deficiencies in the fertilizer distribution system.[41] Efforts in these directions, together with continuous agricultural research to improve fertilizer response on both irrigated and unirrigated areas and improvements in agricultural extension systems, will help to sustain rapid growth in fertilizer consumption beyond the Sixth Plan period.

[41] There are two more reasons. First, even the planned growth in the domestic fertilizer industry is less than the requirements implied by the targets of consumption (India, Planning Commission, *Sixth Five-Year Plan, 1980-85*, p. 46). Attaining fertilizer consumption of 9.6 million tons thus implies aggregate availability of at least 11 million tons, because it would be unrealistic to assume that in any year actual consumption could be more than 85 percent of availability. In fact, past trends suggest that in years of tight supply, the gap between total availability and consumption was less than 18 percent. Second, the location of fertilizer surpluses in the world market appear to be changing due to the changes in the economics of the fertilizer industry after 1973/74.

APPENDIX:

EQUATIONS BASED ON MACRO TIME-SERIES DATA

The equations presented below are intended to illustrate the arguments on specification error presented in Chapter 5. Total fertilizer consumption is considered a function of irrigation, high-yielding varieties, and prices. Available macro data on these variables for the period 1961/62-1976/77 are used to estimate the equations.

The following variables are used:

TFC = total fertilizer consumption (in 1,000 tons of nutrients),

GIA = gross irrigated area (in million hectares),

AHFC = area under high-yielding varieties of five major cereals (in million hectares),

FPI = index number of wholesale prices of fertilizers (1961/62 = 100),

AGPI = index number of wholesale prices of agricultural commodities (1961/62 = 100),

DFPI = index number of deflated FPI, deflated by the index number of wholesale prices of all commodities (1961/62 = 100),

DAGPI = index number of deflated AGPI, deflated by the index number of wholesale prices of all commodities (1961/62 = 100),

RFAGPI = index number of the ratio of FPI to AGPI (1961/62 = 100), and

TIME = time (1961/62 = 1, 1962/63 = 2, . . . 1976/77 = 16).

When the variables are used after logarithmic transformation, they are expressed with the letter L before them.

Results

Table 31 presents the correlation matrix. The correlation coefficients between variables in log form are shown in parentheses.

The following six equations were estimated. Figures in parentheses below the regression coefficients are t-statistics:

$$\begin{matrix} TFC = -4074.5 + 174.7\ GIA + 34.0\ AHFC - 5.5\ FPI + 0.02\ AGPI; \\ \quad\quad\quad\quad (-3.71)\quad (4.68)\quad\quad (2.28)\quad\quad (-3.88)\quad\quad (0.01) \\ \quad\quad\quad\quad\quad\quad \bar{R}^2: 0.98,\ DW: 2.013; \end{matrix} \tag{1}$$

$$\begin{matrix} TFC = -839.3 + 134.4\ GIA + 22.0\ AHFC - 18.3\ DFPI - 9.4\ DAGPI; \\ \quad\quad\quad\quad (-0.48)\quad (2.27)\quad\quad (0.91)\quad\quad (-3.33)\quad\quad (-0.73) \\ \quad\quad\quad\quad\quad\quad \bar{R}^2: 0.97,\ DW: 1.305; \end{matrix} \tag{2}$$

$$\begin{matrix} TFC = -904.7 + 88.5\ GIA + 41.4\ AHFC - 13.2\ RFAPCI; \\ \quad\quad\quad\quad (-0.48)\quad (1.62)\quad\quad (1.89)\quad\quad (-3.03) \\ \quad\quad\quad\quad\quad\quad \bar{R}^2: 0.97,\ DW: 1.91; \end{matrix} \tag{3}$$

$$\begin{matrix} LTFC = -5.400 + 3.580\ LGIA + 0.142\ LAHFC - 1.055\ LFPI + 0.926\ LAGPI; \\ \quad\quad\quad\quad (-1.368)\quad (2.460)\quad\quad (1.427)\quad\quad (-5.153)\quad\quad (2.912) \\ \quad\quad\quad\quad\quad\quad \bar{R}^2: 0.97,\ DW: 1.402; \end{matrix} \tag{4}$$

$$LTFC = -3.439 + 3.090\ LGIA + 0.157\ LAHFC - 1.078\ LDFPI + 0.880\ LAGPI;$$
$$(-0.522)\ (3.087) \qquad (1.584) \qquad (-3.286) \qquad (1.074)$$
$$\bar{R}^2\text{: } 0.97,\ \text{DW: } 1.365; \tag{5}$$

$$LTFC = 0.236 + 3.135\ LGIA + 0.153\ LAHFC - 1.029\ LRFAGPI;$$
$$(0.074)\ (3.372) \qquad (1.652) \qquad (-5.492)$$
$$\bar{R}^2\text{: } 0.98,\ \text{DW: } 1.362. \tag{6}$$

Each of the above equations explains 97-98 percent of the variation in total fertilizer consumption. All partial regression coefficients except the one for DAGPI in equation (2) have expected signs and most of them are statistically significant at 5 percent. One could also virtually eliminate multicollinearity by estimating equations (4) or (6) by dropping the explanatory variable on high-yielding varieties. And yet, as argued in Chapter 5, it would be incorrect to take the results of equations such as these as providing insights into the causal factors behind the growth in total fertilizer consumption between 1961/62 and 1976/77. It is also clear from the high correlation coefficients between TIME, on the one hand, and TFC as well as different explanatory variables, on the other hand, that high statistical significance in the above equations also arises because GIA, AHFC, FPI, and AGPI pick up the influence of the processes behind fertilizer demand, distribution, and supply systems—processes that also developed over time. This is not to argue that changes in the explanatory variables of the above equations had no causal influence on the changes in TFC. But that is quite different from saying that virtually all growth in India's fertilizer consumption was because of growth in demand for fertilizer resulting from changes in the explanatory variables and that the regression coefficients of these equations are unbiased estimates of their influence on the growth in total fertilizer consumption.

Table 31—Correlation matrix

Variables	TFC	GIA	AHFC	FPI	DFPI	AGPI	DAGPI	RFAGPI	Time
TFC	1.0								
GIA	0.98 (0.96)	1.0							
AHFC	0.96 (0.96)	0.98 (0.97)	1.0						
FPI	0.76 (0.76)	0.85 (0.89)	0.88 (0.84)	1.0					
DFPI	−0.38 (−0.50)	−0.27 (−0.30)	−0.16 (−0.31)	0.18 (0.09)	1.0				
AGPI	0.89 (0.93)	0.95 (0.96)	0.94 (0.93)	0.92 (0.91)	−0.19 (−0.33)	1.0			
DAGPI	0.15 (0.35)	0.12 (0.17)	−0.03 (0.22)	−0.15 (−0.08)	−0.66 (−0.65)	0.16 (0.27)	1.0		
RFAGPI	0.35 (−0.50)	−0.25 (0.28)	−0.12 (−0.31)	0.18 (0.09)	0.97 (0.97)	−0.20 (−0.34)	−0.82 (−0.81)	1.0	
Time	0.98 (0.98)	0.99 (0.93)	0.97 (0.90)	0.84 (0.75)	−0.33 (−0.52)	0.95 (0.93)	0.15 (0.37)	−0.31 (−0.52)	1.0

Notes: The values of $R > 0.50403$ are significant at 5 percent. The figures in parentheses represent a correlation matrix of variables in log form.

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