Jour. Ind. Soc. Ag. Statistics
43 (1), 1991 : 81 – 102

ISSUES AND THEMES IN GROWTH OF FERTILIZER USE IN INDIA : AN AGENDA FOR FURTHER RESEARCH AND FUTURE POLICIES *

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I feel deeply honored to give the Panse Memorial Lecture this year. When Dr. Prem Narain suggested it, at first I hesitated because I am not a statistician. Nor did I have the privilege to know Dr. Panse personally. In addition to Dr. Prem Narain's persuasive powers, what made me overcome the hesitation is a personal reason.

Ever since I began to do research on agriculture, I have always has the highest admiration for those who made it possible, in one way or the other, to probe the processes of agricultural development. Among the Third World nations, India has been singularly fortunate in having a galaxy of such persons. Dr. Panse was one amongst them. His contributions as a distinguished researcher and a teacher with brahmanical spirit are known to you all. What stands out for people like me are his common sense and intuitive insights in defining data needs of policies for growth in agriculture; rigorous use of statistics as a discipline in generating and analyzing such data; and a vision backed by relentless efforts in building people, systems and institutions to perform these tasks. This lecture is thus an attempt to pay a tribute to his memory. I am grateful to the Indian Society of Agricultural Statistics for giving me this opportunity, and to Dr. Prem Narain for persuading me to avail of it.

I have chosen "Issues and Themes in Growth of Fertilizer Use in India" as the subject for this lecture. A systematic discussion of this subject seems timely to correctly understand research and policy requirements for future growth of fertilizer use.

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* "Dr. V.G. Panse memorial lecture " delivered on December 4, 1990 during 44th Annual Conference of ISAS held at GAU, Anand.

Until recently, growth of fertilizer use was universally acknowledged as crucial to raise agricultural production of developing countries like India. But now doubts are cast on this position and one increasingly hears about such *alternatives* to fertilizers as organic manures, BNF technology, and alley cropping because of growing concerns for the environment. This has far reaching policy implications. Thus far policies were governed by an unambiguous objective of *facilitating* rapid growth in fertilizer use. Henceforth, they would be expected to *restrict* growth in fertilizer use and promote environmentally benign alternatives. Although the latter viewpoint has not become a dogma as yet in India, it is likely to gain strength over time with growing concerns about environmental degradation in agriculture. Even otherwise it seems timely to discuss research and policy agenda because circumstances governing growth in both agricultural production and fertilizer use have undergone certain fundamental changes over time.

The lecture is divided into four sections. First I shall argue that in countries like India, which need to raise their agricultural production continuously, as yet there is no practical alternative to chemical fertilizers. Thus the pertinent policy issue is not *whether* further rapid growth in fertilizer use is desirable but *how* to sustain it with minimum adverse impact on the environment. To evolve such policies one requires correct understanding of the forces behind growth of fertilizer use in a developing country set-up. And this calls for an appropriate analytical framework. In the second section, I shall briefly outline such a framework. In the third section, this framework is used to demonstrate how the circumstances and a wide variety of factors have governed the past growth of fertilizer use in India. Against this background, the final section draws attention to the changes in the circumstances which will increasingly affect further growth in fertilizer use and thus brings out their implications for future research and policies.

Although my focus is on chemical fertilizers, the essence of many arguments is not confined to this input alone. Thus, this is also an attempt to persuade some of you to take a fresh look at both research and policy agenda for further technology-based agricultural growth. If I succeed in it, I shall feel that the honor you have done to me to deliver this lecture was not totally misplaced.

Continuing Importance of Chemical Fertilizers

To discuss the importance of fertilizer vis a vis other sources of plant nutrients in the context of environmental concerns, it is relevant to distinguish between developed and developing world. This is because major factors behind the environmental degradation in agriculture are fundamentally different in the two worlds. And even more so are the circumstances under which environmental concerns need to be addressed.

In the developed world, environmental degradation in agriculture is commonly attributed to high levels of use of fertilizers and other chemicals.

Furthermore, sustaining *growth* in agricultural production is no more the real issue. Hence, the pertinent question is whether the present high rates of use of fertilizers and other chemicals are really necessary to *maintain* high crop yields per unit of land. Similarly, where there is "excessive" use of these inputs, it seems valid to argue in favor of environmentally benign alternatives and advocate the use of price policy instruments for necessary corrections.

On the other hand, environmental degradation in agriculture of the developing world is far more due to such things as soil erosion and deforestation rather than high levels of use of chemical inputs. Furthermore, major factors behind environmental degradation could be traced to massive incidence of poverty, and the typical interplay of such key factors as arable land, income, population, health and education at low levels of economic development. Viewed thus, alleviation of widespread poverty becomes a necessary condition to arrest environmental degradation. Obviously, fulfillment of this condition depends on employment-oriented economic growth. This, in turn, requires continuous growth in the production of basic wage goods like food and fiber at a rate higher than population growth rate. In land-scarce countries like India this depends on continuous increases in the productivity of land.

Agricultural growth based on continuous increases in per hectare yields requires technological change. Where there are soil fertility constraints, it is impossible to introduce and sustain such technological change on millions of hectares of cultivated land without growing application of plant nutrients. Surely, chemical fertilizers are but one source of plant nutrients. But the historical experiences world over suggests their critical importance in removing soil fertility constraints to land-saving technological change. Even China, with its most meticulous performance in mobilizing organic sources of plant nutrients, has not been an exception.

Undoubtedly, organic manures, the BNF technology and such other alternatives have a definite *complementary* role. But viewing them as substitutes for fertilizers to sustain continuous yield-based growth on millions of hectare seems absurd; even more so because of the persistent scarcity of organic sources of plant nutrients for use in agriculture. In fact, vast empirical evidence on the complementarity between fertilizers and high yielding varieties clearly reveals how critical growth of fertilizer use has been in initiating land- saving technological change not only in India but also in many other countries including China. Without the yield-based growth in food production facilitated by seed-fertilizer technology, human misery and environmental degradation would have been far worse. Thus, the importance of fertilizer in countries like India needs to be viewed in the context of generating and maintaining continuous *growth* in crop yields through technological change. This is because as yet there are no practical cost- effective alternatives to tackle soil fertility constraints on millions of hectares of hungry soils. Similarly, judicious fertilizer use could also become an important tool in combating

soil erosion and deforestation—the two dominant elements in environmental degradation in the developing countries.

This is not to suggest that the danger of adverse environmental effects of high levels of fertilizer use is not real in the developing world. But the available evidence indicates that such effects are commonly due to flawed fertilizer practices like imbalance among different nutrients (especially high use of nitrogenous fertilizers without or very little use of fertilizers containing phosphate and potash), unscientific methods and timing of fertilizer application which reduce their utilization by plants, and deficiencies of micro nutrients/trace elements in soils. Surely, these deficiencies in fertilizer practices must be removed. However, price policy reforms which restrict fertilizer use may not be the answer since growth in the use of even nitrogenous fertilizers is needed to sustain yield-based growth in production on unfertilized land. What is needed are enlarged efforts for location-specific research-based extension as well as improvements in the capabilities of fertilizer supply and distribution systems to make necessary products available to farmers. Such efforts would minimize adverse impact of fertilizer use on the environment. No less importantly they would raise farmers' as well as society's returns through improving the technical efficiency of fertilizer use. And this, in turn, would effectively facilitate removal of fertilizer subsidies.

All these considerations lead me to believe that to argue against growth of fertilizer use in countries like India would be both hasty and short-sighted. The positive contribution of fertilizers in arresting environmental degradation could be greater than its direct negative effects which too could be minimized through appropriate efforts. Thus, the pertinent question is not *whether* further rapid growth in fertilizer use is desirable but *how* to sustain it with minimum adverse impact on the environment. Discussions which ignore this distinction often distract policy makers' attention from many complexities and dilemmas in continuously raising agricultural production through technological change.

Understanding Policy Requirements for Growth in Fertilizer Use

To address fertilizer policy questions meaningfully, we need an appropriate framework to understand forces behind growth of fertilizer use under typical circumstances of developing countries.

Limitations of Conventional Methodologies

Forces behind growth of fertilizer use are usually discussed by estimating statistical relationships between fertilizer consumption and such variables as relative prices of crops and fertilizers, irrigation, and HYVs. The estimated coefficients are then used to draw quantitative conclusions on the impact of changes

in these variables on fertilizer consumption. Policy recommendations are usually based on such conclusions.

In the context of a developing country, this approach is flawed—both to "measure" the impact of changes in explanatory variables on fertilizer use and also to understand forces behind growth in it. There are two main reasons.

First, the conventional framework views growth in fertilizer use as being *causally* driven by growth in *farmers' demand* for fertilizers. This, in turn, implies that supply and distribution systems exert no influence on growth in actual fertilizer use except through fertilizer prices. In most developing countries, where these prices are administratively determined, this means that there are no constraints on the supply side to adjust to changes in farmer's demand in response to administratively determined prices. This is obviously absurd because fertilizer supply and distribution systems are neither fully developed nor their development or working is governed by market mechanism alone.

Second, interpreted even as an outcome of growth in farmers' demand for fertilizers, it is incorrect to say that all *changes* in fertilizer use are only due to *changes* in variables like prices, irrigation and HYVs. Until actual use reaches the potential level as determined by variables which affect profitability of fertilizer use on all individual farms, there is clearly a disequilibrium between variables on two sides of the equation. And such a situation is so very common in developing countries due to deficiencies in various processes which generate fertilizer demand as well as determine aggregate fertilizer supply and its distribution. Under such circumstances, it is just as important to view growth in actual fertilizer consumption as resulting from correction of the disequilibrium as from changes in such demand determining factors as prices, irrigation and HYVs.

Therefore, in the context of developing countries, it is necessary to depart from the conventional neo-classical paradigm of comparative statics. This is not to argue that either farmers' demand or demand-determining factors like prices, irrigation and HYVs are unimportant. That would be preposterous. What is stressed is that a far more complex array of processes governing growth of fertilizer use cannot be ignored because often they are of greater importance. Similarly, price environment and price policies affect growth of fertilizer use in a much more complicated manner than through their impact on farmers' demand for fertilizers alone.

An Alternative Approach

Growth of fertilizer use in developing countries may be viewed as an outcome of four sets of processes and changes in the operating environment which influence their development and interactions.

The four sets of processes are those which (i) influence the agronomic potential for fertilizer use through development of resources like irrigation and also through technological progress which shifts fertilizer response functions upwards, (ii) convert the potential into farmers' *effective* demand for fertilizers through providing them relevant knowledge, credit to buy fertilizer and assured markets for resulting growth in output, (iii) determine growth of aggregate fertilizer supply through imports and domestic production, and (iv) develop fertilizer distribution system and determine its ways of working.

Three major elements in the operating environment which influence development of and interactions among the above processes are prices, institutional set-up, and macro-economic conditions. National objectives and policies pursued to achieve them affect growth of fertilizer use through their direct as well as indirect influence on the four sets of processes and the three major elements of the operating environment.

Viewing growth of fertilizer use in these terms is fundamentally different from interpreting it as being driven by growth in *farmers'* demand for fertilizers as a result of *changes* in factors behind response functions and prices. It has four main advantages in understanding forces driving growth of fertilizer use and devising appropriate policies.

First, in developing countries actual fertilizer use is usually below the *economic* potential as determined by prevailing response function and price environment. But there is also a clear need to raise *agronomic* potential through investment in land-saving technological change. Thus, it is analytically useful to distinguish between actual level and potential of fertilizer use, and also between agronomic and economic potential.

Second, without ignoring the influence of variables like prices, irrigation, and HYVs on farmer's demand for fertilizers, our approach draws attention to the processes on both demand and supply sides which are crucial in generating growth of actual fertilizer use. This is especially important in developing countries. Farmers, though rational, are not omniscient. They need location-specific information to judge which crops could be profitably fertilized and at what rates. Thus, even with favorable changes in variables like prices and HYVs, agricultural research and extension systems are needed. Similarly, sufficient credit is often necessary to convert farmers' perceptions of profitability on fertilizer use into their *effective* demand for this input. But even this is not enough. Actual fertilizer use would still depend on whether adequate fertilizers are available at the right place and time. This depends on the development and working of fertilizer distribution, import and production systems. All these systems seldom develop in a balanced manner. Similarly, there could be imbalances between development of institutions and necessary physical infrastructure.

Third, by viewing growth of fertilizer use in such logical and realistic terms, the paradigm identifies not only all major factors behind growth of fertilizer use but also the ones which are most constraining. Thus it facilitates evaluation of the entire gamut of government policies. This is crucial because fertilizer use begins with some farmers adopting it on a crop or two at modest rates. It grows over time as a result of increasing number of farmers adopting it, the use spreading to more crops, and upward movement in rates of application. The dominant factors behind each of these determinants of growth in total fertilizer use are seldom identical. This means that the most binding constraints on the pace of growth are likely to be different at different stages in total fertilizer use. In a big country like India, they are also likely to be different in different regions at given point in time. This highlights the importance of correctly identify the most binding constraints and address policies to remove them. Policies which rely excessively on one or two mechanisms would most likely lead to prolonged plateaus in fertilizer use.

Finally, a distinction between price and non-price policies is also crucial. Price environment which affects fertilizer use is eventually an outcome of economy-wide forces of *effective* demand for and supply of agricultural output. The degrees of freedom to make the price environment favorable for growth in fertilizer use are never infinite in any economy. In a developing country, they are far more limited because of low income of the masses which restrict demand for agricultural output, scarcity of budgetary resources, and their alternative uses in a wide variety of development tasks including those which affect growth in fertilizer use.

An Interpretation of Forces behind Growth of Fertilizer Use

When the above framework is used to review the evidence on the past growth of fertilizer use in India, four unmistakable conclusions emerge.

First, in generating impressive growth of fertilizer use, policies pursued to achieve the national objective of self-sufficiency in food production have exerted great influence on both demand and supply sides of fertilizers.

Second, between price and non-price factors, the latter have been more important in determining the pace and pattern (cropwise as well as geographical) of growth in fertilizer use.

Third, growth of fertilizer use could have been faster, even under the prevailing environment with respect to responses of crops to fertilizer application and prices, but for deficiencies in the processes which converted the potential into actual use.

Fourth, some of these deficiencies are also responsible for making growth in fertilizer use increasingly dependent on price variables.

I shall now briefly elaborate these conclusions. By late 1980s, India had raised its fertilizer use to over 60 kgs per hectare of gross cropped area. Although this is lower than in many other developing countries, one cannot deny that the growth has been quite impressive. Because of its vast size, the national average for India is misleading. The correct comparison would be between levels attained in some of the states with those in developing countries of comparable size. There are other reasons too. The awareness of fertilizer among Indian farmers is nearly universal; "adoption" has also reached a very high level (perhaps as high as 80 percent); the use was never, not even in the early stages, confined to large and medium size farms, or to only owner cultivators. Nor was the use confined to high value crops, or to irrigated land, or to HYVs. Equally important,trends of fertilizer use were resilient enough to maintain growth despite periodic shocks of such events as oil crises and droughts. And all this has happened under a price environment which was not any more favorable to Indian farmers than to farmers elsewhere. In fact, the relative prices of fertilizers to crops have more often than not been higher for farmers in India than in many other countries.

In generating such growth of fertilizer use, policies pursued to achieve the national objective of self-sufficiency in food production have played a key role-on both demand and supply sides. Surely, iff these policies, fertilizer was just one element and until 1960s it was not even very important. But the policies had the most far-reaching impact in developing the "processes" behind growth of fertilizer use. For instance, investment in irrigation, development of agricultural research system, and policies pursued to propagate HYVs substantially raised the potential of fertilizer use. They also facilitated the conversion of the potential into farmers' demand for fertilizers by making the use more profitable. In this task, it would be mistake to downplay the role of a nationwide extension system, cooperatives and commercial banks in facilitating rapid adoption of fertilizer by millions of farmers. In meeting the resulting growth in fertilizer demand, policies pursued to establish and expand multi-agency fertilizer distribution system, enlarge availability of fertilizers through investment in domestic production, and control regional allocation of supplies have played their own role. Thus, forces behind the past growth in fertilizer consumption cannot be correctly deciphered without taking into account the *whole* set of policies pursued to combat the *food problem*, even though some were not directly related to fertilizer.

Between price and non-price factors, the latter have been more important. This is clear from several features of the pace and pattern of growth in fertilizer use. Bulk of the growth has occurred after the introduction of HYVs—a non-price factor. Diffusion of fertilizer use on the *same* crops has been faster under irrigated than under unirrigated conditions, and also on HYVs than on traditional varieties. Fertilizer use on oilseeds and pulses began in the 1950s but, despite better and continuously improving price environment, the growth has much been slower than on crops like rice and wheat. Similarly, even though fertilizer prices have been

uniform throughout the country, growth of fertilizer use has varied widely among states, districts, and blocks. All this reveals the importance of such non-price factors as irrigation, cropping pattern, spread of HYVs, and development of fertilizer distribution and agricultural credit systems. The impact of increased flow of quality seeds on growth of fertilizer use during 1980s reveals that relevant non-price factors and policies were not confined to fertilizer and irrigation domains.

Yet another point to note is the *way* in which fertilizer supply side has affected growth of fertilizer consumption: Changes in aggregate fertilizer supply have affected pace of growth not so much through impact on farmgate prices of fertilizers but through their constraining or facilitating pressures on promotional efforts, expansion of fertilizer distribution system, and availability of credit.

Though quite impressive, a critical review of the past experience also suggests that the growth of fertilizer use could have been faster. That there was sufficient scope for this is indicated by the persistent gap between actual use and economic potential and certain features of the past growth. Rapid adoption of fertilizer by farmers, early beginnings of use on many crops under even unirrigated conditions, and slow but continuous growth of use on traditional varieties suggest that farmers were willing to tap the unexploited viable potential of fertilizer use. Therefore, it is just as pertinent to ask why the growth was not faster as to emphasize the importance of factors like irrigation and HYVs in the *observed* pace and pattern of growth.

The answer lies in certain weaknesses of the processes which converted the viable fertilizer potential into actual use. Among these the following stand out :

- deficiencies in location-specific research and extension to improve efficiency of fertilizer use,
- inadequate efforts to convince farmers about returns on fertilizer use under unirrigated conditions,
- irrigation and HYV bias in the supply of production credit to farmers,
- slow geographical expansion of and even more importantly various inefficiencies in the workings of fertilizer distribution systems,
- repeated shortfalls in planned domestic fertilizer production,
- lack of appreciation of the role fertilizer imports can play in augmenting total supply to generate *sustained* pressures on various systems for rapid conversion of the unexploited fertilizer potential into actual use.

Wherever the systems which generate growth in actual fertilizer were relatively better developed, growth has been faster despite not-so-favorable environment with respect to response functions. The experience of states like Gujarat and Karnataka and many districts in other dryland states clearly reveals this. Similarly, whenever macro policy decisions addressed the then most binding constraint on growth of fertilizer use, there was accelerated growth in consumption.

All this is not meant to argue that price environment, growth in irrigation and spread of HYVs did not matter. That would be absurd. What is stressed is that many other factors were sometimes even more important in constraining the growth which was potentially possible. To ignore this line of reasoning in understanding the dynamics of growth in fertilizer use in a developing country is to bypass the most valuable lesson which emerges from the past experience. Of course, to draw this lesson, one needs an open mind, common sense and an appropriate framework to examine the experience.

What was, then, the role of price policies in past growth of fertilizer use? It is important to address this question for three major reasons: First, the budgetary subsidies on food and fertilizers have mounted rapidly. Second, the price and subsidy policies continue to occupy central place in discussing fertilizer-related issues. And third, circumstances under which these policies operate seem to have undergone fundamental changes over time.

In the last two decades, the most important impact of price policy for *crops* on growth of fertilizer use has been through accelerating the spread of HYVs and encouraging private investment in irrigation. In the absence of public procurement operations, sudden enlargement of marketable surplus might have lowered the prices of wheat, rice, etc., and made them unstable over time. This,in turn, would have slowed down diffusion of HYVs and growth of irrigation with consequent adverse impact on growth of fertilizer use. But such impact of agricultural price policy on growth of fertilizer use has considerably diminished over time. Currently available HYVs are widely diffused in agro- climatic environments where they are suitable. Similarly, further development of irrigation potential through private investment is a more complex task than in the past for a variety of reasons.

As for the fertilizer price policy, the basic objective has been to keep the farmgate prices at "reasonable" levels. This was to be achieved by (i) insulating the farmgate prices from fluctuations in the world market, (ii) equalizing prices of supplies based on imports and domestic production, and the latter from plants with widely different cost of production, (iii) keeping uniformity in prices all over country.

Until the first Oil Crisis in the early 1970s, budgetary statistics reveal surplus in all but a few years which indicated that there was no major fertilizer subsidy. This distinguished India from many other developing countries where fertilizer was subsidized to accelerate its adoption by farmers. But the situation has changed

since 1973/74 with fertilizer subsidies in the 1989/90 crossing Rs. 4,500 crores. Initially, subsidies were necessitated by the dramatic impact of the oil crisis on the cost of imported fertilizers. After 1975/76, however, both imported and domestic fertilizers were subsidized. The subsidies on domestic fertilizer have risen rapidly since the introduction of the Retention Price Scheme in 1977. This scheme originated from the enhanced cost of fertilizer production after the oil crisis, and the policy to meet growing fertilizer requirements through encouraging investment in demestic fertilizer industry. The average cost of supplying domestic fertilizer has been higher than prices fixed for farmers. The difference between the two has also grown over time due to (i) high investment cost of new fertilizer factories, (ii) escalation in the administered prices of virtually everything which goes into fertilizer production, and (iii) increased cost of fertilizer distribution. All this plus about five-fold growth in fertilizer production since the mid- 1970s has resulted into growth of subsidies on domestic fertilizers. The subsidy on imported fertilizers during the mid- 1970s was mainly due to the high cost of fertilizers in the world market. In recent years, it has been mainly due to relatively much higher cost of distributing imported as compared to domestic fertilizers.

It is thus clear that fertilizer price policy has been deeply embedded in the fertilizer supply and distribution policies. It is also clear that bulk of the fertilizer subsidies originate from domestic production-based fertilizer supply policies and administered prices of feedstocks, fuel etc. In as much as these prices have generated profits in the other public sector enterprises, the volume of subsidies on fertilizers as reported in budgetary statistics is misleading.

Thus, price policy for both crops and fertilizers have been governed by far more complex considerations than keeping real price of fertilizer low to sustain growth of fertilizer use. As mentioned earlier, not with standing food and fertilizer subsidies, relative prices of fertilizers to crops have always been higher for farmers in India than in many other countries. This perspective is important both to appreciate the role of price policies in the past growth of fertilizer use, and also to understand their limitations in the future.

Changed Circumstances: Implications for Research and Policies

My main contention in this section is that circumstances affecting further growth of fertilizer use have changed. This appears to be the case both with respect to the national objectives which influence policies and also ground level realities which affect growth in fertilizer use.

Effective Demand Constraints

Perhaps, the single most important difference in the macro environment is that the objective of self-sufficiency in production is nearly achieved to meet

effective demand for wheat, rice, sugarcane and long-staple cotton. These four crops account for more than 70 percent of the past growth in fertilizer use. Only when viewed in terms of *needs* of the millions of poor people, self-sufficiency is still a long way off. That growth in production of these crops face demand constraints is obvious from the increasing importance of government procurement to support prices farmers receive. Further *rapid* growth in fertilizer use on these crops cannot be taken for granted because of budgetary burden of procurement operations as well as fertilizer and other input subsidies for them. This is, perhaps, the most important circumstantial difference from the past when burden on fiscal resources to raise the production of these crops was low and could be justified on the grounds of replacing their imports.

Permanent resolution of the demand constraint for these crops lies in rapid elimination of poverty through accelerated growth of employment. Since agriculture is unable to absorb all people in need of employment even today, achievement of this national objective requires employment- oriented economic growth in the secondary and tertiary sectors. Both theory and experiences world over point out that such economic development requires cost-reducing growth in the production of basic wage goods (i.e., food and fiber).

The per hectare yields of the four crops which have so far dominated growth of fertilizer use are much higher today than what they were two decades back. But the pertinent question is whether the unit cost of production of these crops has come down in real terms. It is difficult to answer this question for want of sufficient analytical research addressing this issue. However, available data reveals that the use of market purchased inputs like fertilizer on these crops has grown at a much higher rate than the growth of their yields. This means that capital cost of yield-based growth in these crops has gone up over time. This is not surprising because in technology driven yield-based agricultural growth, capital usually substitutes for land. But that does not mean that it has no implications for *further* growth in the use of such capital inputs as fertilizers on these crops, especially when there are genuine demand constraints on further growth in their output.

To overcome the effective demand constraints for these crops, growth in total factor productivity rather than just per hectare yields would have to become increasingly important. Even if careful research were to reveal that total factor productivity has been rising in these crops, there would still be imperatives to lower capital cost in further growth of production of these crops. And there is ample scope in this direction. This is pointed out by growing evidence of technical and economic inefficiency in the use of such inputs as fertilizers and pesticides. The use levels of these inputs on bulk of areas under the four crops have reached fairly high levels. In as much as technical inefficiency at high levels of use of these inputs have an adverse impact on the environment, the urgency to address this question is obvious. In short, the argument that there is still scope for raising per hectare yields through increasing rates of fertilizer use can no more be expected to govern growth of

fertilizer use on these crops. Both economic compulsions and environmental concerns must increasingly influence research and policies for higher efficiency in the use of capital inputs in the case of these crops.

Of course, anti-poverty programs (including subsidized distribution of basic necessities) and subsidies on exports of surplus production may alleviate the demand constraints. Similarly, farmers' capital cost of production could be kept low through fertilizer and other input subsidies. But such policies cannot be sustained for ever in developing countries like India. Much less so when the budgetary costs of such policies have mounted rapidly and there is a pressing need for fiscal resources in other development priorities.

Nature of Tasks for Further Growth in Fertilizer Use

I shall discuss this separately for two broad segments of the agricultural sector—one which has dominated the past growth of fertilizer use and the other which has remained outside the mainstream of efforts so far.

As stated earlier, past growth was dominated by wheat, rice, sugarcane and long-staple cotton. The task of raising fertilizer use on these crops was facilitated by spread of fertilizer responsive varieties in regions better endowed with irrigation and rainfall. Many of these regions also have relatively better developed institutions and physical infrastructure.

Of course, there is still scope for further growth in fertilizer use on the above crops. But the nature of the untapped potential for use at higher levels is quite different. Consequently, efforts needed to tap it are far more complex and sophisticated than in the past. This can be illustrated with results emerging from a study undertaken in IFPRI's research program in India in collaboration with IASRI.

These results, based on an analysis of five years data, pertain to response of rice and wheat to fertilizer use on *cultivators' fields* in Punjab. They show that when nitrogen alone is used, marginal physical product declines very sharply-in most cases it drops below the ratio of nitrogen to rice (or wheat) prices around 100-120 kgs per hectare. But when P_2O_5 and K_2O are used in addition to N, and zinc is also used wherever necessary, the marginal product remains above the ratio of fertilizer to wheat and paddy prices even at such high rates as 250 to 300 kgs of NPK per hectare. Even in Punjab where per hectare rate of fertilizer use has reached 150 kgs of nutrients, 37 percent of paddy fields were not receiving phosphates as late as 1986/87. Fields not receiving potash were as high as 95 percent. Zinc too was used on only about 10 percent of paddy fields. Thus, even in Punjab there is unexploited potential of raising fertilizer use. But the task of converting this potential into effective fertilizer market is fundamentally different than that of generating demand for nitrogenous fertilizers in an environment of rapid diffusion of HYVs, growth of tubewells and expansion of area under rice. A different

orientation and higher degree of sophistication in the workings of support systems is required as illustrated below.

Even in the high consumption regions, farmers' fertilizer practices are not based on testing of soils on their *own* fields. Although India has more than 400 soil testing facilities, so far they have been used mainly to analyze thousands of soil samples to classify districts into high, medium and low soil fertility groups, and then to formulate general fertilizer recommendations for different soil fertility situations. Testing soil to advise individual farmers on farm-specific fertilizer application schedules has not developed as yet. Obviously to promote *efficient* use of fertilizers, especially in regions where rates of nitrogen application have reached fairly high levels, a basic change is needed in the approach. This involves not only farmers' education in using the soil testing facilities but also a change in the *modus operandi* of soil testing laboratories. It also requires ready availability of different fertilizers, micro-nutrients and soil amendments in the distribution systems. And all these must be accomplished in a coordinated manner.

The above reasoning would also apply to other capital inputs since at high rates of application productivity of these inputs critically depends on each other. Promoting technically judicious, environmentally benign and economically efficient use of pesticides requires even higher degree of sophistication and coordination in the ground level support activities of location specific research, extension and distribution of different chemicals. In the case of farm machinery also, farmers' education in safe and efficient use of these machines as well as location - specific R&D effort to develop suitable products are urgently needed. On the other hand, so far these efforts have focused mainly in large-scale production of standardized equipments and supply of credit to farmers to purchase them. To lower capital cost of technology driven yield-based agricultural growth, all this must change even though the task is more complex and demanding than what was needed in the past.

To sustain further rapid growth of fertilizer use, unirrigated segment of the agricultural sector needs to get more attention than in the past. Lack of enthusiasm and sustained efforts to raise fertilizer use on unirrigated areas are mainly due to lacuna in our factual and analytical knowledge on fertilizer use on these areas and the dominance of irrigated areas in the *volume* of fertilizers sold.

A scrutiny of findings available from a large scale nationwide sample survey carried out by the NCAER indicates that fertilizer use had spread to about 62 percent of gross cultivated area (GCA) by the late 1980s. Since by then no more than 33 percent of GCA was irrigated, clearly at least 29 out of 62 percentage points of the fertilized area was *unirrigated.* This, in turn, means that as high as 47 percent of fertilized GCA was under unirrigated conditions. It also means that 43 percent of total unirrigated area was receiving fertilizers. The scrutiny also reveals that the spread of fertilizer use on unirrigated area was *not* confined to high or medium

rainfall regions. In fact, the spread on unirrigated areas was lower in the regions receiving more than 1150 mms rainfall than those receiving less than 750 mms.

Similarly, there is a widespread presumption that the presence of irrigation acts as a catalyst for the spread of fertilizer use on unirrigated areas. Research underway at IFPRI in collaboration with ICRISAT casts doubts on this presumption. Findings of this research, based on nine years' data from the same sample of farmers in six villages of Andhra Pradesh and Maharashtra, reveal that farmers without *any* irrigation were very active in adopting fertilizer. More significantly still, the spread of fertilizer use on their unirrigated land was just as high as on unirrigated areas of those who had irrigation even though the latter had adopted fertilizer much earlier. This research also points at the urgent need to recognize soil fertility constraints in unirrigated agriculture and the role of fertilizers in overcoming them because of persistent scarcity of organic manures. It also reveals that a significant proportion of farmers do not use fertilizer continuously after they adopt it, and that the discontinuation of use is usually temporary rather than permanent. Such periodic discontinuation of fertilizer use by significant proportion of farmers is also revealed by yet another IFPRI study in collaboration with IARI based on a large sample spread over a dozen states.

The widespread acceptance of fertilizer use by farmers by late 1980s, even by small farmers without irrigation, implies that "adoption" is no more a *real* substantive issue, in either research or policy agenda. And yet so much loose talk and efforts (both in research and policies) aim in that direction. On the other hand, our analytical understanding of why farmers periodically discontinue fertilizer use is woefully lacking. Careful research is needed to figure out the relative importance of such varied factors as weather induced changes in cropping pattern,depressed price expectations, deficiency in fertilizer distribution systems which adversely affect timely availability of fertilizers, liquidity constraints, and faulty beliefs about residual effects of fertilizers. Without research in this direction, we cannot expect meaningful policies and programs to address year to year fluctuations in further growth of fertilizer use-fluctuations which have important implications for not only a sound development of fertilizer supply and distribution systems but also sharp year to year fluctuations in growth rates of agricultural output and farmers' income.

The need for enhanced research on the neglected segments of agriculture cannot be over-emphasized because conditions governing growth of fertilizer and other inputs' use in these segments are very different. For instance, in the case of oilseeds and pulses, where domestic production is short of effective demand, no dramatic technological breakthroughs have occurred as yet. Nor the price incentives have been effective in generating yield-based growth in the production of these crops. Similarly, in difficult agro-climatic environments of central, western and eastern India, neither large-scale technological breakthroughs easy nor farmers can be expected to take as much risk as in irrigated areas. In most of these segments, institutions and physical infrastructures are also not well developed.

Vulnerability of Support Systems to Government Policies

The above discussion highlights the nature of challenges in further growth of fertilizer and modern inputs' use. The success in meeting these challenges of course depends on the ingenuity and drive of millions of farmers. But, as the preceding discussion shows, it also depends, perhaps even more critically, on certain basic changes in a variety of off-farm activities of the support systems.

The commercial and non-commercial support systems have played a key role in the past to raise modern inputs' use, not with standing the fact that their task was relatively easy and considerably facilitated by government policies to generate rapid yield-based growth in agriculture. Over time, however, most of these systems seem to have become excessively dependent on *specific* government policies for their survival and growth. For instance, the domestic fertilizer industry has become highly dependent on the Fertilizer Retention Price Scheme. Similarly, the tractor industry is vulnerable to the supply of institutional credit to agriculture; farm implements industry to various subsidies; and the private sector seed industry, which has barely come into existence in the last decade or so, to just one or two elements in the government policies.

With changing circumstances, some of these policies are bound to change. Thus, there is a cause to feel concerned, especially because the support systems not only need to expand geographically to cover more difficult segments of agriculture but also perform more complex and sophisticated tasks in the future.

Despite impressive growth in the domestic input industries, it would be hasty to presume that they have reached a stage of maturity to withstand sudden extreme changes in the policies which affect them vitally. It is important to note this because, as the past experience in India and elsewhere clearly reveals, supply side institutions and processes are no less important than farmers' demand for inputs. This implies need for sharply focused research on support systems, and an open mind and extreme prudence in the resolution of dilemmas in the policies which affect input industries.

Concluding Observations

The above discussion leads to seven major conclusions.

First, despite concerns for the environment, the real question concerning chemical fertilizers in countries like India is not *whether* to raise its use; it is *how* to raise fertilizer use with minimum adverse impact on the environment. This is because of the need for continuous growth in agricultural production. In land scarce countries, agricultural growth requires continuous increases in per hectare yields through technological change. To sustain yield-increasing technological change without growing application of fertilizers is impossible because as yet there are no

cost-effective alternatives which are practical on millions of hectares with soil fertility constraints. Furthermore, available evidence indicates that the adverse effects of fertilizer on environment in developing countries like India is not due to its "excessive" use but flawed fertilizer practices. Thus, as far as fertilizer is concerned, vigorous efforts are needed to remove deficiencies in fertilizer practices. Such efforts will not only safeguard the environment but also raise technical and economic efficiency in the use of a critical but costly input.

Second, to address fertilizer policy questions meaningfully, one needs to depart from stereo-typed methodologies based on the neo- classical economic theory of comparative statics. What is needed is a paradigm which views growth of fertilizer use as an outcome of the inter-play of all essential elements under typical circumstances of developing countries. Such paradigms, even if heuristic, would be far more insightful than precise quantification of dubious relationships.

Third, examination of India's experience in such a framework reveals that many factors other than irrigation, HYVs and prices were behind that pace and pattern of growth in fertilizer use. It also becomes clear that government policies to achieve the national objective of self-sufficiency in food production have exerted great influence on both demand and supply sides of fertilizers.

Fourth, further rapid growth in fertilizer use will be more difficult than in the past despite widespread adoption of fertilizer by farmers and substantial development of the support systems. This is because of changes in certain circumstances at both macro and micro levels. Among these, three seem particularly important: (i) constraints on rapid growth in effective demand for crops like wheat, rice, sugarcane and cotton which have dominated the past growth in fertilizer use, (ii) unsustainable budgetary burden of certain policies adopted to generate yield- based growth in the output of these crops, and (iii) rates of fertilizer application on these crops having reached fairly high levels, especially under irrigated conditions.

Fifth, the above changes in circumstances imply that further rapid growth in fertilizer use critically depends on (i) improvements in the technical and economic efficiency of use and (ii) broadening technology-based growth in agriculture, especially to on unirrigated areas. Growth of fertilizer use will be crucial to accelerate yield-increasing technological change on unirrigated land because of widespread soil fertility constraints and chronic scarcity of organic manures.

Sixth, available evidence clearly reveals ample scope to improve efficiency of fertilizer use and also to accelerate growth of fertilizer use on unirrigated areas. However, a new orientation is needed in both role of the support systems and government policies for vigorous efforts in these directions.

Seventh, this orientation should be based on an understanding and emphatic recognition of four guiding principles:

- Growth in agricultural production is not an end in itself; it is one of the important means to achieve certain basic national objectives like elimination of poverty, employment- oriented economic growth, and balanced regional development.

- Continuous growth in agricultural production requires technological change. And this, in turn, implies growth in the use of modern inputs (including fertilizers) which embody or facilitate technical change in production.

- The progress of technological change in agriculture, however, cannot be correctly judged from growth in the use of modern inputs. Even growth in per hectare yields, by itself, is not a sound indicator. In the final analysis, success of technical change must be judged in terms of its impact on lowering the unit cost of production of different crops. This is especially so if it is to contribute effectively to the elimination of hunger and poverty through facilitating employment-oriented economic growth.

- Cost-reducing agricultural growth based on technical change depends not only on continuous up-gradation technologies but also on continuous improvements in the efficiency of modern inputs' use. The latter, in turn, depends not only on farmers but even more so on support systems. Policy environment contributes to this through its effects on both farming practices as well as development and working of the support systems.

I would like to conclude by saying that time has come to think of research and policy agenda for growth in the use of modern inputs like fertilizers in such as these terms. Of course, no one, least of all me, has a right to dictate the research agenda or what framework to use in analyzing the empirical evidence. And, there is scarcely a statement which I have made that you may not wish to disregard. My purpose has been to share my understanding of *what* the empirical evidence tells me, and *how* and *why* I have reached this understanding. You are entirely within your rights to use some other analytical framework and reach different conclusions. But you may also find it useful to note that the framework I have used raises certain questions which sooner or later will have to be addressed.

Once again, I am grateful to you for giving me this opportunity.

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