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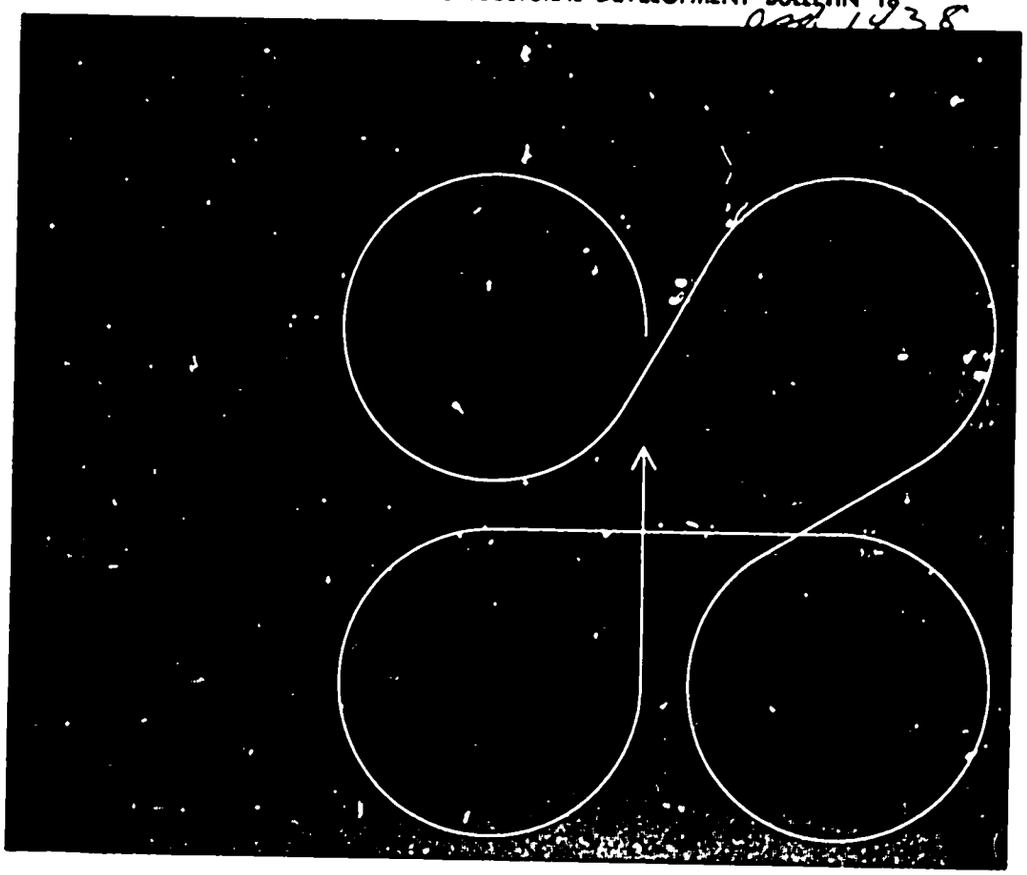

GROWTH OF FERTILIZER USE IN INDIAN AGRICULTURE

PAST TRENDS AND FUTURE DEMAND

GUNVANT M. DESAI

New York State College of Agriculture and Life Sciences
A Statutory College of the State University
At Cornell University, Ithaca

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Preface

Growth in agricultural production is increasingly dependent on greater use of inorganic fertilizers. The resultant strains on supplies of foreign exchange, domestic capital resources, and facilities to distribute fertilizer give importance to the appraisal of future demand for fertilizer. Rapid growth in farmers' demand for fertilizer does not occur automatically. Effective public policy for achieving high growth rates in agriculture must be based on knowledge of the factors which affect farmer demand for fertilizer and the means of increasing that demand. What is the potential for rapid growth in demand for fertilizer under current conditions of technology and complementary input supply? What is the role of new varieties of crops and increased irrigation? How will changes in cropping patterns affect the demand for fertilizer? These are key questions which this work examines.

Ideally, investigation of the demand for fertilizer is based on detailed study of physical production response under differing farm conditions and farmer's reactions to that response under the varying conditions of price relationships, knowledge of available resources, and motivation within which farmers make their decisions. Gunvant Desai has approached the bulk of his analysis indirectly by analyzing relationships among variables at the state and district levels. He has made detailed analysis of farm level data for one area and compiled similar data from secondary sources for many other areas. He has also made an extensive tour of key districts in each of the important types of farming regions of India. Thus, this work includes statistical analysis of aggregate data, study of individual farms, and judgments derived from direct experience. From this comes a detailed and sensible analysis of the demand for fertilizer and the forces which must be influenced if future demand is to grow rapidly.

The demand for fertilizer in the Indian economy is one of a series of studies being carried out at Cornell University as part of a USAID-financed contract for research on agricultural prices. We are grateful for the assistance provided by the Rural Community Development Division of USAID and, in particular, to Douglas Caton, Norman Ward and Voyce Mack of that division.

The broad program of study, of which this work is one part, covers 3 major areas of inquiry: the role of prices in intersectoral income and capital transfers; the effect of price relationships on agricultural production and marketings; and, the factors affecting urban prices of agricultural commodities. These studies are concerned with the effects of agricultural prices on the nonagricultural sectors of the economy, with

their effects in the agricultural sector, and with the manner in which agricultural prices are determined. Over the course of the contract studies will be carried on in several countries dealing with various aspects of the processes. Upon their completion, an effort will be made to compile them into an integrated view of the role and functioning of agricultural prices in the developmental process.

A basic objective of the contract for the conduct of this research is not only to produce useful research results but also to provide a pool of trained manpower for the analysis of such problems. The research in this project is accomplished primarily by Ph.D. candidates at Cornell University who use the specific studies as Ph.D. dissertations. Definition of the overall project has purposely been kept broad and flexible to attain this additional objective. This study by Gunvant Desai is part of that program and is drawn from his Ph.D. dissertation completed at Cornell University in 1969.

John W. Mellor

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Chapter 1. Introduction

In recent years numerous investigators have recommended a vast increase in the use of inorganic fertilizer in India—from less than 1 million tons in the mid-1960's, to over 4 million tons in the early 1970's, and over 7 million tons in the mid-1970's. Though the targets suggested by various agencies differ, all of them have a common objective—rapid increase in foodgrain production to meet greatly increased consumption needs of the projected population in the 1970's and 1980's, without dependence on huge imports.

The emphasis on increased fertilizer use is easy to understand. Since most of the available arable land in the country is already under cultivation, more intensive cultivation must provide for the needed growth in agricultural production. Use of fertilizers is emphasized because of: (a) low levels of soil fertility, (b) low levels of plant nutrient use, (c) alternative uses of major organic manurial resources, (d) possibility of quick production response, (e) dependence of many technological changes in agriculture on increased use of plant nutrients, (f) historical experience of many other countries in the contribution of fertilizers to growth in agricultural production, and finally (g) the possibility of enlarging the supplies of fertilizers by increasing domestic production and by imports.

A comparison of the trends in fertilizer use with the targets suggested by various agencies shows that an increase up to the levels indicated by the need-based targets within the given time span is possible only if there is a considerable acceleration in the past trends.

Attainment of this objective depends on enlargement of supplies, creation of adequate and efficient distribution networks, and growth in cultivators' demand for this input. Each of these aspects is important. The scope of the present study, however, is restricted only to the demand aspect. The specific question to which it is addressed is: What is the likelihood of cultivators' demand growing continuously by magnitudes required to attain the need-based targets of use? Recommendations for increased fertilizer use are mainly based on estimates of fertilizer requirements for raising agricultural production and not on the cultivator's demand. It is obvious that larger supplies and improved distribution channels will not result in increased use if cultivators do not find it profitable to use vastly increased quantities of fertilizer. A satisfactory answer to this question will be helpful not only in appraising the prospects of fulfilling the targets, but also in hinting at the kind of public

policy needed to generate rapid growth in cultivators' demand for this input.

The maximum quantity of fertilizer profitable for cultivators to use depends on: (a) the state of technology, (b) price relationships between crops and fertilizer, and (c) the availability of complementary inputs, particularly irrigation and management. If these conditions are unchanging, the maximum quantity is constant. In such a situation actual level of fertilizer use would increase towards this level, as more farmers adopt fertilizer use. The size of returns from fertilizer use can be considered the single most important factor determining the rate of adoption. The higher these returns, the faster the acceptance by farmers and more rapid would be the growth in effective demand towards the fixed optimal quantity determined by: (a) the state of technology, (b) price relationships, and (c) availability of complementary inputs. A change in any of these 3 conditions would change not only the optimal quantity towards which the effective demand is growing, but also cultivators' returns from fertilizer use, and hence the rate of growth in effective demand.

An ideal set of data for research on growth in cultivators' demand would include fertilizer practices of a random sample of cultivators from various parts of the country at different times and their fertilizer production functions for alternative crops and crop varieties. It would then be possible to determine: (a) the speed with which fertilizer use on different crops was adopted in a variety of farming conditions, (b) their rates of application at different stages of adoption, and (c) influence of factors such as prices, size of farms, tenancy status, and availability of complementary inputs, and credit on (a) and (b). In the absence of such data, the present study analyzes the available information on past fertilizer use pattern and average production functions to identify the past sources of growth in demand and then makes use of this knowledge to study the problem of further rapid growth.

The general plan of the study is as follows: Chapter 2 traces the growth of inorganic fertilizer use in India, the role played by the government in initiating and promoting its use, and the importance given to fertilizer in the agricultural production programs of the Five Year Plans. Chapter 3 presents the need-based targets of fertilizer use suggested by various agencies for the early and mid-1970's and discusses the demand aspect of the problem involved in raising the 1967-68 levels of use to the need-based targets of the 1970's. A conceptual framework to study the problem of growth in cultivators' demand for fertilizer is developed, the data needs for empirical research are discussed, and the approach adopted in this study is outlined. In chapters 4, 5, and 6, the past fertilizer use pattern is analyzed on 3 levels—individual cultivators, districts, and states. These chapters study the nature of the past use pattern, identify the factors behind it, and examine their relative importance in determining the growth in cultivators' demand for fertilizers. Chapter 7 estimates the

scope for rapid growth in demand for nitrogenous fertilizers in different states, brings out the main difficulties likely to be experienced in sustaining rapid growth, and indicates the nature of public policy needed to generate continuous rapid growth in cultivators' demand for fertilizers. The main conclusions are summarized in chapter 8.

Chapter 2. Historical Perspective

The history of fertilizer use in India is divided into 3 periods: (1) before 1942, (2) 1942 to 1947, and (3) since 1947. Although the need for increasing the use of plant nutrients had long been recognized by the colonial government the need was not met until 1942. Between 1942 and 1947, the government not only adopted organic manures and inorganic fertilizer as one of the means for rapidly increasing food production, but took initiative to make them available, and evolved an institutional framework to promote the use of fertilizer in nonplantation agriculture. After 1947, the government of free India expanded these efforts, and later made fertilizer a part of the development strategy behind the Five Year Plans. This review outlines the growth in fertilizer use up to 1967–68.

Period 1: Years up to 1942

Use of fertilizer in appreciable quantities began in India in the 1920's, when tea plantations started using imported ammonium sulfate as well as the by-product from the Tata Iron and Steel Company and from the coal fields of Bengal, Bihar and Orissa. However, there is no evidence of its use outside plantation agriculture until the 1930's when its use was extended to sugarcane and in "economically favorable areas" to rice.[1] Three factors seem to have brought this extension: (1) development of the domestic sugar industry as a consequence of the tariff protection it received in 1932, (2) fixation of minimum sugarcane prices by the governments of the United Provinces and Bihar, (3) efforts of the commercial firms to develop markets for fertilizer outside plantation agriculture.

Estimates of fertilizer consumption during this period are unavailable. However, estimates of production and imports, given in table 1, provide some indication about the amount of fertilizers used in British India.

The table shows that on the eve of World War II India used annually about 15,000 to 18,000 tons of nitrogen, 1,000 to 1,500 tons of phosphorus and about 1,000 tons of potash in the form of fertilizers. Except for 3,000 to 4,000 tons of nitrogen produced domestically as a by-product, all fertil-

[1] Throughout the study the term *plantations* is used to mean tea, coffee, and rubber plantations.

Table 1. **Production and imports of fertilizers in British India: 1926-27 to 1946-47**

Years	Nitrogenous fertilizers (in terms of N)		Phosphatic fertilizers (in terms of P_2O_5)		Potassic fertilizers (in terms of K_2O)
	Imports*	Production	Imports*	Production	Imports*
	Metric tons				
Period I:					
1926-27	561	N.A.†	N.A.	—	N.A.
1927-28	819	N.A.	N.A.	—	N.A.
1928-29	3,766	N.A.	N.A.	—	N.A.
1929-30	5,195	N.A.	N.A.	—	N.A.
1930-31	4,155	N.A.	N.A.	—	N.A.
1931-32	3,430	N.A.	N.A.	—	N.A.
1932-33	8,176	1,699	770	—	2,064
1933-34	6,771	2,031	1,261	—	1,897
1934-35	9,709	2,937	2,297	—	2,400
1935-36	9,569	3,688	2,178	—	2,058
1936-37	13,333	3,358	1,815	—	1,258
1937-38	11,401	3,722	1,644	—	1,785
1938-39	17,047	3,110	1,657	—	1,646
1939-40	17,692	4,139	1,447	—	1,219
1940-41	8,397	6,007	3,210	—	1,219
1941-42	648	6,698	590	—	122
Period II:					
1942-43	480	5,170	—	N.A.	426
1943-44	2,924	4,500	2,865	N.A.	609
1944-45	17,877	4,375	8,628	N.A.	—
1945-46	15,123	4,605	929	N.A.	914
1946-47	27,250	4,640	625	813	785

*Imports less re-exports.

†Not available.

Sources: For years up to 1937-38 and 1946-47, imports are calculated from various issues of Sea-Borne Trade of British India (Department of Commercial Intelligence and Statistics, Calcutta, India) and production statistics from various issues of Statistical Abstract for British India (Department of Commercial Intelligence and Statistics, Calcutta, India). For 1938-39 to 1945-46 see The World Fertilizer Economy, by Mirko Lamer (Stanford, Calif. Stanford Univ. Press, p. 678, 1957).

izers were imported. The first nitrogenous fertilizer factory started production in India in 1940, and while this increased domestic production, the total available was reduced as a result of a sharp decline in imports.

The government policy on fertilizer use was in keeping with its policy towards agriculture in general. From time to time it appointed commissions and committees to inquire into problems related to the improvement of agriculture. As early as the 1890's the government recognized that one

of the most limiting factors in the improvement of agriculture was low soil fertility and that increased use of plant nutrients was imperative to correct this deficiency. This is clearly brought out by the following observation made by John Augustus Voelcker in 1893 after an extensive investigation:

> Improvement in the system of land tenure, improvement of the land by expenditure of public and private capital on it, and similar measures, may alleviate the condition of the Indian cultivator, but they will not give him larger crops, and they will not provide the food that the people *must* have to live upon. For this the *soil* itself must be looked to, as it alone can produce the crops, and *manure* alone can enable it to bring forth the necessary increment. The question of manure supply is, accordingly, indissolubly bound up with the well-being and even the bare existence of the people of India.

Voelcker not only emphasized the importance and urgency of the problem but advocated government action in the matter:

> In conclusion, it is maintained that water and manure constitute the cultivator's chief wants, and that the 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.

In the 50 years that followed Voelcker's pronouncements, some measures were taken to develop irrigation, and to promote agricultural research, but little attention was paid to the problem of increasing the use of plant nutrients.

The agricultural research institutions, which came into existence during this period, devoted a part of their research efforts to the problem of manures and fertilizers. Scientific methods of preparing farmyard manure and compost were developed and manurial and fertilizer experiments were conducted. These research efforts, however, had little influence on the practices of cultivators. This is evident from the continuation of the same "crude" and "inefficient" methods of making farmyard manure absence of organized efforts to use other manurial resources, such as human excreta, garbage, and sewage; continuous large scale exports of oilcakes and bones; and low levels of manure and fertilizer use.

Period 2: Years between 1942 and 1947

The year 1942 marks the beginning of a new era in the history of Indian agriculture. When Japan began its assault on Burma in 1942, the government realized that India could no longer rely on imports of rice from Burma to supplement its food supply. The Grow More Food Campaign was launched to promote a rapid increase in food production. This campaign got further impetus from the Bengal Famine of 1943, in which about a million and a half people perished. Measures undertaken to implement the Grow More Food Campaign marked the end of the laissez-faire policy on fertilizer use, and initiated developments which were to influence its future use.

The basic strategy of the Grow More Food Campaign was to increase

food production by: (1) expanding the area under foodgrain crops, (2) augmenting irrigation, (3) increasing the supply of improved seeds, and (4) extending the use of manures and fertilizers on foodgrain crops.

The importance given to manures and fertilizer during these years is clearly brought out in the following remarks of the Famine Inquiry Commission appointed by the government to report on, among other things, causes of food shortage and the possibility of improving the yields of food crops.

Next to the provision of an assured supply of water, the use of manure offers the most important single means of increasing the yield of crops. Experience has shown that the plant food, abstracted by low yielding varieties of crops, is replaced through the operation of the natural recuperative powers of the soil, assisted by the small quantity of manure occasionally applied, and that 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 very considerable quantities. Hitherto the use of manures has been confined largely to the more profitable among the cash crops, such as tobacco, sugarcane and vegetables, and the amount of manure applied to land on which the main crops are grown has been very small. The problems of increasing the amount of manure used is, however, not a single problem but a whole series of problems, none of which, is easy of solution. Yet, if the standard of living of the Indian cultivator is to be raised, it is essential that the use of organic and inorganic manures should be greatly extended. If this is to be achieved, every source of fertilizing material must be utilized to the fullest extent, the supply and distribution of manures and fertilizers must be so organized as to ensure that they are available in all parts of the country at the cheapest possible rates, cultivators must be educated in their use and Agricultural Departments must be in a position to give detailed advice as to the quantity and the manner in which they should be applied.

There was one obstacle—limited availability of fertilizer. As shown in table 1, at the end of the 1930's 80 percent of the fertilizer used was imported; the supply declined sharply as the war gathered momentum. Nor was it possible to step up domestic production in the short run. On the other hand, war conditions generated their own requirements of fertilizer materials for armament industry. Thus, the beginnings of a period in which the government was actively interested in promoting fertilizer use in foodgrains production were marked by its limited availability.

During the war years the world supply of fertilizer was limited, and the amount available for exports in the surplus countries was allotted to various governments on a global basis by the International Emergency Food Council. In 1943 the Government of India established a Central Fertilizer Pool in the Ministry of Food and Agriculture to import fertilizer, to procure the entire quantity of fertilizers produced in the country, and to ensure equitable distribution of available fertilizers throughout the country at a uniform reasonable price. The Pool arrangements were restricted to nitrogenous fertilizers, both because scarcity was most serious in their case, and because it was generally believed that Indian soils were deficient mainly in nitrogen.

The Pool made estimates of requirements and domestic production, and worked out the needed amount of imports. Allotments of foreign exchange

by the Ministry of Finance determined the actual imports. The domestically produced and imported fertilizers were then pooled together, and distributed among the provincial (state) governments, plantation boards, and industrial users on the basis of their estimates of demand, past consumption performance, and total availability. The provincial governments represented non-plantation agriculture in their areas; plantation boards represented tea, coffee and rubber plantations. Besides controlling the available supplies and their distribution, the Pool also fixed the prices at which fertilizers were to be sold to the cultivators.

Again, estimates of consumption during 1942–1947 are not available, but from table 1 showing production and imports of fertilizers, it is clear that despite the resolve on the part of the government to increase fertilizer use, the actual levels of use till 1946–47 must have been below those in the years immediately preceding the war.

The scarcity of fertilizers and the responsibility assumed by the government under the Grow More Food Campaign to ensure adequate supplies initiated the development of the fertilizer industry in India. On the recommendation of the Foodgrains Policy Committee of 1943, it was decided to construct a state-owned, state-managed factory to manufacture ammonium sulfate. Construction of this factory, with an annual capacity of 73,000 tons of nitrogen, began in 1946 at Sindri in Bihar. Another plant with an annual capacity of about 15,000 tons of nitrogen was constructed at Ellur in the United States of Travancore. The phosphatic fertilizer industry also was established.

Thus, on the eve of independence, though the level of fertilizer use in India was not much higher than in the years immediately preceding the war, there was a complete transformation of the environment. Fertilizer came to be recognized as the surest and the quickest means of increasing agricultural, particularly foodgrain, production. The function of promoting its use shifted from market to the government. An institutional framework came into existence to augment supplies as well as to control its distribution at reasonable prices throughout the country. Finally, the fertilizer industry found its feet in the country.

Period 3: Years Since 1947

In the years immediately following political independence in August 1947, the government policy on fertilizer use underwent little change. Due to partition of the country, the food deficit as well as the deficit in some industrial raw materials, such as cotton and jute, increased. Consequently, the Grow More Food Campaign was extended to cover such nonfood crops. This did not strain the supply situation of fertilizer because there was increased availability as the domestic factories went into production and the world supply situation eased.

It is estimated that in 1951, when the First Five Year Plan began, the country was using annually about 59,000 tons of nitrogen and 7,000 tons each of phosphorus and potash in the form of fertilizers. About half of the nitrogen and all of the potash were imported. On the other hand, all of the phosphorus was produced domestically. The levels of use in 1951–52 cannot be compared directly with those before and during the war years, as the geographical coverage of India before and after August 15, 1947 was completely different. They do indicate substantial progress; and yet, on the basis of per unit of cultivated land, the level of fertilizer use in India was one of the lowest in the world, about 0.5 kilograms per hectare.

The role assigned to fertilizers in the development efforts undertaken within the framework of the Five Year Plans underwent complete change with the formulation of the Second Five Year Plan.

In the First Five Year Plan the importance of fertilizer was recognized, but only in general terms. It was observed that Indian soils were deficient both in nitrogen and phosphorus, but "rich in potash," and that manuring was necessary to provide nourishment to soil. Prime importance was given to organic manures but it was also laid down that there was no necessity to wait for full mobilization of organic manures before introducing inorganic fertilizers. Against this general recognition of the importance of fertilizers to supplement organic manures for the nourishment of soil, the Second and the subsequent Five Year Plans interpreted the role of fertilizer and other agricultural inputs in the context of a planned approach to agricultural production. Over the years rough input-output coefficients (referred to as "yardsticks" in the literature on Planning in India) indicating increase in foodgrains production as a result of increase in irrigated areas, use of fertilizers, use of improved seeds, etc., were evolved. These yardsticks were used to estimate the requirements of various inputs to achieve the agricultural production targets of the Second Plan. The importance given to fertilizers and manures in this plan is brought out by the fact that 25 percent of the target of 10 million tons of additional production of foodgrains was to be achieved by increase in their use.

The role assigned to fertilizers in achieving the targets of agricultural production in general and foodgrains in particular was further emphasized in the 1960's. There was little scope for bringing additional land under cultivation, the main factor behind growth in production during the 1950's. The strategy for promoting intensive cultivation was formalized in the Intensive Agricultural District Programme (also known as the "Package Programme"), and was initiated on an experimental basis in 7 districts in 1960–61. The importance of fertilizer grew as a consequence of this program. It was enhanced by rising imports of foodgrains to fill the gap between consumption and domestic production and a widespread recognition of the imperative need for a rapid increase in fertilizer use for a quick impact on yields.

The government played an active role in popularizing the use of fertilizers. Measures undertaken towards this aim included thousands of demonstrations on cultivators' fields, creation of a vast network of extension service, use of cooperatives to sell fertilizer to cultivators, supply of cheap credit, subsidy on transport cost in remote areas, rebate on purchase of fertilizers during "off-season," and control of fertilizer prices.

The principles for controlling prices were: (a) equalization of prices of imported and domestically manufactured fertilizers, and (b) price uniformity in different parts of the country. There were, however, no major subsidies. Although prices of various nitrogenous fertilizers were to be fixed by the Central Fertilizer Pool on a no-profit no-loss basis by pooling all costs (those of purchasing, handling, and transporting fertilizers), by 1963–64 the Pool had made profits of Rs. 433.59 million on its operations since 1944–45. There was a provision for subsidy on phosphatic fertilizers on the condition that the cost of subsidy would be shared equally by the central and the state governments. The initiative for granting this subsidy was left with the state governments. Perhaps as a result of the condition to share the cost of subsidy, only a few state governments granted subsidy on phosphatic fertilizers

Between 1952–53 and 1967–68 there was a substantial increase in the amount of fertilizers produced and used in the country as table 2 illustrates. The most important features of the table are:

(1) During the 16 years, annual distribution of the 3 types of fertilizers increased from 81 thousand tons to 1,680 thousand tons.

(2) Except for 3 years, nitrogenous fertilizers accounted for over 70 percent of the total fertilizers distributed in the country.

(3) All potassic fertilizers and some nitrogenous fertilizers were imported. Domestic production of nitrogenous fertilizers was less than 50 percent in 14 out of 16 years. Domestic production of phosphatic fertilizers fell short of distribution only after 1958–59, and even then, until 1965–66, it accounted for nearly 90 percent of distribution.

This survey brings out: (1) considerations which influenced the government in initiating fertilizer use outside plantation agriculture, (2) importance given to fertilizers in agricultural production programs, (3) establishment of the Central Fertilizer Pool for controlling distribution and prices of supplies, (4) limited availability of fertilizers, and (5) rapid growth in fertilizer use without major subsidies.

This kind of historical development has created an environment in which problems of increasing fertilizer use are usually discussed in terms of requirements of fertilizers to achieve planned targets of agricultural (mainly foodgrains) production, increasing the domestic production of fertilizers, and improving the efficiency of the distribution system. Important and relevant though these issues are, focus on them has resulted in relative neglect in studying the amount and nature of effective demand for fertilizers.

Table 2. **Production, imports, and distribution of fertilizers in India: 1952-53 to 1966-66**

Year	Nitrogenous (in terms of N)*			Phosphatic (in terms of P_2O_5)*			Potassic (in terms of K_2O)*	
	Production	Imports	Distribution†	Production	Imports	Distribution†	Imports	Distribution†
	Metric Tons							
1952-53	53,067	44,294	73,040	7,445	—	4,552	3,311	N.A.
1953-54	52,905	19,346	85,404	13,831	—	8,261	7,490	N.A.
1954-55	68,478	19,984	77,847	14,345	--	15,027	11,097	N.A.
1955-56	76,859	53,370	112,469	12,365	--	13,018	10,265	N.A.
1956-57	78,788	56,768	135,483	17,585	--	15,874	14,791	N.A.
1957-58	81,144	110,100	179,266	25,785	—	21,922	12,786	N.A.
1958-59	80,766	97,540	169,735	30,987	—	29,490	22,366	N.A.
1959-60	83,694	142,335	229,326	51,407	3,819	53,930	33,103	21,342
1960-61	111,987	171,926	211,685	53,722	128	53,134	24,845	29,052
1961-62	154,326	142,920	291,536	65,360	645	63,932	30,381	27,982
1962-63	194,194	229,462	360,033	88,300	7,959	81,385	44,276	36,503
1963-64	219,072	197,691	406,976	107,836	12,267	116,674	64,060	50,570
1964-65	243,230	256,517	434,473	131,021	12,293	147,652	57,176	70,440
1965-66	237,889	376,270	547,363	118,779	21,766	132,178	93,641	77,746
1966-67	308,993	574,628	838,736	145,678	129,158	248,602	143,337	115,710
1967-68	402,648	975,897	1,051,785	207,142	370,776	422,096	276,465	205,578

*Complex fertilizers containing more than one nutrient are included but bonemeal and rockphosphate are not included in P_2O_5 as these data are not available. Import figures for 1965-66 include basic slag in the case of P_2O_5 and Kanex (38-42% K_2O) in the case of K_2O.

†Figures are on financial year (April-March) basis except those for distribution of P_2O_5 from 1952-53 to 1957-58, which are on calendar year basis. In calculating distribution of K_2O for sulphate of potash quantity imported is taken as distributed.

Source: All statistics except distribution of nitrogen from 1952-53 to 1958-59 are from Fertiliser Statistics, 1967-68 (Fertiliser Association of India, New Delhi, pp. 147-48, 1968). Distribution of nitrogen from 1952-53 to 1958-59 is calculated from information supplied by the Department of Agriculture, Government of India.

The importance of the knowledge of the amount and nature of effective demand for fertilizer is obvious. In each production period the amount and pattern of its use depend ultimately on the total of various cultivators' decisions on how much fertilizer they should use. In the Indian context, the need for an understanding of the demand for fertilizer is crucial because fertilizer is an integral part of the strategy to achieve agricultural production goals of the Five Year Plans. While availability of adequate fertilizers is a prerequisite for achieving this objective, their utilization will be brought about largely by the play of economic forces behind cultivators' demand for them. An insight into these forces is, therefore, tantamount to gaining knowledge about policy parameters to achieve the objective.

Chapter 3. Fertilizer Use Beyond 1967–68

Need-based Targets of Fertilizer Use and the Demand Aspect of the Problem

The targets of fertilizer use suggested by various agencies to fulfill the agricultural production goals of the early and mid-1970's are presented in table 3. The amount of fertilizer distributed in 1967–68 is also shown. The rationale behind the need-based targets is in the planning technique (known as "yardsticks approach") adopted for agricultural production in India. This technique plans for the needed expansion in stocks and flows of different resources available to the agricultural sector to attain the targets of agricultural production set in the plans. The requirements of various inputs are derived from the input-output coefficients (referred to as "yardsticks") developed over years from trials on farmers' fields. Though the targets suggested by various agencies differ, all of them indicate one thing—the need for a vast increase in fertilizer use in the next few years. This explains the emphasis on supplies in India. It also explains concerted efforts in recent years to accelerate domestic production of fertilizers and also to develop marketing channels. It is estimated that the capacity for the production of nitrogenous and phosphatic fertilizers will go up from 715,750 and 416,860 tons (in terms of nutrients) in 1967–68, to 2,094,750 and 893,070 tons, respectively, in 1970–71. It will rise to 3,034,600 tons and 1,168,280 tons in early to mid-1970's, when the plans approved (by October 1968) for the creation of additional capacity are completed.

It is clear from a comparison of the estimates of distribution in 1967–68 with various targets that a substantial growth in cultivators' demand is needed for the 1967–68 level of use to rise to the recommended levels.

Table 3. **Amount of fertilizers distributed in 1967-68 and various need-based targets of fertilizer use for 1970's**

	Nitrogenous	Phosphatic	Potassic	Total
	million metric tons of N, P_2O_5 and K_2O			
Distribution in 1967-68.....	1.05	0.42	0.21	1.68
Need-based targets for 1970-71 suggested by:				
Committee on Fertilisers	2.40	1.00	0.77	4.17
USAID (standstill)*	1.96	0.98	0.49	3.43
USAID (minimum acceptable)†	2.69	1.34	0.67	4.70
Holst (for food self-sufficiency in 1976)	1.96	0.88	0.43	3.27
Holst (for food self-sufficiency in 1971)	2.50	1.10	0.60	4.25
Need-based targets for 1973-74 suggested by:				
Ministry of Food and Agriculture	3.73	1.74	1.11	6.58
Fertiliser Association of India	3.80	1.90	0.90	6.60
Need-based targets for 1975-76 suggested by:				
USAID (standstill)	3.08	1.54	0.77	5.39
USAID (minimum acceptable)	4.37	2.18	1.09	7.64
Holst (for food self-sufficiency in 1976)	3.88	1.96	0.97	6.81

*These targets are derived from requirements of foodgrains which implies no change in dietary levels, and self-sufficiency by mid-1970's/

†These targets are derived from requirements of foodgrains which implies some improvement in dietary levels and self-sufficiency by 1970-71.

Sources: Committee on Fertilisers. Report of the Committee on Fertilisers. Government of India. Department of Agriculture. New Delhi. 1965.
USAID: United States Agency for International Development Mission to India. Fertiliser Proposal for Increased Agricultural Production. New Delhi. American Embassy. 1964. Mimeographed.
Holst. The World Food Problem, A Report of the President's Science Advisory Committee. The White House. Vol. 2, pp. 673-711. May 1967.
Ministry of Food and Agriculture. C. Sahai. Developments of Fertiliser Industry in India. Fertiliser Association of India. New Delhi. 1968.
Fertiliser Association of India. op. cit.

In the 16 years between 1952–53 and 1967–68 the total annual consumption of the 3 fertilizers taken together increased from about 80 thousand tons to about 1,680 thousand tons—an average annual increment of about 100 thousand tons. In order to reach even the lowest need-based target shown in table 3 (that of Holst for 1975–76) fertilizer use in the country will have to grow annually by 640 thousand tons for 8 consecutive years. To attain the target recommended by the Ministry of Food and Agriculture for 1973–74, it must grow by over 800 thousand tons annually for 6 years. This, then, is the demand aspect of the problem of increasing fertilizer use in India. It is neither a problem of once and for all rise in the level of demand up to some fixed level, nor one of demand maintaining the upward trend. It is a problem of demand growing continuously, in the next few years, at rates higher than in the past.

What is the likelihood of farmers' demand growing continuously by such magnitude? What kind of public policy is needed to generate the required growth in demand? These questions cannot be answered without knowledge of the nature of the demand for fertilizer in India and factors which determine its growth. The available studies do not offer much help in these directions, mainly because of the normative approach to the problem and the inadequate analysis by those investigators who have approached it from the positive angle.[2]

A Framework to Study the Growth in Cultivators' Demands

In each production period fertilizer use depends on the cultivator's demand for it. Demand is an outcome of 2 decisions, whether to use fertilizer and how much to use. These decisions are governed by cultivators' returns.

The cultivator's returns depend on: (a) fertilizer production function, (b) price of crop, and (c) cost of fertilizer. If the cultivator knows these 3 factors when he makes the decision to use fertilizer, he will demand the "optimum" amount of fertilizer. As the physical response function and price of crop are uncertain, the cultivator's expected returns would be usually lower than those estimated from realized production function, realized crop price, the cost of fertilizer. If these subjectively estimated returns, discounted for yield and price uncertainty are very small, then

[2] For instance, Panse's investigation (1964) into the scope of using nitrogenous fertilizer in India takes into account productivity of fertilizers on cultivators' fields under the prevailing technological conditions, and the prevailing relative prices of crops and fertilizers. But it cannot be considered an inquiry into cultivators' demand for fertilizer, insofar as it is not based on actual fertilizer practices of cultivators. The trend-oriented investigations of Brown (1965) and Dahiya (1967) are based on historical fertilizer use data; they do not offer much help in appraising prospects of higher rates of growth than in the past or in providing guidelines for formulating the policy to attain such rates, because they do not bring out the relative strength of the various factors in generating the past growth in use.

the cultivator may not adopt fertilizer use out of inertia. On the other hand, if the returns over cost of fertilizer are significant and he opts to use fertilizer, his effective demand is still likely to be lower than the optimum amount, because he does not know the optimum rate under conditions on his farm and also because of cautiousness. In subsequent production periods too, his effective demand may remain below the optimum level if the fertilizer production function is unstable due to variations in weather conditions and/or if the marginal returns are small.

What is true of an individual cultivator is also true of all cultivators taken together. For a given state of technology (as reflected in the fertilizer production functions) and level of crop and fertilizer prices there would be an optimum level of total demand as represented by the sum total of optimum rates of fertilizer application on all farms.[3] As compared to this, the total effective demand in any production period would be the sum total of effective demand of all cultivators as determined by their subjective notions of fertilizer production functions on their farms, expected crop prices, and cost of fertilizer.

This distinction between optimum (or equilibrium) and effective demand for fertilizer, identification of reasons for discrepancy between the two and recognition of the importance of the size and certainty of returns in determining the effective demand are useful in understanding the problem of growth in total effective demand for fertilizers.

Visualize an economy with no fertilizer use at some point of time. Even for this point of time, it is possible to determine the equilibrium level of total demand for the economy from: (a) fertilizer production functions on all farms, (b) prices of crops, and (c) cost of fertilizer. Let us assume that these factors are constant over time and, therefore, the equilibrium level of total demand is unchanging.

In such an economy, initially fertilizer use would be an innovation, and the total effective demand would be much lower than the total equilibrium level. But it would grow over time as an increasing number of cultivators adopt the use on seeing the beneficial experience of the innovators, and as those who have already adopted the use move towards their individual optimum levels. The strength of these 2 forces which determine the rate of growth in total effective demand would be a func-

[3] Panse's estimate of 3.57 million tons of nitrogen to fertilize (a) the entire cultivated area under rice, irrigated wheat, maize, sugarcane, potato, groundnut, jute, and irrigated cotton; and (b) half the cultivated area under unirrigated wheat, ragi, jowar, bajara, barley, and unirrigated cotton at "optimum" rates under the technological and price conditions prevailing in the early 1960's can be considered an estimate of the equilibrium level of demand for nitrogen for the part of the Indian agriculture taken into account by him if we assume that: (1) fertilizer production functions used by him are applicable to all areas he includes, (2) price of nitrogen is the only cost of using it, and (3) relative prices of nitrogen and crops are the same as those used by him. See V. G. Panse, *Technical and Economic Possibilities of the Use of Nitrogen Fertiliser in India* (New Delhi, 1964). Mimeographed.

tion of the spread of knowledge about benefits of fertilizer use among cultivators. This in turn would depend, to a large extent, on the size and certainty of returns from fertilizer use to the cultivators.[4] Initially the rate would be low because only the most enterprising cultivators would adopt the use. Their experience, however, would have a strong demonstration effect on those growing fertilizer responsive crops with availability of complementary inputs (particularly irrigation) on their farms, and this would accelerate the growth in effective demand. But eventually the growth would slow down in this static world because the cultivators who have not yet adopted the use are those who do not expect high returns on crops they grow, particularly under conditions on their farms, and those who have adopted the use find that raising the rates from near-

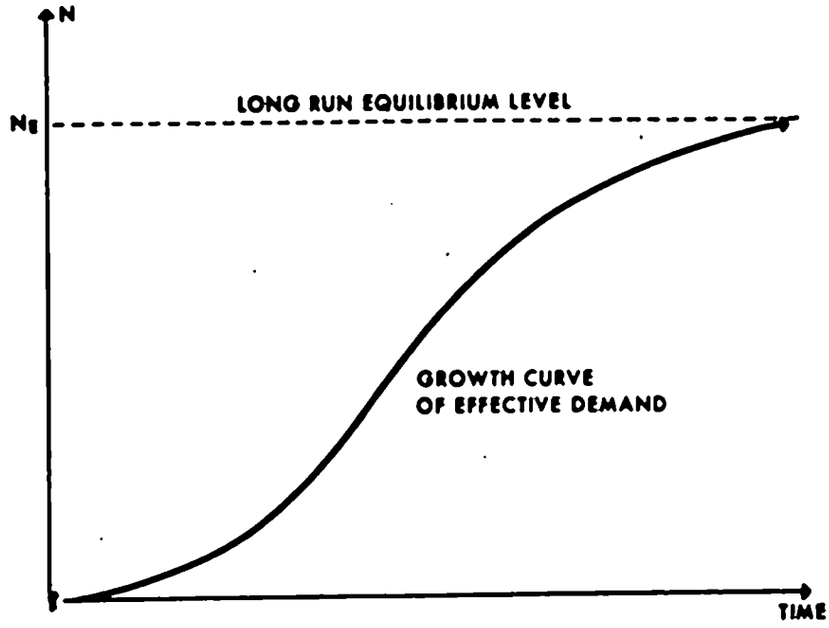

Figure 1. **Growth in effective demand toward a long run equilibrium level.**

[4] The absolute size of return is more important than rate of return on investment in this context where the focus is on cultivators getting over the uncertainty and inertia to adopt a new practice. The "rate of return over investment" often exaggerates the incentive cultivators would have to adopt fertilizer use. For instance, a return of Rs. 10 on Rs. 30 invested in fertilizer means as high as 33 percent rate of return. Yet, it is easy to see why a farmer who has never used this input on his farm may not find it worthwhile, for an extra Rs. 10 over 6 months' operations, to undergo the entire process of acquiring credit and fertilizer, and developing the skill to use it.

optimum to optimum levels brings only small increments in returns because of the law of diminishing marginal returns.

What influence will an effective extension service have on (a) equilibrium level of demand and (b) growth in effective demand?

If the extension work improves the fertilizer production functions (say, through spreading the knowledge on gains from applying fertilizer at the right time or in the right manner) it will accelerate the growth in effective demand for fertilizer by reducing uncertainty in the minds of cultivators who can expect sizable returns because of conditions on their farms. Nonetheless, as the total effective demand approaches the total equilibrium level, the influence of extension work on rate of growth in effective demand will diminish because at this stage the cultivators who have not adopted use are those who lack incentive to adopt fertilizer use because of small and uncertain return, under conditions on their own farms rather than awareness about the existence of this input and also because at this stage those who do not raise their rates of application to optimum levels do so because of the small size of marginal returns, rather than lack of knowledge about benefits of fertilizer use.

Thus far the discussion has been in the oversimplified framework in which values of the 3 parameters which determine the total equilibrium demand for fertilizer were unchanging over time. The aim of this discussion was to show that: (1) even under such conditions, once some cultivators start using it, effective demand for fertilizer would grow over time, (2) there would be an upper limit to growth in total effective demand represented by the sum total of the optimum rates of application on all farms, (3) the rate of growth in effective demand would be determined by the rate at which fertilizer use spreads among cultivators, and the rate at which individual cultivators raise their rates to their optimum levels; and (4) the rate of growth in effective demand would be low initially then accelerate, and finally, slow down after cultivators whose returns from fertilizer use are high have adopted the use. Now we broaden the framework by dropping the assumption of constancy in the parameters and examine the influence of change in them on. (a) total equilibrium demand and (b) rate of growth in effective demand for fertilizers.

Since total equilibrium demand represents the sum total of optimum rates of application on all farms, and as these rates are derived from fertilizer production functions, crop prices, and cost of fertilizer, any change in the set of values of these 3 factors will affect the total equilibrium demand. It will also have an impact on the growth in effective demand because the size of cultivators' returns on fertilizer use depends on them. The degree of this impact will depend on the number of cultivators whose returns are affected, and the extent to which they are affected. For instance, improvement in the fertilizer production function of crops grown on a relatively small proportion of land (e.g., tobacco) will

have a much smaller impact on the rate of growth in effective demand than that of sustained improvement in the prices of crops grown by a large majority of cultivators (e.g. foodgrains). On the other hand, a definite improvement in the availability of a complementary input, such as irrigation, or in the varieties of crops commonly grown, will have a more decisive impact on growth in effective demand than an uncertain improvement in product prices or small reductions in cost of using fertilizer because the former would increase the incentive to use fertilizer in a much larger measure than the latter.

The usefulness of the above conceptual framework for discussing the problem of accelerating the growth of fertilizer use in India can be shown by pointing out the following 4 major factors which will determine the future growth in effective demand: (1) wider spread of fertilizer use and increase in rates of application on land already fertilized, (2) development of irrigation, (3) replacement of the existing varieties by high yielding varieties of crops, and (4) change in the ratios of fertilizer cost to crop prices. It is reasonable to expect some growth in demand beyond 1967–68 because of (1), (2) and (3) even if the price situation were not to remain as favorable to the cultivators as in the last 2–3 years. However, in the context of the necessity for a rapid and huge increase in fertilizer use, the important question is not whether the effective demand will grow or not, but will it grow fast enough to socially desirable levels by mid-1970's. An equally important question is how critical are the 2 structural changes, increase in irrigation and replacement of crop varieties, for generating the rapid increase in effective demand for fertilizer?

Data Needs and Outline of the Approach

An ideal set of data for empirical research on growth in cultivators' demand for fertilizer would be those on fertilizer practices of a random sample of cultivators from various parts of the country at different points in time and their fertilizer production functions for alternative crops and crop varieties. It would then be possible to determine: (a) the speed with which fertilizer use on different crops was adopted in different categories of farming conditions; (b) optimum and actual rates of application under different price conditions; (c) actual rates of application at various stages of adoption; and (d) influence of specific factors such as change in prices, change in varieties, size of returns, size of farms, tenancy conditions, and availability of irrigation on (a) and (b).

Such data, however, are not available. What is more, replacement of local varieties by those which respond to high rates of fertilizer application on a significant scale began only in 1966 with the introduction of the High Yielding Varieties Programme. Many of these varieties are still in the experimental stage, and very little information is available on the

rate of adoption of those which are "released," fertilizer practices of cultivators who have adopted them, and response of these varieties to fertilizer use under field conditions.

In this study an attempt is made to analyze the available information on fertilizer use pattern up to 1964–65 and average fertilizer production functions of the old varieties of crops to understand the nature of the past fertilizer use pattern and identify the past sources of growth in cultivators' demand for this input. The rationale behind analyzing the past use pattern up to 1964–65 is that in the absence of any major change in the varieties of crops between the early 1950's and mid-1960's, the growth in fertilizer use during this period can be interpreted as growth due to wider spread of fertilizer use under relatively constant fertilizer production functions. Therefore, the findings on the use pattern give us an opportunity to examine the forces behind growth in effective demand for fertilizer under the technological conditions represented by the old varieties, assess scope for further growth in demand under such conditions, and thus judge the importance of structural changes which would shift the fertilizer production functions upwards and generate acceleration in the growth of effective demand.

We begin our search for an understanding of the nature of the past fertilizer use pattern in chapter 4 by analyzing the observed fertilizer practices of about 800 cultivators from one part of the country. The 3 main objectives of this analysis are: (1) to study the distinguishing characteristics of users and non-users of fertilizers, (2) to determine the extent to which fertilizer use had spread on different crops among these cultivators, and (3) to indicate the underlying forces behind the observed fertilizer practices. These findings are then compared with those of other 36 sample surveys conducted by the Institute of Agricultural Research Statistics between 1954–55 and 1963–64 in 19 districts located in different parts of the country. To test the validity of the insights gained from the analysis of the fertilizer practices of cultivators and to enlarge the scope of inquiry, the analysis is extended in Chapters 4 and 5 to higher levels of observation. In Chapter 4 nitrogen sales patterns observed among various districts within different states are analyzed to bring out their essential features and to identify the main factors behind the cross-sectional variation in sales. In Chapter 5 the nitrogen use pattern in various states of India between 1956–57 and 1964–65 is analyzed to study the relative importance of irrigation and prices in determining the interstate variation in levels of nitrogen use.

The guiding objective behind analysis in Chapters 4, 5, and 6 is to understand: (1) the true nature of the past fertilizer use pattern, (2) the relative importance of various factors in controlling demand for fertilizers, and (3) the nature of role these factors play in governing the growth in demand for fertilizers. By drawing on this analysis, an attempt is made in

Chapter 7 to estimate the scope for rapid growth in demand for nitrogenous fertilizers in different states under technological conditions represented by old varieties of crops. These estimates are then adjusted upwards to take account of the probable impact of the change in varieties of major foodgrain crops. This exercise brings out the main difficulties likely to be experienced in sustaining rapid growth in demand for fertilizers in different states beyond certain limits because it is based on the analysis of fertilizer use data as opposed to normative considerations. For this reason it also indicates the nature of public policy needed to generate continuous rapid growth in cultivators' demand for fertilizers.

Chapter 4. Analysis of the Observed Fertilizer Use Pattern: Fertilizer Practices of Cultivators

One of the important sources of growth in demand for fertilizer is increase in its use under the prevailing technological conditions. To examine the importance of this source, it is necessary to understand the nature of the past fertilizer use pattern.

Data on 1964-65 fertilizer practices of about 800 cultivators from Gujarat State are analyzed in section 1 of this chapter to study: (1) the characteristics of the users and non-users of fertilizer, (2) fertilizer practices of users, and (3) the forces behind the use pattern. In the second section the findings of the first section are compared with those of 36 other sample surveys conducted by the Institute of Agricultural Research Statistics between 1954-55 and 1963-64 in 19 districts of the country.

The most serious limitation of the information on fertilizer practices analyzed here is that in none of the sample surveys was the region (i.e., district) selected randomly. On the contrary, the surveys were conducted either in the districts covered by the Intensive Agricultural District Programme or in those where fertilizer use had made more headway than in other districts of the same state. This purposive selection of districts restricts the generality of the conclusions on the past fertilizer use pattern reached in this chapter. The other limitation of the information used here is that it is available for only 1 year for more than half the districts to which it relates. This restricts its usefulness to reveal the factors behind growth in fertilizer use. In spite of the limitations, the information used here is an important source to study past fertilizer practices because it relates to over 25,000 randomly selected cultivators from districts located in different parts of the country. Figure 2 shows the location of these districts.

Figure 2. Map of India showing districts where samples of cultivators studied were located. (*Source:* Adapted from Government of India, Ministry of Food and Agriculture, Directorate of Economics and Statistics, *Indian Agricultural Atlas*, New Delhi, 1958.)

Section I

Fertilizer Practices of 3 Groups of Cultivators from Gujarat State

The data used in this section were collected by the Agro-Economic Research Centre for Gujarat and Rajasthan for its 2 research projects, *An Enquiry into the Implementation of Farm Plans in Bardoli Taluka* and *Economic Survey of Borsad Taluka*. They refer to fertilizer practices in the agricultural year 1964–65 of 3 groups of cultivators: 71 cultivators from Bardoli Taluka of Surat District in south Gujarat, 392 cultivators from the Charotar tract and 333 cultivators from the Mahikantha tract, both in Borsad Taluka of Kaira District in central Gujarat. These 3 groups will be referred to as the Bardoli group, the Charotar group, and the Mahi group.

Major Characteristics of the 3 Groups

The 3 samples of cultivators differed in many respects. The Bardoli group was located in 1 of the 16 districts covered by the Package Programme, while the other 2 were in a region not covered by the program. Though the Charotar and the Mahi groups were neighboring, they differed significantly due to differences in the physical features of the regions and their relative levels of development. The Charotar tract is an unbroken plain, while the Mahikanthe tract is cut by deep ravines formed by the river Mahi. The former had a higher level of socio-economic development than the latter, in such facilities as roads and schools, and in diversification of economic activities. The 3 groups also differed in size of farms, availability of irrigation, and crop pattern. Tables 4, 5, and 6 present these characteristics.

Table 4. Distribution of cultivators according to size of holdings

Groups	Number of cultivators in each size class as percentage of total cultivators in the group		
	Less than 2 hectares	2 to 5 hectares	More than 5 hectares
	percent		
Bardoli	28	23	49
Charotar	72	23	5
Mahi	85	12	3

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

Table 5. Availability of irrigation to the 3 groups

Groups	Percent of cultivators in each group with irrigated land	Percent of total cultivated area irrigated in each group
Bardoli----	94	32
Charotar----	63	43
Mahi-------	22	20

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

Table 6. Crop pattern of the 3 groups of cultivators

Groups	Percent of total cultivated area of each group under:								
	Rice	Wheat	Bajra	Jowar	Banana	Sugar-cane	Cotton	Tobacco	Miscel-laneous
Bardoli----	22	6	-	12	3	6	29	-	22
Charotar----	14	4	26	2	2	*	*	33	19
Mahi-------	10	*	36	2	-	-	-	25	27

*Less than 0.5 percent.

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

Levels of Fertilizer Use

Levels of fertilizer use in the 3 groups are shown in table 7. The differences in the levels are as expected. The Bardoli group, located in a region covered by the Package Programme had not only the highest levels, as reflected in average rates per unit of land, but it used all the 3 plant nutrients. On the other hand, the Mahi group was using only nitrogen and the level was the lowest. The Charotar group came in between.

Though the average rates of fertilizer use, as computed in table 7 indicate the differences in the levels of fertilizer use by the 3 groups, they do not reveal the true nature of the differences. Not all farmers in each group used fertilizers nor did those using it fertilize their entire areas. Table 8 brings out these features. About two-thirds of the cultivators in the Mahi group did not use any fertilizers. For the Charotar and Bardoli

Table 7. Average rates of fertilizer use by the 3 groups

Groups	Total cultivated area	Average rate of use			
		N	P_2O_5	K_2O	M*
	hectares	kilograms/hectare			
Bardoli	410	33	6	9	1
Charotar	791	23	†	-	3
Mahi	422	14	-	-	-

* M refers to fertilizer mixtures. It was not possible to convert the mixtures into nutrients because the information on composition of mixtures was not available. As the nutrient content of a kilogram of mixture would be considerably less than 1, the importance of mixtures would be much less than indicated by the figures in the table.

† Less than 0.5 kilograms per hectare.

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

Table 8. Non-users of fertilizers and unfertilized areas in the 3 groups

Groups	Total cultivators		Total cultivated land with:		
			Users		Non-users
	Users	Non-users	Fertilized	Unfertilized	Unfertilized
			percent		
Bardoli	80	20	54	40	6
Charotar	63	37	50	35	15
Mahi	32	68	31	28	41

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

groups this proportion was much lower, a little over one-third and one-fifth, respectively. Furthermore, it was not only the cultivated areas of the "non-users" of fertilizer which remained unfertilized. In fact, in all groups large proportions of unfertilized areas were on farms where the cultivators had adopted fertilizer use

The difference between levels of fertilizer use by the 3 groups was

Table 9. Rates of fertilizer use on fertilized areas by the 3 groups

Group	N	P_2O_5	K_2O	M
	kilograms/hectare			
Bardoli	61	11	17	1
Charotar	47	*	0	6
Mahi	44	0	0	0

*Less than 0.5 kg./hectare.

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

primarily in terms of varying proportion of cultivators using fertilizers on varying proportions of total cultivated areas, rather than varying rates of fertilizer use per unit of land, as suggested by table 7 earlier. Table 9, which shows rates of fertilizer use per unit of land which was fertilized clearly supports this observation for difference in the levels of fertilizer use between the Charotar and Mahi groups.[5] The difference in the levels of fertilizer use between the Bardoli group on the one hand and the Charotar and Mahi groups on the other was in terms of both extent of fertilizer use and rates of fertilizer use on a unit of cultivated land.

Distinguishing Characteristics of Users and Non-Users

To see if the users and non-users had any distinguishing characteristics, their distribution was examined for: size of holding, tenancy status, availability of irrigation, and crop pattern.

The importance of these factors in affecting a cultivator's basic decision regarding whether to use fertilizers is obvious. Cultivators with very small holdings may not have adequate marketable surplus to invest in purchased inputs. Weather and price uncertainties may hinder the desire and ability to experiment with an unknown input. Tenants may lack the willingness and ability to use fertilizers, particularly if they are crop sharers and the cost of fertilizers is not shared by the land owners. Their ability to use fertilizers would be further impaired if credit institutions discriminate against them either by not granting credit or by charging

[5] Land which received at least one fertilizer is deemed as fertilized land; cultivators who were using at least one fertilizer are referred to as users

higher rates of interest on account of their lower credit-worthiness. Availability of irrigation can affect a cultivator's decision to invest in fertilizers in 2 ways: by increasing the productivity of fertilizers and by reducing yield uncertainty. Finally, the crop pattern of a cultivator can affect his decision to use fertilizers as returns from and, hence, incentive to use fertilizers would vary for different crops. The crop pattern can also affect his ability to invest in purchased inputs and thus influence his decision to use fertilizers.

An attempt was made to see if there was any association between the use of fertilizer and the size of holding or tenancy status.

The number of cultivators among tenancy classes and size-holding classes was obtained and cultivators using fertilizers in each class were distinguished from those not using any fertilizers. The findings, presented in tables 10, 11, and 12, are summarized:

(1) A high proportion of non-users in each group were those whose holdings were smaller than 2 hectares.

(2) A similar conclusion could not be drawn about the distribution of non-users among tenancy classes. A majority of the non-users in each group were owners. This, however, was due to the importance of the category of "owners" in each group.

Table 10. **Distribution of users and non-users of fertilizers according to size of holdings and tenancy status: Bardoli group**

Size of holdings (in hectares)	Tenancy status	Non-users	Users	Total
		percent of total cultivators (71)		
Smaller than 2	Tenants	-	-	-
	Owner-cum-tenants	-	-	-
	Owners	15	13	28
Sub-total		15	13	28
2 to 5	Tenants	-	-	-
	Owner-cum-tenants	-	-	-
	Owners	3	20	23
Sub-total		3	20	23
Larger than 5	Tenants	-	-	-
	Owner-cum-tenants	-	4	4
	Owners	1	44	45
Sub-total		1	48	49
Total		19	81	100

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

Table 11. **Distribution of users and non-users of fertilizers according to size of holdings and tenancy status: Charotar group**

Size of holdings (in hectares)	Tenancy status	Non-users	Users	Total
		percent of total cultivators (392)		
Smaller than 2	Tenants	7	4	11
	Owner-cum-tenants	5	8	13
	Owners	22	26	48
Sub-total		34	38	72
2 to 5	Tenants	1	1	2
	Owner-cum-tenants	1	7	8
	Owners	1	11	12
Sub-total		3	19	22
Larger than 5	Tenants	-	-	-
	Owner-cum-tenants	-	2	2
	Owners	-	4	4
Sub-total		-	6	6
Total		37	63	100

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

(5) While most of the non-users had "small" holdings, between two-fifths to a little over one-half of the cultivators with farms smaller than 2 hectares were using fertilizers in all groups.

This aspect—an overwhelming proportion of non-users being small cultivators and at the same time a sizeable proportion of the cultivators with less than 2 hectares using fertilizers—was investigated by studying 2 conditions which can substantially influence the cultivators' incentive to use fertilizers by affecting the returns on its use: availability of irrigation and crop pattern.

A close association is revealed between fertilizer use and availability of irrigation (table 13). In both the Charotar and Mahi groups, while a large proportion of users with small farms had irrigated land, a vast majority of non-users with small farms were without irrigation. In Bardoli all users had irrigation; in contrast to the other groups, nearly three-fourths of non-users also had irrigated land.

As shown in table 14, crop pattern was another factor which distinguished users from non-users of fertilizers with holdings smaller than 2 hectares. In each group a much smaller proportion of non-users were growing superior grains or commercial crops.[6] In each of the groups every

[6]In India, rice and wheat are referred to as superior grains and command higher prices compared to other cereals such as jowar, bajara, and maize.

Table 12. **Distribution of users and non-users of fertilizers according to size of holdings and tenancy status: Mahi group**

Size of holdings (in hectares)	Tenancy status	Non-users	Users	Total
		percent of total cultivators (111)		
Smaller than 2	Tenants	3	1	4
	Owner-cum-tenants	6	4	10
	Owners	57	14	71
Sub-total		66	19	85
2 to 5	Tenants	-	-	-
	Owner-cum-tenants	1	2	3
	Owners	2	7	9
Sub-total		3	9	12
Larger than 5	Tenants	-	-	-
	Owner-cum-tenants	-	-	-
	Owners	-	3	3
Sub-total		-	3	3
Total		69	31	100

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

Table 13. **Availability of irrigation to users and non-users with "small" farms**

	Bardoli	Charotar	Mahi
Non-users:			
Total cultivators	11	134	219
Cultivators having irrigation	8	34	8
Users:			
Total cultivators	9	147	64
Cultivators having irrigation	9	113	32
Percentage of non-users having irrigation	72	25	2
Percentage of users having irrigation	100	77	50

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

Table 14. Crop patterns of the users and non-users

Crops	Percentage of total non-users in the group who grew the crop			Percentage of total users in the group who grew the crop		
	Bardoli	Charotar	Mahi	Bardoli	Charotar	Mahi
Rice	82	25	12	100	51	31
Wheat	-	2	*	22	18	2
Jowar	27	2	*	22	5	8
Bajara	-	84	95	-	92	86
Banana	-	-	-	-	5	-
Cotton	27	-	-	33	2	-
Tobacco	-	11	10	-	64	83
Miscellaneous†	54	52	50	89	65	75

* Less then 0.5 percent of the cultivators.

† The category "miscellaneous" is a catch-all term for the remaining crops. It includes, in order of importance, other cereals, pulses, fodder crops, fruits, oilseeds and vegetables.

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

cultivator grew more than 1 crop, sometimes as many as 5 or 6; seldom did anyone fertilize all the crops he grew.

To conclude, most of the non-users of fertilizers were cultivators of small farms without irrigation, growing mainly inferior grains and fodder crops.

Pattern of Fertilizer Use

It was shown earlier that farmers who had adopted fertilizer use did not fertilize all areas they cultivated. This could be an outcome either of limited availability of fertilizers or lack of incentive to use them on certain areas, or both. Even if it were due to limited availability, this feature needs to be examined because it indicates the existence of an allocation problem for the cultivators.

Spread of Fertilizer Use on Different Crops

The spread of fertilizer use on a crop was measured as percentage of area under the crop which received at least 1 fertilizer. Table 15 presents the findings.

In each group certain crops were more extensively fertilized than others. These crops were sugarcane, banana, and rice in the Bardoli group; sugarcane, banana, and tobacco in the Charotar group; and tobacco in the Mahi group. In the Bardoli group rice was the only foodgrain crop

Table 15. Spread of fertilizer use on different crops

Crops	Fertilized area of the crop as percent of area under the crop cultivated by users			Fertilized area of the crop as percent of total area under the crop in the group		
	Bardoli	Charotar	Mahi	Bardoli	Charotar	Mahi
Foodgrains:						
Rice	98	52	52	92	43	34
Wheat	39	68	67	27	63	58
Bajara	*	49	42	*	38	16
Jowar	25	26	-	22	24	-
Non-foodgrains:						
Banana	100	85	*	100	85	*
Sugarcane	100	100	*	100	100	*
Cotton	68	50	*	66	50	*
Tobacco	*	86	83	*	82	73
Miscellaneous	7	20	22	7	15	13

* Not grown in the group.

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

being fertilized as extensively as the 3 commercial crops. Cotton was the only non-foodgrain commercial crop which was not highly fertilized. Table 15 also shows differences between the Bardoli and the other 2 groups in fertilizer use on foodgrains. In the former, almost all areas under rice were fertilized, but less than one-third of the area under wheat and only one-fourth of that under jowar were fertilized. In the Charotar and Mahi groups wheat (a higher proportion of which was irrigated) was more extensively fertilized than rice and bajara. Jowar was fertilized to a small extent in the Charotar group, but not in the Mahi group.

It is also clear from the table that when spread is measured as the percentage of all cultivated areas under these crops which were fertilized, rather than as percentage of areas cultivated only by the users, the discrepancy between the spread of fertilizer use on foodgrains crops and that on the non-foodgrain commercial crops becomes still wider. This is due to the foodgrain-oriented crop pattern of the non-users discussed earlier.

Amount of Fertilizers Used on Different Crops

Table 16 shows the rates of fertilizer use on fertilized areas under different crops in each of the groups. Within each group, the rates of fertilizer use on different crops varied. In spite of the variations, a consistent pattern can be seen. Non-foodgrain commercial crops, with the exception of cotton in the Bardoli group, were fertilized at higher rates than the foodgrain crops. Rice and wheat were fertilized at higher rates than jowar and bajara. The most striking feature of the rates of fertilizer use on different crops is the wide differences in the rates of use on sugarcane, banana, and cotton in the Bardoli group, and tobacco in the Charotar and Mahi groups. The rates used on sugarcane and banana were about 4–5 times higher than on tobacco. Cotton was fertilized at the lowest rate among the commercial crops and at a rate lower than rice and wheat.[7]

The amount of fertilizers used on different crops can also be viewed in terms of the distribution of total fertilizers among crops (table 17). The findings are similar and can be summarized as.

(1) In each of the 3 groups there was a heavy concentration of fertilizer use on some non-foodgrain crops. Sugarcane and banana, which occupied 9 percent of the total area in the Bardoli group, received 57 percent of the nitrogen, 62 percent of the phosphorus, and 96 percent of the potash used by that group. In the Charotar group 74 percent of nitrogen, 67 percent of phosphorus, and 76 percent of mixtures were used on banana and tobacco, which occupied only 35 percent of the area. The Mahi group, which used only nitrogen, applied 81 percent of it to tobacco grown on 25 percent of the area.

[7] Sugarcane and cotton in the Charotar group were grown by only 2 cultivators.

Table 16. **Rates of fertilizer use on different crops**

Crops	Bardoli group				Charotar group*			Mahi group†
	N	P_2O_5	K_2O	M	N	P_2O_5	M	N
	Kilograms/hectare							
Foodgrains:								
Rice	47	7	§	2	44	-	-	22
Wheat	44	5	9	-	37	2	22	38
Bajara	0	0	0	0	24	-	-	17
Jowar	16	3	-	-	26	-	-	-
Non-foodgrains:								
Bananas	223	69	80	-	130	-	36	0
Sugarcane	202	29	105	-	62	-	-	0
Cotton	16	4	-	1	59	-	-	0
Tobacco	0	0	0	0	57	§	7	60
Miscellaneous	37	1	-	16	33	1	9	17

* No K_2O used by this group.

† Used only N.

0 Crop not grown.

§ Less than 0.5 kilograms/hectare

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

(2) On the other hand, foodgrains which occupied substantial areas in each group received a very small proportion of the total fertilizers. The 3 groups, however, differed in the use of fertilizer on foodgrains. The Bardoli group, in which rice and wheat were the main foodgrain crops, allocated a higher proportion of its fertilizers to foodgrain crops than the other 2 groups, for whom bajara was the dominant foodgrain crop.[8]

(3) Among the non-foodgrain commercial crops cotton presents an interesting case. It was grown on 29 percent of the cultivated land in the Bardoli group, but it received only 10, 11, and 23 percent of nitrogen, phosphorus, and mixtures, respectively. This was in sharp contrast to tobacco, occupying about the same proportion of land in the Charotar and Mahi groups.

These findings raise 2 questions: What forces were responsible for the observed fertilizer use pattern? Do these findings have wider applicability?

Since the groups studied represent 3 dissimilar situations, and since

[8] Greater allocation of fertilizers to foodgrains in the Bardoli group was not as much due to its location in the Package Programme District as it was due to a higher proportion of its land under rice and wheat; jowar was little fertilized.

Table 17. **Distribution of fertilizers among crops**

Crops	Percent of area under the crop	Percent used on the crop			
		N	P_2O_5	K_2O	M
	Bardoli group				
Rice----------	22	28	24	2	45
Wheat----------	6	2	1	2	-
Jovar----------	12	1	1	-	-
Banana---------	3	20	33	26	-
Sugarcane------	6	37	29	70	-
Cotton---------	29	10	11	-	23
Miscellaneous--	22	2	1	-	-
	Charotar group				
Rice----------	14	7	-	-	-
Wheat----------	4	4	22	-	16
Bajara---------	26	10	-	-	-
Jovar----------	2	1	-	-	-
Banana---------	2	8	-	-	16
Sugarcane------	*	*	-	-	-
Cotton---------	*	*	-	-	-
Tobacco--------	33	66	67	-	60
Miscellaneous--	19	4	11	-	8
	Mahi group				
Rice----------	10	7	-	-	-
Wheat----------	*	1	-	-	-
Bajara---------	36	7	-	-	-
Jovar----------	2	-	-	-	-
Tobacco--------	25	81	-	-	-
Miscellaneous--	27	4	-	-	-

* Less than 0.5 percent.

Source: Agro-Economic Research Centre for Gujarat and Rajasthan.

fertilizer use in each was common among all types of cultivators and to a varying extent on all crops, one cannot attribute the observed pattern to ignorance or prejudice. There must have been some reasons for the observed use pattern. The most plausible explanation for the chief features of the observed fertilizer use pattern lies in varying levels of profitability of fertilizer use on different crops. Two factors which affect profitability of fertilizer use differently for different crops are their prices and their physical response to fertilizers. In the absence of these data for the culti-

vators studied here, it is possible to verify if profitability considerations governed the observed use pattern only in a general way.

Hopper has analyzed the data from fertilizer trials in cultivators' fields to estimate average physical response functions for a number of crops. The response functions are estimated by analyzing the summarized findings on the farmers' field trials conducted by the Institute of Agricultural Research Statistics on thousands of farms between 1951–52 and 1961–62 to obtain information on crop response to fertilizer use under prevailing conditions. These functions are used here to see if profitability considerations governed the observed use pattern. The limitation of this procedure is obvious. The physical production conditions encountered by the 3 groups would be different from those underlying the average all-India response functions But because they bring out the basic differences in the responsiveness of different crops to fertilizers, these response functions provide an opportunity to check if the observed use pattern was governed by variations in profitability of fertilizer use on different crops.

To analyze fertilizer trials, Hopper used the quadratic production function:

$$Y = bX + cX^2 + dXI$$

where:

Y is yield in pounds per acre,
X is either nitrogen or phosphorus in pounds per acre,
I indicates the presence or absence of irrigation as 1 or 0, respectively.

In most cases d could not be determined, as the data were not available. This is not a serious limitation for the present objective because we can assume that the data from the trials represent reasonably sufficient quantity of water on rice and sugarcane, and average rain-fed conditions for jowar and bajara—a situation similar to the one for the 3 groups of cultivators studied here. Non-estimation of c, in the case of cotton, makes the production function linear and hence it is interpreted strictly within the limits of fertilizer use in the trials.

Hopper's equations covered 6 of the crops grown by the 3 groups studied in the present chapter, namely rice, wheat, jowar, bajara, cotton, and sugarcane. This leaves out banana, tobacco, and the crops covered in the miscellaneous category. In view of the importance of tobacco in the Charotar and Mahi groups, the response function for this crop, estimated by Raheja and others from the experiments conducted by the Indian Agricultural Research Institute, is used. The parameters of the response functions for these 7 crops are given in table 18.

To compare returns from fertilizer use on different crops the response functions were multiplied by 1963–64 average farm prices of these crops in Gujarat, and revenue functions were obtained for different crops. On the

Table 18. Parameters of the response functions

Crops	Nitrogen			Phosphorus		
	b	c	d	b	c	d
Rice, all-India	+ 13.40	- 0.130	-	+ 8.70	- 0.080	-
Wheat, all-India	+ 10.20	- 0.130	+ 6.50	+ 5.30	- 0.060	+ 4.6
Bajara, all-India	+ 10.65	- 0.080	-	-	-	-
Jowar, all-India	+ 10.52	- 0.072	-	-	-	-
Sugarcane, South-India	+ 74.87	- 0.068	-	-	-	-
Cotton (lint), all-India	+ 0.85	-	+ 0.17	+ 0.50	-	+ 0.55
Tobacco, experiment station	+ 10.34	- 0.084	-	+ 2.68	-	-

Sources: For all crops except tobacco, Planning 'Yardsticks' for Fertilizers and Irrigation, by W. David Hopper, in Agricultural Situation in India, Vol. 20, No. 6, pp. 465-66, Sept. 1965. For tobacco, Fertilization of Crops by P. C. Raheja, A. G. Kavitkar, and R. P. Mehta, (Indian Agr. Res. Inst., Bul. 2, p. 110. New Delhi. 1965).

basis of nitrogen and phosphorus prices in Gujarat during 1964–65, two cost functions were developed for nitrogen and phosphorus. The assumption behind using 1963–64 crop prices and 1964–65 fertilizer prices is that fertilizer practices in 1964–65 were governed by returns as determined by realized crop prices of the previous year and prevailing fertilizer prices.[9] These functions are:

Rice:	$R = 4.42N - 0.043N^2$
	$R = 2.87P - 0.026P^2$
Wheat:	$R = 3.06N - 0.039N^2 + 1.95NI$
	$R = 1.59P - 0.018P^2 + 1.38PI$
Jowar:	$R = 2.10N - 0.014N^2$
Bajara:	$R = 2.56N - 0.019N^2$
Sugarcane:	$R = 3.52N - 0.003N^2$
Cotton:	$R = 1.46N + 0.29NI$
	$R = 0.86P + 0.95PI$
Tobacco:	$R = 5.89N - 0.048N^2$
	$R = 1.52P$
Nitrogen:	$C = 0.85N$
Phosphorus:	$C = 0.72P$

where:

R is revenue in rupees per acre from fertilizer use,
C is cost of fertilizer in rupees per acre,
N and P are nitrogen and phosphorus, in pounds per acre,
I indicates the presence and absence of irrigation as 1 and 0, respectively.

The revenue and cost functions are plotted in figures 3 and 4; in tables 19 and 20 returns over cost of fertilizer (R-C) are shown. While examining these figures it may be noted that the rates of nitrogen and phosphorus application in the trials were only up to 40 pounds per acre for the food-grain crops, 20 and 50 pounds per acre for sugarcane, and 80 pounds per acre for tobacco.

The returns from fertilizer use on different crops shown in tables 19 and 20 cannot be said to represent with precision the relative profitability of fertilizer use on them for the 3 groups of cultivators, because the production functions used in developing the argument represent the average all-India situation and not the production conditions confronting these cultivators. However, it is reasonable to assume that they do indicate the broad nature of the differences in size of returns and, therefore, the incentive to use fertilizer on various crops for the cultivators studied.

[9] These prices, in rupees per pound, were: rice 0.33, wheat 0.30, jowar 0.20, bajara 0.24, maize 0.19, sugarcane 0.047, tobacco 0.57, cotton (lint) 1.72, nitrogen 0.85, and phosphorus 0.72.

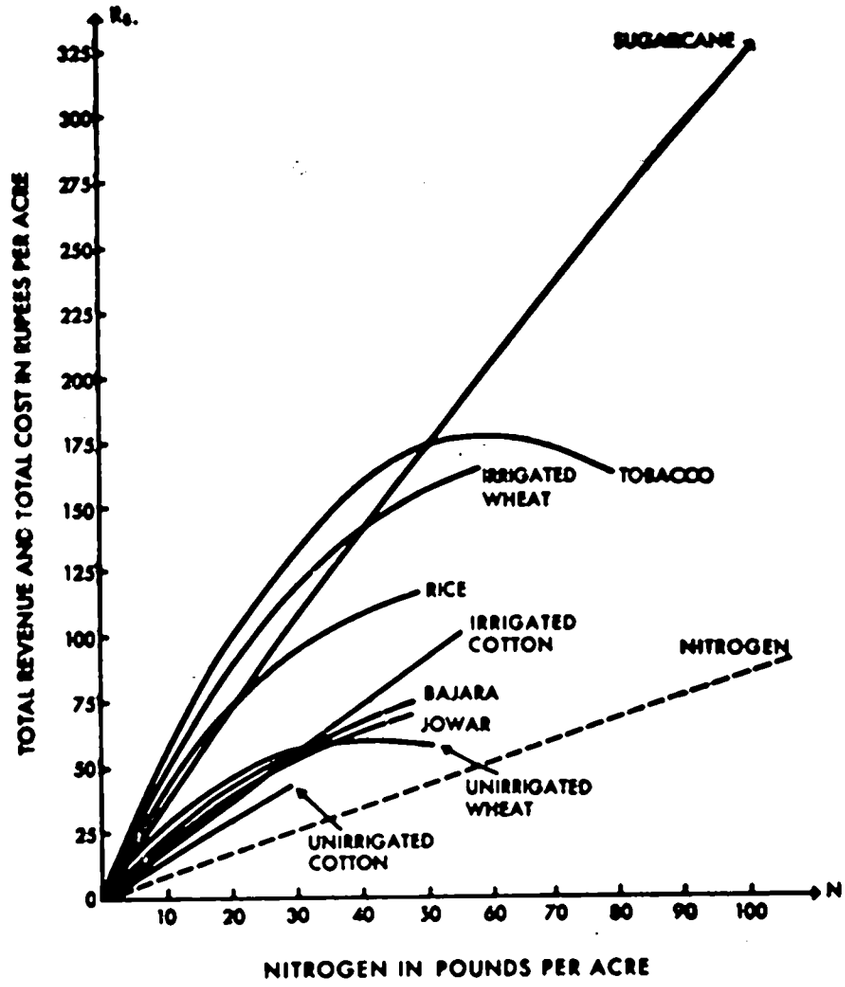

Figure 3. Total revenue from and total cost of using nitrogen on different crops.

Given such differences in returns from fertilizer use on different crops, it is easy to see why: (a) sugarcane was fertilized by all cultivators who grew it and at very high rates; (b) the spread of fertilizer use on tobacco, the most important commercial crop for the Charotar and Mahi groups, was very high but the rates were lower than on sugarcane; (c) cotton, the most extensively cultivated commercial crop in the Bardoli group, was less extensively fertilized than crops such as sugarcane and rice and at low rates; (d) rice and wheat were more extensively fertilized than other

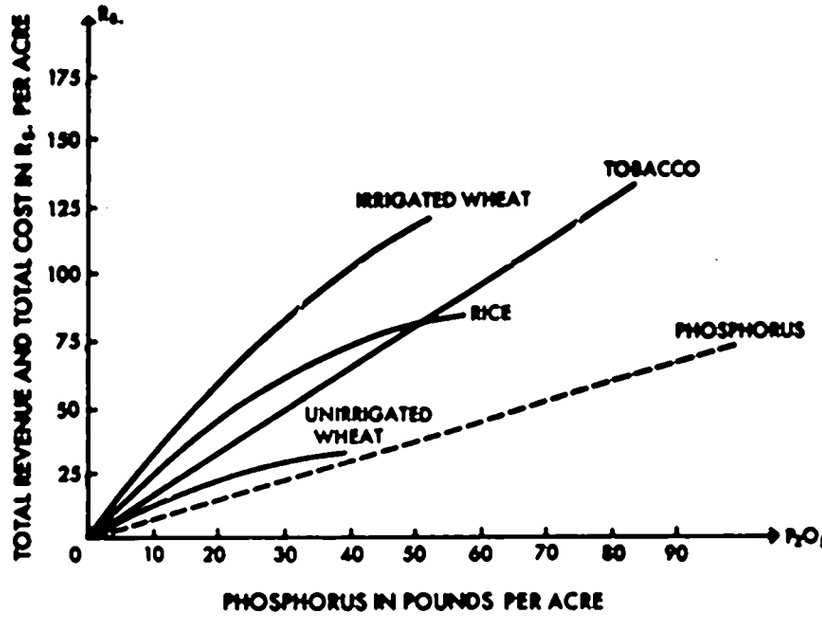

Figure 4. Total revenue from and total cost of using phosphorus on different crops.

foodgrains; (e) wheat was much less commonly fertilized in the Bardoli group, where almost all of it was grown under unirrigated conditions, than in the Charotar and Mahi groups where most of it was irrigated; and (f) in general, phosphorus was much less commonly used than nitrogen in all the groups.

Why did cultivators who had adopted fertilizer use not fertilize a significant proportion of their cultivated land in spite of positive returns from fertilizer use on crops grown on this land?

Any one or more of the following reasons might have been responsible for this feature: (1) limited availability of fertilizers, (2) inferior production functions of the cultivators, (3) high discounting of returns by cultivators, and (4) relatively early stage growth in fertilizer use on some of these crops.

If fertilizers were available in limited quantity (either due to short supply of fertilizers or due to lack of adequate credit facilities), concentration of fertilizer use on crops with high returns would be the logical outcome. Systematic and complete information on this subject is not available, but the impression gathered from the investigators who did the original field survey and the scanty information on credit distribution do not support this line of reasoning.

Table 19. **Returns over cost of nitrogen on different crops**

Level of N use	Rice	Unirrigated wheat	Irrigated wheat	Bajara	Jowar	Sugarcane	Unirrigated cotton	Irrigated cotton	Tobacco
lbs./acre					rupees per acre				
10——	31.40	18.20	37.70	14.20	11.10	26.40	6.10	9.00	45.20
20——	54.20	28.60	67.60	24.60	19.40	52.20	12.20	18.00	80.80
30——	68.40	31.20	89.70	31.20	24.90	77.40	18.30	27.00	106.80
40——	74.00	26.00	104.00	34.00	27.60	102.00		36.00	123.20
50——	71.00	13.00	110.50	33.00	27.50	126.00		45.00	130.00
60——			109.20			149.40		54.00	127.20
70——						172.20			114.80
80——						194.40			92.80
90——						216.00			
100——						237.00			
150——						333.00			
200——						414.00			

Note: The returns are calculated from the functions given in the text. For each crop they are calculated only a little beyond the rates of application in the trials. Hence, calculations are not extended up to peak levels for sugarcane.

Table 20. Returns over cost of phosphorus on different crops

Levels of P_2O_5 use	Rice	Unirrigated wheat	Irrigated wheat	Tobacco
lbs./ acre		rupees per acre		
10	18.90	6.90	23.70	8.00
20	32.60	10.20	43.80	16.00
30	41.10	9.30	60.30	24.00
40	44.40	6.00	73.20	32.00
50	42.50		82.50	40.00
60				48.00
70				56.00
80				64.00

Note: The returns are calculated from the functions given in the text. For each crop they are calculated only a little beyond the rates of application in the trials. Hence, calculations are not extended up to peak levels for irrigated wheat. For tobacco there is no peak level because up to 80 lbs., the highest rate in trial, a linear production function is given by Raheja.

The production functions used in this analysis are average all-India functions. It is not unlikely that the physical response to fertilizer use was lower than indicated by these functions on farms of some of the cultivators studied. This would further reduce the low returns on crops which remained unfertilized to the highest extent, namely jowar, bajara, and other foodgrains. This seems particularly plausible for tenants and small cultivators without irrigation. It is equally likely that the non-use of fertilizers on crops with low returns was due to heavy discounting of returns by cultivators. Discounting returns on fertilizer use due to yield uncertainty is likely because of the non-irrigated conditions under which these unfertilized crops were grown.

How wide an applicability do these findings have? Information on fertilizer practices of cultivators is available through published findings of a number of sample surveys conducted in several districts of the country between 1954–55 and 1963–64. In the second section these findings are studied to trace the pattern of fertilizer use within groups of cultivators and also to verify if the observed use pattern within each group was governed by considerations of varying profitability of fertilizer use on different crops.

Section II

Fertilizer Practices of Cultivators in Other Parts of India

The Institute of Agricultural Research Statistics has conducted a number of sample surveys in different parts of India to assess the spread of improved practices. Their findings are available for 36 surveys conducted in 19 districts. Data in these surveys were collected by drawing a random sample of 800 to 1000 cultivators from each of the 19 districts. The findings deal with: (1) spread and rates of fertilizer use on various crops, and (2) distribution of fertilizers among foodgrain and non-foodgrain crops.

Spread of Fertilizer Use on Different Crops

Table 21 shows the percentage of areas under different crops which were fertilized in the samples from the 19 districts. Potash in straight form was used only in 3 districts. These findings are given separately in the footnote to make the table more readable. M refers to mixtures.

In interpreting the table it may be noted that in some cases only partial information is available. For example, the sample of cultivators from Shahabad District had land under several crops (table 25), but for 1962–63 the findings on fertilized areas under different crops are available only for rice and wheat. While this partial availability restricts the usefulness of the findings for the present analysis, the table does show that

Table 21. Spread of fertilizer use on different crops

District, state	Crop	Percent of areas under crops that received nitrogen(N), phosphorus(P), and mixtures(M)†																				
		1954-55			1957-58			1958-59			1959-60			1961-62			1962-63			1963-64		
		N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M
Ferozepur, Punjab‡	Rice				2	0	0															
	Wheat				10	*	0															
	Maize				7	0	0															
	Cotton				17	0	0															
	Other fgs.§				*	0	0															
Ludhiana, Punjab	Wheat													61	21	0	74	23	0	81	51	0
	Maize																46	8	0	59	22	0
	Sugarcane													47	0	0						
	Garden crops													78	33	0						
	Cotton																25	2	0	26	2	0
	Groundnut																58	13	0	57	22	0
	Other fgs.													7	3	0						
Pali, Rajasthan	Wheat													1	1	0	5	3	0	3	*	0
	Maize																4	3	0	5	1	0
Barabanki, U.P.‖	Rice				22	0	0										54	0	0			
	Wheat				25	0	0										29	0	0			
	Sugarcane				23	0	0															
	Garden crops				32	0	0															
	Oilseeds				0	0	0															
	Other fgs.				*	0	0															
	Fodder crops				8	0	0															
Meerut, U.P.	Rice										10	0	0									
	Wheat										8	0	0									
	Maize										20	0	0									
	Sugarcane										42	0	0									
	Garden crops										21	0	0									
	Cotton										4	0	0									
	Other fgs.										*	0	0									

(continued)

Table 21. (continued)

District, state	Crop	Percent of areas under crops that received nitrogen(N), phosphorus(P), and mixtures(M)†																				
		1954-55			1957-58			1958-59			1959-60			1961-62			1962-63			1963-64		
		N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M
Aligarh, U.P.	Wheat													6	1	2	19	2	3	35	3	51
	Maize													7	0	0	18	*	*	25	1	1
	Bajara													3	0	0	14	1	1	15	*	1
	Barley													1	0	0	5	1	0	14	1	1
	Sugarcane													9	0	0	19	1	3	40	3	1
	Cotton													7	0	0	13	2	1	25	1	2
	Other fgs.													1	0	0						
Varanasi, U.P.	Rice													32	0	0						
	Wheat													12	0	0						
	Sugarcane													21	0	0						
	Garden crops													22	0	0						
	Other fgs.													4	0	0						
Shahabad, Bihar	Rice													45	5	0	53	24	0	67	50	0
	Wheat													16	2	0	29	16	0	48	44	0
	Sugarcane													77	5	0						
	Potatoes													96	23	0						
	Other fgs.													13	4	0						
Sambalpur, Orissa	Rice																3	3	0			
Raipur, M.P.	Rice							14	*	0				33	17	0	25	16	0	24	16	0
	Wheat													28	0	0						
	Garden crops													9	9	0						
	Oilseeds													2	2	0						
	Other fgs.													3	3	0						
Bhandara, Maharashtra	Rice																10	5	0			

(continued)

Table 21. (continued)

District, state	Crop	Percent of areas under crops that received nitrogen(N), phosphorus(P), and mixture(M)†																				
		1954-55			1957-58			1958-59			1959-60			1961-62			1962-63			1963-64		
		N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M
Surat, Gujarat	Rice																16	4	0			
	Jowar																3	1	0			
	Cotton																7	1	0			
W. Godavari, Andhra	Rice	27	10	5										36	9	*				62	25	10
	Sugarcane	51	0	72										62	5	*				90	15	0
	Garden crops	38	0	0																		
	Banana													36	0	0				50	4	0
	Chillies													36	0	0				70	4	0
	Tobacco	54	0	9										40	12	0				70	22	0
	Groundnut													5	7	0						
	Millets	*	0	0																		
	Pulses													0	4	0						
Krishna, Andhra	Rice													60	53	3						
	Sugarcane													59	3	23						
	Garden crops													41	11	8						
	Tobacco													68	38	7						
	Oilseeds													6	28	0						
	Millets													1	1	6						
Mandya, Mysore	Rice																65	56	0			
	Sugarcane																93	88	0			
	Ragi																8	8	0			
Thanjavur, Madras	Rice													48	26	7	61	43	4	66	39	12

(continued)

Table 21. (concluded)

District, state	Crop	Percent of areas under crops that received nitrogen(N), phosphorus(P), and mixtures(M)†																				
		1956-55			1957-58			1958-59			1959-60			1961-62			1962-63			1963-64		
		N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M
Coimbatore, Madras	Rice	22	2	0										78	52	51						
	Sugarcane													79	0	16						
	Tobacco													46	0	21						
	Cotton													4	0	1						
	Oilseeds													2	0	2						
	Millets													1	0	1						
Palghat, Kerala	Rice																34	3	35			
Alleppey, Kerala	Rice																22	16	58			

* Less than 0.5 percent.
† Where more than one rice crop was grown in a year, the spread is calculated by taking a weighted average of the percentage of areas fertilized in different seasons, weights being areas under rice in different seasons.
♦ Findings for 1957-58 related to 1957-59.
§ Other foodgrains
'' Findings for 1957-58 related to 1956-68.

The spread of potash, in samples where it was used in straight form, was as follows:

District, state	Crop	1961-62	1962-63	1963-64
Shahabad, Bihar	Rice	3	15	30
	Wheat	1	15	29
Mandya, Mysore	Rice		5	
	Sugarcane		3	
Alleppey, Kerala	Rice		5	

Sources: Compiled from information given in:
Reports of the Expert Committee on Assessment and Evaluation. Intensive Agricultural District Programme, 1961-63 and 1960-65. Ministry of Food and Agr. Government of India. New Delhi.

Fertilizer Practices Followed by the Farmers. Agricultural Situation in India, pp. 213-220. June 1964.

within each sample, fertilizer use was more common on certain non-foodgrain commercial crops, such as sugarcane, tobacco, and potatoes.[10] In almost all cases either rice, or wheat, or both were also extensively fertilized. On the whole, a higher proportion of area under rice was fertilized than under wheat. Foodgrains other than rice, wheat, and maize were either not fertilized or fertilized to a low extent. The relatively higher spread of nitrogen use on maize than on jowar, bajara, or such other foodgrains in some samples could be due to the use of hybrid varieties of this crop.

It is also clear from the districts for which findings are available for more than 1 year that the percentage of land fertilized increased even in as short a time as 2 or 3 years, and within such districts, the increase was greater on crops extensively fertilized than on crops of which only a small percentage was fertilized in the first instance.

Rates of Fertilizer Use on Different Crops

Findings on rates of fertilizer application on some crops grown in these 19 districts are also available. They are presented in table 22 and summarized. Again the focus is on variation in rates of fertilizer use on different crops within a district and not on variation among the districts.

As one would expect, the rates of fertilizer use on different crops varied within each sample. The degree of this variation differed for the districts, but the general pattern was quite uniform. Though in the samples from the north and east, rates on sugarcane were not always substantially higher than on rice and wheat, in general, certain non-foodgrain commercial crops were fertilized at higher rates than the foodgrain crops. Generally, rates of fertilizer use on cotton and groundnut were lower than those on rice and wheat. Wherever rice and wheat both were grown, there was not much difference between the rates of application on these crops. Other foodgrains were fertilized at rates lower than rice and wheat, with the exception of maize in some cases.

The other feature brought out by the table relates to variation of rates over time in the same district. Most of the information relates to rice and wheat. It appears from these findings that, in general, the rates of fertilizer application on these crops changed little over time. This is an interesting finding, because during the period covered by the surveys, the ratios between prices of fertilizer and crops were declining. On the grounds of marginal analysis, this feature of the fertilizer practices appears inconsistent with economic rationality on the part of the cultivators. On the other hand, when uncertain yields and the small size of marginal returns

[10] The average all-India production function for potato estimated by Hopper is: $Y = 55.29N - 0.145N^2$, where Y and N are yield and nitrogen in Pounds per acre, respectively. This high production function makes nitrogen use on potato more profitable than all other crops considered so far.

Table 22. Rates of fertilizer use on different crops

District, state	Crop	Rates of nitrogen(N), phosphorus(P), and fertilizer mixture(M), application on different crops*																				
		1955-56			1956-57			1957-58			1958-59			1959-60			1961-62			1962-63			1963-64		
		N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M
		lbs./acre																							
Ferozepur, Punjab†	Rice				15	0	0																		
	Wheat				16	4	0																		
	Maize				21	0	0																		
	Cotton				21	0	0																		
Ludhiana, Punjab	Wheat																19	8	0	21	14	0	25	15	0
	Maize																			20	17	0	18	16	0
	Sugarcane																19	0	0						
	Garden crops																65	22	0						
	Cotton																			20	22	0	22	16	0
	Groundnut																			12	9	0	14	13	0
Pali, Rajasthan	Wheat																			19	10	0	14	20	0
	Maize																			28	13	0	20	32	0
Barabanki, Uttar Pradesh♦	Rice				14	0	0																		
	Wheat				12	0	0																		
	Sugarcane				22	0	0																		
Meerut, Uttar Pradesh	Rice													12	0	0									
	Wheat													11	0	0									
	Maize													10	0	0									
	Sugarcane													19	0	0									
	Cotton													8	0	0									
Aligarh, Uttar Pradesh	Wheat																13	14	97	13	12	105	11	5	63
	Bajara																11	0	0	13	5	64	9	15	61
	Maize																5	0	0	8	13	110	12	10	79
	Sugarcane																13	0	0	19	8	186	23	22	100
	Cotton																6	0	0	21	5	86	13	21	70

(continued)

Table 22. (continued)

District, state	Crop	Rates of nitrogen(N), phosphorus(P), and fertilizer mixture(M), application on different crops*																				
		1954-55			1957-58			1958-59			1959-60			1961-62			1962-63			1963-64		
		N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M
		lbs./acre																				
Varanasi, Uttar Pradesh	Rice													8	0	0						
	Wheat													16	0	0						
	Sugarcane													19	0	0						
Shahabad, Bihar	Rice													13	31	0	7	5	0	7	5	0
	Wheat													13	24	0	14	12	0	12	6	0
	Sugarcane													8	38	0						
	Potato													23	104	0						
Sambalpur, Orissa	Rice																17	11	0			
Raipur, Madhya Pradesh	Rice							10	3	0				9	6	0	12	11	0	13	12	0
	Wheat													2	2	0						
	Garden crops													36	13	0						
Bhandara, Maharashtra	Rice																11	7	0			
Surat, Gujarat	Rice																25	19	0			
	Jowar																17	4	0			
	Cotton																19	10	0			
W. Godavari, Andhra Pradesh	Rice	17	13	0										21	22	0	22	22	85	21	24	79
	Sugarcane	56	0	0										73	0	0						
	Tobacco	56	0	0										51	0	0						
Krishna, Andhra Pradesh	Rice													13	27	0						
	Sugarcane													126	51	0						
	Tobacco													23	19	0						

(continued)

Table 22. (concluded)

District, state	Crop	Rates of nitrogen(N), phosphorus(P), and fertiliser mixture(M) application on different crops*																				
		1956-55			1957-58			1958-59			1959-60			1961-62			1962-63			1963-64		
		N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M	N	P	M
		lbs./acre																				
Mandya, Mysore	Rice																29	21	0			
	Ragi																13	11	0			
	Sugarcane																108	62	0			
Thanjavur, Madras	Rice													26	23	118	15	18	71	16	21	146
Coimbatore, Madras	Rice	32	27	0										32	0	0						
	Sugarcane	43	0	0										64	0	0						
	Tobacco	29	0	0										29	0	0						
	Cotton													25	0	0						
Palghar, Kerala	Rice																29	4	86			
Alleppey, Kerala	Rice																15	26	157			

* Where more than one rice crop was grown in a year, the average rates are calculated by taking weighted averages of the rates of application in different seasons, weights being equal to areas under the crop in different seasons.

† Findings for 1957-58 relate to 1957-59.

‡ Findings for 1957-58 relate to 1956-58.

The rates of potash application, where it was used in straight form, were as follows:

District, state	Crop	1961-62	1962-63	1963-64
Shahabad, Bihar	Rice	27	6	4
	Wheat	24	11	5
Mandya, Mysore	Rice		39	
	Sugarcane		116	
Alleppey, Kerala	Rice		20	

Sources: Compiled from information given in:

Reports of the Expert Committee on Assessment and Evaluation. Intensive Agricultural District Programme, 1961-62 and 1962-63. Ministry of Food and Agr. Government of India. New Delhi.

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from raising the rates of fertilizer application on these crops are taken into account, this feature does not appear surprising.

This is demonstrated in table 23 by calculating marginal returns over cost of nitrogen in 2 price situations. The first price situation refers to 1958–59, when rice, wheat, and nitrogen prices (in rupees per quintal) were about 48.50, 42.00, and 187.00, respectively, in the major producing areas. The second price situation refers to 1963–64, when prices of the same 3 commodities were about Rs. 60.00, Rs. 50.00, and Rs. 172.00. The marginal returns are calculated by using the same production functions discussed in the first section of this chapter. It can be seen from the table that while improvement in the price situation increased considerably the incentive to adopt fertilizer use, it did not raise the marginal returns considerably. This was due to the nature of the fertilizer production functions of the prevailing varieties of foodgrains.

Table 23. Returns over cost of nitrogen at different levels

Crop	Price situation	Optimum rate	Returns over cost of N at: 50% opt. rate	75% opt. rate	Optimum rate	Increase in marginal returns between: 50% and 57%	75% and opt. rate
		lbs./acre	rupees/acre			rupees/acre	
Rice	I	36	29	36	38	7	2
	II	41	43	54	58	11	4
Irr. wheat	I	46	40	50	54	10	4
	II	51	59	74	78	15	4
Unirr. wheat	I	22	9	11	12	2	1
	II	26	15	19	20	4	1

The findings on spread and rates of fertilizer use taken together also reveal that the main factor behind the growth in fertilizer use was increase in the proportion of areas under these crops which received fertilizer application, rather than increase in the rates of fertilizer use per unit of land already fertilized.

Distribution of Fertilizers Among Various Crops

Table 24 shows the distribution of nitrogen and phosphorus between foodgrain and non-foodgrain crops by cultivators from the 19 districts. From these findings it appears that the general pattern of distribution of fertilizers among foodgrain and non-foodgrain crops within each sample

Table 24 Distribution of fertilizers between foodgrain and non-foodgrain crops

District†	Reference year	Percent of N used on:		Percent of P_2O_5 used on:	
		Foodgrains	Non-foodgrains	Foodgrains	Non-foodgrains
Thanjavur*	1961-62	100	-	100	-
	1962-63	100	-	100	-
	1963-64	100	-	100	-
Bhandara*	1962-63	100	-	100	-
Raipur*	1958-59	100	-	100	-
	1961-62	97	3	95	5
	1962-63	100	-	100	-
	1963-64	100	-	100	-
Palghat*	1962-63	98	2	100	-
Shahabad*	1961-62	94	6	84	16
	1962-63	95	4	98	2
	1963-64	91	9	96	4
Sambalpur*	1962-63	89	11	99	1
Alleppey*	1962-63	88	12	97	3
Aligarh*	1961-62	89	11	100	-
	1962-63	79	21	89	11
	1963-64	78	22	72	28
Varanasi	1961-62	78	22	-	-
Barabanki	1956-58	76	24	100	-
	1962-63	76	24	72	28
Mandya*	1962-63	76	24	71	29
Krishna	1961-62	75	25	94	6
W. Godavari*	1954-55	62	38	100	-
	1961-62	83	17	93	7
	1962-63	72	28	96	4
	1963-64	70	30	84	16
Ludhiana*	1961-62	69	31	91	9
	1962-63	74	26	74	26
	1963-64	75	25	81	19

(continued)

Table 24. (concluded)

District†	Reference year	Percent of N used on:		Percent of P_2O_5 used on:	
		Foodgrains	Non-foodgrains	Foodgrains	Non-foodgrains:
Pali*	1962-63	85	15	75	25
	1963-64	72	28	67	33
Coimbatore	1954-55	56	44	100	-
	1961-62	60	40	-	-
Ferozpur	1957-59	59	41	100	-
Surat*	1962-63	50	50	74	24
Meerut	1959-60	19	81	-	-

*Package Programme District,

†Districts are arranged according to percentage of nitrogen used on foodgrain crops.

Sources: Compiled from information in:
Expert Committee on Assessment and Evaluation. Intensive Agricultural District Programme, Second Report (1960-65), Ministry of Food and Agr. Government of India. New Delhi.
Fertilizer Practices followed by the Farmers. Agricultural Situation in India, pp. 213-220. June 1964.

is just the opposite of the one observed in the first section. In 6 out of the 19 districts, over 90 percent of fertilizers were used on foodgrain crops. In 9 more cases, between 60 to 90 percent were used on foodgrain crops. Only in the remaining 4 districts less than 60 percent was used on foodgrains and in only 1 of these 4 was it less than 25 percent. These findings have been emphasized by more than one analyst and an impression is conveyed that they can be generalized for the country.

An attempt has been made by one critic to explain the concentration of fertilizer use on foodgrain crops in these districts in terms of most of them (13 out of the 19) being covered by the Package Programme. The chief aim of the Programme has been rapid increase in foodgrain production by intensive efforts in the selected districts, and as fertilizer was the chief instrument of these efforts, it is argued that the concentration of fertilizer

use on foodgrains in these districts is not surprising. While such reasoning is sufficient to doubt the generalization for the country as a whole from the findings in these districts, it is misleading because it implies that it was possible, through the administrative arrangements of the Programme, to divert fertilizer use to foodgrains from crops more profitable to cultivators.

Information on the crop patterns of the cultivators selected in these surveys is presented in table 25. Considering their crop patterns, the distribution of fertilizers between foodgrain and non-foodgrain crops in these samples does not appear exceptional. It appears as much governed by considerations of profit as the distribution in the 3 groups of the first section. It is easy to see why, for example, fertilizers were used on rice and/or wheat in Thanjavur, Bhandara, and Raipur (all Package Programme districts) which had no crops like sugarcane or tobacco, while the cultivators from the Package Programme districts of Aligarh, Mandya, and West Godavari, and the nonpackage districts of Krishna and Coimbatore, with only a small fraction of their land under sugarcane, tobacco, and garden crops, allocated only a part of their fertilizers to foodgrains. The arrangement of the districts in tables 24 and 25 makes it clear that even among the Package Programme districts, the proportion of fertilizers used on foodgrains diminished as the importance of fertilizer-responsive commercial crops in the crop patterns increased. Furthermore, though in most of these 19 districts sizable proportions of cultivated areas were under foodgrains other than rice and wheat (column 5, table 25), they were either not fertilized or fertilized to a very low extent (table 21). Thus, the generally high proportions of fertilizers used on foodgrain crops in most of these groups as compared to those of cultivators studied in the first section can be interpreted mainly as an outcome of the difference in the crop patterns and the alternatives available to them, rather than in terms of differences in preference to use fertilizers on various crops or influence of the Package Programme.

Summary

The analysis of the fertilizer practices of cultivators from different parts of the country shows that within each sample the spread and rates of fertilizer use on different crops were unequal, that in this variation there was a consistent pattern, and that the observed pattern was governed by returns from fertilizer use on different crops.

If generalized for the country as a whole, the observed fertilizer use pattern has an implication for the prospects of high rates of growth in demand for fertilizers. It can be argued that the main source of the past growth in demand for fertilizers was spread of its use on areas under crops which were relatively more responsive to fertilizer use, and hence, where profitability of fertilizer use was high. It can be further argued that once the areas under such crops are fertilized, unless the basic production

Table 25. Crop patterns of the samples of cultivators from the 19 districts

Districts	Reference year	Percentage of total cultivated area of each sample under:										
		Foodgrain crops			Non-foodgrain crops							
		Rice	Wheat	Others	Sugar-cane	Potato	Garden-crops	Chil-lies	Cotton	Tobacco	Oilseeds	Miscel-laneous
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Thanjavur*	1963-64	86	-	4	-	-	1	-	-	-	3	6
Bhandara*	1962-63	59	6	24	-	-	-	1	-	-	6	4
Raipur*	1961-64	65	2	23	-	-	†	-	-	-	4	4
Palghat*	1962-63	72	-	-	-	-	6	-	-	-	7	15
Shahabad*	1961-64	50	12	36	1	†	-	-	-	-	-	1
Sambalpur*	1962-63	88	-	7	1	-	-	-	-	-	3	1
Alleppey*	1962-63	39	-	-	-	-	3	-	-	-	24	34
Aligarh*	1961-64	2	13	65	4	-	-	-	4	-	-	12
Varanasi	1961-62	36	7	49	4	-	2	-	-	-	-	2
Bersbanki	1956-58	29	17	41	6	-	2	-	-	-	1	4
Mandya*	1962-63	27	-	60	4	-	1	-	-	-	-	8
Krishna	1961-63	64	-	28	1	-	1	-	-	2	4	-
W. Godavari*	1961-64	63	-	8	2	-	9	3	-	2	-	13
Ludhiana*	1961-64	-	29	26	4	-	-	-	14	-	13	14
Pali*	1961-64	-	16	49	-	-	-	1	2	-	20	12
Coimbatore	1961-62	15	-	50	2	-	-	-	14	2	17	-
Ferozpur	1957-59	4	22	34	-	-	-	-	16	-	3	21
Surat*	1962-63	20	-	38	-	-	-	-	24	-	10	8
Meerut	1959-60	3	22	44	20	-	1	-	1	-	-	17

Where information for sample was unavailable, crop pattern for district is given.

*Package Programme District.

†Less than 0.5 percent.

Source: Compiled from:

Expert Committee on Assessment and Evaluation. Intensive Agricultural District Programme, Second Report (1960-65). Ministry of Food and Agr. Government of India. New Delhi.

Fertilizer Practices followed by the Farmers. Agricultural Situation in India, pp. 213-220. June 1964.

conditions and/or price relationships change favorably, the rate of growth in demand for fertilizers will slacken even though sizable proportions of acreage in the country under crops such as jowar, bajara, other minor foodgrains, and oilseeds would be still unfertilized. But can the findings of this chapter be generalized?

Given the accuracy of the data, the generality of the conclusions reached in an inductive inquiry depends on the representativeness of the observations. Neither the 3 groups of cultivators covered in the first section nor the groups of cultivators from the 19 districts covered in the second section can be said to represent a majority of cultivators in India. It would be, therefore, premature, to draw inferences for the country as a whole without further inquiry.

Chapter 5. Analysis of the Observed Fertilizer Use Pattern: Sales of Nitrogen in Districts

The analysis of fertilizer practices of cultivators has revealed that the fertilizer use pattern was quite similar in different parts of the country. Within each group the bulk of fertilizer was used on a few crops with high returns on its use, and many crops with low returns remained unfertilized or fertilized on small scale.

The main objective of this chapter is to determine the generality of the findings. If information on use of fertilizer by crops were available, this would be easy. But no such data are available. Only some estimates of fertilizer sold in various districts of different states are available. These data are analyzed to test the hypothesis that the cross-sectional variation in sales of nitrogen among various districts of a state was mainly due to differences in crop patterns and levels of irrigation.

The focus of analysis is on variation in sales among districts within different states and not on variation among all districts of the country because of the nature of district sales data discussed in the first section. This approach may be more appropriate also because of the nature of the institutional arrangements for the distribution of nitrogenous fertilizers during the period covered in the study. As discussed in chapter 2, since 1948 over 95 percent of these fertilizers were distributed by the Central Fertilizer Pool among various state governments, plantation boards, and industrial users on the basis of the estimates of demand made by these agencies, past consumption in the regions covered by them, and total availability of fertilizers to the Pool. The state governments in turn sold their quota to cultivators in their areas. Therefore, it may be more appropriate to study cross-sectional variation within different states to verify the play of economic forces behind the observed use pattern.

Section I

Data on Sales of Nitrogen by Districts

Estimates of annual "sales" of nitrogen in different districts of 14 out of 15 states of India have been made by Brown (1965) for 4 to 6 years, between 1959–60 and 1964–65, from the information supplied by the Directors of Agriculture in various states. Brown points out 3 limitations of these estimates. First, in some cases sales are defined as shipments into the districts. To treat shipments as estimates of sales, it is assumed that nitrogen shipped into a district was sold in the same district, and the opening and closing stocks were equal. Second, while in most cases the estimates of nitrogen sold are arrived at by taking into account nitrogen content of all straight nitrogenous fertilizers, fertilizer mixtures, and complex fertilizers, in some cases nitrogen sold in the form of fertilizer mixtures was not included for want of information. Finally, the possibility of the movement of fertilizers between neighboring districts through non-reported channels (not reflected in the estimates) is also recognized. As a result of these limitations, the inter-district variation in sales of nitrogen reflected by the estimates may be distorted, but there is no way to ascertain this.

It is, however, possible to compare the total amount of nitrogen sold in various districts of each state with an alternative set of estimates of annual consumption of nitrogen in different states.

The Department of Agriculture of the Government of India together with the Fertiliser Association of India has estimated annual "consumption" in various states, and union territories, and tea, coffee, and rubber plantations between 1961–62 and 1964–65, by adding opening (April 1) stocks to the supplies received during the year (April to March) and subtracting from that the closing stocks (March 31) with each of them. While such a comparison of state totals does not establish the accuracy of the estimates of sales in districts because of the likelihood of inter-district movements within a state through nonreported channels, it can point to the discrepancy between 2 sets of state totals made independently. This in turn can help determine the scope of analysis and also indicate the manner in which district data should be organized to overcome some of their limitations. Such a comparison reveals that the 2 state estimates seldom coincide. However, the discrepancies between the 2 differ widely for different states. In the case of 7 states—Andhra Pradesh, Bihar, Gujarat, Mysore, Punjab, Rajasthan, and West Bengal—the discrepancies between the 2 estimates are substantially reduced when the entire period between 1961–62 and 1964–65 is taken into account.[11] For 3 more states,

[11] For Orissa and West Bengal, 3 years' average is taken because data for 1964–65 are not available for the former and the discrepancies between the 2 estimates for West Bengal nearly cancel out, if the period between 1962–63 and 1964–65 is taken into account, instead of that between 1961–62 and 1964–65.

Madhya Pradesh, Orissa, and Uttar Pradesh, not only the discrepancies are reduced for the entire period, but Brown's estimates appear more reliable than those given by the Committee on Fertilisers.

In order to overcome the doubt that the annual estimates made by Brown for these 10 states may not be reflecting inter-district variation in sales because of the possibility of movement of fertilizers through non-reported channels, as well as to minimize the discrepancy between the 2 alternative estimates of nitrogen sold in various states, an average of either 3 or 4 years' sales between 1961-62 and 1964-65 is taken to represent cross-sectional variation in sales of nitrogen in districts during this period. The underlying assumption behind averaging is that by cancelling out inter-district movement in fertilizers through nonreported channels and by reducing the discrepancies between 2 alternative estimates of total amount of nitrogen sold in different states, such an average series represents a more reliable cross-sectional nitrogen sales pattern among districts during the reference period than would estimates for any single year.[12] In the case of Assam, Kerala, Madras, and Maharashtra, the 1964-65 estimates are taken to represent the cross-sectional sales pattern because the discrepancies between the 2 estimates do not cancel out over time and also because Brown's estimates for the other years appear weaker.

Section II

Main Features of Nitrogen Sales Pattern Among Districts

The most striking feature of the cross-sectional nitrogen sales pattern is the wide variation in the amount of nitrogen sold in different districts of each state. Table 26 presents the average sale per district in different states during the reference period, the limits between which the sales varied in each state, and 2 statistical measures of the magnitude of this variation within each state i e , the standard deviation and the coefficient of variation. The coefficient of variation (S.D /Mean × 100) is also computed, because while it is possible to judge the magnitude of variation within each state from its standard deviation, it is incorrect to compare the standard deviations of different states because the average amount of nitrogen sold per district differs substantially in different states. The coefficient of variation permits such a comparison. It is evident from the table that though the average amount of nitrogen sold per district differed widely from state to state, the sales pattern among districts within different states shared one common feature—a wide inter-district variation.[13] As a consequence of such variation in nitrogen sales among districts, in

[12] It is recognized that averaging will not help in cancelling out those inter-district movements of fertilizers through nonreported channels which might have been only in one direction.

[13] The inter-state variation in levels of nitrogen use is discussed in the next chapter.

Table 26. **Inter-district variation in sales of nitrogen in different states**

States	Reference period	Total Districts	Average annual sale per district	Limits of variation		Standard deviation	Coefficient of variation
				Lowest	Highest		
			metric tons of nitrogen				percent
Andhra Pradesh	1961-62 to 1964-65	20	514	323	13,181	3,664	104
Assam	1964-65	11	106	3	319	103	98
Bihar	1961-62 to 1964-65	17	1,003	39	4,949	1,287	128
Gujarat	1961-62 to 1964-65	17	774	0	3,392	1,030	133
Kerala	1964-65	9	1,416	680	3,002	742	52
Madhya Pradesh	1961-62 to 1964-65	43	220	22	2,037	394	179
Madras	1964-65	12	4,631	26	8,478	2,325	50
Maharashtra	1964-65	25	2,085	83	5,916	1,663	80
Mysore	1961-62 to 1964-65	19	1,215	86	6,023	1,378	113
Orissa	1961-62 to 1963-64	13	382	26	2,157	655	172
Punjab	1961-62 to 1964-65	18	1,746	375	5,320	1,245	71
Rajasthan	1961-62 to 1964-65	26	207	1	2,162	416	201
Uttar Pradesh	1961-62 to 1964-65	48	1,036	173	3,165	732	71
W. Bengal	1962-63 to 1964-65	15	1,042	93	4,006	1,185	114

each state except Madras and Kerala, between 50 to 75 percent of total nitrogenous fertilizers were sold in a few districts, which accounted for only about 25 percent of the cultivated land in the state (table 27). It is also evident from the table that these districts accounted for most of the growth in sales between 1961–62 and 1964–65. Figure 5 shows the location of these districts on the map of India.

NOTE: SEE LEGEND ON NEXT PAGE

Figure 5. Map of India showing districts where sales of nitrogen were concentrated within different states of India. (Source: Adapted from Government of India, Ministry of Food and Agriculture, Directorate of Economics and Statistics, *Indian Agricultural Atlas*, New Delhi, 1958. Data on sales of nitrogen from Dorris Brown.)

Legend for Figure 5:

Punjab:
1 Gurdaspur
2 Hoshiarpur
3 Amritsar
4 Kapurthala
5 Ludhiana
6 Ferozepur

Uttar Pradesh:
1 Saharanpur
2 Muzaffarnagar
3 Meerut
4 Bulandshahr
5 Bijnor
6 Moradabad
7 Farrukhabad
8 Lucknow
9 Bara Banki
10 Faizabad
11 Deoria
12 Jaunpur
13 Varanasi

Bihar:
1 Shahabad
2 Gaya
3 Patna

West Bengal:
1 Birbhum
2 Burdwan
3 Hooghly
4 Howrah

Assam:
1 Nowgong
2 United Khasi-Jaintia Hills
3 Cachar

Orissa:
1 Cuttack
2 Ganjam
3 Sambalpur

Madhya Pradesh:
1 Bilaspur
2 Raipur
3 Durg
4 Balaghat
5 East Nimar
6 West Nimar

Rajasthan:
1 Ganganagar
2 Pali
3 Sirohi
4 Udaipur
5 Bhilwara
6 Bundi
7 Kota
8 Sawai Madhopur

Gujarat:
1 Kaira
2 Baroda
3 Broach
4 Surat

Maharashtra:
1 Nasik
2 Jalgaon
3 Buldana
4 Amraoti
5 Ahmadnagar
6 Kolaba
7 Kolhapur

Mysore:
1 Belgaum
2 Bellary
3 Mandya
4 Bangalore
5 Kolar
6 Coorg

Andhra Pradesh:
1 Nizamabad
2 East Godavari
3 West Godavari
4 Krishna
5 Guntur

Madras:
1 Chingleput
2 Thanjavur
3 Coimbatore
4 Kanniyakumari

Kerala:
1 Palghat
2 (Part of) Alleppey

Table 27. **Concentration of nitrogen sales in different states**

States	Reference period	Total number of districts (A)	Number of districts in which sales were concentrated (B)	Cultivated land in (B) as percent of cultivated land in (A)	Sales in (B) as percent of sales in (A) during the reference period	Percent share of (B) in growth of sales in (A) between 1961-62 and 1964-65
Andhra Pradesh	1961-62 to 1964-65	20	5	24	66	47
Assam	1964-65	11	3	24	62	63
Bihar	1961-62 to 1964-65	17	3	26	61	42
Gujarat	1961-62 to 1964-65	17	4	24	69	52
Kerala	1964-65	9	2	22	41	61
Madhya Pradesh	1961-62 to 1964-65	43	6	27	66	60
Madras	1964-65	12	4	31	38	22
Maharashtra	1964-65	25	7	27	56	52
Mysore	1961-62 to 1964-65	19	6	26	63	55
Orissa	1961-62 to 1963-64	13	3	28	76	75*
Punjab	1961-62 to 1964-65	18	6	25	52	46
Rajasthan	1961-62 to 1964-65	26	8	27	71	76
Uttar Pradesh	1961-62 to 1964-65	48	13	26	51	43
W. Bengal	1962-63 to 1964-65	15	5	26	62	73

* Refers to growth between 1961-62 and 1963-64.

Section III

Factors Behind the Cross-Sectional Variation in Nitrogen Sales

An attempt is made in this section to test the hypothesis that cross-sectional variation in nitrogen sales among various districts within different states was mainly due to differences among districts in crop patterns and levels of irrigation. The hypothesis is first expressed in the form of a single equation multiple regression analysis model, and various limitations of the model are examined. The models for 10 states, for which data on explanatory variables were available, are specified and results of the analysis discussed.

The General Model

The hypothesis can be expressed in the form of a cross-section model as:

$$N = f\,(I_1, I_2, \ldots I_j;\ U_1, U_2 \ldots U_j;\ I_0, U_0)$$

where,

N = average annual sale of nitrogen in a district during the reference period,

$I_1, I_2 \ldots I_j$ = irrigated areas in a district under crops 1 to j on which profitability of nitrogen use is generally considered high,

$U_1, U_2 \ldots U_j$ = unirrigated areas in a district under crops 1 to j,

I_0 = irrigated areas under other crops (other than 1 to j) in a district,

U_0 = unirrigated areas under other crops in a district.

In developing the model from the hypothesis a distinction is made between irrigated and unirrigated areas, because it is reasonable to assume that both spread and rates of nitrogen use on a crop grown under irrigated conditions would be higher than on the same crop grown under unirrigated conditions due to superior response and higher certainty of yield.

Though the model is developed from the insights gained in the last chapter from the fertilizer practices of cultivators during the early 1960's (the same years as the reference period of the district nitrogen sales pattern) it appears unsatisfactory because it does not include all the factors that can cause variation in sales among various districts of a state. Among these, the omission of prices appears serious at first sight. However, this omission, necessitated by unavailability of data, is not serious in the present context, because the focus is on cross-sectional variation in nitrogen sales within a state. Under the prevailing arrangements of distribution, different nitrogenous fertilizers were sold at uniform prices in various districts of each state, thus having no influence on the variation in sales

among the districts. It is reasonable to assume that variation in crop prices among different districts in a state would be little, and hence, its influence on the variation in sales of nitrogen, would be negligible. While the omission of prices as explanatory variables can be defended, it cannot be denied that districts differ in such factors as weather, soils, land tenure system, and availability of credit which can affect the nitrogen sales pattern among districts.

Viewed in such broad terms, not only does the model appear unsatisfactory, but the task of sorting out the influences behind cross-sectional variation in sales of nitrogen among various districts of a state appear insurmountable for 3 reasons: (1) difficulty of quantifying some of the variables, (2) no available district data on many of the variables which can be quantified, and (3) restrictions imposed by the number of observations on which estimation of an equation can be attempted. Despite these considerations, it was decided to pursue the estimation of the model for the following reasons.

It is reasonable to assume that districts within a state would differ little in their complex, and hence, the influence of such factors as farm size or land tenure systems on cross-sectional variation in sales of nitrogen can be ignored. Further, it is possible to assume that the districts with higher acreage under a few crops on which fertilizer use was profitable were also the districts with superior soils, better weather conditions, more effective extension service, and more efficient marketing systems. By omitting these factors from the model the effect on the nature of the results can be ascertained in a general manner. It has been shown by Griliches that when a relevant variable excluded from the analysis is highly and positively correlated with one of the included variables, the regression coefficient of the latter will be biased upwards. Finally, the previous chapter showed that in spite of near constancy of most of these omitted variables within each group of cultivators, the bulk of fertilizers were used on a few crops and only a small proportion of areas under the other crops were fertilized.

Models for Different States

Models for different states were specified after taking into account: (1) importance of various crops in the state and whether each of them was grown mainly under irrigated or unirrigated conditions, (2) findings on spread of fertilizer use on different crops in that state, (3) availability of district data, (4) number of observations available for estimation of the model, and (5) intercorrelations among different crops.

In these models no distinction is made between irrigated and unirrigated areas for many crops because of one or more of the following reasons: (1) most of the areas under these crops were irrigated or unirrigated as shown in table 28, (2) number of observations to estimate the

Table 28. Percent of areas under various crops irrigated in different states

States	Rice	Wheat	Sugarcane	Potato	Cotton	Tobacco	Groundnut
Andhra Pradesh	90		94		1	10	
Bihar	34	23	27	100*			
Gujarat	12	53	100		7		17
Madhya Pradesh	13	6			1		
Madras	92		100		27	100	12
Maharashtra	21		100		3	6	1
Punjab	70	52	76	100*	94		2
Rajasthan		53			60		
Uttar Pradesh	12	49	64	95	83	80	
West Bengal	27		29	100*			

* Information not available, hence assumed to be fully irrigated.

Source: Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India.

equation were small, and (5) high intercorrelations were found between irrigated areas under different crops. The latter factor is also responsible for combining areas under cotton and wheat in the equation for Punjab, and irrigated areas under rice, wheat, and sugarcane in the equation for Bihar.

When estimated by ordinary least squares, the following equations were obtained.[14] The figure in parentheses under each coefficient is its estimated *t value* (i.e. coefficient divided by its standard error).

Andhra Pradesh:

$$N = -141.59 + 14.94\,A_R + 144.79\,A_S + 109.40\,A_T + 11.91\,A_O - 2.60\,I_O - 1.84\,U_O$$

t values = (3.48) (2.41) (6.27) (1.16) (−0.19) (−0.80)

$R^2 = 0.84$ Degrees of freedom = 13

[14] Reference period of the equation for each state is the same as indicated in table 26.

Bihar:

$N = -132.60 + 3.01\ I_{RWS} + 573.78\ A_P - 0.47\ A_O$

t values = (3.67) (6.31) (−0.74)

$R^2 = 0.85$ Degrees of freedom = 13

Gujarat:

$N = -21.03 + 6.28\ A_R + 10.99\ I_W + 268.23\ A_S + 53.94\ A_T + 3.51\ A_O - 1.15\ A_O$

t values = (2.24) (0.78) (2.89) (6.79) (2.77) (−1.16)

$R^2 = 0.84$ Degrees of freedom = 10

Madhya Pradesh:

$N = -331.14 + 2.08\ A_R + 1.37\ A_W + 8.06\ A_S + 3.57\ A_C + 0.55\ A_O + 11.71\ I_o +$

t values = (8.75) (2.27) (0.32) (3.06) (0.23) (2.61)

$0.31\ U_o$

(0.87)

$R^2 = 0.77$ Degrees of freedom = 35

Madras:

$N = 1079.76 - 8.02\ A_R + 228.13\ A_S + 117.39\ A_T + 11.17\ A_O - 2.27\ A_O$

t values = (3.18) (1.21) (0.59) (1.01) (−0.16)

$R^2 = 0.71$ Degrees of freedom = 6

Maharashtra:

$N = -338.62 + 6.63\ A_R + 143.84\ A_S + 41.50\ A_T + 7.66\ A_O + 7.84\ A_O$

t values = (1.29) (3.67) (0.42) (2.66) (1.05)

$R^2 = 0.44$ Degrees of freedom = 19

Punjab:

$N = 71.34 + 10.07\ A_{CW} - 8.68\ A_R + 0.51\ A_S + 344.07\ A_P + 26.37\ A_O - 0.53\ A_O$

t values = (5.94) (− 1.28) (0.03) (2.08) (1.60) (−0.70)

$R^2 = 0.73$ Degrees of freedom = 11

Rajasthan:

$N = -215.24 + 3.70\ A_W + 14.55\ A_C + 0.24 A_O$

t values = (3.77) (7.03) (2.24)

$R^2 = 0.82$ Degrees of freedom = 22

Uttar Pradesh:

$N = 54.96 + 7.65\ I_R + 0.72\ U_R + 5.95\ I_W - 2.12\ U_W + 16.78\ A_S + 5.84\ A_C$

t values = (2.22) (0.70) (2.03) (−0.67) (5.23) (0.23)

$+ 60.56\ A_T + 174.92\ A_P - 1.52\ I_O - 0.45\ U_O$

(0.41) (3.26) (−0.69) (−0.40)

$R^2 = 0.79$ Degrees of freedom = 37

West Bengal:

$$N = -428.88 + 1.49\,A_R + 83.49\,A_S + 210.99\,A_P$$

t values = (1.98) (1.14) (6.09)

$R^2 = 0.76$ Degrees of freedom = 11

Where,

N = Sale of nitrogen in a district in metric tons,
A_R = Area under rice in a district in 000 hectares,
A_W = Area under wheat in a district in 000 hectares,
A_S = Area under sugarcane in a district in 000 hectares,
A_T = Area under tobacco in a district in 000 hectares,
A_C = Area under cotton in a district in 000 hectares,
A_P = Area under potato in a district in 000 hectares,
A_G = Area under groundnut in a district in 000 hectares,
A_{CW} = Area under cotton and wheat in a district in 000 hectares,
A_O = Area under 'other crops' in a district in 000 hectares ('other crops' defined as crops other than those specified in the equation),
I_R = Irrigated area under rice in a district in 000 hectares,
I_W = Irrigated area under wheat in a district in 000 hectares,
I_{RWS} = Irrigated area under rice, wheat and sugarcane in a district in 000 hectares,
I_O = Irrigated area under other crops in a district in 000 hectares,
U_R = Unirrigated area under rice in a district in 000 hectares,
U_W = Unirrigated area under wheat in a district in 000 hectares,
U_O = Unirrigated area under other crops in a district in 000 hectares.

Evaluation of Results

As the dependent variable is annual nitrogen sales (in metric tons) in a district, and independent variables are areas (in 000 hectares) under specified crops, the regression coefficient of a particular independent variable indicates the amount by which sales of nitrogen changed per 1000 hectares in areas under the specific crop among various districts of that state during the reference period. The usual procedure to determine the quality of the coefficients is to examine whether they are statistically significant, whether they have correct signs, and whether their sizes appear reasonable. Most of the regression coefficients are statistically significant at .05 probability level and all significant coefficients have the expected (positive) signs. The size of a regression coefficient in our equations would depend on the proportion of areas under that crop on which nitrogen use had spread and rates of application on that crop during the reference period. For instance, sugarcane in the Gujarat equation would have a much higher coefficient than rice or cotton because a much higher proportion-

of areas under sugarcane was fertilized, and at substantially higher rates, than areas under rice or cotton. Since the reference period of the findings on rates and spread of fertilizer use on different crops in the last chapter is roughly the same as the one used in developing the equations of this chapter, the findings prove useful in evaluating the size of coefficients of the estimated equations. To elaborate, we would expect large coefficients for those crops on which both spread and rates of fertilizer use were found to be high, medium size coefficients for crops on which spread of use can be considered to have been high but at low rates of application per unit of land and finally, small or statistically nonsignificant coefficients for crops on which both spread and rates of fertilizer use were found to have been low. Further, we would also expect a similar pattern in the size of coefficients for the same crop in equations for different states, because the findings in the last chapter on the spread and rates of fertilizer use on the same crop in samples from different states indicated a wide variation. Equations for states where both spread and rates of fertilizer use on a certain crop were high should have relatively large coefficients for these crops. Judged in this manner, the pattern in the size of coefficients in various equations is remarkably consistent with the findings of the last chapter.

For instance, in the case of Gujarat one would expect the highest coefficient for sugarcane, next for tobacco, then for irrigated wheat, rice, and cotton on the basis of the findings on spread and rates of fertilizer use on these crops in the last chapter. The estimated coefficients in the equation for Gujarat follow exactly this pattern. A pattern similar to Gujarat (with the exclusion of wheat) can be expected for Andhra Pradesh because of the similarity in the observed fertilizer use patterns between samples from these two states in the last chapter. The estimated equation for Andhra Pradesh again meets this norm. While in equations for Gujarat (or for Andhra Pradesh) one would expect a large difference in the coefficients for sugarcane and other crops because of the differences in the spread and rates of fertilizer use between sugarcane and other crops one would not expect such a difference in the equation estimated for Uttar Pradesh, because the spread and rates of fertilizer use on sugarcane did not differ widely from those on the other crops in the fertilizer use pattern of all 5 samples of cultivators in this state. Again, the coefficients for the estimated equations for Uttar Pradesh meet this expectation. The pattern in the size of coefficients for the same crop in equations for different states is also consistent with the findings of the last chapter. For instance, one would expect a higher coefficient for rice in the equation for Andhra Pradesh rather than for either Gujarat, or Madhya Pradesh, or Uttar Pradesh, because a much higher proportion of rice was fertilized at significantly higher rates in samples from Andhra Pradesh than in samples from the other states. The coefficients for rice in the estimated equations meet this expectation. The same thing can also be said for co-

efficients for cotton in equations for Punjab and Gujarat. On the other hand, it is surprising that the coefficient for sugarcane in the equation for Punjab is statistically nonsignificant and that for Uttar Pradesh is considerably smaller than for the southern or western states. It is difficult to say conclusively whether these features are due to some specification bias in the models for these states or due to the nature of sugarcane cultivation in the north Indian states, which is generally known to be relatively less efficient in comparison to that in the states in west or south India. The size of the coefficients for potato is also surprising even though it was one of the most profitable crops to fertilize under the prevailing conditions.

The value of the coefficient of multiple determination (R^2) indicates the proportion of inter-district variation in sales of nitrogen explained by the independent variables in the equation taken together. This coefficient is over 0.70 for all states except Maharashtra. For cross-sectional analyses, this is usually considered high. It is, therefore, reasonable to conclude that the analysis in the present chapter confirms the insights gained in the last chapter about the nature of the past fertilizer use pattern and the importance of crop pattern and irrigation in determining it. The significance of these findings for continuous rapid growth in demand for fertilizer becomes clear in chapter 7.

Chapter 6. Analysis of the Observed Fertilizer Use Pattern: Consumption of Nitrogen by States

The nature of the past fertilizer use pattern is analyzed here by using various states of India as units of observation. This gives 3 advantages. First, significant use of fertilizer in non-plantation agriculture in India began in the 1940's when the government started playing an active role in promoting its use for rapid increase in foodgrain production. Since administration of the agricultural policy has been the responsibility of the state governments, and since nitrogenous fertilizers were allotted to different state governments under the Pool arrangements, it would be of interest to study the interstate variation in levels of nitrogen use. Second, in the analysis so far it was not possible to study the influence of prices on fertilizer use because prices were (chapter 4), or could be assumed to be (chapter 5), constant for all units studied. An inquiry into the causes of interstate variation in nitrogen use, even when it focuses on a single year, affords scope to study the influence of prices. Because of the nature of available data, the focus of analysis in chapters 4 and 5 was on level of fertilizer use during a single period of time. Using states as units of observation enables us to study not only levels of use in different states

during a single year but also the movements in the levels over a 9-year period.

The scope and nature of analysis have been determined by the kind and amount of data available on levels of nitrogen use in different states. As pointed out, no data on fertilizer use by crops are available. Only the estimates of total annual consumption in different states between 1956–57 and 1964–65 are available.

Section I

Inter-State Variation in the Levels of Nitrogen Use

The amount of cultivated area in a state varies from less than 1 million hectares in Jammu and Kashmir to over 20 million hectares in Uttar Pradesh. Therefore, the level of nitrogen use in each state is expressed in terms of nitrogen use per hectare of cultivated land rather than total nitrogen in each state, to make interstate comparison possible. Table 29 shows these levels for different states in each year between 1956–57 and 1964–65. Even a cursory examination of the table reveals that levels of nitrogen use varied widely among states. The presistence of wide variation in levels over time is brought out by figures 6 and 7.

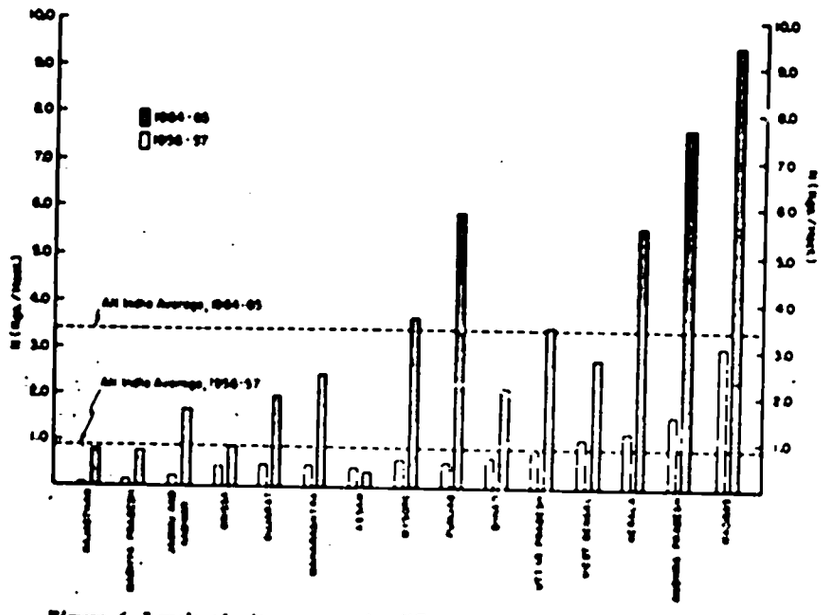

Figure 6. Levels of nitrogen use in different states in 1956–57 and 1964–65.

Table 29. Levels of nitrogen use in various states of India

States*	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
	kilograms per hectare of cultivated land								
Rajasthan	0.06	0.06	0.10	0.08	0.19	0.13	0.26	0.28	0.77
Madhya Pradesh	0.20	0.38	0.33	0.31	0.30	0.34	0.41	0.51	0.77
Jammu and Kashmir	0.29	0.57	0.85	1.14	0.61	0.57	1.45	N.A.	1.66
Orissa	0.46	0.37	0.52	0.79	0.71	0.71	0.83	0.81	0.92
Gujarat†	0.49	0.58	0.57	0.57	0.59	0.97	1.05	1.84	2.01
Maharashtra†	0.49	0.58	0.57	0.57	1.55	1.73	1.76	2.31	2.35
Assam	0.54	0.89	0.85	0.50	0.09	0.14	0.07	0.29	0.39
Mysore	0.55	0.68	0.90	1.06	1.15	0.73	1.42	2.46	3.73
Punjab	0.57	0.80	0.60	0.53	0.79	1.30	1.86	3.37	5.87
Bihar	0.70	0.56	0.65	0.74	0.92	1.19	1.36	1.40	2.24
Uttar Pradesh	0.90	0.93	1.34	1.09	1.24	1.10	1.68	2.76	3.49
West Bengal	1.12	1.30	1.03	0.85	1.49	1.86	1.59	2.75	2.79
Kerala	1.20	1.63	1.29	2.30	2.45	2.91	3.68	4.49	5.59
Andhra Pradesh	1.57	1.[illegible]5	2.07	2.17	2.03	3.58	5.18	5.90	7.70
Madras	3.07	3.77	4.39	4.24	3.38	4.21	4.83	9.26	9.49
All-India Average (exclusive of plantations)	0.88	1.00	1.12	1.16	1.33	1.60	1.92	2.75	3.38

* States are arranged in the ascending order of level of use in 1956-57.

† These 2 states were created in 1960 by bifurcating the Bombay State. Therefore, the figures up to 1959-60 refer to the level in the former Bombay State.

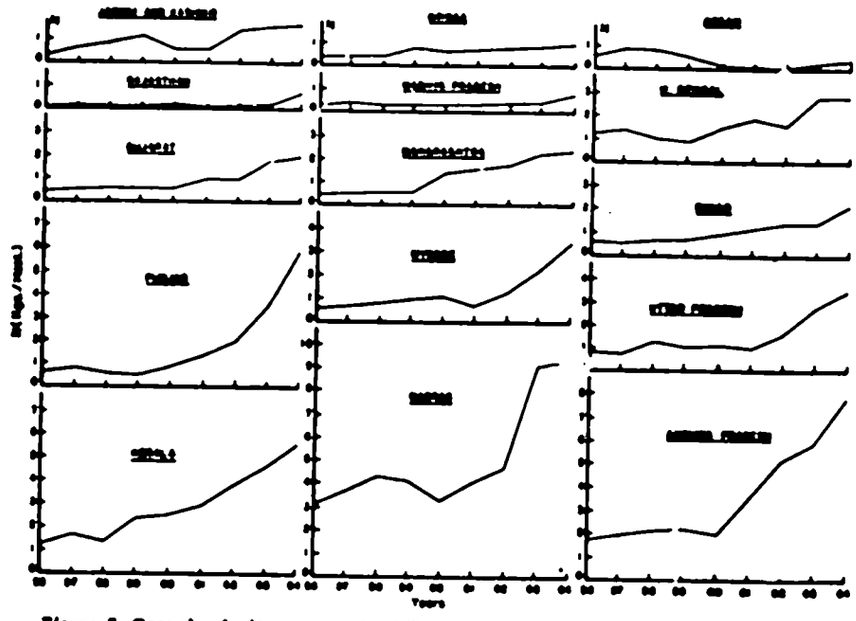

Figure 7. Growth of nitrogen use in different states between 1956–57 and 1964–65.

The table and the figures also indicate that though the level of nitrogen use went up during the 9 year period in all states except Assam,[18] there was considerable interstate variation in the growth patterns of nitrogen use. Its main features are:

(1) In some states (e.g. Punjab, Madras, Andhra Pradesh) the growth was more rapid than in some others (e.g. Uttar Pradesh, West Bengal), while in the remaining few (e.g. Madhya Pradesh, Rajasthan) there was very little growth.

(2) In some states (e.g. Punjab, Rajasthan, and Madhya Pradesh) there was almost no growth during the first 4 to 5 years, while in the others (e.g. Kerala, Mysore) there was some growth even during this period.

(3) The rate of growth in nitrogen use increased markedly around 1960–61 in some states (e.g. Andhra Pradesh, Madras, Punjab) but not in the others (e.g. Madhya Pradesh, Rajasthan, Orissa). There was considerable variation among the former group. Compare, for instance, acceleration in growth during the second half of the period in West Bengal with that in Madras, or the one in Uttar Pradesh with that in Punjab.

[18] Assam presents a unique case. It is not clear if this is due to errors in data or due to some special characteristics of the state. Hence, in the third and fourth sections it is not included in the analysis. The states of Orissa, Jammu and Kashmir are also excluded, as data on irrigation and prices are not available for them.

These features of interstate variations in nitrogen use raise 2 questions: (1) Why did the level of nitrogen use during any single year vary among states? (2) Why did the states differ in growth patterns in nitrogen use during the 9-year period? However, before these questions are pursued, it is necessary to examine if the interstate variation was due to the amount of nitrogen available for consumption in different states.

Section II

Availability of Nitrogen in Different States

It is relevant to inquire into the amount of nitrogen available to different states at this stage because of the nature of arrangement which existed for the distribution of nitrogenous fertilizers among them. As pointed out in chapter 2, this distribution has been controlled by the Central Fertilizer Pool since 1943. Although it was the policy of the Pool to allocate fertilizers to different states after taking into account their past consumption performance, it remained true that under the Pool arrangements the amount of nitrogen available in a certain year to a certain state formed an upper limit for consumption in the state. Therefore, this factor, more than anything else, could determine the interstate variation in levels of nitrogen use.

To examine whether this variation was due to inadequate availability of nitrogen, information on carry-over stocks of nitrogen in different states during each year between 1956–57 and 1964–65 was compiled. The underlying reasoning was that if states were carrying large stocks of unsold nitrogen year after year, then it is reasonable to assume that the availability was not restricting consumption. Obviously this is an oversimplified way of examining the issue because it does not take into account if fertilizers were available at the right time and right place in the states. Nonetheless, in the absence of detailed information, the data on annual carryover stocks do throw some useful light on the subject.

Table 30 shows annual carry-over stocks of nitrogen in states between 1956–57 and 1964–65. Each figure in parenthesis expresses the carry-over stock as a percentage of the amount of nitrogen available to that state during that year.[16] The table shows that in most states, particularly those

[16] The amount of nitrogen available in a state during a year was calculate[illegible] dding opening stocks for the year and supplies received during the year (i.e. Apr.-[illegible]). The data on opening (April 1) stocks were compiled from the *Report of the Fertil[illegible] Distribution Enquiry Committee* (New Delhi: Govt. India, Ministry Food and Agr., Dept. Agr., 1960); *The Report of the Committee on Fertilisers* (New Delhi: Govt. India, Ministry Food and Agr., Dept. Agr., 1965); and the information received from the Department of Agriculture, Government of India. The data on supplies were compiled from various issues of *Fertiliser Statistics* (New Delhi: Fertiliser Assoc. India), and the information received from the Department of Agriculture, Government of India.

Table 30. Carry-over stocks of nitrogen with different states (figures in parentheses represent stocks as percentages of available nitrogen)

States†	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
	metric tons of nitrogen								
Rajasthan	N.A.*	880 (54%)	1,322 (48%)	1,333 (53%)	N.A.	1,417 (44%)	1,238 (25%)	2,700 (40%)	494 (4%)
Madhya Pradesh	N.A.*	2,688 (30%)	3,216 (36%)	7,466 (57%)	6,747 (55%)	7,985 (56%)	16,970 (69%)	14,426 (60%)	16,523 (53%)
Jammu and Kashmir	N.A.*	N.A.	231 (26%)	N.A.	469 (49%)	618 (56%)	N.A.	N.A.	1,307 (48%)
Orissa	N.A.*	579 (21%)	2,416 (43%)	2,893 (38%)	2,929 (41%)	5,186 (55%)	3,812 (43%)	413 (7%)	N.A.
Gujarat		1,2[illegible]1♦ (7%)	2,958♦ (15%)	6,112♦ (27%)	2,587 (31%)	2,054 (18%)	4,968 (32%)	N.A.	2,407 (11%)
Maharashtra					9,604 (25%)	6,[illegible]78 (17%)	N.A.	N.A.	18,529 (29%)
Assam	684 (34%)	220 (9%)	282 (11%)	543 (29%)	225 (52%)	101 (22%)	188 (49%)	277 (27%)	467 (32%)
Mysore	1,536 (21%)	2,447 (26%)	3,470 (27%)	2,592 (19%)	N.A.	8,782 (53%)	16,597 (52%)	21,750 (45%)	11,490 (22%)

(continued)

Table 30. (concluded)

States†	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
	metric tons of nitrogen								
Punjab	N.A.*	5,935 (43%)	8,250 (58%)	6,376 (56%)	4,745 (38%)	7,007 (36%)	13,837 (43%)	24,760 (43%)	16,411 (22%)
Bihar	N.A.*	4,410 (45%)	3,214 (31%)	6,497 (44%)	9,087 (47%)	10,550 (44%)	12,909 (46%)	17,325 (53%)	9,109 (27%)
Uttar Pradesh	N.A.*	17,081 (47%)	15,489 (37%)	33,486 (58%)	42,235 (61%)	48,195 (66%)	52,841 (59%)	65,136 (52%)	30,790 (29%)
West Bengal	N.A.*	7,484 (48%)	N.A.	848 (14%)	N.A.	2,966 (20%)	3,311 (25%)	1,682 (9%)	2,822 (14%)
Kerala	N.A.*	N.A.	1,353 (34%)	1,656 (25%)	2,054 (28%)	4,651 (43%)	6,797 (45%)	7,165 (41%)	3,634 (22%)
Andhra Pradesh	N.A.*	7,455 (25%)	6,275 (20%)	4,226 (14%)	3,970 (14%)	14,251 (24%)	30,476 (31%)	36,220 (32%)	16,875 (15%)
Madras	N.A.*	8,030 (24%)	5,418 (14%)	5,413 (15%)	4,706 (16%)	7,214 (19%)	20,345 (37%)	14,230 (18%)	12,666 (16%)

* Not available.

† States are arranged in the same order as in table 28.

♦ Refers to the former Bombay State.

Sources: Compiled from:
Report of the Fertiliser Distribution Enquiry Committee. Ministry of Food and Agr. Government of India. 1960
Report of the Committee on Fertilisers. Ministry of Food and Agr. Government of India. 1965.
Information received from the Department of Agriculture, Government of India.

with low levels of use, a fairly large proportion of available nitrogen remained unsold during any year studied. While it is recognized that it would be seldom possible for a state to sell all fertilizer available during a given year, the size of carry-over stocks in states like Rajasthan, Madhya Pradesh, or Punjab can be taken to indicate that the interstate variation in the levels of nitrogen use was unlikely to have been due to restrictions on use imposed by the amount of nitrogen available.

Section III

Factors Behind Cross-Sectional Variation

The influence of 2 economic factors—level of irrigation and ratio of nitrogen to crop prices—on cross-sectional variation in the levels of nitrogen use among 12 states is examined by estimating the following single-equation multiple-regression-analysis model for each year between 1957–58 and 1964–65. The model could not be estimated for 1956–57 for want of complete data on crop prices.

$$N_t = f(I_t, P^n_t/P^c_{t-1})$$

where,

N_t = nitrogen consumed (in Kilograms per hectare of cultivated land) in a State during year t,

I_t = percentage of cultivated land irrigated in the State in year t,

P^n_t = weighted average price of nitrogen (in rupees per quintal[17]) in the State during year t,

P^c_{t-1} = weighted average price of crops (in rupees per quintal) received by the cultivators in the State in year t−1.

Among several economic factors which could have caused the interstate variation in levels of nitrogen use, the level of irrigation and ratio of nitrogen to crop prices are considered more important than the others because profit on nitrogen use would be determined primarily by them.[18]

The level of irrigation in a state is defined as the percentage of total cultivated land which is irrigated. There are limitations in defining the level of irrigation in this manner. First, it takes into account only one aspect of the interstate variation in levels of irrigation, namely, the spread of irrigation, and ignores the variation among states with respect to ade-

[17] Quintal = 100 kilograms.

[18] Throughout this chapter "ratio of nitrogen to crop prices" means ratio of average price of nitrogen (in rupees per quintal) in year t to average price of crops (in rupees per quintal) in year t-1.

quacy of water supply on a unit of irrigated land. Secondly, it ignores the problem of interstate variation in quality of irrigation, as reflected in control of water supply.

The other explanatory variable is the ratio of nitrogen to crop prices. To explain nitrogen consumption in year t, the ratio of nitrogen price in year t to crop prices in year t−1 (one year lagged) is used because decisions regarding nitrogen use in year t would be influenced by prevailing nitrogen prices and "expected" (as against "realized") crop prices. It is assumed that in year t, farmers would expect the prices they received in the previous year. Since price of a quintal of nitrogen varies in different forms of nitrogenous fertilizers, such as ammonium sulfate, urea, calcium ammonium nitrate, the price of nitrogen in a state is defined as the weighted average price of a quintal of nitrogen, weights being equal to percentage of total nitrogen consumed in different forms in that state. The importance of different crops varies widely in the crop pattern of each state (e.g. rice and wheat in Punjab). It would, therefore, be incorrect to assume that prices of all crops had the same influence in determining the level of nitrogen consumed in a state. Similarly, it would also be incorrect to assume that the price of an individual crop (e.g. rice) would be equally important in determining the amount of nitrogen used in 2 different states (e.g. Madras and Punjab). For these reasons, the average crop price received by farmers of a particular state is defined as the weighted average of different crop prices, weights being percentages of area under different crops in that state. Since the set of weights would differ from state to state, the interstate variation in the ratio of nitrogen to crop prices as defined here would be due not only to the variation in the prices of nitrogenous fertilizers and of crops, but also to variation in the relative importance of different nitrogenous fertilizers and of crop patterns among states.

Data on Explanatory Variables

Level of irrigation

Table 31 presents the percentage of cultivated land irrigated in different states between 1956–57 and 1964–65. The data for years through 1960–61 were compiled from various issues of *Agricultural Statistics in India*, while the data for years after 1960–61 were compiled from the records of the Directorate of Economics and Statistics in the Ministry of Food and Agriculture.

Average price of nitrogen

The average price of nitrogen in a state was calculated in 2 stages. First, the prices of a quintal of nitrogen in different nitrogenous fertilizers (published in *Fertilizer Statistics)* were used after making the following adjustments to bring prices in different states to a comparable basis: (1) The prices for Madras were adjusted downwards by subtracting the sales

Table 31. Percentage of cultivated land irrigated in different states between 1956-57 and 1964-65

States	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
Rajasthan	12.4	13.4	12.0	11.6	12.5	12.1	12.5	12.9	13.4
Madhya Pradesh	4.8	6.0	4.8	5.2	5.2	5.2	5.6	5.6	5.8
Gujarat	6.4	6.5	6.5	7.2	7.5	7.8	7.0	7.5	7.5*
Maharashtra	5.6	5.8	5.9	6.2	6.5	6.5	6.7	6.9	6.9*
Mysore	7.4	7.6	7.4	8.6	9.3	9.6	9.3	9.3	9.3*
Punjab	38.5	38.7	38.8	39.8	39.9	41.1	42.2	44.4	44.4*
Bihar	17.5	19.9	18.6	16.5	18.6	17.5	17.9	18.1	18.3
Uttar Pradesh	23.4	26.3	24.4	26.1	25.4	23.8	26.4	26.9	26.9
West Bengal	20.8	22.2	22.8	23.5	23.1	22.8	23.0	23.5	23.5*
Kerala	22.0	24.0	24.7	21.3	21.0	21.7	21.1	21.6	21.7
Andhra Pradesh	27.2	28.1	28.9	29.5	29.2	29.4	29.5	28.7	30.2
Madras	42.3	44.7	43.1	42.6	44.5	44.5	45.6	45.8	45.8*

* 1963-64 figure repeated due to non-availability of data.

Sources: For years through 1960-61 various issues of Agricultural Statistics in India (Directorate Econ. and Stat., Ministry of Food and Agr., Government of India, New Delhi). For years after 1960-61, information supplied by the Directorate of Economics and Statistics.

tax included in them. This was necessary because prices for all other states are given exclusive of sales and other local taxes and information on these taxes is not available. (2) Certain nitrogenous fertilizers were subsidized during 1963–64 and 1964–65 in Bihar, Kerala, and Maharashtra. These prices were adjusted downward by the amount of subsidy, as the prices given in *Fertilizer Statistics* are exclusive of subsidy. From the prices of a quintal of nitrogen in various nitrogenous fertilizers, the average price of nitrogen in each state during different years was calculated by taking their weighted average, with weights equal to the relative importance of nitrogenous fertilizers in the consumption pattern. These prices are given in table 32. There is not much interstate variation in them during any single year. This is as expected, because the prices of various nitrogenous fertilizers were controlled by the Central Fertilizer Pool which made fertilizers available at roughly the same price to cultivators in different regions. But over time the variation in them is quite significant even in the same state. This is due to both decline in prices of different nitrogenous fertilizers, as well as growing importance of fertilizers, such as urea, which costs less per unit of nitrogen.

Average crop prices

To compute average crop prices received by farmers in different states, data on average farm prices of important crops, compiled by the Directorate of Economics and Statistics, were used because they come closest to the prices received by farmers.[19] To weigh these prices according to the relative importance of different crops, a set of weights was calculated for each state from its crop pattern between 1957–58 and 1964–65.

Strictly speaking, the weights should change not only between states during any single year but also from year to year for the same state. However, a scrutiny of the percentage of area under different crops in each state revealed that while there was wide variation in relative importance of different crops between states, the variation over time was very little within each state. Therefore, a constant set of weights was computed for each state by taking an average of 8 years' crop pattern. The advantage of using a constant set of weights is that the series on average price of crops for each state reflects the movement in the general farm price level alone, rather than the movement in the prices mixed with changes in the crop pattern.

Using these data on farm prices and the sets of weights, weighted average crop prices were calculated for each state for the period between 1956–57 and 1963–64. These prices are presented in table 33. The wide interstate variation in them is due to variation in both farm prices of

[19] The average farm price of a commodity is defined as, "the average wholesale price at which the commodity is disposed of by the producer to the trader at the village site during the specified harvesting period."

Table 32. Average price [illegible] : [illegible] in different states between 1956-57 and 1964-65

States	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
	rupees per 100 kgs. of N								
Rajasthan	151.00	178.00	173.72	171.93	171.21	174.12	167.00	158.41	154.84
Madhya Pradesh	151.00	177.72	180.52	179.96	180.56	177.07	168.92	166.46	160.04
Gujarat	150.45	176.10	174.76	174.69	178.24	172.31	169.08	162.39	158.12
Maharashtra	150.45	176.10	174.76	174.69	176.88	174.24	171.04	165.77	158.80
Mysore	149.57	175.57	175.41	171.38	175.55	171.90	167.44	158.73	153.68
Punjab	151.00	176.67	178.29	175.79	176.21	173.43	162.36	152.92	152.68
Bihar	151.00	178.00	182.00	181.60	180.08	178.21	171.48	164.58	156.02
Uttar Pradesh	150.83	177.80	182.58	182.92	179.76	173.97	172.82	165.92	161.75
West Bengal	151.00	175.92	178.56	182.00	180.44	176.65	171.68	169.20	166.36
Kerala	151.00	178.00	182.00	177.09	177.42	172.60	166.62	162.43	157.06
Andhra Pradesh	159.98	175.34	174.56	174.94	177.31	171.31	166.82	157.94	155.10
Madras	147.35	170.85	177.63	174.63	176.99	171.00	167.30	157.94	149.78

Source: Calculated from prices of nitrogenous fertilisers as reported in various issues of Fertiliser Statistics, (Fertiliser Assoc. of India, New Delhi). Method of calculation discussed in the text.

Table 33. **Average farm price of crops in different states between 1956-57 and 1964-65**

States	1955-56	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64
Rajasthan	31.75	40.43	39.87	39.20	41.75	42.79	42.52	42.36	53.49
Madhya Pradesh	*	42.57	41.64	46.24	40.67	43.49	47.43	42.45	49.19
Gujarat	*	51.54	55.30	58.11	63.04	65.10	66.35	64.42	74.00
Maharashtra	*	48.39	47.00	50.91	54.82	53.37	54.37	59.24	67.33
Mysore	35.39	43.27	44.48	48.70	49.29	53.01	58.07	59.11	57.84
Punjab	36.12	40.13	38.66	42.28	42.73	43.43	45.62	[illegible]	53.17
Bihar	38.88	44.28	50.23	48.25	44.34	46.36	46.03	47.43	52.32
Uttar Pradesh	*	38.37	38.34	43.02	39.89	40.88	39.94	39.64	49.83
West Bengal	44.53	50.29	55.84	55.17	58.52	57.30	58.09	65.96	69.69
Kerala	45.06	55.38	51.76	54.67	59.96	60.65	65.5	61.52	67.04
Andhra Pradesh	37.50	44.10	44.65	48.87	52.75	53.54	54.[illegible]0	53.60	57.27
Madras	42.62	46.19	45.68	47.26	50.66	52.67	5[illegible].71	56.96	61.62

*Means not calculated because of non-availability of complete data.

The method of computing these indices is discussed in the text of Chapter 6. The farm prices of following crops were taken into consideration for different states: Rajasthan: rice, jowar, bajara, maize, wheat, barley, gram, sugarcane, potato, tobacco, groundnut, rape and mustard, sesame, linseed, castorseed, cotton; Madhya Pradesh: same as Rajasthan minus potato; Gujarat: same as Rajasthan minus barley and linseed, plus ragi; Maharashtra: same as Gujarat minus castorseed plus linseed; Mysore: same as Gujarat plus linseed; Punjab: same as Madhya Pradesh minus castorseed; Bihar: same as Rajasthan minus jowar, bajara, groundnut, castorseed plus ragi and jute; Uttar Pradesh: same as Rajarthan plus ragi and jute; West Bengal: rice, wheat barley, gram, sugarcane, potato, rape and mustard, jute; Kerala: rice; Andhra Pradesh: same as Maharashtra minus rape and mustard and potato, plus castorseed; Madras: same as Gujarat minus wheat, and rape and mustard.

Source: Data on farm prices of different crops in various states were from Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India.

crops as well as crop patterns. On the other hand, variation in these prices over years in each state is due to movement in farm prices of crops alone, because of the constancy of weights for each state.

Ratio: of nitrogen to crop prices

The ratios of nitrogen to crop prices for each state were then calculated by dividing the respective weighted average prices of nitrogen (table 32) by 1 year lagged weighted average prices of crops (table 33). These ratios are given in table 34.

Estimation of the model and discussion of the results

The model was then estimated by ordinary least squares for each year between 1957–58 and 1964–65. The general form of the estimated equation is shown here, while the estimated values for the parameters are presented in table 35. The values in parenthesis under b_1 and b_2 in the table are computed t values of the regression coefficients.

$$N_t = a + b_1 I_t + b_2 P^n_t/P^c_{t-1}$$

where,

N_t = nitrogen consumed (in kilograms per hectare of cultivated land) in a State, during year t,

I_t = percentage of cultivated land irrigated in the State in year t,

P^n_t/P^c_{t-1} = ratio of weighted average price of nitrogen in year t to weighted average price of crops in year t−1.

The values of the coefficient of multiple determination (R^2) show that between 53 to 76 percent of variation in levels of nitrogen use among different states during any year between 1957–58 and 1964–65 can be explained by differences among states with respect to levels of irrigation and ratio of nitrogen to crop prices.

The regression coefficients of both explanatory variables have expected signs in all years, and their computed t values indicate that all but 3 (that of the ratio of nitrogen to crop prices in 1958–59, 1959–60, and 1964–65) are statistically significant at .05 level. There is very little correlation between the 2 explanatory variables, thus indicating absence of multicollinearity. The values of the regression coefficients indicate the amount by which nitrogen used (in kilograms per hectare) changed among the 12 states with 1 unit change in the values of the variables in different years. The sizes of the 2 coefficients are very different; the regression coefficient of the ratio of nitrogen to crop prices is much larger (12 to 20 times in all cases when it is significant) than that of the level of irrigation. It would be incorrect to conclude that ratio of nitrogen to crop prices exerted greater influence than level of irrigation on interstate variation in levels of nitrogen use because the units of the 2 variables are different. One unit

Table 34. Ratio of nitrogen to crop prices in different states between 1956-57 and 1964-65

States*	1956-57	1957-58	1958-59	1959-60	1960-61	1961-62	1962-63	1963-64	1964-65
Rajasthan	4.80	4.40	4.36	4.39	3.91	4.07	3.93	3.74	2.89
Madhya Pradesh	†	4.17	4.34	3.89	4.44	4.07	3.56	3.92	3.25
Gujarat	†	3.42	3.16	3.01	2.83	2.65	2.55	2.52	2.14
Maharashtra	†	3.64	3.72	3.43	3.23	3.26	3.15	2.60	2.36
Mysore	4.23	4.06	3.94	3.52	3.56	3.24	2.88	2.69	2.66
Punjab	4.18	4.40	4.61	4.16	4.12	3.99	3.56	3.74	2.87
Bihar	3.88	4.02	3.62	3.76	4.06	3.84	3.73	3.47	2.98
Uttar Pradesh	†	4.63	4.76	4.25	4.51	4.26	4.33	4.19	3.25
West Bengal	3.39	3.50	3.20	3.30	3.08	3.08	3.00	2.57	2.39
Kerala	3.35	3.21	3.52	3.23	2.96	2.85	2.54	2.64	2.34
Andhra Pradesh	4.00	3.98	3.91	3.58	3.36	3.20	3.07	2.95	2.71
Madras	3.45	3.70	3.89	3.70	3.49	3.25	3.06	2.77	2.48

* States are arranged in the same order as in table 29.

† Means not calculated because of non-availability of data on farm prices.

Source: Calculated by dividing average nitrogen prices (table 32) by 1 year lagged average farm prices of crops (table 33).

Table 35. **Estimated parameters of the model***

Year	Constant a	Regression coefficients (b's) of: I_t	$\frac{P^n_t}{P_{t-1}}$	R^2	Degrees of freedom	Correlation between I_t and $\frac{P^n_t}{P^c_{t-1}}$
1957-58	3.811	0.059 (4.059)*	-0.998 (-2.341)*	0.73	8	0.03
1958-59	1.795	0.067 (2.943)	-0.504 (-0.871)	0.53	8	0.13
1959-60	4.626	0.067 (2.962)	-1.277 (-1.786)	0.57	8	0.16
1960-61	3.273	0.046 (3.070)	-0.790 (-2.303)	0.60	9	0.10
1961-62	4.619	0.065 (4.032)	-1.247 (-3.006)	0.73	9	0.06
1962-63	4.762	0.084 (3.470)	-1.341 (-2.262)	0.63	9	0.11
1963-64	5.974	0.136 (4.435)	-1.823 (-2.494)	0.74	9	0.02
1964-65	6.165	0.165 (5.056)	-2.134 (-1.742)	0.76	9	0.04

* Figures in parentheses are computed t values of the regression coefficients.

change in the ratio of nitrogen to crop prices would involve 20 to 25 percent change in the price either of nitrogen or of crops. It is, therefore, not surprising that the estimated coefficient of this variable is much larger than that of the level of irrigation.

It is possible to overcome this difficulty and determine their relative importance in influencing the cross-sectional consumption pattern among states by estimating the proportion of variation in the level of nitrogen use explained cumulatively by the 2 variables. Table 36 presents these results. If there were high intercorrelation between the explanatory variables, then the "determination" attributed to the level of irrigation by this procedure of breaking up the coefficient of multiple determination (R^2) into "coefficients of incremental determination" would include not only the influence of irrigation on level of nitrogen use, but also the influence of the ratio of nitrogen to crop prices which is merely channeled through I_t. However, in our estimated equations there is very low intercorrelation between the explanatory variables (table 35); therefore, the determination attributed to the 2 variables reflect the role played by each of them in explaining the cross-sectional variation in nitrogen consumed per unit of cultivated land among the 12 states.

While this analysis shows the greater relative importance of irrigation over the ratio of nitrogen to crop prices in influencing levels of nitrogen used in the states during the 8-year period between 1957–58 and 1964–65, it also raises some new questions. For instance, why did Punjab, with a level of irrigation surpassed only by Madras (table 31), rank low in levels of nitrogen use for most of the years (table 29)? Or, why did levels of nitrogen use start rising rapidly around 1960–61 in some states (figure 6), in spite of no major changes in levels of irrigation (table 31), but not in others?

Section IV

Factors Behind Movement in Levels of Nitrogen Use

This section analyzes the role played by irrigation and ratio of nitrogen to crop prices in determining the growth in nitrogen use in the 12 states. For this purpose the following 3 questions are raised:

(1) What influence did over-all level of irrigation and movement in it have on growth in nitrogen use in different states?

(2) What influence did the level and movement in the ratio of nitrogen to crop prices have on growth in nitrogen use?

(3) Did the general decline in the ratio of nitrogen to crop prices have the same degree of influence on rate of growth in nitrogen use in all states?

These questions are studied with figure 7 and a set of 2 scatter diagrams

Table 36. **Inter-state variation in nitrogen used (N_t) explained by levels of irrigation and ratio of nitrogen to crop prices**

Years	Variation explained by I_t	Additional variation explained by $\frac{P^n_t}{P^c_{t-1}}$	Total variation explained by I_t and $\frac{P^n_t}{P^c_{t-1}}$
1957-58	.54	.19	.73
1958-59	.48	.05	.53
1959-60	.40	.17	.57
1960-61	.36	.24	.60
1961-62	.46	.27	.73
1962-63	.43	.21	.64
1963-64	.56	.18	.74
1964-65	.67	.09	.76

for each state which show the relationship between movements in: (1) percentage of area irrigated (I_t) and kilograms of nitrogen used per hectare of cultivated land (N_t), and (2) ratio of nitrogen to crop prices (P^n_t/P^c_{t-1}) and nitrogen consumed per hectare (N_t) during 1956–57 to 1964–65.

The analysis by states is advantageous. It illustrates growth in nitrogen use in different states, which is useful in the next chapter where fertilizer use beyond 1964–65 in the states is studied. Assuming that quality of irrigation did not change radically from year to year between 1956–57 and 1964–65 in the same state, and that small changes (if any) had only negligible influence on year to year movement in the amount of nitrogen used, studying each state separately helps us to overcome the limitations of the variable of irrigation used in the analysis. This procedure also enables us to focus on the influence of prices as compared to influence of prices mixed with that of crop pattern, because we have used constant weights in calculating the average crop prices for each state.

In the following presentation different states are discussed in descending order of over-all levels of irrigation to illustrate the importance of irrigation in determining the effect of decline in the ratio of nitrogen to crop prices on growth in nitrogen use. Madras is discussed in detail. In the scatter diagrams the 9 years from 1956–57 to 1964–65 are numbered 1 to 9. It may be noted that a different scale is used in diagrams for different states to bring out the movement in the level of nitrogen use.

Madras

Though nitrogen used per hectare of cultivated land in Madras went up from 3.07 kilograms to 9.49 kilograms between 1956–57 and 1964–65, the first few years of the 9-year period cannot be considered a period of sustained growth in nitrogen use (table 29). Nor was the favorable movement in irrigation and relative prices of nitrogen and crops uniform over time. Between 1956–57 and 1960–61, the percentage of land irrigated fluctuated between 42.5 and 44.5 and then increased to 45.8 by 1963–64 (table 31). The ratio of nitrogen to crop prices increased in the first 3 years from 3.45 to 3.89, and then continuously declined in the remaining 6 years from 3.89 to 2.48 (table 34). Two questions arise from such movements in the levels of nitrogen use, irrigation, and relative prices of nitrogen and crops: (1) Why did nitrogen use grow in the first 3 years in spite of unfavorable movements in the ratio of nitrogen to crop prices? (2) What brought about a marked increase in the rate of growth in nitrogen use after 1961–62?

The most plausible answer to the first question is in the prevailing low level of nitrogen use in 1956–57—about 3 kilograms per hectare. At this level the market for nitrogen in this state, with over 40 percent of its land irrigated, can hardly be called saturated for a range in the ratio of nitro-

gen to crop prices between 3.5 and 4.0. Therefore, some growth in nitrogen use, mainly through adoption of fertilizer use by more cultivators, even with a little unfavorable movement in the relative prices of nitrogen to crops is not inconceivable.

The low and uncertain growth in nitrogen use between 1956–57 and 1961–62 seems associated with the movement in the ratio of nitrogen to crop prices and the relative scarcity of nitrogen in the state. During the first 5 years, the movement in the ratio was uncertain, significant and continuous improvement in it came only after 1960–61 (figure 8B or table 34). During 1958–59 to 1961–62 carry-over stocks of nitrogen were between 14 to 19 percent of availability (table 30). These levels are considered indicative of relative scarcity of nitrogen because we are not taking into account factors such as availability of fertilizers at the right time and at the right place within the state for want of information. The relative scarcity of fertilizer until 1961–62 may also explain why the marked acceleration in the growth of nitrogen use came not in 1960–61 when the ratio of nitrogen to crop prices dropped significantly, but in 1962–63.

What role did irrigation play? It appears that year to year movement in the level of irrigation did not have any significant influence on the movement in the level of nitrogen use. Between 1956–57 and 1958–59 when nitrogen use rose (from 3.07 to 4.39 kgs. per hectare) the level of irrigation fluctuated between 42.5 and 44.7. Again, during the last 3 years of the 9-year period, when nitrogen use was rising rapidly, the percentage of land irrigated was more or less constant. This lack of relationship between year to year movement in nitrogen use and level of irrigation is not surprising because of the over-all high level of irrigation and low level of nitrogen use. One can argue that in such an environment, once the ratio of nitrogen to crop prices improved, nitrogen use would grow rapidly, irrespective of year to year fluctuations in the overall level of irrigation, because most of the irrigated land is yet to be fertilized. From this it also follows that while one can give secondary importance to about 3 percent increase in irrigated land (from 42.5 to 45.8) while explaining growth in nitrogen use during 1956–57 to 1964–65, one cannot extend the reasoning to the over-all level of irrigation and conclude that the observed growth in nitrogen use would have occurred in Madras even at low levels of irrigation. This obvious point gets empirical support from slow acceleration in growth of nitrogen use, in spite of favorable movements in the relative prices of nitrogen and crops, in states with low levels of irrigation, as shown later.

Punjab

A high level of irrigation or even continuous improvement in it, without an improvement in the relative prices of nitrogen and crops, was not sufficient to bring about a rapid growth in nitrogen use. This is illustrated

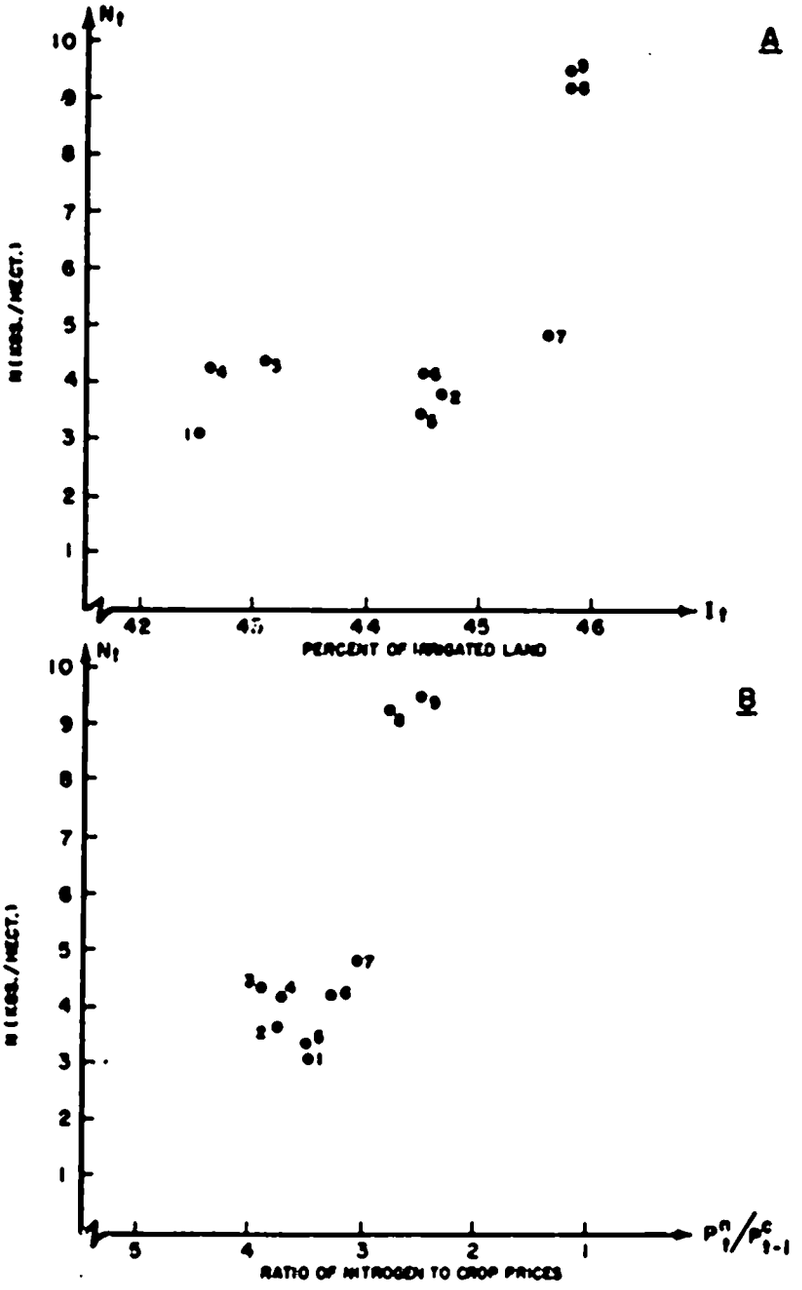

Figure 8. Madras: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956-57 and 1964-65.

by the growth curve for Punjab in figure 6 and the 2 scatter diagrams in figure 9.

Until 1960–61 there was virtually no growth in nitrogen use in spite of the fact that over 38 percent of cultivated land was irrigated. There were high carry-over stocks of nitrogen, between 38 to 58 percent of that available. But the ratio of nitrogen to crop prices was one of the most unfavorable in the country (table 31). Not only was the ratio very high, but during 1956–57 to 1958–59 it became more unfavorable to the cultivators and did not improve significantly until 1961–62. It is reasonable to conclude that under the prevailing conditions, the price situation was holding up growth in nitrogen use. This is also supported by acceleration in the growth curve after 1960–61 (figure 7) in response to a more or less continuous decline in the ratio of nitrogen to crop prices. Though the level of irrigation went up by about 3.5 percent between 1961–62 and 1963–64, most of the growth in nitrogen use was due to improvement in the price situation. Even in the absence of increase in the percentage of land irrigated, once the price situation improved, nitrogen use would have grown from the stationary low levels because of the already high overall level of irrigation in the state.

Andhra Pradesh

The growth curve of nitrogen use for Andhra Pradesh (figure 6) shows that the 9-year period of increase in the level of nitrogen use is divided into 2 periods: slow growth up to 1960–61 and rapid growth after 1960–61. There were also 2 distinct periods of movement in the level of irrigation and ratio of nitrogen to crop prices roughly corresponding to these 2 periods. During the first period, the percentage of land irrigated increased from 27.8 to 29.5, while in the second period it fluctuated between 29.2 and 30.2. Though the ratio of nitrogen to crop prices was falling continuously during the 9 years, the decline was slow and insignificant during the first 4 years compared to the later 5 years (figure 10 and table 34). It appears that slow growth in nitrogen use up to 1960–61 was due to the high level of the ratio of nitrogen to crop prices, relatively slow improvement in it and perhaps, scarcity of fertilizer in 1959–60 and 1960–61 (carry-over stocks at 14 percent of availability). The rapid growth in nitrogen use after 1960–61 coincides with a period of continuous and significant improvement in the price situation.

Uttar Pradesh

As in the case of Punjab, the restrictive effect of a high ratio of nitrogen to crop prices and uncertain movements in it on growth in nitrogen use, is obvious from figures 7 and 11 for Uttar Pradesh. Table 30 shows that between one-third to two-thirds of nitrogen remained unused in any year (except 1964–65) in the state. We may conclude that the slow growth in the

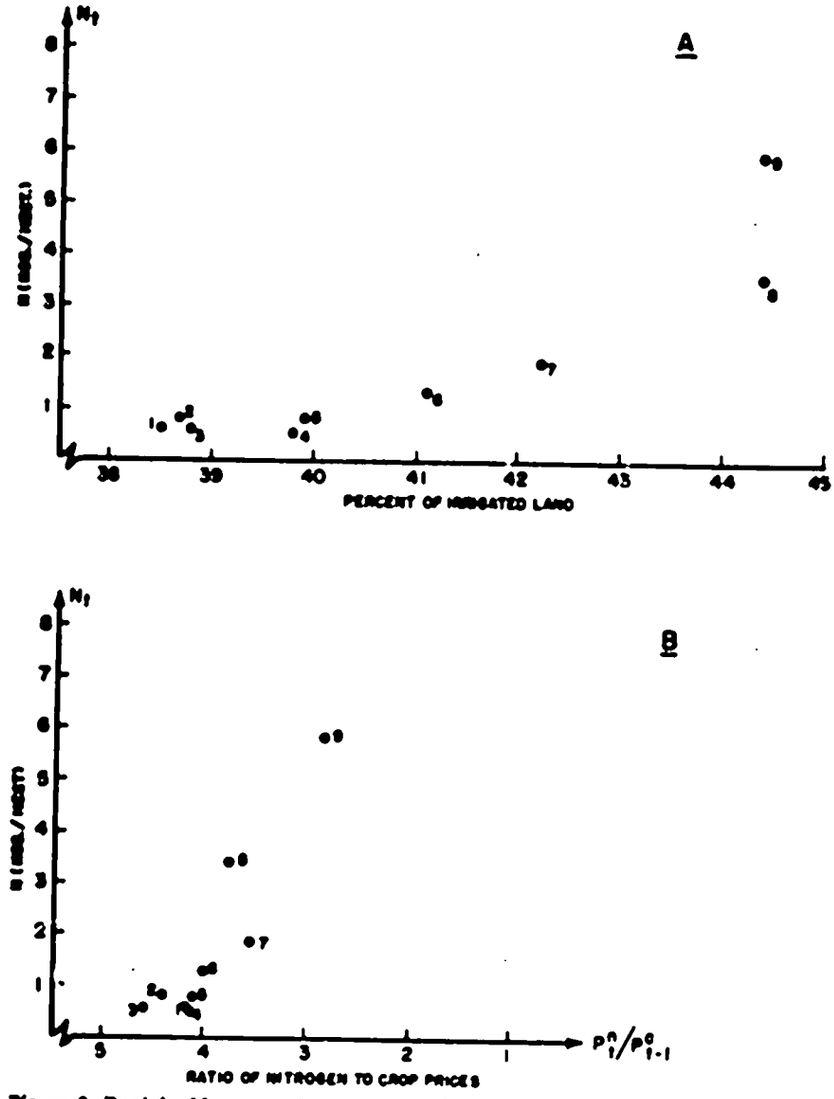

Figure 9. Punjab: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

first 6 years was not due to inadequate supplies. The fluctuation in the percent of land irrigated (23.4 to 26.3) also cannot be held responsible because of the relatively high level of irrigation. On the other hand, the period of steady growth in nitrogen use after 1961–62 coincides with improvement in the relative price situation (table 34).

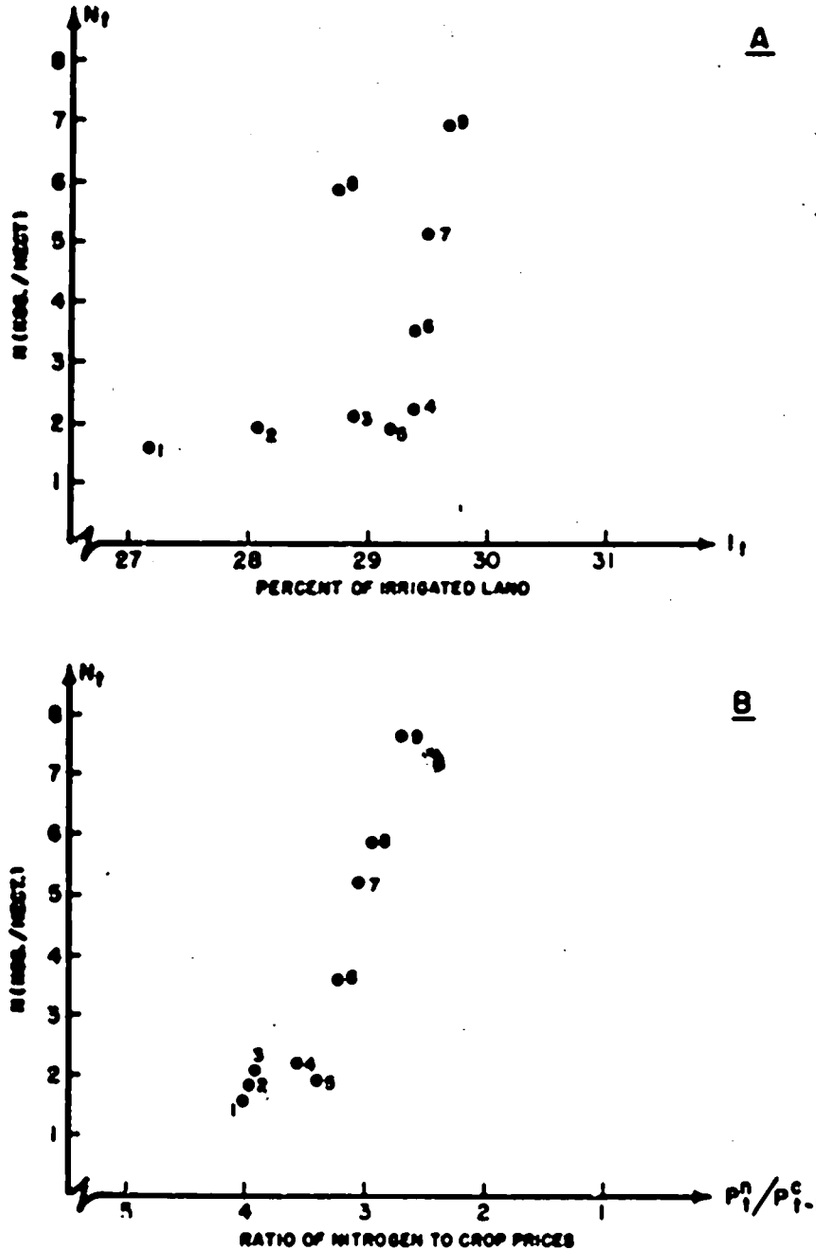

Figure 10. Andhra Pradesh: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956-57 and 1964-65.

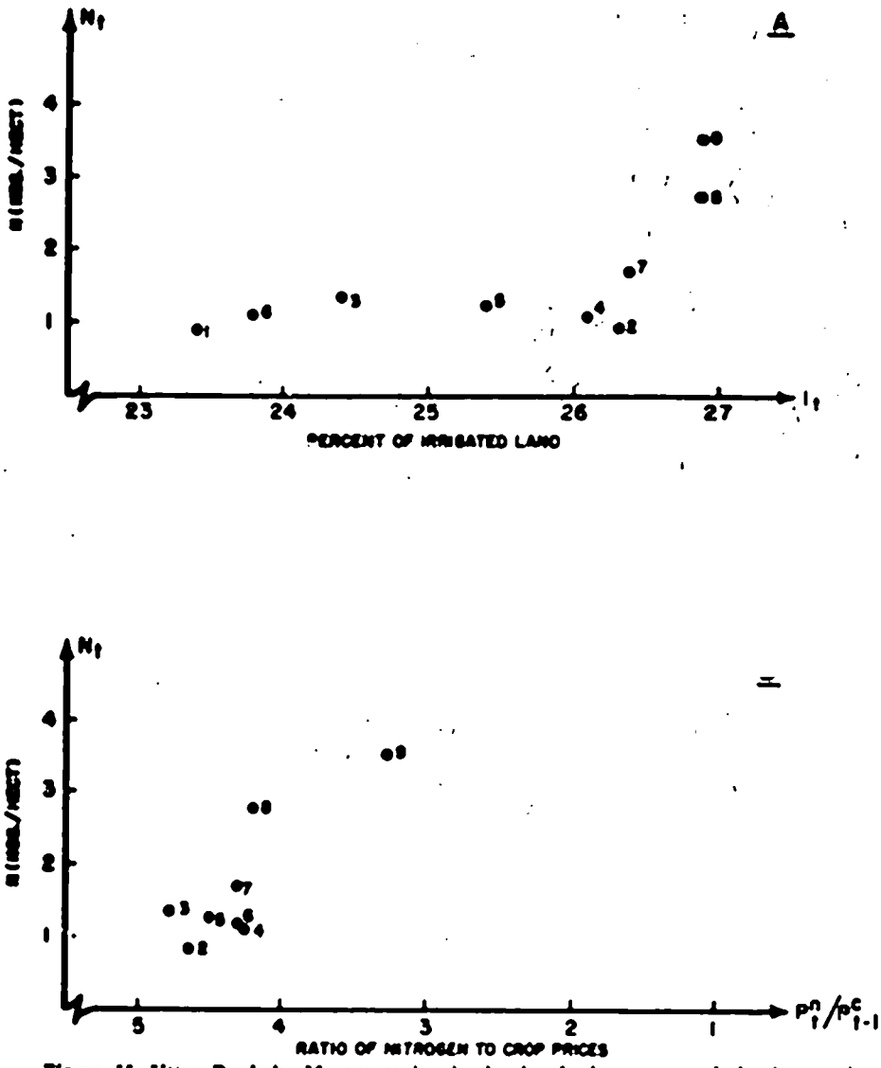

Figure 11. Uttar Pradesh: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956-57 and 1964-65.

Kerala

In contrast to the states discussed so far, Kerala presents a unique case. With the exception of 1958–59, the growth in nitrogen use during the 9 years was continuous and at a gradually accelerating rate (figure 7). During the same period, while the percentage of land irrigated was more or

less constant, varying between 21 and 22 percent for 7 out of 9 years, the ratio of nitrogen to crop prices was at a low level and became increasingly favorable to cultivators more or less continuously (figure 12B). It appears that the growth in nitrogen use was due to the favorable price situation.

Table 30 shows that the drop in the level of nitrogen use in 1958–59 was not due to inadequate supplies. It was probably due to a deterioration in the price situation as indicated by a rise in the ratio of nitrogen to crop prices, which made the price situation in this year the worst during the entire period. It is surprising that during 1958–59, the level of irrigation was at its highest in the 9-year period.

West Bengal

In contrast to Kerala, West Bengal again presents a case for which the 9 years of movement in nitrogen use can be divided into 2 periods: up to and after 1959–60 (figure 7). Between 1956–57 and 1959–60, there was a decline in use, while after 1959–60 there was an unsteady growth. During the first period, the percentage of land irrigated increased steadily from 20.8 to 23.5 (table 31) while the ratio of nitrogen to crop prices fluctuated between 3.21 and 3.56 (table 34). This again indicates that an improvement in irrigation was not sufficient to bring about a growth in nitrogen use in the presence of an unfavorable price situation. On the other hand, only a gradual improvement in the price situation after 1959–60 initiated a growth in the level of nitrogen consumption. From table 30 it appears that availability might have restricted growth during 1963–64 and 1964–65 when the ratio of prices had dropped significantly from previous years (table 34) and when the growth in nitrogen use was already under way.

Bihar

The 9-year period of nitrogen use in Bihar can also be divided into 2 sub-periods, as in West Bengal: up to and after 1959–60 (figure 7). During the first 4 years there was virtually no growth, while after 1959–60, nitrogen use grew slowly. Throughout the entire period of 9 years, the intensity of irrigated land fluctuated around 18 percent (figure 14A). However, there is no systematic association between year to year fluctuations in irrigation and movement in levels of nitrogen use. Nor can the growth pattern be explained in terms of inadequate supplies (table 30). The over-all influence of level and movements in the ratio of nitrogen to crop prices on movements in the level of nitrogen use appears clear. During the first 5 years the ratio was high and fluctuating and so was the level of nitrogen use (figure 14B). Between 1960–61 and 1963–64, it declined gradually from a 9-year high of 4.06 and the level of nitrogen consumption rose slowly. In 1964–65 there was a substantial drop (from 3.47 to 2.98) and this was associated with an upward jump in the level of nitrogen use (figure 14B). Thus, there is a close association between upward movement in nitrogen use and improvement in the price situation.

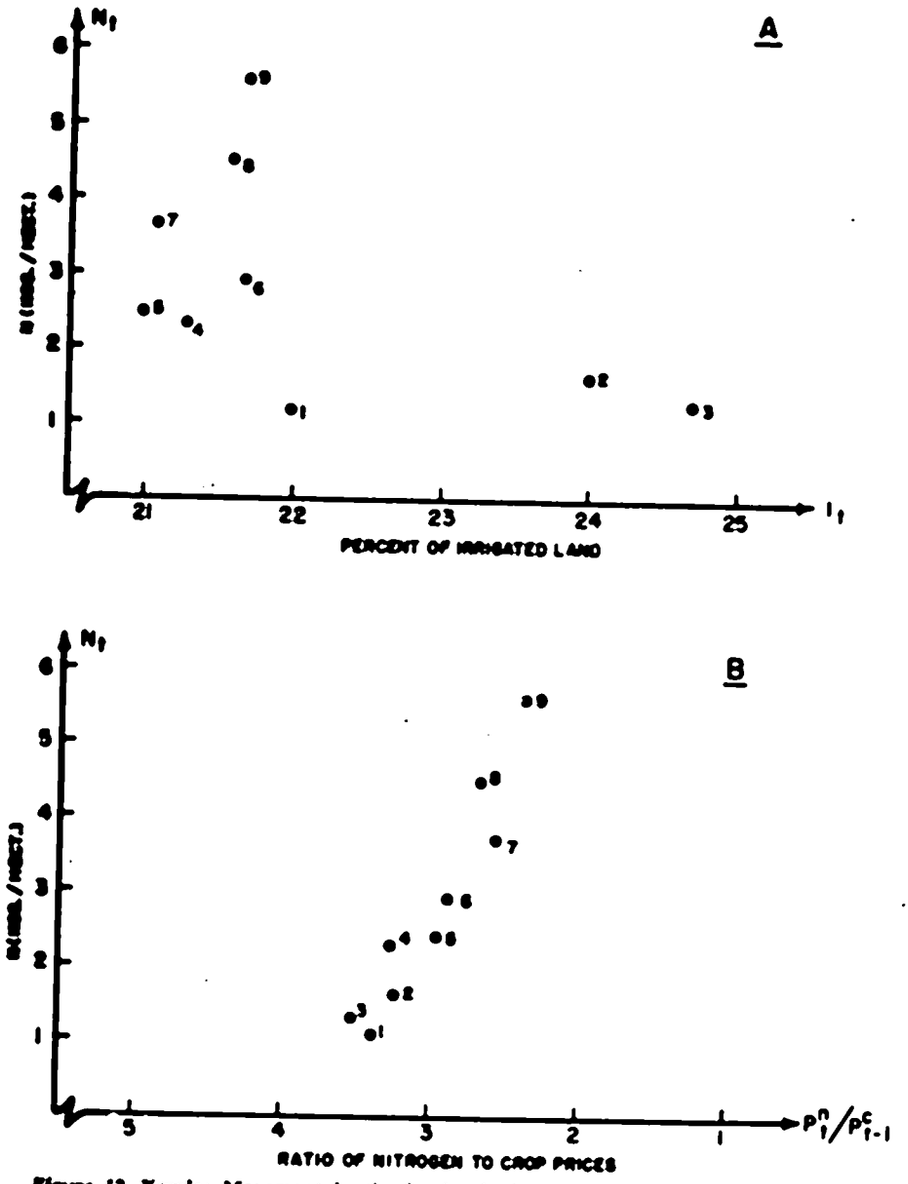

Figure 12. Kerala: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

Rajasthan

Among all states Rajasthan had the lowest level of nitrogen use and one of the most unfavorable sets of nitrogen to crop prices during most of

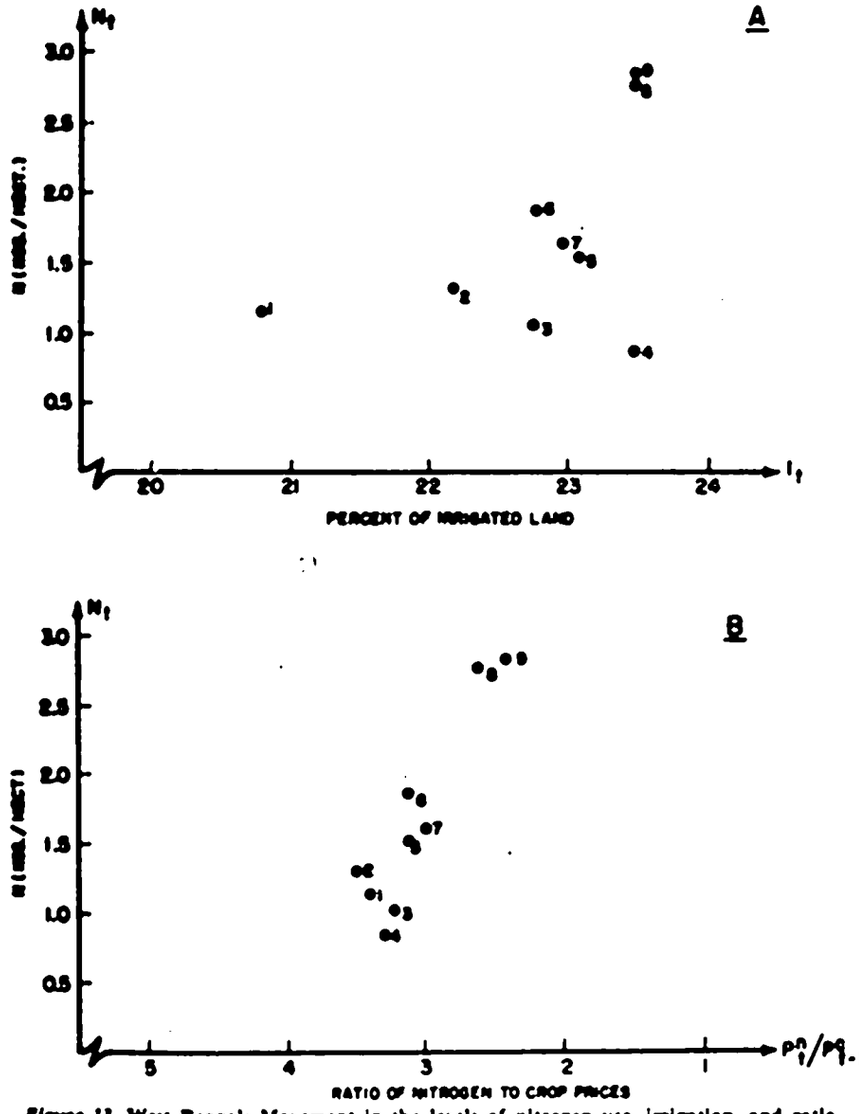

Figure 13. West Bengal: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

the years between 1956–57 and 1964–65 (tables 29 and 34). All the major features of its 9-year period of growth in nitrogen use, as well as year to year movements in irrigation and in the ratio of nitrogen to crop prices, are similar to Bihar (figures 7 and 15).

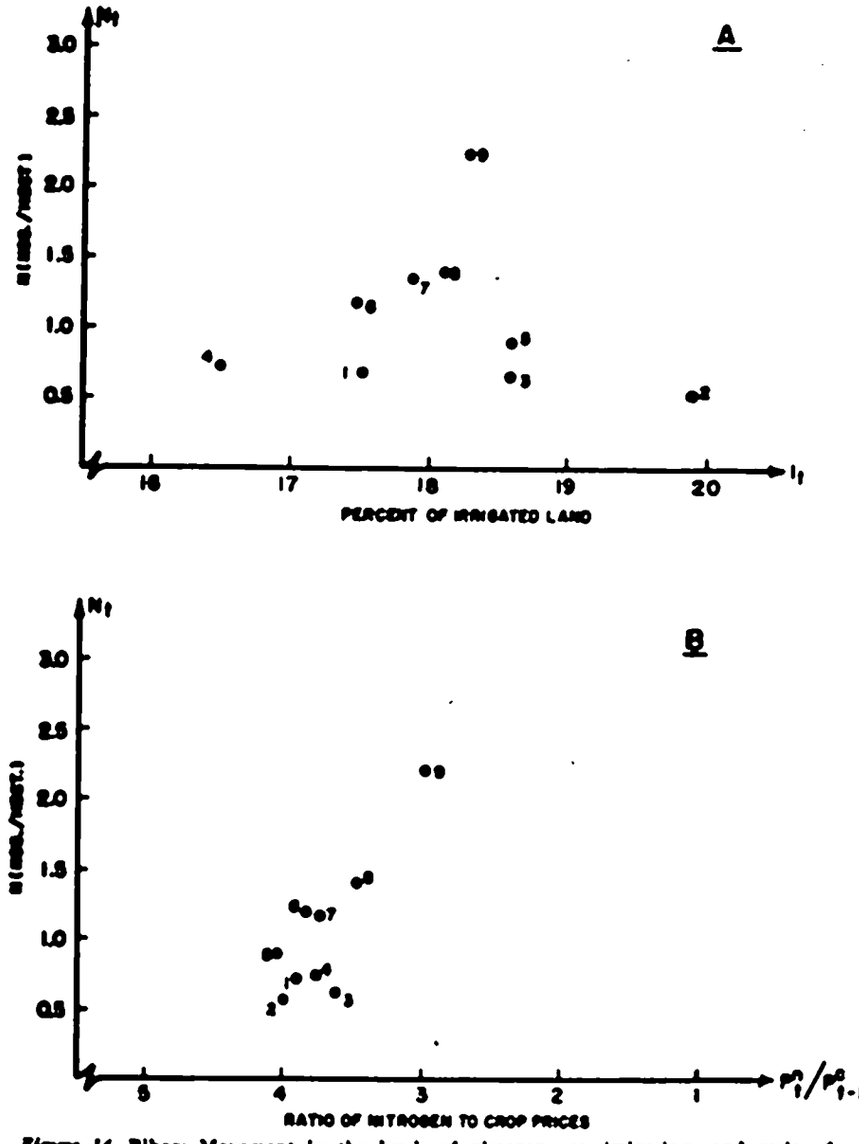

Figure 14. Bihar: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

Mysore

Compared to other States, Mysore had an impressive growth in nitrogen use, particularly after 1961–62, when its low level of irrigation, 7.5 to

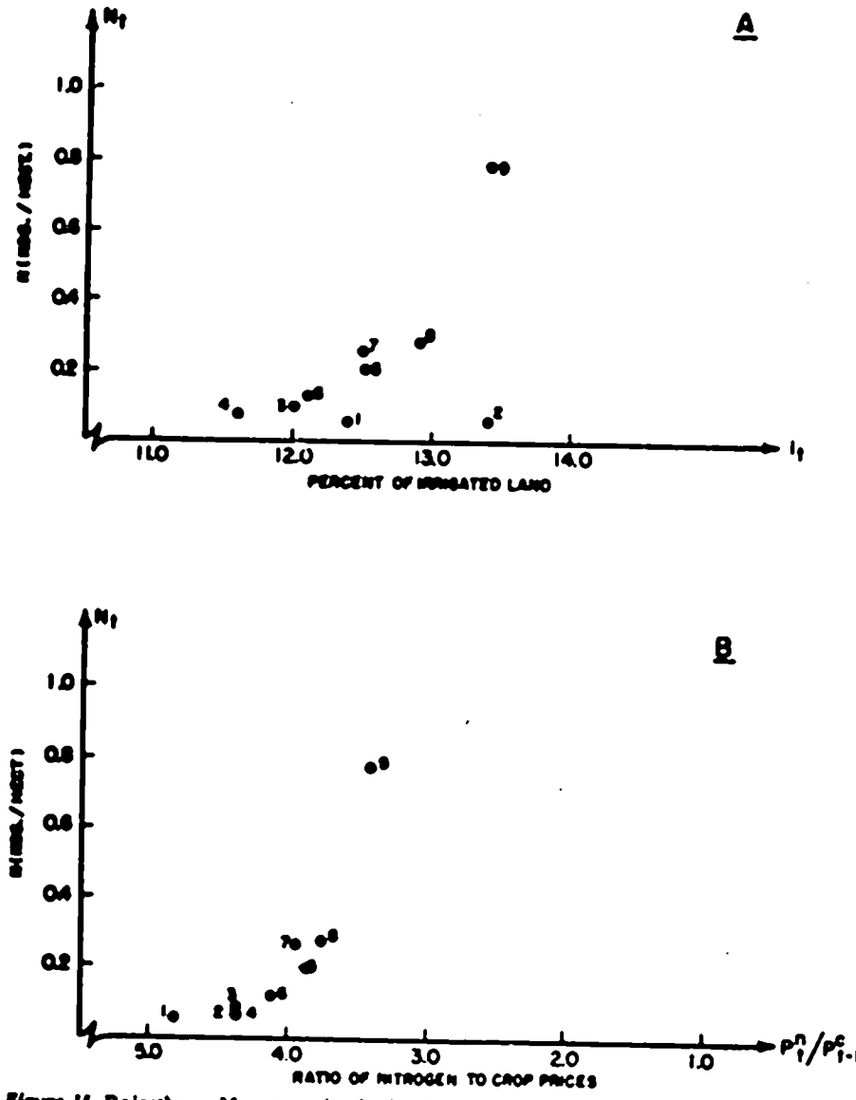

Figure 15. Rajasthan: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

9.5 percent, is taken into account (figure 7) Between 1956–57 and 1960–61 there was a slow but steady growth in nitrogen use. Then in 1961–62 the level declined sharply; later a period of rapid growth began. It is not possible to explain the drop in the level of nitrogen use in 1961–62 with

the variables considered here. Neither the level nor the movement in them were unfavorable enough to cause this decline. Nor could it have been due to inadequate supplies (table 30).

The period of slow growth in nitrogen use coincides with a period of substantial improvement in irrigation, about 25 percent, and a steady drop in the ratio of nitrogen to crop prices (figure 16). The slow growth appears to have been due to the relatively high level of the ratio (over 3.75). This line of reasoning also explains the rapid growth in nitrogen use after 1961–62, when the relative prices of nitrogen to crops were becoming increasingly favorable to cultivators. While during the period of rapid growth there was no further improvement in irrigation, one cannot minimize the importance of the substantial increase in the level of irrigation in the first period, because of the low levels of irrigation in the state. At such low levels of irrigation, an improvement in the price situation alone cannot bring about a rapid growth in nitrogen use. This is more clearly illustrated by growth of nitrogen use in Gujarat and Madhya Pradesh.

Gujarat

Data on nitrogen used in this state and Maharashtra are available only from 1960–61, when the former Bombay State was bifurcated and these 2 states were created. Data on irrigation are available for the entire period of 9 years, while that for prices are available for all years except 1956–57. To extend the analysis to the entire period, it is assumed that the amount of nitrogen used per unit of land in Gujarat and Maharashtra between 1955–57 and 1959–60, was the same as that in the former Bombay State.

Figure 7 shows that slow growth in nitrogen use in Gujarat, much slower than in Mysore, began in 1960–61. Before that, the level of use was more or less constant for 4 years. During the same 4 years there was some improvement in irrigation (6.4 to 7.2 percent), while after that it fluctuated around 7.5 percent. Prior to 1960–61 the ratio of nitrogen to crop prices was fluctuating, while after 1960–61 it became increasingly more favorable to cultivators, in the range of 2 to 2.75. It appears that the growth in nitrogen use after 1960–61 was in response to improvement in the price situation. On the other hand, the over-all low level of irrigation (less than 8 percent) and absence of improvement in it clearly show that a favorable price movement did not have much influence on growth in nitrogen use.

Maharashtra

The growth curve for Maharashtra (figure 7) shows that between 1956–57 and 1959–60 there was no increase in the level of nitrogen use; in 1960–61 it went up sharply, and then a period of slow growth began. It is difficult to say whether the sudden upward jump in 1960–61 was a lagged response to decline in the ratio of nitrogen to crop prices between 1958–

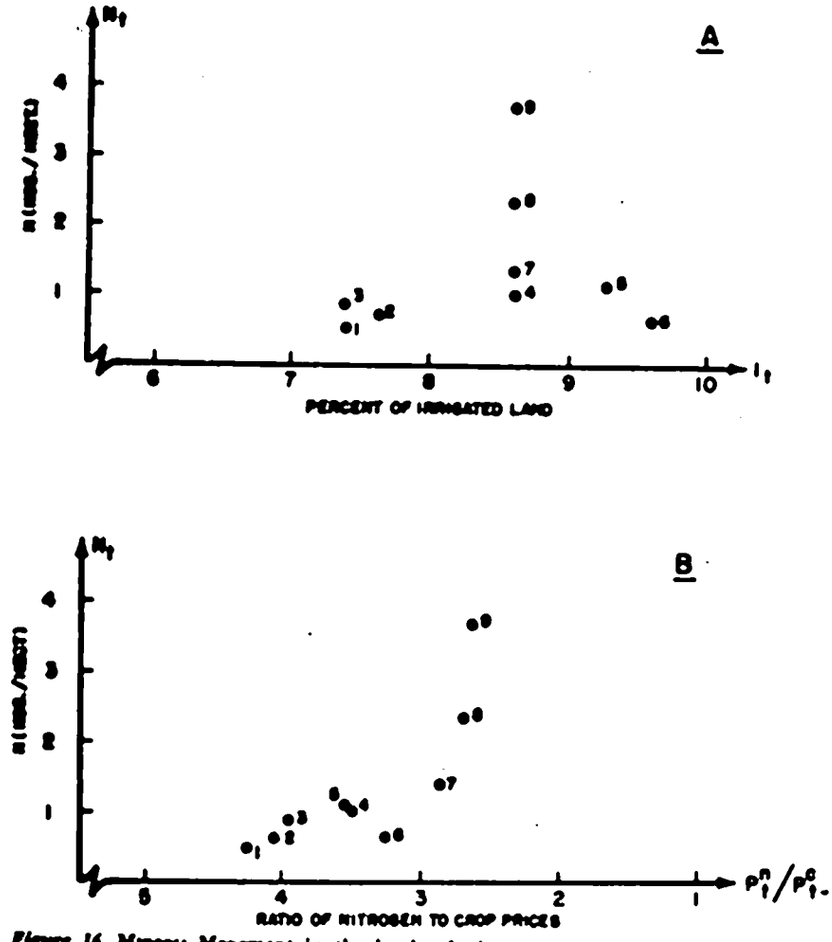

Figure 16. Mysore: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

59 and 1960–61 (figure 18B), because the observations on nitrogen use for the first 3 years are obtained by assuming that nitrogen used per hectare of land in Maharashtra was the same as in the entire former Bombay State. However, the slow growth in nitrogen use since 1960–61, in spite of a more or less continuous decline in ratio of nitrogen to crop prices again, indicates the limitations of improvement in price situation alone to generate a high rate of growth in nitrogen use in a state where only 6 to 7 percent of the land is irrigated.

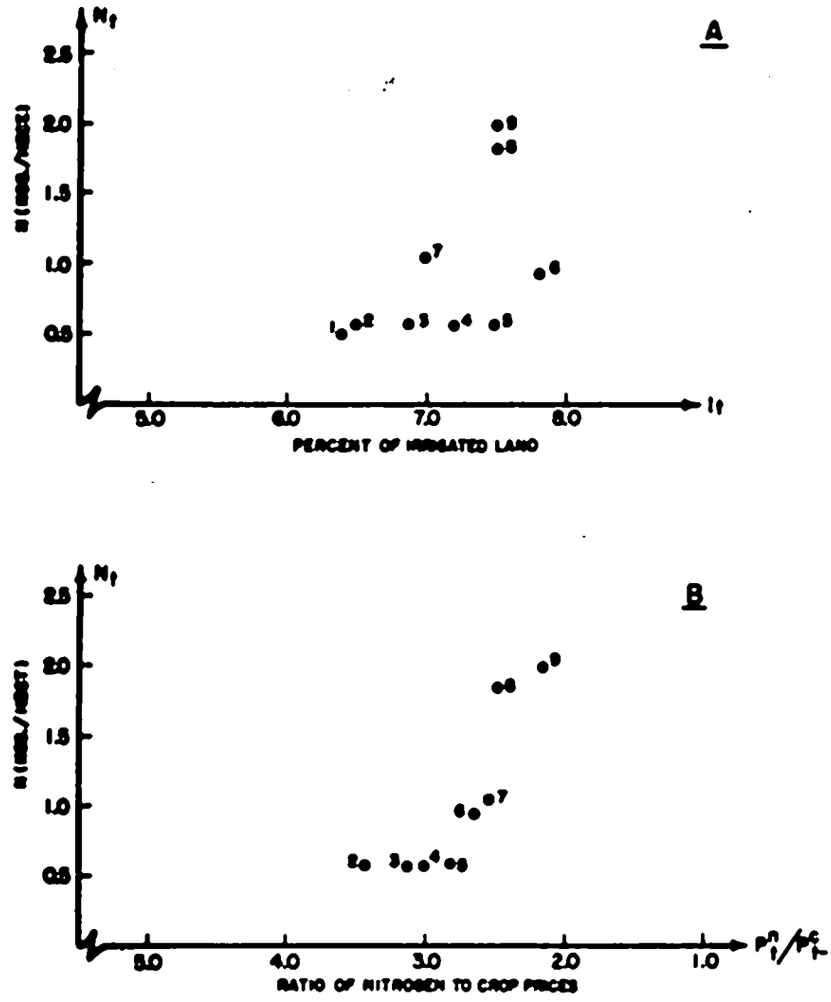

Figure 17. Gujarat: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

Madhya Pradesh

While the analyses for Gujarat and Maharashtra show that at low levels of irrigation improvement in the relative prices of nitrogen to crops alone could not generate a rapid growth in nitrogen use, the growth curve for Madhya Pradesh (figure 7) and the 2 scatter diagrams (figure 19) show that

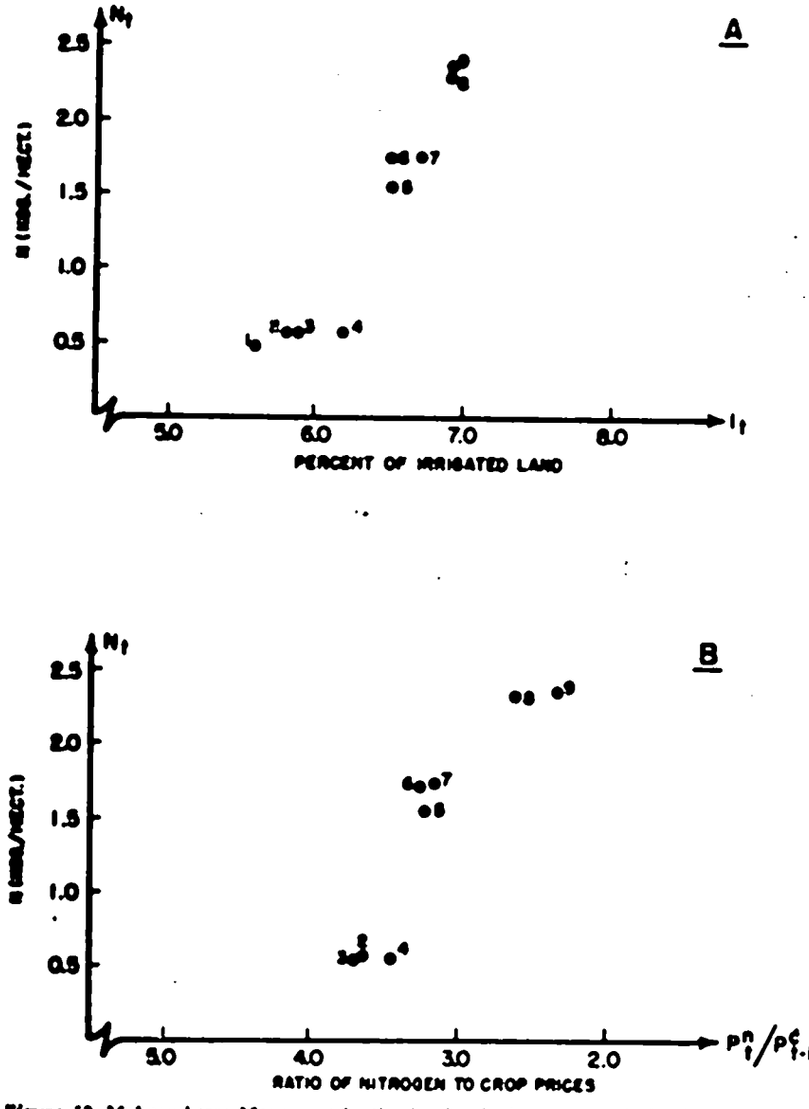

Figure 18. Maharashtra: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

at roughly the same level of irrigation there was virtually no trend growth in nitrogen use until the ratio of nitrogen to crop prices dropped substantially at the end of the 9-year period.

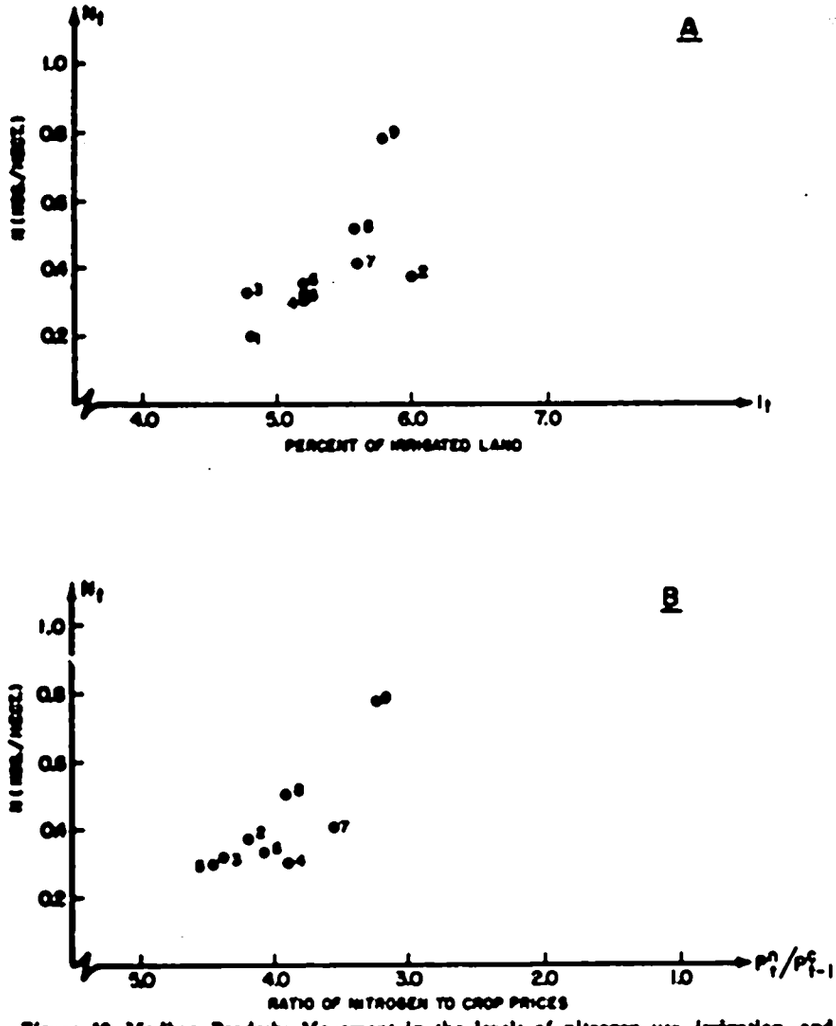

Figure 19. Madhya Pradesh: Movement in the levels of nitrogen use, irrigation, and ratio of nitrogen to crop prices between 1956–57 and 1964–65.

Summary

In 8 out of the 12 states—Punjab, Uttar Pradesh, West Bengal, Bihar, Rajasthan, Gujarat, Maharashtra, and Madhya Pradesh it appears that an unfavorable price situation (a relatively high ratio of nitrogen to crop prices) was holding up growth in nitrogen use in roughly the first half of

the 9-year period between 1956–57 and 1964–65. These 8 states include both states with high and growing levels of irrigation (e.g. Punjab), as well as states with low and relatively constant levels of irrigation (e.g. Madhya Pradesh). They include states with superior crop patterns (e.g., Punjab, Uttar Pradesh) as well as states with inferior crop patterns (e.g. Rajasthan and Madhya Pradesh). For none of these 8 states, the movement in levels of nitrogen use during the first 4 to 6 years of the period can be interpreted as a beginning of significant and consistent upward movement (figure 7). On the other hand, once the price situation improved, a definite upward movement in nitrogen use (though at varying rates) began in each of these 8 states.

In the other 4 states, Madras, Andhra Pradesh, Kerala, and Mysore, there was a slow but obvious growth in nitrogen use even during the early years of the 9-year period. However, in each of them, significant acceleration in growth did not occur until the price situation improved.

Once the price situation improved, the acceleration in the growth of nitrogen use in the 12 states was in accordance with levels of irrigation in them. In states with high levels of irrigation (e.g. Madras, Punjab, Andhra Pradesh), there was a remarkable acceleration as shown by the growth curves for these states in figure 7. Against this, in states with low levels of irrigation (e.g. Madhya Pradesh, Maharashtra, Gujarat) a similar improvement in the relative price situation did not lead to comparable acceleration in the growth curves.

Chapter 7. Future Growth in Demand

Analysis of the past fertilizer use pattern reveals that: (1) by mid-1960's nitrogenous fertilizer use had increased substantially from low levels of the early 1950's, (2) growth in use initiated by the government through extension work was reinforced by the favorable price situation, and (3) most of the growth was concentrated in states with high levels of irrigation on a few crops with relatively high returns.

In the absence of widespread replacement of existing varieties of crops by varieties more responsive to fertilizer use between the early 1950's and mid-1960's, the growth in fertilizer use during this period can be considered growth under relatively stable fertilizer production functions. Viewed thus, the growth in cultivators' demand for fertilizer during this period was mainly due to diffusion of fertilizer use on irrigated areas under 2 major foodgrains and a few fertilizer-responsive, commercial crops. Improvement in the price situation after 1960–61 brought a marked acceleration in this process.

This interpretation has some important implications for further growth in the demand for fertilizer. As entire areas under crops on which fertilizer use was common and growing were not fertilized by mid-1960's, as the price situation continued to become increasingly favorable to the cultivators until 1967–68, and as new varieties of foodgrains responsive to high rates of fertilizer application are being introduced on a significant scale since 1966, it is easy to see why growth in demand for fertilizer continued after 1964–65 (the last year covered in the analysis) and is likely to continue for some more years still. However, in the context of the need for a rapid and huge increase in fertilizer use, the more relevant question is not whether cultivators' demand would continue to grow or not but whether it will grow fast enough to raise the current level to the need-based high levels by mid-1970's.

This question is studied by estimating the limits up to which the farmer's demand for nitrogenous fertilizers can be expected to grow rapidly in different states. These estimates are made by drawing on the analysis of the past fertilizer use pattern and findings of some investigators on the new varieties of crops. The purpose behind this exercise is not just to appraise the prospects of continuous rapid growth in demand required to attain the need-based targets of use suggested for mid-1970's, but also to point at the nature and source of difficulties likely to be experienced in sustaining rapid growth in demand, and thus, indicate the nature of public policy needed in this area.

Section I

The Methodology

To determine the limits of rapid growth in demand for nitrogenous fertilizers the potential for growth in demand as a result of the diffusion of fertilizer use under the technological conditions represented by old varieties is estimated for each state. These estimates are then scrutinized by drawing on the analysis in the previous chapters to arrive at the limits of rapid growth in demand. Finally, the limits are adjusted upwards to take into account the probable impact of the replacement of old varieties by new varieties of crops on rapid growth in demand.

The potential for growth in demand in each state as a result of diffusion of fertilizer use is estimated in 2 steps. First, the potential for an individual crop is estimated by taking a product of the area and the average rate of application at which the area is expected to be fertilized.

$$D_{ij} = A_{ij} \times R_{ij}$$

where,

(continued)

D_{ij} = Potential demand for nitrogen for use on crop i in state j,

A_{ij} = Area under crop i in state j,

R_{ij} = Average rate of nitrogen application on a unit of land under crop i in state j.

The total potential demand for state j is then arrived at by adding the estimates of demand for use on various crops grown in that state,

$$D_j = \sum_{i=1}^{n} D_{ij}$$

where,

D_j = total potential demand in state j,

D_{ij} = demand for use on crop i in state i, and i = 1 ..... n.

This approach is considered appropriate to study the problem of continuous rapid growth in demand for fertilizers because the past growth was primarily due to rapid diffusion of use on a few crops with relatively high returns from fertilizer use. Accordingly, there are upper limits to rapid growth in demand, limits which are set by areas under crops yielding high returns and rates of fertilizer application on them. These limits become explicit in this methodology.[20] Furthermore, by bringing out the relative importance of various factors in determining the growth in demand, this approach points at the main sources of difficulties likely to be experienced in maintaining rapid growth in fertilizer use beyond certain levels in different states. However, use of this methodology requires detailed information to determine the series on A_{ij} and R_{ij} and involves a number of assumptions.

[20] If time series data were available on fertilizer use by crops for different states, then it would be possible to determine the proportions of areas under different crops which were fertilized at various points in time and from that estimate the proportions of areas under different crops on which fertilizer use would spread by a specific year in the future (the series on P_{ij}'s). A multiplication of the 3 series—$A_{ij} \times R_{ij} \times P_{ij}$—would then give an estimate of the level of cultivators' demand for fertilizer for that year. In the absence of such information, the use of this methodology to predict the level of demand at a specific date in the future involves considerable subjective judgment to develop the series on P_{ij}'s. Two such attempts have been made to predict the 1970–71 level of fertilizer use. Donahue (1966) estimated that by 1970-71 level of nitrogen use would rise to 2.7 million tons, 2.0 million tons as a result of diffusion on old varieties of crops and 0.7 million tons as a result of the impact of the new varieties. In 1969 I estimated that in 1970–71 the level of nitrogen use in the country would be in the range of 1.4 to 1.8 million tons. These estimates were arrived at by adjusting 1.0 to 1.4 million tons of use on old varieties of crops due to diffusion upwards by 0.4 million tons for the impact of the new varieties by that year. The difference between the estimates of Donahue and myself is mainly due to differences in the series on R_{ij} and P_{ij} used by both of us. While Donahue used recommended rates for R_{ij}'s and proportions of areas expected to be fertilized by the state government officials for P_{ij}'s, I developed the 2 series from the past observed fertilizer use pattern.

Prices of Crops and Fertilizers

To estimate the potential for growth in demand for fertilizers it is necessary to know relative prices of fertilizers and crops. Table 37 presents the available information on movement in the wholesale prices of important agricultural commodities and prices paid by cultivators for 4 important nitrogenous fertilizers between 1964–65 and 1967–68. If we assume that the movement in the farm prices of various crops was similar to those of the indices of wholesale prices in table 37, then it appears that despite considerable rise in the price of fertilizers, the relative prices of nitrogen to crops continued to become increasingly favorable to farmers up to 1967–68. It is assumed here that the relative price situation will not remain as favorable to farmers as in 1967–68, nor will it become less favorable than it was during early to mid-1960's. The methodology employed here assumes stable average rates of application for the implied range of relative prices on the basis of the findings on fertilizer practices of cultivators and the nature of fertilizer production functions of the old varieties of crops.

Crop Patterns

No attempt is made to forecast future crop patterns or levels of irrigation in states to get the series on A_{ij}. Instead, the crop pattern in each state for the most recent year for which data by irrigated and unirrigated areas are available is used. Irrigated areas are distinguished from unirrigated areas as limits of rapid growth in demand for fertilizer would be affected by levels of irrigation. Table 38 gives the reference years of the data on crop patterns used for different states.[21]

As neither the relative importance of different crops nor the amount of irrigated areas under them are likely to remain the same as the ones used here, the estimates of potential for growth in demand for nitrogen are likely to have a bias. The direction and magnitude of this bias depend on: (1) the rate of growth in total cultivated and irrigated land, (2) the nature of crop pattern on the additional land brought under cultivation, (3) distribution of the additional irrigated land among different crops, and (4) the nature of shifts in the cropping pattern on land already under cultivation.

Theoretically, the 2 sources of increase in gross cultivated land beyond reference years of table 38 are extensive cultivation and double cropping. The first is of minor importance because there is not much scope to extend margin of cultivation and even if some marginal land is brought under cultivation, it is doubtful if normally fertilized crops will be grown

[21] As findings on the fertilizer use pattern relate to the undivided Punjab state, the analysis in this chapter also refers to the geographical area covered by the former Punjab state.

Table 37. **Movement in index numbers of wholesale prices of important agricultural commodities and prices of important nitrogenous fertilizers between 1964-65 and 1967-68**

Average of months	Index numbers of wholesale prices of important agricultural commodities							
	Rice	Wheat	Jowar	Gur	Spices and condiments	Raw cotton	Raw jute	Groundnut
	Base: 1952-53=100							
1964-65	134	130	189	210	164	126	164	186
1965-66	141	138	197	162	181	129	219	223
1966-67	173	158	199	211	237	139	266	288
1967-68	206	202	227	458	245	159	211	242

	Prices of 4 important nitrogenous fertilizers when sold to cultivators			
	Ammonium sulphate	Ammonium sulphate nitrate	Urea	Calcium ammonium nitrate
	rupees per metric ton			
Apr. 1, 1964	360.00	435.00	615.00	310.00
Aug. 8, 1965	360.00	435.00	615.00	342.00
Feb. 1, 1966	405.00*	515.00	680.00	365.00†
Apr. 1, 1967	492.00	577.00	840.00	385.00
Apr. 1, 1968	437.00	577.00	780.00	437.00

* 416.00 if supplied in 50 kgs. packing; † 385.00 from Apr. 1, 1966

Sources: Index numbers of wholesale prices are from the Reserve Bank of India Bul., pp. 822-23, June 1968, and fertilizer prices are from the Fertilizer Association of India.

Table 38. **Reference years for data on crop patterns**

States	Reference year
Andhra Pradesh	1964-65
Assam	1961-62
Bihar	1964-65
Gujarat	1962-63
Jammu and Kashmir	1962-63
Kerala	1964-65
Madhya Pradesh	1963-64
Madras	1963-64
Madras	1963-64
Maharashtra	1963-64
Mysore	1963-64
Orissa	1961-62
Punjab	1964-65
Rajasthan	1964-65
Uttar Pradesh	1963-64
West Bengal	1962-63

on it. However, the possibility of increase in gross cultivated land as a result of double cropping, through an increase in irrigation and shortening of the growing season cannot be ruled out. Similarly, increase in the levels of irrigation, even when it does not increase the amount of land under cultivation, will generate additional demand through its impact on cropping pattern and rates of fertilizer application. But changes in the cropping pattern resulting from other sources are unlikely to affect growth in demand for fertilizers because such changes would not involve major shifts in land between crops which are expected to be fertilized rapidly (e.g. sugarcane, banana, vegetables, rice, and wheat) and those on which fertilizer use is expected to be adopted slowly (e.g. jowar, bajara, pulses, oilseeds). To conclude, while the estimates made here are unlikely to be seriously biased for not taking into account most of the changes in cropping pattern which may take place after the reference years, they are likely to be biased downwards for states where levels of irrigation would rise rapidly.

Average Rates of Nitrogen Application

Two means were available to obtain the series on average rates of application needed to calculate the potential for growth in demand for nitrogenous fertilizers. Either the rates recommended by extension agencies could be used or personal judgment could determine them from the findings on actual rates of application in the past and other related information. The latter was preferred.

We are interested in examining the problem of growth in cultivators' demand for fertilizers and not in estimating the amount of fertilizer needed at some normative rates. The observed fertilizer practices are better guidelines than recommendations of extension agencies, particularly when they differ significantly. Table 39 compares the average rates of nitrogenous fertilizer application observed among samples of farmers (chapter 4) with those recommended by 3 different agencies, Departments of Agriculture of state governments, the Fertilizer Association of India, and the Indian Potash Supply Agency. The table shows that on almost all crops the rates of application were substantially lower than recommended rates. This observation is consistent for samples from different districts as well as for those from the same district for more than 1 year. The discrepancy between the observed and recommended rates can be explained in terms of decisions made by farmers under conditions of price and yield uncertainty, and of very small marginal returns beyond 50 to 75 percent of the recommended rates.[22] It would be, therefore, incorrect to ignore this evidence and use the recommended rates to estimate the potential for growth in cultivators' demand.

For these reasons, it was decided to develop the series on average rates of nitrogen application for each state based on rates observed among samples of cultivators from the same or neighboring states. For crops on which no information on rates of application was available, "realistic" assumptions were made after taking into account the recommended rates on those crops, the nature of the crops and conditions under which they are mainly grown, and discrepancy between observed and recommended rates on other crops in the same region. In order to examine how the estimates of potential growth in demand for nitrogen based on these rates would change if the more usual assumption that farmers would generate demand for fertilizer at near-recommended rates is made, another series of average rates is also developed by adjusting the first series upwards. For fertilizer responsive crops grown mainly under irrigated conditions, the adjusted rates roughly approximate the recommended rates, while they are below the recommended rates for other crops which are not so responsive to fertilizer use and which are grown mainly under unirrigated conditions. The 2 series on average rates of nitrogen application are presented in table 40. The rates expected on the basis of observed fertilizer practices are referred to as R-I, while those arrived at by adjusting the expected rates upwards are referred to as R-II.

[22] This argument is based on the analysis in chapter 4.

Table 39. Observed and "recommended" rates of nitrogen application on different crops

Location of sample, District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state			Rates used in this study		
			Agency*	Irrigated or unirri. land†	Rates (N lbs./acre)	Irrigated or unirri. land	Rates (N lbs./acre) R-I	R-II
		Rice						
Thanjavur, Madras	1961-62	38	1	irri.	30	irri.	35	40
	1962-63	22		unirri.	20	unirri.	30	35
	1963-64	30	2	all	40			
Coimbatore, Madras	1954-55	32	3	all	40			
	1961-62	32						
Alleppey, Kerala	1962-63	31	1	all	30	irri.	40	45
Palghat, Kerala	1962-63	38	2	all	20-50	unirri.	35	40
			3	all	30-40			
W. Godavari, Andhra	1954-55	17	1	irri.	60	irri.	35	40
	1961-62	21		unirri.	40	unirri.	30	35
	1962-63	31	2	all	20-60			
	1963-64	30	3	all	30-40			
Krishna, Andhra	1961-62	13						
Mandya, Mysore	1962-63	29	1	all	30	irri.	35	40
			2	all	30-40	unirri.	30	35
			3	all	30-40			
Bhandara, Maharashtra	1962-63	11	1	all	30	irri.	25	30
			2	all	20-40	unirri.	15	25
			3	all	30-40			
Surat, Gujarat	1962-63	23	1	irri.	60-75	irri.	30	35
Surat(Bar.), Gujarat‡	1964-65	42		unirri.	30	unirri.	20	30
Kaira (Cha.), Gujarat§	1964-65	39	2	all	20-40			
Kaira (Ma.), Gujarat"	1964-65	20	3	all	40			

(continued)

Table 39. (continued)

Location of sample District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state: Agency*	Recommended rates for state: Irrigated or unirri. land†	Recommended rates for state: Rates (N lbs./acre)	Rates used in this study: Irrigated or unirri. land	Rates used in this study: Rates R-I (N lbs./acre)	Rates used in this study: Rates R-II (N lbs./acre)
	Rice							
Raipur, M.P.	1958-59	10	1	irri.	40	irri.	15	25
	1961-62	9		unirri.	20	unirri.	10	15
	1962-63	12	2	all	10-40			
	1963-64	13	3	irri.	40			
				unirri.	20			
Sambalpur, Orissa	1962-63	17	1	all	40	irri.	25	30
			2	all	22-33	unirri.	20	25
			3	all	30			
Shahabad, Bihar	1961-62	13	1	all	40	irri.	15	25
	1962-63	7	2	irri.	30-50	unirri.	10	15
	1963-64	7		unirri.	25			
			3		40			
Barabanki, U.P.	1956-58	14	1	all	30-40	irri.	15	25
Meerut, U.P.	1959-60	12	2	all	15-50	unirri.	10	15
Varanasi, U.P.	1961-62	8	3	all	40			
Ferozpur, Punjab	1957-59	15	1	all	40	irri.	20	25
			2	all	40	unirri.	15	20
			3	all	40			
	Wheat							
Ludhiana, Punjab	1961-62	19	1	irri.	40	irri.	30	40
	1962-63	21		unirri.	30	unirri.	15	20
	1963-64	25	2	irri.	40			
Ferozpur, Punjab	1957-59	16		unirri.	20-31			
			3	all	45			

(continued)

Table 39. (continued)

Location of sample District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state: Agency[a]	Recommended rates for state: Irrigated or unirri. land[b]	Recommended rates for state: Rates (N lbs./acre)	Rates used in this study: Irrigated or unirri. land	Rates used in this study: Rates R-I (N lbs./acre)	Rates used in this study: Rates R-II (N lbs./acre)
		Wheat						
Pali, Rajasthan	1962-63	19	1	irri.	40-60	irri.	20	30
	1963-64	14		unirri.	20	unirri.	10	15
			2	irri.	40			
				unirri.	20			
Aligarh, U.P.	1961-62	22	1	irri.	25-45	irri.	30	35
	1962-63	23		unirri.	15-20	unirri.	15	18
	1963-64	16	2	all	10-50			
Varanasi, U.P.	1961-62	16	3	all	40			
Meerut, U.P.	1959-60	11						
Barabanki, U.P.	1956-58	12						
Shahabad, Bihar	1961-62	13	1	all	40	irri.	20	30
	1962-63	14	2	irri.	25-40	unirri.	10	15
	1963-64	12		unirri.	25			
			3	irri.	50			
Raipur, M.P.	1961-62	2	1	irri.	30	irri.	15	25
				unirri.	15	unirri.	7	12
			2	all	20-40			
			3	all	40			
Surat(Bar.), Gujarat	1964-65	39	1	irri.	60	irri.	35	40
Kaira (Cha.), Gujarat	1964-65	34		unirri.	30	unirri.	15	20
			2	irri.	40			
				unirri.	20			
			3	irri.	40			
				unirri.	20			

(continued)

Table 39. (continued)

Location of sample District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state: Agency*	Recommended rates for state: Irrigated or unirri. land†	Recommended rates for state: Rates (N lbs./acre)	Rates used in this study: Irrigated or unirri. land	Rates used in this study: Rates (N lbs./acre) R-I	Rates used in this study: Rates (N lbs./acre) R-II
		Jowar						
Surat, Gujarat	1962-63	17	1	unirri.	20	irri.	20	25
Surat(Bar.), Gujarat	1964-65	14	2	all	20	unirri.	10	12
Kaira(Cha.), Gujarat	1964-65	23						
		Bajara						
Aligarh, U.P.	1961-62	11	1	all	20			
	1962-63	20	2	all	10-30	irri.	20	25
	1963-64	15	3	all	40	unirri.	10	12
Kaira(Cha.), Gujarat	1964-65	21						
Kaira(Ma.), Gujarat	1964-65	15	1	all	40	irri.	20	25
			2	all	20	unirri.	10	12
		Maize						
Ferozpur, Punjab	1957-59	21	1	all	50	irri.	20	30
Ludhiana, Punjab	1962-63	20	2	local	51	unirri.	10	15
	1963-64	18		hybrid	99			
			3	local	50			
				hybrid	100			
Meerut, U.P.	1959-60	10	1	all	35	irri.	20	25
Aligarh, U.P.	1961-62	6	2	local	20-50	unirri.	10	12
	1962-63	19		hybrid	60-80			
	1963-64	20	3	local	50			
				hybrid	100			

(continued)

Table 39. (continued)

Location of sample District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state			Rates used in this study		
			Agency*	Irrigated or unirri. land†	Rates (N lbs./acre)	Irrigated or unirri. land	Rates (N lbs./acre) R-I	R-II
				Maize				
Pali, Rajasthan	1962-63	28	1	irri.	50	irri.	20	30
	1963-64	20		unirri.	20	unirri.	10	15
			2	hybrid	100			
				local, irri.	50			
				local, unirri.	20			
				Ragi				
Mandya, Mysore	1962-63	13	1	irri.	30	irri.	15	25
				unirri.	20	unirri.	7	15
			2	irri.	60			
				unirri.	30			
			3	irri.	60			
				unirri.	30			
				Sugarcane				
Coimbatore, Madras	1954-55	43	1	all	250	irri.	175	225
	1961-62	64	2	all	198-247	unirri.	125	175
			3	all	250			
W. Godavari, Andhra	1954-55	66	1	all	150-225	irri.	150	200
	1961-62	73	2	all	150-300	unirri.	100	150
Krishna, Andhra	1961-62	126	3	all	300			
Mandya, Mysore	1062-63	108	1	all	150-300	irri.	175	225
			2	all	150-300	unirri.	125	175
			3	all	300			

(continued)

Table 39. (continued)

Location of sample District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state: Agency*	Recommended rates for state: Irrigated or unirri. land†	Recommended rates for state: Rates (N lbs./acre)	Rates used in this study: Irrigated or unirri. land	Rates used in this study: Rates R-I (N lbs./acre)	Rates used in this study: Rates R-II (N lbs./acre)
		Sugarcane						
Surat(Bar.), Gujarat	1964-65	180	1	all	225	irri.	150	200
Kaira(Ch.), Gujarat	1964-65	55	2	all	220-325			
			3	all	200			
Shahabad, Bihar	1961-62	8	1	all	60	irri.	40	60
			2	all	60-80	unirri.	20	40
			3	all	100			
Aligarh, U.P.	1961-62	13	1	all	60-110	irri.	50	80
	1962-63	37	2	all	60-120	unirri.	30	50
	1963-64	33	3	all	150			
Varanasi, U.P.	1961-62	19						
Meerut, U.P.	1959-60	19						
Barabanki, U.P.	1956-58	22						
Ludhiana, Punjab	1961-62	19	1	irri.	100-150	irri.	60	90
				unirri.	100-150	unirri.	40	60
			2	all	99-150			
			3	all	150			
		Tobacco						
Coimbatore, Madras	1954-55	29	2	all	60	all	40	50
	1961-62	29						
W. Godavari, Andhra	1954-55	36	1	irri.	40-200	Vir.	30	40
	1961-62	51		unirri.	20	Natu	60	70
Krishna, Andhra	1961-62	23	2	Virginia	20			
				Natu	40			

(continued)

Table 39. (continued)

Location of sample District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state: Agency*	Recommended rates for state: Irrigated or unirri. land†	Recommended rates for state: Rates (N lbs./acre)	Rates used in this study: Irrigated or unirri. land	Rates used in this study: Rates R-I (N lbs./acre)	Rates used in this study: Rates R-II (N lbs./acre)
	Cotton							
Coimbatore, Madras	1961-62	25	1	irri.	40	irri.	20	30
				unirri.	20	unirri.	10	15
			2	irri.	40			
				unirri.	20			
			3	irri.	40			
				unirri.	20			
Surat, Gujarat	1962-63	19	1	irri.	40	irri.	20	30
Surat(Bar.), Gujarat	1964-65	14		unirri.	20	unirri.	10	15
			2	irri.	40			
				unirri.	20			
			3	irri.	60			
				unirri.	20			
Meerut, U.P.	1959-60	8	2	all	10-30	irri.	25	35
Aligarh, U.P.	1961-62	6				unirri.	12	18
	1962-63	29						
	1963-64	19						
Ferozpur, Punjab	1957-59	21	1	American, irri.	100	irri.	30	40
Ludhiana, Punjab	1962-63	20		American, unirri.	50	unirri.	15	20
	1963-64	22		Desi, irri.	40			
				Desi, unirri.	45			
			2	all	40-200			
			3	American, all	80			
				Desi, all	40			

(continued)

Table 39. (concluded)

Location of sample District, State	Reference year	Observed rate (N lbs./acre)	Recommended rates for state: Agency*	Recommended rates for state: Irrigated or unirri. land†	Recommended rates for state: Rates (N lbs./acre)	Rates used in this study: Irrigated or unirri. land	Rates used in this study: Rates R-I (N lbs./acre)	Rates used in this study: Rates R-II (N lbs./acre)
		Groundnut						
Ludhiana, Punjab	1962-63	12	1	irri.	0	irri.	10	15
	1963-64	14		unirri.	0	unirri.	5	10
			2	all	0			
			3	all	15			

* The 3 agencies are: Departments of Agriculture of the various State Governments, Fertiliser Association of India, and Indian Potash Supply Agency.

† Different rates are recommended for irrigated (irri.) and unirrigated (unirri.) areas. Where no distinction is made, the rates are considered for all (all) areas.

♦ Surat (Bar.) = sample from Bardoli taluka, Surat District.

§ Kaira (Cha.) = sample from Charotar tract, Kaira District.

▪ Kaira (Ma.) = sample from Mahi tract, Kaira District.

Sources: Observed rates: Chapter 4 findings.
Recommended rates are: Agency 1: Roy L. Donahue. Estimates of Fertiliser Consumption in India in 1970-71. Fertiliser Assoc. of India. New Delhi. 1966.
Agency 2: Fertiliser Statistics, 1964-65. Fertiliser Assoc. of India. New Delhi. pp. 114-145. 1965.
Agency 3: N, P, K -- The Way to High Yields. Indian Potash Supply Agency Limited. Madras. 1967.

Table 40. **Average rates of nitrogen application used to estimate potential for growth in demand**

States	Andhra Pradesh		Assam		Bihar		Gujarat		Jammu & Kashmir		Kerala		Madhya Pradesh		Madras	
Crops	R-I*	R-II*	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II
	lbs./acre															
Food crops other than foodgrains:																
Sugarcane—— I†	150	200	40	60	40	60	150	200	50	80	100	125	60	90	175	225
UI†	100	150	20	40	20	40	100	150	30	50	75	100	40	40	125	175
Potato				50	75	100	75	100	75	100			75	100	75	100
Other vegetables	40	60	30	50	40	60	40	60	40	60	40	60	30	50	40	60
Banana	150	200	100	150	150	200	50	200			150	200			150	200
Other fresh fruits	30	40	30	40	15	25	30	40	40	60	30	40	30	40	30	40
Chillies	80	100	40	60	50	75	60	80			60	80	50	75	80	100
Other spices	40	50	40	50	40	50	40	50			40	50	40	50	40	50
Two major foodgrains:																
Rice—— I	35	40	15	20	15	25	30	35	20	25	40	45	15	25	35	40
UI	30	35	10	15	10	15	20	30	15	20	35	40	10	15	30	35
Wheat—— I	20	30			20	30	35	40	30	40			15	25		
UI	10	15	10	15	10	15	15	20	15	20			7	12		

(continued)

Table 40. (continued)

States	Andhra Pradesh		Assam		Bihar		Gujarat		Jammu & Kashmir		Kerala		Madhya Pradesh		Madras	
Crops	R-I*	R-II*	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II
	lbs./acre															
Non-food commercial crops:																
Tobacco	60	70	30	40	40	50	60	70	30	40	50	60	40	50	60	70
Cotton I	20	30			10	15	20	30	10	20	15	25	20	30	20	30
Cotton UI	10	15			10	15	10	15	10	20	15	25	10	15	10	15
Jute			10	20	10	20										
Groundnut I	10	20					10	15			10	15			10	15
Groundnut UI	5	10					5	10					5	10	5	10
Other oil-seeds I	5	10			5	10	5	10	5	10	5	10	5	10	5	10
Other foodgrains:																
Jowar I	15	25					20	25							15	25
Jowar UI	7	12			5	7	10	12					5	7	7	12
Bajara I	15	25					20	25							15	25
Bajara UI	7	12			5	7	10	12	5	10			5	7	7	12
Maize I	15	25			10	20	20	25	20	30			10	15		
Maize UI	7	12	5	7	5	10	10	12	10	15			5	7		
Ragi I	15	25			10	15			10	15	15	25			15	25
Ragi UI	7	12			5	7			5	10			5	7	7	12
Barley I					15	25			10	15			10	15		
Barley UI					10	15			5	10			5	7		
Other cereals I	10	15			10	15	10	15	10	15	10	15	10	15	10	15
Other cereals UI	5	7	5	7	5	7	5	7	5	7			5	7	5	7
Pulses I	10	15			10	15	10	15	10	15	10	15	10	15	10	15
Pulses UI	5	7	5	7	5	7	5	7	5	7			5	7	5	7

(continued)

Table 40. (continued)

States	Maha-rashtra		Mysore		Orissa		Punjab		Rajasthan		Uttar Pradesh		West Bengal	
Crops	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II
	lbs./acre													
Food crops other than foodgrains:														
Sugarcane—— I--	150	200	175	225	40	60	60	90	50	80	50	80	50	75
UI--	100	150	125	175	25	40	40	60	30	50	30	50	30	50
Potato————	75	100	75	100	75	100	100	125	75	100	100	125	100	150
Other vegetables	40	60	40	60	40	60	40	60	30	50	40	60	40	60
Banana————	150	200	150	200	150	200								
Other fresh fruits————	30	40	30	40	20	30	30	40	20	30	30	40	15	25
Chillies————	60	80	60	80	50	75	80	100	60	80	60	80	50	75
Other spices———	40	50	40	50	40	50	40	50	40	50	40	50	40	50
Two major foodgrains:														
Rice———— I--	25	30	35	40	25	30	20	25	20	25	15	25	20	25
UI--	15	25	30	35	20	25	15	20	10	15	10	15	15	20
Wheat———— I--	30	35	35	40	25	30	30	40	20	30	30	35	25	30
UI--	15	18	15	20	10	15	15	20	10	15	15	18	10	15

(continued)

Table 40. (concluded)

States	Maharashtra		Mysore		Orissa		Punjab		Rajasthan		Uttar Pradesh		West Bengal	
Crops	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II	R-I	R-II
	lbs./acre													
Non-food commercial crops:														
Tobacco	50	60	50	60	40	50	40	50	40	50	40	50	40	50
Cotton I	20	30	20	30	20	25	30	40	25	35	25	35		
Cotton UI	10	15	10	15	10	15	15	20	12	18	12	18		
Jute					15	25					20	30	15	25
Groundnut I	10	15					10	20	10	15	10	15		
Groundnut UI	5	10	5	10	5	10	5	10	5	10	5	10		
Other oilseeds I	5	10					5	10	5	10	5	10		
Other foodgrains:														
Jowar I	20	25	15	25	10	15	15	25	15	25	10	15		
Jowar UI	10	12	7	12	5	10	7	12	7	12	5	7		
Bajara I	20	25	15	25	5	10	20	25	20	25	20	25		
Bajara UI	10	12	7	12			10	12	10	12	10	12		
Maize I	20	25	15	25	10	20	20	30	20	30	20	25	10	20
Maize UI	10	12	7	12	5	10	10	15	10	15	10	12	5	10
Ragi I	20	25	15	25	10	15					10	15		
Ragi UI	10	12	7	12	5	7					5	7		
Barley I							20	30	20	30	20	30	15	25
Barley UI							10	15	10	15	10	15	10	15
Other cereals I	10	15	10	15	10	15	10	15	10	15	10	15		
Other cereals UI	5	7	5	7	5	7	5	7	5	7	5	7	5	7
Pulses I	10	15	10	15	10	15	10	15	10	15	10	15	10	15
Pulses UI	5	7	5	7	5	7	5	7	5	7	5	7	5	7

* R-I = Expected average rates; R-II = Expected averages adjusted upwards.

† I = Irrigated areas; UI = Unirrigated areas.

Section II

The Estimates and Their Implications

The estimates of potential for growth in demand for nitrogenous fertilizers at the expected rates of application (R–I) as well as at rates adjusted upwards to bring them closer to the recommended rates (R–II) are presented in table 41. The former are referred to as estimates I and the latter as estimates II. In the table, crops are divided into 7 groups based on the findings on the speed with which fertilizer use was being adopted on different crops.

Group A: sugarcane, spices, vegetables, fresh fruits, and tobacco.
Group B: irrigated rice and irrigated wheat.
Group C. irrigated cotton, jute, irrigated oilseeds.
Group D: irrigated foodgrains other than rice and wheat.
Group E: unirrigated rice, unirrigated wheat.
Group F: unirrigated cotton and unirrigated groundnut.
Group G: unirrigated foodgrains other than rice and wheat.

In interpreting the estimate of total potential for growth in demand for "all-crops," it may be noted that the 3 plantation crops (tea, coffee, and rubber) are not included[23]; the totals for "all states" do not include about 7 percent of the country's cultivated land located in various Union Territories and centrally administered regions.

Assuming the conditions prevailing in the early to mid-1960's with respect to crop pattern, crop varieties, levels of irrigation, and relative prices of nitrogen to crops, the grand totals for all states in table 41 indicate the potential for growth in demand for nitrogen. At the expected rates of application (i.e., at R–I) the estimate of potential demand for nitrogen in the non-plantation agriculture of the country would be about 2.19 million tons. It would go up to about 2.99 million tons, if we assume that cultivators would generate demand at rates arrived at by adjusting the expected rates upwards (i.e., at R–II).

These estimates, however, do not indicate the limits up to which demand for fertilizer can be expected to grow rapidly, because they represent the potential for growth in demand for almost all non-plantation crops. It is unlikely that demand for fertilizer would grow at the same speed for all these crops and under all farming conditions, in view of the wide variation in incentive to adopt fertilizer use. This is brought out in chapter 4 by the close association between relative size of returns from fertilizer use on various crops and proportions of areas under these crops fertilized. It is also illustrated in chapters 5 and 6 by the importance of

[23] Also, it does not include unirrigated oilseeds other than groundnut and various fodder crops.

Table 41. Estimates of potential for growth in demand for nitrogen in various states

States	Estimate	Group A				
		Sugarcane	Spices	Potatoes	Other vegetables	Fresh fruits
		Metric tons of nitrogen				
Andhra Pradesh	I	24,227	20,778		2,232	8,276
	II	32,372	25,975		3,348	11,034
Assam	I	681	2,105	2,064	2,341	3,339
	II	1,361	2,713	3,096	3,902	4,823
Bihar	I	4,864	2,500	7,111	4,827	3,477
	II	8,584	3,540	9,482	7,241	5,411
Gujarat	I	3,675	3,021	272	1,434	2,734
	II	4,900	3,883	363	2,151	3,648
Jammu & Kashmir	I	40		136	835	345
	II	81		181	1,252	517
Kerala	I	941	10,254		8,820	12,032
	II	1,214	12,835		12,039	16,042
Madhya Pradesh	I	3,503	5,418	1,123	2,096	1,375
	II	5,254	7,066	1,496	3,493	1,833
Madras	I	14,348	9,473	544	3,031	7,513
	II	18,443	11,841	726	4,546	10,018
Maharashtra	I	23,048	13,048	1,259	3,303	5,703
	II	30,738	17,254	1,679	4,954	7,604
Mysore	I	18,278	11,315	647	2,377	4,314
	II	20,348	14,736	862	3,566	5,753
Orissa	I	1,105	1,043	919	3,684	2,622
	II	1,660	1,306	1,225	5,526	3,843
Punjab	I	16,968	2,704	2,041	1,833	939
	II	25,480	3,381	2,552	2,749	1,252
Rajasthan	I	2,341	8,956	136	803	218
	II	3,752	11,361	181	1,338	327
Uttar Pradesh	I	59,090	2,813	13,702	5,481	3,512
	II	95,522	3,628	17,127	8,221	4,682
West Bengal	I	1,383	717	7,395	3,593	157
	II	2,127	998	11,093	5,390	261
All states	I	174,492	94,145	37,349	46,690	56,557
	II	251,836	120,617	50,063	69,736	77,048

(continued)

Table 41. (continued)

States	Estimate	Group A	Total	Group B		Total
		Tobacco	Group A	Irri. Rice	Irri. Wheat	Group B
		Metric tons of nitrogen				
Andhra Pradesh	I	7,554	63,067	124,718	64	124,782
	II	9,445	82,174	142,534	95	142,629
Assam	I	354	10,884	9,603		9,603
	II	472	16,367	12,803		12,803
Bihar	I	635	23,414	29,760	3,775	33,535
	II	794	35,052	49,601	5,662	55,263
Gujarat	I	6,206	17,343	2,205	8,829	11,034
	II	7,241	22,186	2,572	10,090	12,662
Jammu & Kashmir	I	14	1,370	4,628	694	5,322
	II	18	2,049	5,785	924	6,709
Kerala	I	45	32,092	17,513		17,513
	II	54	42,204	19,702		19,702
Madhya Pradesh	I	145	13,660	9,010	3,872	12,882
	II	181	19,323	15,017	6,454	21,471
Madras	I	980	35,889	93,927		93,927
	II	1,143	46,717	107,345		107,345
Maharashtra	I	998	47,359	7,996	4,859	12,855
	II	1,198	63,427	9,596	5,669	15,265
Mysore	I	2,042	38,973	25,851	412	26,263
	II	2,450	47,715	29,545	472	30,017
Orissa	I	327	9,700	27,506	102	27,608
	II	408	14,068	33,007	122	33,129
Punjab	I	50	24,575	8,448	46,931	55,379
	II	113	35,527	10,560	62,574	73,134
Rajasthan	I	417	12,871	408	15,689	16,097
	II	522	17,481	510	23,533	24,043
Uttar Pradesh	I	726	85,324	9,371	64,748	74,119
	II	907	130,087	15,619	75,539	91,158
West Bengal	I	690	13,935	28,628	749	29,377
	II	862	20,731	35,786	898	36,684
All states	I	21,223	430,456	399,572	150,724	550,296
	II	25,808	595,108	489,982	192,032	682,014

(continued)

Table 41. (continued)

States	Estimate	Group C			Total Group C	Group D	
		Jute	Irri. cotton	Irri. oilseeds		Irri. lower	Irri. bajara
		metric tons of nitrogen					
Andhra Pradesh	I		91	978	1,069	218	851
	II		136	1,955	2,091	363	1,418
Assam	I	1,547			1,547		
	II	3,094			3,094		
Bihar	I	1,924	18	50	1,992		
	II	3,848	27	100	3,975		
Gujarat	I		2,523	632	3,155	1,225	907
	II		3,784	1,041	4,825	1,531	1,134
Jammu & Kashmir	I		14	14	28		
	II		27	27	54		
Kerala	I						
	II						
Madhya Pradesh	I		118	20	138		
	II		177	41	218		
Madras	I		2,532	1,429	3,[illegible]41	2,382	844
	II		3,797	2,211	6,008	3,917	1,440
Maharashtra	I		1,633	173	1,806	7,005	708
	II		2,450	282	2,732	8,756	885
Mysore	I		408		408	1,048	27
	II		612		612	1,747	45
Orissa	I	776	54		830	5	
	II	1,293	68		1,361	7	
Punjab	I		21,288	558	21,846	994	1,769
	II		28,383	1,116	29,499	1,656	2,212
Rajasthan	I		5,104	252	5,356	436	681
	II		7,146	494	7,640	728	851
Uttar Pradesh	I	426	2,348	207	2,981	122	91
	II	640	3,033	411	4,084	184	113
West Bengal	I	7,309			7,309		
	II	12,182			12,182		
All states	I	11,982	36,131	4,313	52,426	13,435	5,898
	II	21,057	49,640	7,678	78,375	18,889	8,098

(continued)

Table 41. (continued)

State	Estimate	Group D					Total Group D
		Irri. maize	Irri. ragi	Irri. barley	Irri. other cereals	Irri. pulses	
		metric tons of nitrogen					
Andhra Pradesh	I	470	2,144		204	100	3,987
	II	783	3,573		306	150	6,593
Assam	I						
	II						
Bihar	I	27	27	830	36	549	1,469
	II	54	41	1,383	54	823	2,355
Gujarat	I	172			50	100	2,454
	II	216			100	200	3,181
Jammu & Kashmir	I	508	77	17	36	41	679
	II	762	115	34	54	61	1,026
Kerala	I						
	II						
Madhya Pradesh	I	18		526	5	717	1,266
	II	27		789	7	1,075	1,898
Madras	I		2,280		172	68	5,766
	II		3,800		259	102	9,518
Maharashtra	I	254	18		23	490	8,498
	II	318	23		36	735	10,753
Mysore	I	204	851		68	59	2,257
	II	340	1,418		102	88	3,740
Orissa	I	23	91		9	390	518
	II	45	136		14	585	787
Punjab	I	5,871		1,252	23	5,803	15,712
	II	8,806		1,878	34	8,704	23,290
Rajasthan	I	1,906		7,477	32	3,208	13,740
	II	2,858		11,215	48	4,811	20,511
Uttar Pradesh	I	2,151	132	17,867	304	13,112	33,779
	II	2,688	197	26,800	456	19,668	50,106
West Bengal	I	91		68		481	640
	II	182		113		721	1,016
All states	I	11,695	5,620	28,037	962	25,118	90,765
	II	17,079	9,303	42,212	1,470	37,723	134,774

(continued)

Table 41. (continued)

States	Estimate	Group E		Total Group E	Group F		Total Group F
		Unirri. rice	Unirri. wheat		Unirri. cotton	Unirri. groundnut	
		Metric tons of nitrogen					
Andhra Pradesh	I	12,631	150	12,781	4 138	5,689	9,827
	II	14,736	224	14,960	6,207	11,379	17,586
Assam	I	15,077	45	15,117			
	II	22,608	69	22,677			
Bihar	I	39,685	5,249	44,934			
	II	59,528	7,874	67,402			
Gujarat	I	11,152	3,294	14,446	17,781	12,474	30,255
	II	16,728	4,392	21,120	26,671	24,949	51,620
Jammu & Kashmir	I	361	2,545	2,906			
	II	480	3,394	3,874			
Kerala	I	16,118		16,118	143	163	306
	II	18,400		18,400	238	245	483
Madhya Pradesh	I	41,318	24,267	65,585	8,471	1,867	10,338
	II	61,978	41,601	103,579	12,706	3,724	16,430
Madras	I	7,581		7,581	3,221	4,474	7,695
	II	8,845		8,845	4,832	8,947	13,779
Maharashtra	I	17,919	12,515	30,434	30,602	6,304	36,906
	II	29,865	15,018	44,883	45,903	12,608	58,511
Mysore	I	14,618	5,063	19,681	11,356	500	11,856
	II	17,055	6,751	23,806	17,034	1,000	18,034
Orissa	I	69,362	59	69,421	54	145	199
	II	86,702	88	86,790	82	290	372
Punjab	I	2,504	17,803	20,307	483	721	1,204
	II	3,339	23,738	27,077	644	1,443	2,087
Rajasthan	I	985	5,422	6,407	1,062	1,100	2,162
	II	1,477	8,133	9,610	1,592	2,200	3,792
Uttar Pradesh	I	42,788	33,817	76,605	174	1,666	1,840
	II	64,183	40,580	104,763	261	3,332	3,593
West Bengal	I	53,280	250	53,530			
	II	71,040	374	71,414			
All states	I	345,374	110,479	455,853	77,485	35,103	112,588
	II	476,964	152,236	629,200	116,170	70,117	186,287

(continued)

Table 41. (continued)

States	Estimate	Group C				
		Unirri. jowar	Unirri. bajra	Unirri. maize	Unirri. ragi	Unirri. barley
		Metric tons of nitrogen				
Andhra Pradesh	I	19,476	4,297	1,407	1,655	
	II	33,385	7,366	2,411	2,837	
Assam	I			125		
	II			175		
Bihar	I	45	116	4,160	1,025	3,258
	II	64	162	8,321	1,436	4,886
Gujarat	I	14,047	15,684	2,364		
	II	16,856	18,822	2,837		
Jammu & Kashmir	I		141	2,550	25	84
	II		282	3,825	50	168
Kerala	I				88	
	II				147	
Madhya Pradesh	I	11,302	1,082	2,538	82	631
	II	15,822	1,515	3,554	114	883
Madras	I	4,716	3,119		1,455	
	II	8,085	5,346		2,494	
Maharashtra	I	65,483	18,760	191	2,518	
	II	78,579	22,514	229	3,022	
Mysore	I	23,140	4,237	16	7,644	
	II	39,742	7,276	27	12,785	
Orissa	I	41	30	179	358	
	II	82	59	358	502	
Punjab	I	1,842	9,773	3,689		1,307
	II	3,158	11,727	5,533		1,783
Rajasthan	I	9,171	54,067	7,454		1,121
	II	15,723	64,880	10,501		1,681
Uttar Pradesh	I	4,923	11,315	11,111	844	8,806
	II	6,892	13,578	13,333	1,210	13,209
West Bengal	I			261		499
	II			522		749
All states	I	154,186	122,621	36,045	15,514	15,706
	II	218,388	153,527	51,626	24,597	23,359

(continued)

Table 41. (concluded)

States	Estimate	Group C: Unirri. Other cereals	Group C: Unirri. pulses	Total Group C	Total all crops
		metric tons of nitrogen			
Andhra Pradesh	I	5,054	7,806	39,695	255,208
	II	7,076	10,928	64,003	330,036
Assam	I	36	472	633	37,784
	II	51	661	887	55,828
Bihar	I	1,105	12,109	21,818	127,162
	II	1,547	16,953	33,369	197,416
Gujarat	I	1,824	3,224	37,143	115,830
	II	2,296	4,512	45,323	160,917
Jammu & Kashmir	I	61	252	3,113	13,418
	II	86	353	4,764	18,476
Kerala	I	86	490	664	66,693
	II	129	735	1,011	81,800
Madhya Pradesh	I	7,835	21,499	44,969	148,838
	II	10,970	30,098	62,956	225,875
Madras	I	2,607	2,298	14,195	169,014
	II	3,649	3,217	22,791	215,003
Maharashtra	I	1,139	13,098	101,189	239,047
	II	1,594	18,338	124,276	319,847
Mysore	I	2,298	7,075	44,210	143,648
	II	3,219	9,906	72,955	196,879
Orissa	I	218	2,611	3,437	111,713
	II	304	3,655	4,960	141,467
Punjab	I	191	9,711	26,313	165,536
	II	267	13,596	36,064	226,678
Rajasthan	I	451	14,655	86,919	143,552
	II	632	23,088	116,505	199,582
Uttar Pradesh	I	4,140	20,757	61,916	336,564
	II	5,796	29,059	83,077	466,868
West Bengal	I	107	3,866	4,733	109,524
	II	149	5,412	6,832	148,859
All states	I	27,152	119,923	491,147	2,183,531
	II	37,765	170,511	679,773	2,985,531

crop patterns and levels of irrigation in explaining the cross-sectional variation in sales among districts within states and also among various states. Analysis of growth patterns in nitrogen sales in different states shows that growth in demand is likely to be at varying rates under different farming conditions. Finally, diffusion of fertilizer use on unirrigated areas under crops such as wheat, jowar, bajara, and cotton is unlikely to be rapid under the assumed varietal and price conditions. This can also be demonstrated by pointing out that low returns from fertilizer use on these crops would be further reduced if farmers further discount these low returns for uncertainty in yields.

As pointed out in chapter 3, in the context of rapid and huge increase in fertilizer use within a short time, the most relevant question is not whether cultivators' demand for fertilizer will grow or not, but will it grow fast enough to attain need-based levels by mid-1970's. Therefore, it is necessary to examine the estimates in table 41 from the viewpoint of rapid growth in demand.

Our analysis of the past fertilizer use pattern showed that rapid growth of fertilizer use, despite widespread improvement in the price situation, was confined to irrigated areas (under almost all crops) and unirrigated areas under a few fertilizer responsive commercial crops. These represent groups A, B, C, and D of table 41. Table 42 which shows the cumulative totals of the estimates of potential for growth in demand for nitrogenous fertilizers for the 7 groups of crops illustrates that the limits of rapid growth in demand are quite low—1.13 million tons on the basis of the expected rates (R-I) and 1.49 million tons on the basis of the expected rates adjusted upward (R-II). The estimate made with adjusted rates is considered the uppermost limit for rapid growth in cultivators' demand for nitrogen under the assumed conditions because the methodology employed here includes both irrigated areas with good water control and those with poor water control. For this reason, even if demand were to grow rapidly in some exceptional cases from groups E, F, and G (e.g., unirrigated rice or cotton grown in the "assured" rainfall areas), it is unlikely that the upper limit of rapid growth in demand for nitrogen would exceed 1.49 million tons under the assumed conditions. The table also indicates the states where accelerating growth in cultivators' demand is likely to be most difficult, despite fairly high overall potential for fertilizer use.

How does the introduction of the new high yielding varieties of rice, wheat, jowar, bajara, and maize modify the above conclusion? Since the new varieties are fertilizer responsive they would increase returns from fertilizer use, and thus raise the limits of rapid growth in effective demand for fertilizers. But quantification of the effect of planting new varieties on growth in demand for fertilizers is difficult. This is due to lack of sufficient information on fertilizer production functions of the new varieties under farm conditions; farmers' fertilizer practices on them; additional cost of

Table 12. **Cumulative totals of the estimates of potential for growth in demand for nitrogen for different groups of crops**

States	Cumulative totals of estimates-I							Cumulative totals of estimates-II						
	Groups: A	A-B	A-C	A-D	A-E	A-F	A-G	Groups: A	A-B	A-C	A-D	A-E	A-F	A-G
	000 metric tons nitrogen													
Andhra Pradesh	63	188	189	193	206	216	255	82	225	227	234	248	266	330
Assam	11	21	22	22	37	37	38	16	29	32	32	55	55	56
Bihar	23	56	58	60	105	105	127	35	90	94	97	167	164	197
Gujarat	17	28	31	34	48	79	116	22	35	40	43	64	116	161
Jammu and Kashmir	1	7	7	7	10	10	13	2	9	9	10	14	14	18
Kerala	32	50	50	50	66	66	67	42	62	62	62	80	81	82
Madhya Pradesh	14	27	27	28	94	104	149	19	41	41	43	147	163	226
Madras	36	130	134	140	147	155	169	47	154	160	170	178	192	215
Maharashtra	47	60	62	71	101	138	239	63	79	81	92	137	196	320
Mysore	39	65	66	68	88	100	144	48	78	78	82	106	124	197
Orissa	10	37	38	39	108	108	112	14	47	49	49	136	137	141
Punjab	25	80	102	118	138	139	166	36	109	138	162	189	191	227
Rajasthan	13	29	34	48	55	57	144	18	42	49	70	79	83	200
Uttar Pradesh	85	159	162	196	273	275	337	130	221	225	275	380	384	467
West Bengal	14	43	51	51	105	105	110	21	57	70	71	142	142	149
All states	430	980	1,033	1,125	1,581	1,693	2,186	595	1,278	1,355	1,492	2,122	2,308	2,986

Groups: A: sugarcane, spices, vegetables, fresh fruits, tobacco.
B: irrigated rice, irrigated wheat.
C: irrigated cotton, jute, irrigated oilseeds.
D: irrigated foodgrains other than rice and wheat.
E: unirrigated rice and unirrigated wheat.
F: unirrigated cotton, unirrigated groundnut.
G: unirrigated foodgrains other than rice and wheat.

labor; seed, insecticides, etc., associated with replacement of varieties; and acreage under the 5 foodgrains on which replacement of the varieties would be technically feasible and economically profitable. If we assume that: (1) the upper limits of replacing the old varieties by the new varieties are set by irrigated areas under these crops, (2) the irrigated areas under the 5 foodgrains used in the calculation (about 48 million acres) represent the amount of areas on which replacement of old varieties would be technically feasible and economically profitable, and that (3) per acre average increment in rates of nitrogen application due to change in varieties would be 40 pounds for wheat and 20 pounds each for rice, jowar, bajara, and maize, then the total additional demand from nitrogen as a result of change in varieties would be about 0.54 million tons. Inclusive of this additional demand for the high yielding varieties of the 5 foodgrains, the lower limit of rapid growth in cultivators' demand for nitrogen would be 1.67 million tons and upper limit would be 2.03 million tons.

These figures are considerably lower than the need-based targets of nitrogenous fertilizer use recommended by various agencies for 1970's—roughly over 3.50 million tons of nitrogen by 1973–74. It appears that there is a real problem on the demand side in the offing. The precise nature of the problem is the slowing down of the rate of growth in cultivators' demand as it approaches about 1.75 to 2 million tons of nitrogen per year.

What kind of public policy is needed to raise these limits of rapid growth in cultivators' demand for fertilizers? In view of the analytical results of this study showing the importance of significant returns to cultivators from fertilizer use in generating rapid growth in their demand for this input, it is obvious that improvement in the marketing channels alone cannot raise these limits substantially. Nor would provision of cheap credit be sufficient to sustain continuous rapid growth beyond the limits indicated as it would not substantially raise the returns from fertilizer use. While continuous reduction in the prices of fertilizers through a stream of cost reducing innovations in the fertilizer industry would fulfill the objective, it might not be feasible in the short run. Similarly, it might not be feasible to maintain high prices of agricultural commodities of the past 2 to 3 years, because of increasing agricultural production and also because of the adverse effects of such prices on growth in the non-agricultural sector.

The solution to the problem of sustaining continuous rapid growth in cultivators' demand for fertilizers lies mainly in accelerating the pace of the following 3 structural changes: (1) continuous improvement in the currently available new varieties of foodgrains crops, (2) development of new fertilizer responsive varieties of crops such as jowar, bajara, cotton, and groundnut commonly grown under unirrigated conditions, and (3) expansion in irrigated acreage. Efforts in these directions will maintain a rapid growth in demand by continuing the process of technological

change underway in the presently irrigated areas and by expanding the areas on which technological change is possible.

Chapter 8. Conclusions

The main objective of this study has been to analyze the past fertilizer use pattern in India in order to identify different sources of growth in effective demand for fertilizer, examine their strength, and then to use this knowledge to study the problem of continuous rapid growth in fertilizer use from the viewpoint of cultivators' demand. The main conclusions of the study are:

(1) A consistent pattern was observed for 39 groups of cultivators from different parts of the country as far as the relative spread of fertilizer use on different crops was concerned. Within each group, some non-foodgrain commercial crops such as sugarcane, tobacco, banana, vegetables, and the two major foodgrains, rice and wheat, were more extensively fertilized than some commercial crops such as cotton and oilseeds, and other foodgrains. The most plausible explanation for this was the small size of returns on low fertilized crops. The small returns on these crops were due to their low production response to fertilizer use, and, in most cases, low prices.

(2) The average rates of fertilizer applied by these cultivators were significantly below the recommended rates. The rates recommended were approximately equal to the optimum rates as determined by some investigators from fertilizer production functions developed from trials data on cultivators' fields and relative prices of fertilizers and crops. The most satisfactory explanation for this feature is found in the small size of marginal returns, beyond 50 to 75 percent of optimum rates, and high discounting of physical response by farmers on the old varieties of crops.

(3) Findings on fertilizer practices of cultivators at different points of time, indicate that the main source of growth in fertilizer use until the mid-1960's was an increase in proportions of fertilized areas under a few crops, such as sugarcane, tobacco, rice, and wheat, rather than rise in the rates of application. It appears that this was also an outcome of the nature of returns from fertilizer use to the cultivators During the reference period of the surveys the price situation became increasingly favorable to the cultivators raising the returns from fertilizer use. This in turn accelerated the diffusion of fertilizer use on unfertilized areas, particularly under crops such as rice, irrigated wheat, sugarcane, tobacco, and potato, on which there were significant returns from its use even under the price conditions of the 1950's. The improvement in the price situation, however, did not significantly raise the marginal returns on these crops be-

cause of the nature of their fertilizer production functions. Consequently, there was no widespread increase in the average rates of application on these crops.

(4) Data on average annual sales of nitrogenous fertilizers in various districts revealed wide cross-sectional differences within different states. Analysis of these data showed that this feature was largely due to variations in crop patterns and levels of irrigation. A high proportion of total sales in each state was concentrated in a few districts in which levels of irrigation were high and where crops such as rice, wheat, sugarcane, potato, and tobacco dominated the crop pattern. Districts with low levels of irrigation, and hence, where these crops were less important, shared a low proportion of total fertilizers sold in the states.

(5) The nitrogenous fertilizer use pattern in various states between 1956–57 and 1964–65 showed persistent cross-sectional differences in the levels and striking variation in patterns of growth over time. Throughout the 9-year period, the level of nitrogen use in some states (e.g., Rajasthan and Madhya Pradesh) remained substantially below that in other states (e.g., Madras and Andhra Pradesh). The growth patterns varied between extremes of little growth in Rajasthan and Madhya Pradesh to dramatic growth in Punjab and Madras. These features of interstate variation were mainly due to underlying differences among states in levels of irrigation, and relative prices of nitrogen and crops. Of the 2 factors, irrigation was more important in determining the cross-sectional variation in levels. However, by itself the high level of irrigation in a state was not sufficient to generate a rapid growth in fertilizer use under the price conditions of the period up to 1960–61, even though a large proportion of irrigated areas were still unfertilized. Once the price situation improved, the growth in fertilizer use was related to levels of irrigation. In states with high levels of irrigation (e.g., Madras, Punjab) there was a remarkable acceleration in the growth of fertilizer use. In states with low levels of irrigation (e.g., Madhya Pradesh, Rajasthan, Maharashtra) a similar improvement in the price situation did not lead to growth at comparable rates.

(6) In the absence of any major change in varieties of crops in terms of responsiveness to fertilizers between the early 1950's and mid-1960's, the findings taken together lead to the conclusion that growth in fertilizer use during this period was mainly due to diffusion of fertilizer use on irrigated areas under most crops and unirrigated areas under a few non-foodgrain fertilizer-responsive commercial crops. Improvement in the price situation after 1960–61 brought a marked acceleration in this process.

(7) The interpretation of growth in fertilizer use until 1964–65 has important implications for further rapid growth in cultivators' demand needed to fulfill the need-based targets of use suggested for 1970's. Findings on the past use pattern reveal the importance of the absolute size of returns in generating effective demand for fertilizer, and the crucial role irrigation and crop pattern play in determining the returns under the

old technological conditions. It is clear that cultivators' demand would continue to grow rapidly as long as all areas on which returns from fertilizer use are high are not fertilized, and the price situation is at least as favorable to cultivators as the average of early to mid-1960's. It appears that this upper limit of rapid growth in cultivators' demand for nitrogenous fertilizer for conditions of irrigation, crop pattern, crop varieties, and relative prices of nitrogen to crops of the early to mid-1960's would be about 1.13 million tons of nitrogen. It would rise to 1.49 million tons if we assume that farmers would generate demand at higher rates than those observed. These 2 estimates would go up as a result of the introduction of new varieties of rice, wheat, jowar, bajara, and maize as it would raise cultivators' returns from fertilizer use by shifting the production functions upwards. For instance, replacement of the old varieties on about 48 million acres of irrigated land under them would raise the 2 estimates to 1.67 and 2.03 million tons of nitrogen. However, these upper limits of rapid growth in cultivators' demand are considerably below the need-based targets of nitrogen use, over 3.5 million tons by 1973–74, recommended by various agencies

(8) On the basis of the kinds of crops and cultivated land expected to be fertilized as the level of nitrogen use in the country approaches about 1.75 to 2 million tons a year, it appears that further continuous rapid growth in effective demand for nitrogenous fertilizers would depend on the pace of these 3 structural changes: (a) continuous improvement in the varieties of foodgrain crops, (b) development of new fertilizer-responsive varieties of major foodgrains suited to unirrigated conditions and of important non-foodgrain commercial crops, and (c) increase in the level of irrigation. The first is needed to continue the process of technological change which is under way in the irrigated areas, while the other two are needed to expand areas in which technological change is possible.

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Other Publications Reporting Research on the Economics of Indian Agriculture

This study is one of several studies of the Indian rural economy carried on in the Department of Agricultural Economics at Cornell University. The following studies have been published in this series:

1. Lele, Uma J., and Mellor, John W., *Estimates of Change and Causes of Change in Foodgrains Production, India, 1949–50 to 1960–61*, Cornell International Agricultural Development Bulletin 2.
2. Mellor, John W., and de Ponteves, Bruno, *Estimates and Projections of Milk Production and Use of Concentrate Feeds: India, 1951–1976*, Cornell International Agricultural Development Bulletin 6.
3. Weaver, Thomas F., *Irrigation Evaluation under Monsoon Rainfall Patterns—A Case Study for Raipur District, Madhya Pradesh, India*, Cornell International Agricultural Development Bulletin 10.
4. Dar, Ashok K., *Domestic Terms of Trade and Economic Development of India, 1952–53 to 1964–65*, Cornell International Agricultural Development Bulletin 12.
5. Nightingale, Ray W., *The Modernization Decision in Indian Urban Fluid Milk Markets*, Cornell International Agricultural Development Bulletin 15.
6. Bawa, Ujagar S., *Agricultural Production and Industrial Capital Formation, India, 1951–52 to 1964–65*, Cornell International Agricultural Development Bulletin 17.

In addition, several studies of Indian rural development have been published in the Occasional Paper Series of the Cornell University–USAID Prices Research Contract, Department of Agricultural Economics, Cornell University.

Much of the research on India performed in the Department of Agricultural Economics is summarized in a policy context in: *Developing Rural India: Plan and Practice*, by John W. Mellor, Thomas F. Weaver, Uma J. Lele, and Sheldon R. Simon, Cornell University Press, Ithaca, New York, 1968.

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