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PRODUCTION AND POVERTY IN INDIAN AGRICULTURE

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The views expressed here are the authors' own and
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Chapter 1. Overview of the Issues and Findings

Introduction

The development of Indian agriculture is governed by complex interactions among such factors as population growth, land and water resources, agricultural technology, markets, and public policies. In this study we have attempted to understand the effects of these forces on production and poverty in Indian agriculture in the past and assess the prospects for the future. While limitations of data on certain important variables have prevented a complete analysis, and more research is needed in these aspects of the study, we do believe that the analysis has yielded a reasonably accurate picture that is not likely to change substantially with more detailed studies.

As the mainly statistical analysis of the first phase of this study progressed and we struggled to develop a synthetic picture of the whole from the various and sometimes paradoxical parts, we found ourselves continually drawn back to the theories of that great economist and humanitarian, Thomas Robert Malthus. Indeed, as we progressed we increasingly felt that the fundamental terms of reference for this study were written by Malthus nearly two hundred years ago.

Malthus' reputation has suffered more from the excesses of his disciples than from the often misplaced attacks of his critics. Since his theory plays a substantial background role in this analysis, we may say a few words in his defense here.

Just as Marx declared, "I am not Marxist", Malthus could have said, "I am not Neo-Malthusian." Neither are we. Malthus did not believe, as Neo-Malthusians do, that there are ultimate limits to the productive capacity of agriculture. He said that food production "...may increase forever, and be greater than any assignable limit" (Malthus, 1798). Malthus thought in terms of <u>dynamics</u>--not, as his more simple disciples do, in terms of statics. In true Malthusian theory it is not the limit, which recedes forever into the future, that counts, but, rather, the relative rates of change of variables in dynamic equilibrium. It is not the end, but the <u>race</u>, that determines the outcome.

There are two important races in Malthusian theory, with population growth a major competitor in each. The "First Malthusian Race", as we call it, is the familiar one between the growth of population and food production. The "Second Malthusian Race" is less commonly known, but is just as important. This is the race between the growth of labor supply and labor demand. Both races are of fundamental importance to Malthus' theory and, we believe, to India. The status of each of these races in India is briefly reviewed below.

Review of the Two Malthusian Races in India

Perhaps the best introduction to the First Malthusian Race in India is through the historical perspective provided in Figure 1a (see also Appendix A). This graph shows population growth in

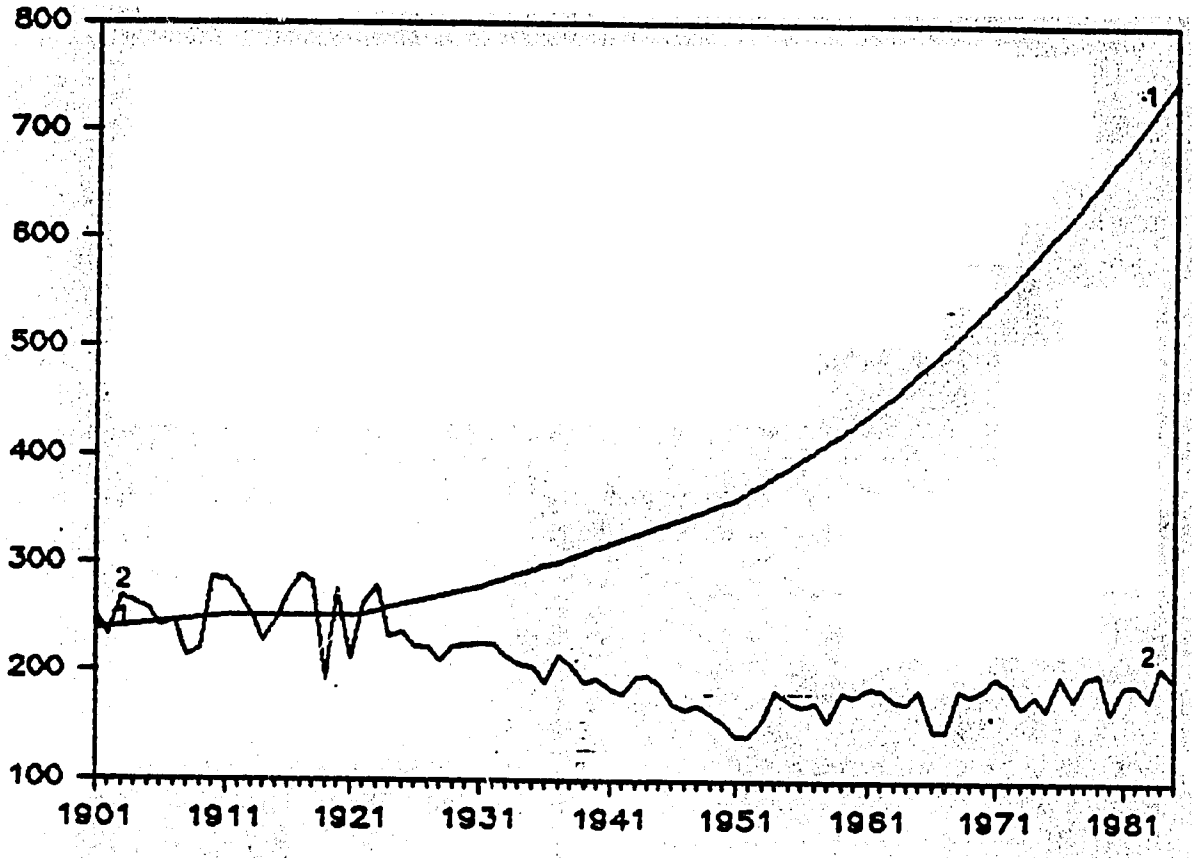

Figure 1a. Population and Per Capita Foodgrain Production in India 1901-1985

1. Population in millions
2. Gross per capita foodgrain production in kg pa

relation to gross per capita production of foodgrain (cereals and pulses, which provide over 80% of the energy intake of the Indian population) through this century. It must surely be a sobering experience for technological enthusiasts, as it was to us, to see that per capita production of foodgrain in the second decade of this century, in a pre-technological era of agriculture, was at least 25% more than it is today, in the full flush of the Green Revolution.

As this graph implies, the degree and severity of rural poverty in India has undoubtedly worsened from its state in the early part of this century. Also, the use of per capita foodgrain production as the only poverty indicator undoubtedly <u>understates</u> the real extent of the decline in the condition of the rural poor. It does not reflect the even more precipitous decreases in real income due to lost products from pasture and forest lands that were in abundance in the early period but which are now largely gone. Nor can there be any doubt about the direct cause of increased poverty in India: population, in the denominator, grew faster than production, in the numerator. While this may be an arithmetically obvious fact, it is the kind of fact too often ignored by technological enthusiasts.

As Figure 1a shows, per capita foodgrain production plunged in the post-Independence (1947) period and then gradually began to improve. From the 1950s to the present, foodgrain production has grown, so far as can be statistically determined, at a remarkably constant rate of 2.7% pa. Population, on the other hand, has grown at a slower but increasing rate: rising from 2.1% pa in the 1950s to 2.3% pa in the 1970s. Thus gross per capita foodgrain production has been increasing, but at a decreasing rate, from about 170 kg in the early 1950s to about 195 kg in the early 1980s (Appendix A, Table A1). In terms of average per capita production, India is now producing sufficient foodgrain to satisfy the recommended daily allowances (RDAs) of the population.

However, another rather remarkable constant in Indian agriculture is that the percentage of the Indian population below the poverty line has remained constant, as a trend, at 40% over the past three decades. Thus the trend rate of growth of poverty has been equal to the rate of growth of population. It is odd that during three decades of substantial growth in total agricultural production, India has not been able to reduce the degree and severity of poverty--even though 80% of the poor live in rural areas and principally obtain their living, such as it is, from agricultural production. This is a consequence of the Second Malthusian Race, discussed below.

The relationship between production and poverty in Indian agriculture has resulted in the peculiar situation that India now has a substantial foodgrain <u>surplus</u> problem on its hands. The GOI has 15 million tonnes (MT) of foodgrain in stocks, over and above reserve requirements, which it has not been able to sell either on domestic or international markets, or even adequately to store. The cause of this surplus problem is clear, even if the solution is not. The 40% of the population who need and want this food are too poor to purchase it: the problem is deficient <u>effective</u> demand. In fact, we have estimated (Appendix C) that

if the people in India who are below the poverty line were just brought up to the poverty line, they would purchase 16 MT of foodgrain, almost precisely the amount of the surplus.

Such are the results, to date, of the two Malthusian races. In the next few pages we briefly describe some of the major factors behind these races and our analysis of their likely future outcomes.

Sources of Growth in Foodgrain Production

It is important to understand that agricultural production in India is highly dependent on the development of land and water resources. This is not, of course, to deny the important role played by biochemical technology in the form of high-yielding varieties (HYVs), chemical fertilizers, pesticides, and the necessary know-how. However, the Green Revolution in India is not just biochemical technology; it is mainly the application of this technology to irrigated land. Except in rare and limited areas with naturally favorable agro-climatic conditions, there has been no Green Revolution in India on unirrigated land.

This is an important fact because irrigated land, unlike biochemical technology, or even other land, is far from being a limitless resource. Irrigation development is subject to diminishing returns as it spreads farther from sources of water and over progressively rougher terrain. The basic technology of surface irrigation has not changed substantially in three thousand years and is unlikely to do so in the future. Other irrigation technologies, like sprinkler and drip irrigation, can increase the efficiency of water use but only under special conditions and often at substantially increased cost. India is rapidly approaching the physical and economic limits of irrigation development. What will happen to the Green Revolution then? That is the question upon which much of the future of agricultural production in India depends.

Some of the relationships between foodgrain production and basic factors of production are illustrated in Figure 1b. This graph shows foodgrain production and yield in India in relation to total gross cropped area in foodgrains (i.e., including cropping intensity), irrigation, and use of chemical fertilizers (NPK). Gross foodgrain area grew very slowly through the 1950s and 1960s and (as shown by the trend line, T) reached virtually a plateau since 1973.* Thus nearly all of the increase in food-

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*The index of area under all crops shows a similar pattern. It should be noted that, while India has an index of all crops which shows production increasing at a rate of 2.9% over the past three decades, we have reservations about the weights and, therefore, the results of this index. This report concentrates on foodgrain production, which represents about 70% of total agricultural production in India.

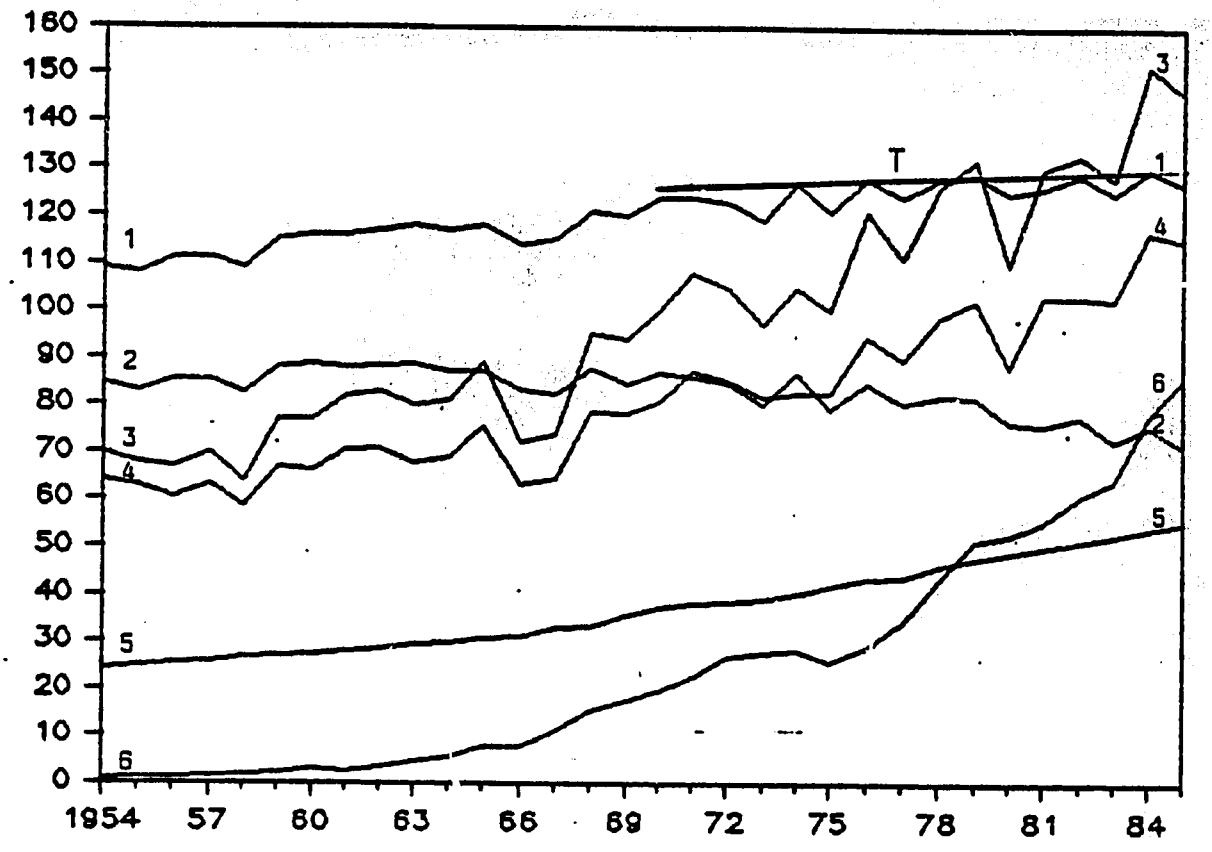


Figure 1b. Foodgrain Production and Factors

1. Gross foodgrain area (MH)
2. Dry foodgrain area (MH)
3. Total foodgrain production (MT)
4. Foodgrain yield (10 kg)
5. Gross irrigated area (MH)
6. NPK (100.000 T)

grain production since that time has been from increased yield. Increased yield has stemmed from the accelerated rate of irrigation development combined with the steep rise in NPK consumption and application of HYVs since the great drought of 1966-1967. It is notable that dryland has been decreasing since the late 1950s as it has been converted to irrigated land. All of the increase in total foodgrain area in the early period was from irrigation development.

The relationships between cropped area, yield, and NPK illustrated in Figure 1a are often used by technological enthusiasts to argue that population growth and limited resources do not matter, that if governments "get their policies right", biochemical technology can provide sufficient food for virtually any population. As indicated above, we believe this is a false conclusion based on a fundamentally erroneous but surprisingly common misinterpretation of the Green Revolution in India which emphasizes biochemical technology rather than irrigation development. This misinterpretation quite simply puts the cart before the horse.

Unfortunately, it is very difficult to quantify the relative contributions of irrigation and biochemical technology (as indexed by use of NPK) on foodgrain production in India. First, irrigation and biochemical technology constitute a "basket" of inputs that vary together. A cross-sectional study of agricultural districts in India, for example, found a correlation of 90% between irrigation and use of NPK (Mitra, et al., 1980). Second, an outstanding lacuna in the otherwise excellent set of Indian agricultural statistics is the lack of time series data on use of NPK by crops: it is only known in terms of regions, or in the aggregate. Third, an even more important lacuna is the lack of time series data on production of crops from irrigated and non-irrigated land separately; only production from both together is known. Fourth, there is a puzzling and potentially important discrepancy between two different reports on the growth of irrigated area over the past few years that is discussed below. Given these empirical and statistical problems, it is necessary to be very cautious when estimating the relative contributions of these factors. However, the analysis in Chapter 4 indicates that irrigation accounts for one half to two-thirds of the increase in foodgrain production in India over the past three decades; and without the indirect effect of irrigation development enabling the use of HYVs and NPK, most of the remainder would not have occurred. Irrigation is the sine qua non of Indian foodgrain production, and as it reaches its practical limits over the next 25 years, the rate of growth of foodgrain production is likely to decrease in correspondence.

To place this conclusion in perspective, a three-stage model of Indian agricultural production is briefly outlined below.

Three Stages of Indian Agriculture

The development of Indian agriculture may be interpreted as a palimpsest, consisting of three overlapping stages, with each

stage characterized by different combinations of the factors of production.

In Stage I, which extended from prehistoric times to the late 1960s, the growth of agricultural production was primarily dependent on the development of additional cultivated land, both irrigated and dryland. While yields of certain crops gradually increased during this stage, especially in the last century, much of the increase was due to conversion of dryland to irrigated land, not to improvements in biochemical technology. Conversion of dryland to irrigated land itself increases yield, under the same technology, and has a double effect by reducing the proportion of low-yielding dryland to high-yielding irrigated land in the denominator of average yield calculations. This stage ended in the late 1960s, when the growth of gross cropped area basically ceased, while irrigation development accelerated.

Stage II, beginning in the late 1960s and continuing through today, is characterized by an accelerated rate of irrigation development and explosive growth in use of HYVs and NPK, with increased foodgrain yield as a result. This stage is destined to end as the frontiers of irrigation development are reached.

According to official statistics, India now has developed 62.9 million ha (MH) of the estimated 113 MH ultimate potential irrigation (not including economically infeasible inter-basin diversion schemes). At the current rate of development of about 2.6 MH pa, India will reach its ultimate irrigation potential in about 25 years, or one generation from now. Even worse, it appears that the development of "minor" irrigation--mainly tubewell irrigation, which has contributed a disproportionately high share of irrigation productivity--will end in only about 11 years from now, around the year 1996 (Dhawan, 1983).

Thus, in Stage III, with the end of substantial irrigation development around the year 2010, virtually all increases in production will depend solely on increased yields through biochemical technology. It is difficult--even, in principle, impossible--to predict what agricultural production will be in this third stage, because it is impossible to predict what new biochemical technology will be available. But to continue at present rates of growth in foodgrain production, the rate of growth of "pure biochemical yield" (i.e., without increased yield due to irrigation) will have to be around 2.7% pa. To our knowledge, this is a much higher rate of growth of pure biochemical yield over an entire foodgrain sector than any nation has been able to achieve for an extended period of time. Certainly India has not even been able even to approach this rate of pure yield growth to date, and it is most unlikely that it will be able to do so in the foreseeable future.

Therefore, as Chapter 4 shows in considerable statistical detail, the outlook for foodgrain production in India is for approximately the same rate of growth as in the past, around 2.7% pa, until about 1996, when the development of additional minor irrigated area draws to an end. The growth of foodgrain production then decreases to about 1.9% pa through the period 1996-2010, after which all irrigation development ends. If population continues to grow at present rates, breaking the accelerating trend of the past, per capita foodgrain production will grow very

slowly from the present level of 195 kg to 204 kg in 1996, after which it will decrease to 193 kg in 2010. With all land and water resource frontiers closed, the true Malthusian stage then begins. Barring miracles, and given current rates of population growth, the Malthusian deluge could also begin. We hope this outlook is wrong, but we can find no theoretical or empirical grounds for believing so.

The Second Malthusian Race

The situation with respect to the Second Malthusian Race between the supply and demand for agricultural labor and, therefore, of rural poverty, appears to us to be of even more pressing concern.

The growth of the working age population in rural areas, at about 2.9% pa, is higher than the growth of the population as a whole. The trend rate of growth of total agricultural production as a whole, including non-food crops, is close to this figure. Thus, assuming constant labor force participation rates and constant employment elasticities (the percentage change in employment divided by the percentage change in production), the supply and demand curves for agricultural employment probably have been shifting out at about the same rate over time. If this is true, then one can understand why the percentage of the people below the poverty line, most of whom are directly or indirectly employed in agriculture, has remained constant: demand and supply for agricultural labor has been in dynamic equilibrium, with constant real wages as a result.

However, we believe there is a very real threat that, as Indian agriculture shifts progressively away from the resource-based mode of production characteristic of the first and second stages toward the biochemical mode of production of the third stage, this dynamic equilibrium will fail, with the growth of demand for agricultural labor falling progressively behind the growth of labor supply.

The reason for believing this is a hypothesis that employment elasticity in the resource-intensive mode of agricultural production is higher than it is in the biochemical mode. It is hypothesized that in the biochemical mode of production, labor input per ha of land increases as yield increases, but labor input per unit of output decreases. The following example shows why this hypothesis is likely to be true.

About 70% of total on-farm labor input in irrigated agriculture is in the pre-harvest activities of land preparation, sowing, irrigation, and interculture; the remaining 30% is in harvest and post-harvest operations. In the resource-intensive mode, while land and irrigation is being developed, labor input in both phases probably rises in rough proportion to increased production--i.e., the employment elasticity is about one, or even more. Once the land and water resources are developed, however, yields can be increased substantially through the application of biochemical technology with very little additional labor input in pre-harvest operations. Shifting seed varieties to HYVs requires virtually no additional labor; chemical fertilizers may require

less labor than manuring; herbicides may substantially replace labor in weeding; and so on. On the other hand, in the absence of mechanization, labor inputs in the harvest and post-harvest phase rise roughly in proportion to yield.

Thus, for example, assume that yield increases 100% due to the application of biochemical technology. Labor input may increase 10% in the pre-harvest stage and 100% in the harvest and post-harvest stage. The total increase in labor input per unit of output is ((10% X 70% = 7%) + (100% X 30% = 30%)) = 37%. Therefore, in this case, the demand for labor would increase only slightly more than one-third of the increase of production. For a landowning farmer, on his own land, this is the best of worlds, but for landless agricultural labor, it can be a disaster. And it can also be a disaster for the farmer after he has produced enough for household needs and wishes to sell his surplus production to others. The main market may be landless laborers, who now do not have sufficient earnings to purchase the surplus. Here, in microcosm, is a basic dilemma of Indian agriculture as it moves into the third stage. As shown in Chapter 5, progressive dependence on the biochemical mode of agricultural production is likely to create a large surplus of agricultural labor that can be absorbed by the other sectors of the Indian economy only through very high rates of growth and investment in these sectors.

Recommendations

Our analysis of the two Malthusian races of production and poverty in Indian agriculture results in a rather grim outlook for both, much more so than we expected at the start. We would like to join with current fashion and say that these are only problems to be solved by better technology and market systems, that history has shown that man is capable of rising to all challenges. While this may be a comforting belief, it does not correspond very well to historical fact (as Figure 1a and the present state of the poorest 40% of the Indian population testifies all too well), nor does it provide specific directions for solving problems. We do not find exhortations to "keep the faith, baby," comforting.

Nor can we pretend to have found new and exciting solutions to these problems ourselves. Indeed, we are convinced that, barring some unforeseeable miracle, there is <u>no</u> solution without drastic reductions in the rate of growth of population. Many people have been saying this for a long time, and it has become something of a bore; but that does not mean it is wrong. To put it more aggressively, we may say that optimists who believe modern technology and free markets will make the population problem in India go away are quite wrong on any rational, empirical grounds we comprehend. Even if some miracle of "bioengineering" solves the production problem of the third stage of Indian agriculture, it will require a second miracle to solve the employment problem created by the first miracle. If, on the other hand, the rate of growth of population were reduced to the neighborhood of 1% pa, no miracles would be required at all. In

time, both the production and employment problems would more or less automatically solve themselves. Again, it is the race between population, production, and employment opportunities that counts.

Thus, to us, the major agricultural problem in India is the population problem. We would be in favor of moving investments out of agriculture into family planning activities, if that were necessary to solve this problem. Unfortunately, the problem is not simply one of money. Neither is it a social problem, as many contend. It is purely and simply a managerial problem. The demand for safe and effective family planning services among rural Indian women (as opposed to rural men) is enormous. With some encouragement, the demand would be sufficient to get fertility rates down to the required levels, but the capacity to supply these services simply is not there. Compared to the achievements of a country like Indonesia (where, by the way, abortion is illegal), the record of family planning in India can only be described as deplorable. Thus, even though this is an agricultural report, we have no hesitation in recommending to the GOI and to USAID that they give highest priority to improving the managerial effectiveness of the family planning program, and then to provide whatever resources it takes to get the job done.

However, it must also be recognized that no matter how effective family planning programs are, their effects will not substantially affect food needs nor reduce the supply of surplus agricultural labor for about two decades. Therefore, there is an urgent need for agricultural and resource development programs over the next two decades that will create additional food production and employment opportunities. Irrigation development is, of course, the major instrument to serve this objective, but the development of major and medium surface irrigation systems is probably already proceeding faster than it effectively can. Other alternatives, including different kinds of irrigation development, must be found. This means finding presently underutilized resources with which to work.

Fortunately, there are two large areas of opportunity in this regard. First, there are the vast but highly underutilized land and water resources of the central and eastern Gangetic Plains, where about 60% of the rural people below the poverty line live. Second, there are the "wastelands" of India--mainly areas that once were forest and pasture but which are now denuded and eroding lands now being used far below their productive potential. Together, these resources could be used to substantially increase production and alleviate poverty over the next several decades. No technological miracles are required to do so. However, the many agro-climatic, social, economic, and managerial problems that have made these areas what they are will not be easy to solve.

The following paragraphs outline a broad approach to these opportunities that we recommend for consideration. We have not discussed these recommendations in greater detail in the text because they require much deeper analysis and field investigations than we have been able to undertake. However, there are excellent studies by others on both subjects that we recommend for study in conjunction with the following observations (Planning

Commission, 1985; and the publications of the Society for Promotion of Wastelands Development [SPWD]).

The Gangetic Plains

The Gangetic Plains have vast resources of surface and underground water, and if there is a chance of extending the ultimate irrigation potential of minor irrigation, it surely is here. In the Gangetic Plains, the central problem is water management--the problem of not enough water at the right time in the dry season, quickly followed by too much water at the wrong time in the wet season. The latter problem perhaps cannot be solved; the Gangetic Plains are full of water in the wet season, and it may not be possible to improve drainage except in small areas. This is a subject that needs detailed hydrologic investigations on a basin-wide basis. However, it may be possible to avoid some of these problems by regulating the crop season through pump irrigation in the pre- and post-monsoon seasons. While we have not been able to study the agro-climatic details adequately, it appears that pump irrigation for nurseries and pre-sowing irrigation would permit the summer planting period in the Gangetic Plains to be moved forward 1-2 months, much as it is in the Punjab, thereby improving synchronization between the crop and the weather.

By "pump irrigation" we mean both tubewells and pumping water from rivers and lakes in the region. We specifically recommend small pump units owned by individuals or small groups, not large, government-owned and operated deep tubewell operations. The managerial problems of these large units are nearly insolvable (Seckler, 1985). It would also be necessary to support this pump irrigation program with a network of farm service centers to provide HYVs, fertilizers, extension, and storage/marketing services for this underdeveloped region.

Another problem is energy supply to the pumps. Here we recommend detailed investigations of the feasibility of small, decentralized power plants designed to serve a radius of, say, 10-20 km of pump irrigation area. These plants could be fueled by coal carried by trucks or trains from the nearby fields of South Bihar and Orissa. The coal could be stockpiled on the site in the off-seasons to avoid peak season shortages. In this system, electrical supply to the tubewells could be rotated by blocks, as in the Warabandi System of surface irrigation (Malhotra, et al., 1984). This would smooth peak-load requirements. These small power plants could be owned and operated by private sector firms under public utility agreements with the GOI. While irrigation should have priority in use of the power, off-peak capacity could be used to supply electricity to this power-deficient region through tie-ins to the central grid.

We believe this package of pumps, energy, and farm service centers could create an economic revolution in this resource-rich but desperately underdeveloped and poverty-stricken area of India.

The Wastelands

A rough working definition of "wastelands" is land that is now being used at less than 20% of its economic potential. By this definition, there are perhaps 20-30 million ha of wastelands, mainly denuded forest and pasture lands, in India. With proper development, this land could generate at least one person-year of employment per ha on a permanent basis. We have estimated in Chapter 5 that the additional surplus of agricultural labor in India in the year 2000 will be about 30-50 million standard person-years. Thus the wastelands could potentially absorb most of the additional surplus labor, at an investment cost of less than one-third the cost of absorbing them in the non-agricultural sectors. But here, as usual, there can be "many a slip between the cup and the lip."

The first and most difficult problem of wastelands development is to establish property rights to the land. Currently the land is owned and/or controlled by a bewildering system of government entities, local committees, and traditional rights. As the very wise Indian saying goes, "Everybody's property is nobody's property." Much of this land should, in our opinion, be "privatized": It should be legally allocated to landless labor and small farmers to provide them a permanent source of livelihood. If 5-10 million landless families could be allocated this land and provided the necessary support services, the cutting edge of poverty in India would be blunted. For all its well-known problems and abuses, land reform does, in fact, work--as, indeed, the case of India shows so well. However, India is also finding that it is sometimes easier to allocate land away from large, private landowners than from its own government agencies.

Once the right to the land is settled, the owner needs help in developing this historically abused resource. Much of this land can be brought under supplemental irrigation through small water harvesting reservoirs ("tanks") and/or through pump irrigation. In these cases, the production and employment response can be spectacular (SPWD, 19841; Joshi and Seckler, 1982). There are many successful models of this technique in India that could be replicated on a large scale, but, perhaps because they are small, replication has not happened to date.

When supplemental irrigation is not possible, agro-forestry provides an important and underexploited opportunity for wasteland development. The wastelands were once areas of highly productive forests, and these lands can be economically restored to forestry and rainfed agricultural crops. The problem here is essentially one of cash flow: How do the people live while the trees are growing? The only answer is payments in advance, using the growing crop as collateral. Here, we believe, private sector enterprise could make a substantial contribution to wastelands development through providing these contractual, marketing, and financial services, along with other inputs and extension services, to obtain good tree crops. In the establishment phase, it may be feasible to create large private sector estates which would be reduced to small plots and allocated to landless labor

after they become productive assets--and, of course, the private sector firm has received a reasonable return on its investment.

Last, we should note an important technological development that could be of enormous significance to wasteland development. This is biomass gasification (not to be confused with "biogas" digesters) which can convert fast-growing tree species and some agricultural residues into a fuel substitute for diesel engines (Joshi, Seckler, and Jain, 1984). The problem with fast-growing tree species is the lack of markets for their products. With gasification technology, these trees can be converted into valuable energy resources: into a cash crop. These small, inexpensive gasification units can, of course, also be used to provide local energy supplies for pump irrigation and other productive local energy uses in wasteland areas (as well as in other areas, notably, in the Gangetic Plains).

The newly created "Wastelands Development Board" demonstrates the commitment of the GOI to this program, and it deserves full support by USAID.

Finally, it may be noted that, in one important respect, the problem contains the solution. We have already noted that the 15 MT foodgrain surplus represents only a deficiency of effective demand, not of need or desire on the part of poor people to consume it. It was also noted that, if the people below the poverty line were just brought up to the poverty line, they would purchase 16 MT of foodgrain with their additional income. These people spend 60% of their income on foodgrain. It follows that the GOI now has in surplus foodgrain stocks fully 60% of the resources needed to eliminate poverty, so defined, in India, for at least one year. We believe this resource of surplus foodgrain should be used to support a new and ambitious food-for-work program in India concentrated primarily on wastelands development.

While the foodgrain surplus is perhaps a temporary phenomenon due largely to the exceptionally favorable foodgrain production in the past two years, our analysis indicates that these were normally favorable years, and other years like them will occur in the future, with further foodgrain surpluses to invest. In poor years, the GOI should consider importing foodgrains to support this program on a sustained basis. This would make it possible to productively invest India's own surpluses in food-for-work programs in good years. A properly managed wastelands development program would add substantially to local food production, as well as increase effective demand for food through improved employment opportunities. There is a feeling in India that past food-for-work programs did not work. In terms of the effectiveness of the projects, there is some truth to this. But it certainly worked for the poor people in these programs; with better planning and management systems, it can work in terms of projects as well.

In sum, we believe that tubewell irrigation and input-output services in the Gangetic Plains, combined with food-for-work and land redistribution programs in the wastelands, could make substantial contributions to alleviating current problems of production and poverty in Indian agriculture. And these programs can help prepare the way for addressing the very difficult challenges

of the third stage of Indian agricultural development at the turn of the century.

Chapter 2. Production and Poverty in Historical Perspective

India has a remarkably good statistical series on agricultural production dating back to the last century (see Table A1 of Appendix A). This chapter briefly examines some of this information in order to provide an historical perspective on contemporary issues in Indian agriculture.

Figure 2a shows the growth of total foodgrain production in relation to population over the period 1901-1985. Since the foodgrain production is obviously "swamped" by the population curve, foodgrain production is given its own graph in Figure 2b. This creates a remarkably different impression of the past three decades.

Figure 2b also shows the "market chartist" technique of defining upper and lower "resistance" lines by connecting the high and low points in a time series. While rigorous statistical tools are used later where required, these chartist lines provide a guide to the eye, and a stimulus to thought.

Foodgrain production had a very stable and gradually rising lower resistance line through the entire period 1901-1947 (all crop years are stated in terms of <u>end</u> years, e.g., 1947 refers to the 1946-1947 crop year). The upper resistance line indicates a cap at about 70 MT over the second decade of the century, after which it declined to about 60 MT (just as population started growing rapidly) and then gradually increased until 1945. The political and social upheaval surrounding Independence in 1947 had a traumatic effect on foodgrain production, especially in the Punjab, with 1951 and 1952 establishing record lows. By 1954, the pre-Independence levels of production were reestablished. For this reason, most of the analysis in this report begins with 1954.

The period 1950 to the present has had a stable floor, with the exception of the great drought years of 1966 and 1967, but the upper resistance line appears to be broken into two segments, with a transition period occurring around 1970. This corresponds to the period of the development of the Green Revolution. Appearances, however, can be misleading when growth curves are interpreted in terms of linear relationships. As shown in the more detailed analysis in the next chapter, the trend rate of growth of foodgrain production has been remarkably constant, at 2.7% pa through the period 1954-1985, both before and after the Green Revolution.

The immediate point of interest here is in the historical relationship between foodgrain production and poverty. As noted in the previous chapter, per capita foodgrain production today, after the two largest crops of record, is only about 72% of its level in the <u>second decade of this century</u> (see Table A1 and the cautionary notes in Appendix A).

This finding can be placed in a nutritional perspective by using the recommended daily allowance (RDA) of the Indian Council of Medical Research (ICMR) for energy intake of 2150 kcal per capita (70% from foodgrain) and a figure of 3460 kcal/kg of utilizable energy from rice and wheat (ICMR, 1981). On this basis, average per capita foodgrain consumption should be

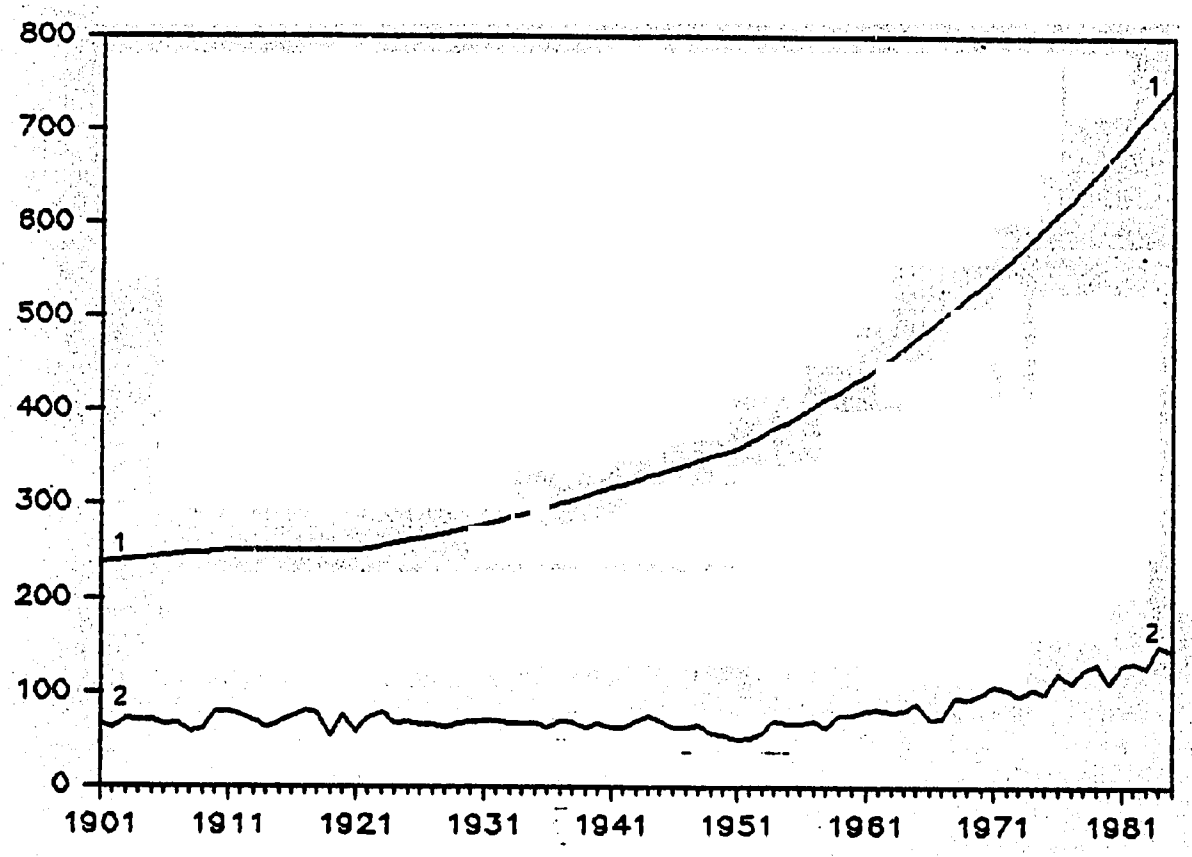


Figure 2a. Population and Foodgrain Production 1901-1985

1. Population (millions)
2. Foodgrain production (MT)

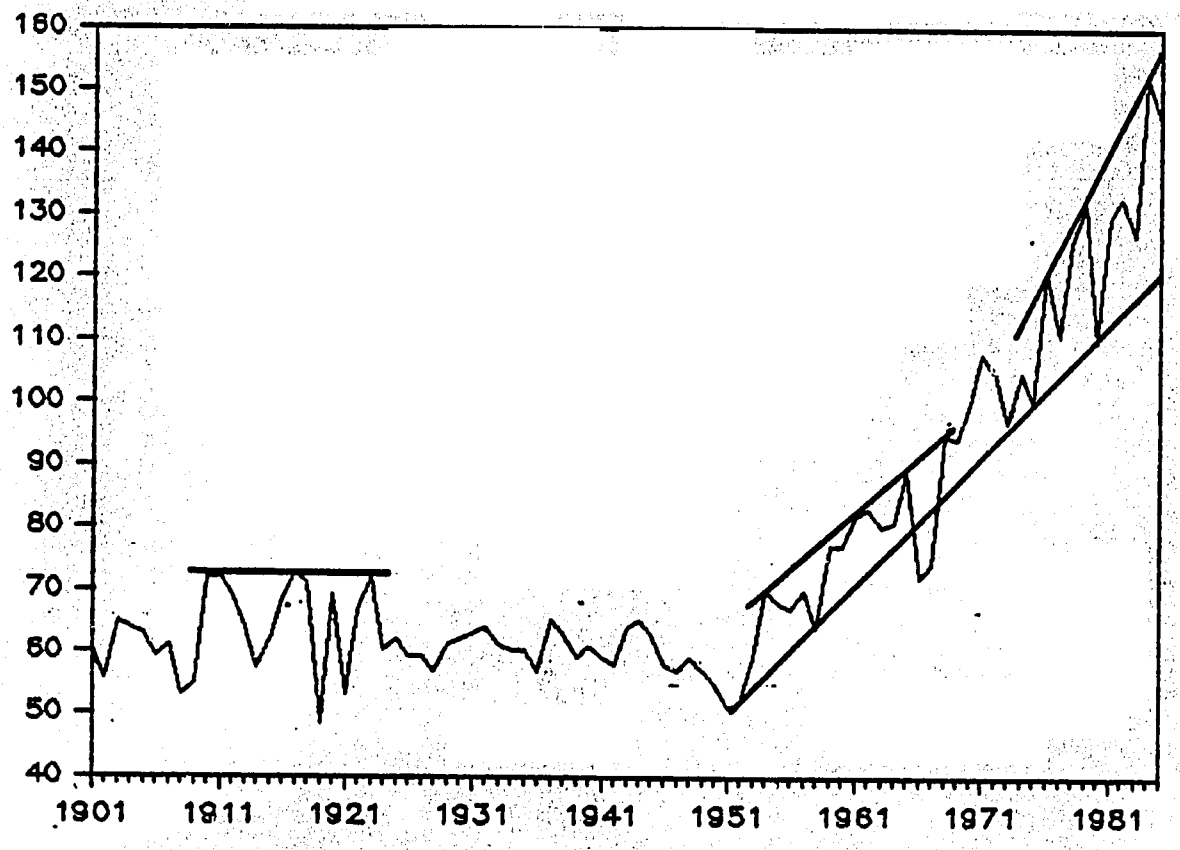


Figure 2b. Foodgrain Production 1901-1985 (MT)

((2150/3460).70) 0.435 kg of foodgrain per day, or 159 kg pa. (It should be noted that the RDAs are a matter of considerable controversy that will not be gone into here.) With a population of 252 million in 1911, India required about 40.2 MT of net foodgrain production to satisfy the RDA. It produced 72 MT gross or, assuming 12.5% for seeds and losses, 63 MT net. In that year, exports from India were at record highs, at 2.5 MT (Chaudhuri, 1984). Thus, India produced a surplus of foodgrain (i.e., above the total energy RDA from foodgrain) of about 20 MT.

On the other hand, in 1985, with a population of 749 million people, India requires 119.1 MT of foodgrain to satisfy the RDA. Its estimated production is 146 MT gross, or 127.8 MT net--about 7% above the average RDA. If the 15 MT undistributed surplus is taken out of this figure, then net average consumption is 113 MT, or 5% below that required on the average.

The foodgrain problem in India in the first part of this century clearly was not one of average production, but a problem of localized droughts and famines caused mainly by lack of irrigation, storage, and transportation facilities. It is much to the credit of the British Raj that one of the major considerations in undertaking the construction of railways and irrigation facilities was famine relief (Whitcombe, 1984).

The problem of famine is illustrated in Figure 2b. The period of highest per capita production, in the first two decades of the century, was also the period of highest variability. Hazell (1982) contends that there has been a tendency to increasing variability in Indian foodgrain production since 1950 (see also Ray, 1983). Whatever the case for the recent period may be, it is clear that variability was much larger in the first two decades of the century. It is possible that as yet undetermined weather cycles are involved in this series (Ray, 1983).

When one turns to consideration of non-foodgrain necessities, the decline in the standard of living of the Indian poor in this century must have been even more severe than that indicated by decreased per capita foodgrain production alone. At the beginning of the century, with only one-third its present population, India was a land of vast forests and pastures surrounding agricultural areas in the alluvial valleys. The forests provided building materials, firewood, fruit, nuts, and other products that could be obtained at little more than labor cost for personal consumption and sale by the poor. The same is true for meat, milk, and other livestock products obtained from open pasture lands. Today, this open land is nearly gone. Much has been converted to cultivation, and most of the remainder is overgrazed and denuded. This has undoubtedly caused a substantial rise in the real cost of non-foodgrain necessities for the rural poor, who represent 80% of the poor in India.

These considerations have an important bearing on the hypothesis, advanced by Ram and Schultz (1979), that since population growth is governed by nutritional and health factors, the accelerating growth of population in India since the 1920s indicates a substantial improvement in the real standard of living. The above analysis indicates that, insofar as this logic holds, nutritional improvements can only be considered in terms of diminishing local famines against an overall background of

dramatically declining average foodgrain availability. Thus it would appear that most of the growth in population was due to health factors--particularly, as Ram and Schultz observe, in preventive measures against epidemic diseases such as influenza, cholera, typhoid, malaria, and smallpox. For example, the slightly negative growth of population in 1911-1921 was mainly due to the worldwide influenza epidemic.

In sum, the change in the welfare of the Indian poor over this century represents a mixed picture of decreased incidence and severity of local famines and epidemic diseases against substantial declines in average per capita food and non-food necessities. Certainly, in terms of average per capita production of these necessities alone, India in the early part of this century appears virtually as a land of milk and honey from the perspective of today.

Chapter 3. The Trend of Foodgrain Production, 1954-1985

Introduction

Variations in foodgrain production in India appear to occur in "runs", with a few good years followed by a few bad years. Whatever the causes of these runs (if, indeed they exist other than randomly; Ray, 1983)--whether from weather cycles, policies, or cobweb cycles--they create alternating periods of euphoria and depression about the prospects for Indian agriculture. One of the advantages of trend analysis is that it puts these short-term fluctuations in a longer-term perspective. Thus, for example, it is possible to evaluate rationally, although not to decide definitively, such questions as whether the past two favorable years of foodgrain production are really exceptional years, representing a systematic breakthrough in foodgrain production, or are just normally good years, likely to be followed by normally bad years.

This chapter presents our contribution to the excellent studies of trends in foodgrain production by Indian economists (see, especially, Ray, 1983) and others. This chapter concentrates on the trend of foodgrain production, 1954-1985, while the next chapter analyzes some of the major factors behind the trend.

First, it is necessary to make a methodological point. Some function can usually be found to fit any set of data. Therefore, there are always questions of how to select functions that both fit and make sense, and when to quit searching for even better functions. The procedure followed here is first to examine the most simple and obvious kinds of functions (e.g., in the case of a more or less continuously growing system, the "semi-log," or exponential function) and then examine the statistics and the residuals (the difference between calculated and observed values) to see if they appear to be satisfactory or not. If the residuals appear to be randomly distributed and everything else looks good, that is good enough. If they are not, and/or there are other problems, then other independent variables and functions are tried. At some point, one has to decide that the analysis is good enough, and that is ultimately a subjective, although arguable, decision. Nor do we wish to bore the reader with all the regression analyses performed for this and subsequent chapters. The full printouts of the regression analyses used in this study (which represent a minute fraction of the total) are included at the end of each chapter. All of the basic data used in this study is provided either in the tables of the text or in Appendix D.

The Trend of Foodgrain Production

As noted in the preceding chapter, an important issue is whether the apparent break in the upper resistance line from the mid-1970s--and especially the very favorable years 1984-1985--represents a systematic breakthrough in foodgrain production due

to the Green Revolution or not. Figure 3a illustrates a means of properly addressing this question by plotting the logarithm (base e) of foodgrain production against time. In this transformation, the slope of the trend line indicates the percentage rate of growth of the series. There appears to be very little, if any, difference in the trend before or after the Green Revolution in the late 1960s, although this conclusion is subject to more refined statistical tests below.

It also appears from the upper resistance line of Figure 3a that while 1984 was a good year, it was just another of the 5-8 normally good years over the past 30 years. The high production in 1984 was due to a large increase in NPK application, due to a GOI campaign in that year, combined with nearly normal rainfall conditions.

Figure 3a also indicates that while the upper resistance line and the trend line are growing in parallel, the lower line is growing at a slower rate. This implies that foodgrain production may be subject to increasingly severe variations (i.e., the coefficient of variation will increase) as time goes on. This finding corresponds to those of Hazell (1982) and Ray (1983). However, as explained in Appendix B, these effects may also be due to more variable rainfall patterns in the past few years.

To properly estimate the trend rate of growth of foodgrain production, the effects of weather on variations around the trend should be included in the analysis. Cummings and Ray (1968) constructed the first rainfall index for India based on agricultural factors. Ray (1983) subsequently refined and updated this index to 1980. Sanderson and Roy (1979) have also compiled a different index. In order to have a rain index to use through 1985, a very simple index was developed for this study. Appendix B examines these various indices.

Equation 3Ra shows the results of regressing the logarithm of foodgrain production against time, the rain index, and the square of this index. This equation results in a trend rate of growth of foodgrain production of 2.67% pa, and accounts for fully 97% of the variance in foodgrain production over the period.

Since this rain index is of considerable importance in the trend analysis and in the later statistical analyses, it is worth pausing for a moment here to see how it behaves. Figure 3b shows the hypothetical effect on 1985 foodgrain production and yield, other factors constant, given the amount of rain (as a percent of normal in the monsoon season for selected states, as explained in Appendix B). It is seen that, so long as rain is between 100% and 110% of normal, there is very little effect on foodgrain production. However, there can be too much rain, as well as too little, and deviations from normal greater than 10% in either direction cause production to decrease. The exact coefficients for the rainfall function of course change in the different equations below, but the general form of the equation remains the same throughout the analysis.

To return to the trend analysis, the trend was further tested by deleting the drought years 1966 and 1967 from the data set and running a new regression. Both the trend rate of growth and the R2 value are virtually the same as in 3Ra. Finally, the

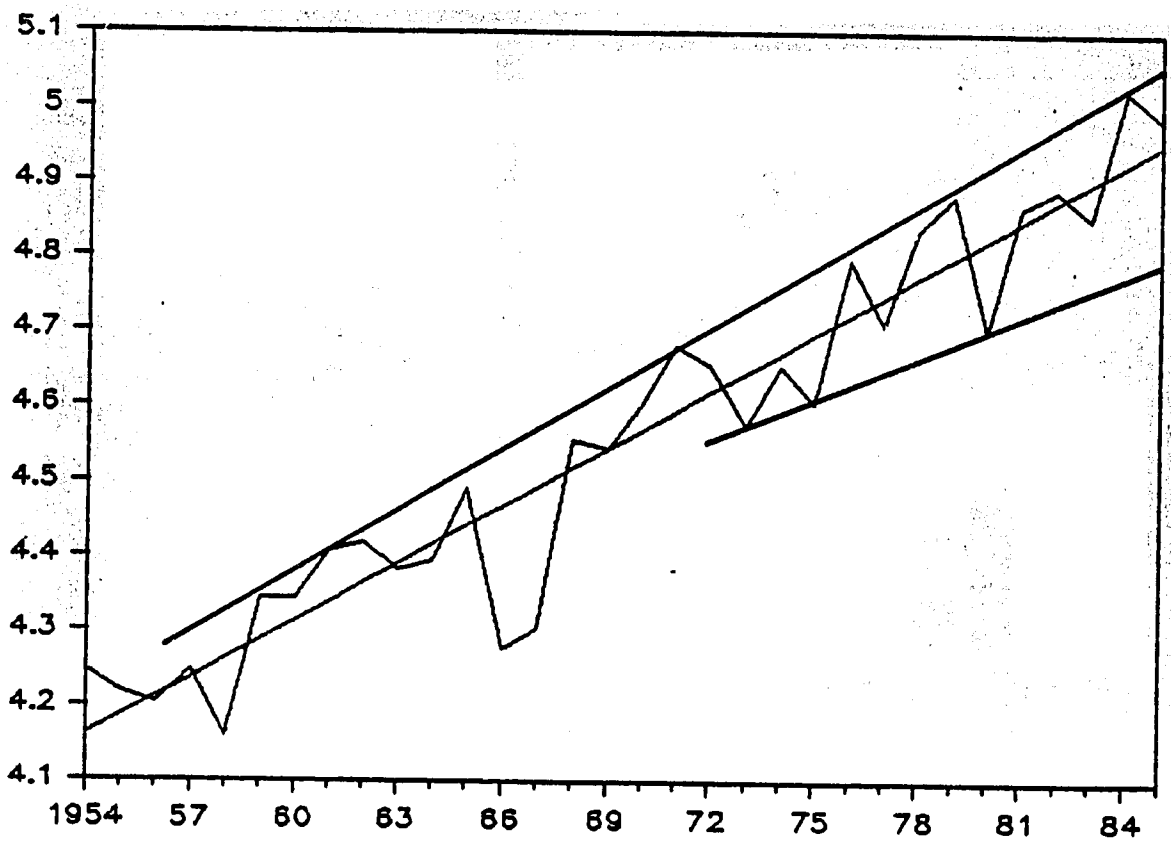


Figure 3a. Foodgrain Production 1954-1985 (LOG)

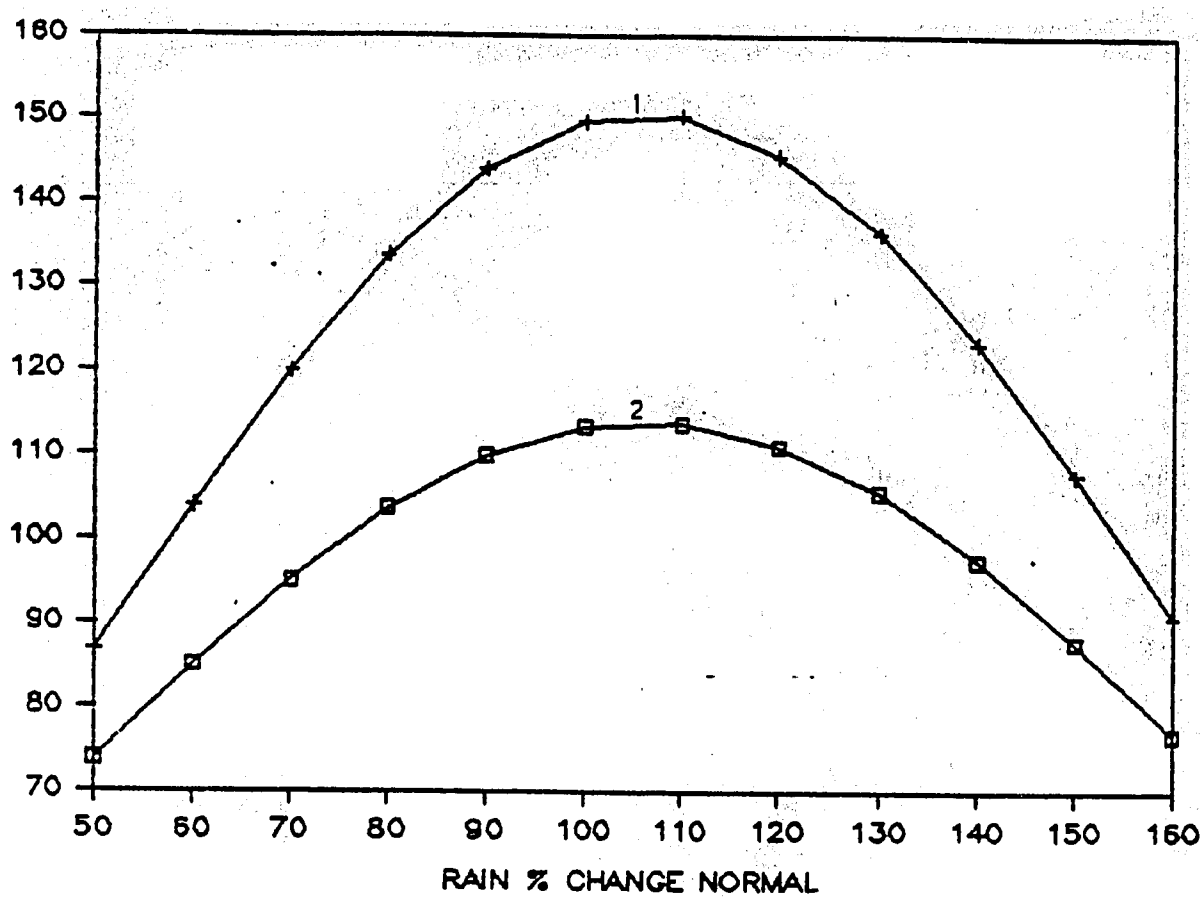


Figure 3b. Rain, Foodgrain Production and Yield

1. Foodgrain production (MT)
2. Foodgrain yield (10 kg)

data were divided into two sets: from 1954-1965 and from 1968-1985. Separate regressions were run on these sets, with the results compared to 3Ra by the Chow test. This test shows that there is no significant difference (even at only the 90% level) between the two periods--i.e., before and after the Green Revolution.

In conclusion: (a) The trend rate of growth of foodgrain production in India from 1954 to the present has been right at 2.7% pa; (b) The trend, together with the rainfall index, accounts for 97% of the variance in foodgrain production over the period; (c) There has been no significant change in the trend of foodgrain production before and after the Green Revolution; and (d) The very favorable years 1984 and 1985 appear to be just normally favorable years, which do not represent a fundamental improvement in the trend of Indian foodgrain production.

The Growth of Foodgrain Yield

The above conclusions do not belie the fact that the structure of Indian agriculture underwent an important transformation with the Green Revolution in the late 1960s. As shown before, in Figure 1b, the rate of growth of irrigation development increased, HYVs were introduced, and the use of NPK was launched on an explosive growth path. These inputs enabled foodgrain production to stay at the same trend rate of growth through increased yield, even though gross cropped area reached an effective plateau.

The trend rate of growth of foodgrain yield since 1954 has been 2.1% pa. However, this trend hides important changes between periods. In the 1954-1965 period, the trend was only 1.4% pa, while in the period 1968-1985, it has been 2.4% pa, an increase of 63%. Lest this statement be misinterpreted, it should be reiterated that much of the increase in yield in the latter period is due to irrigation development.

Foodgrain Production by Principal Crops

With these broad conclusions in mind, the discussion can proceed to a brief look at major crops within the foodgrain basket.

Figure 3c shows the division of foodgrain production between wheat, rice, and all other foodgrains (other cereals and pulses). Of the roughly 70 MT increase in total foodgrain production over the 1954-1985 period, wheat and rice have each contributed about 30 MT and other cereals 10 MT, with no increase in pulses. Thus rice and wheat, together, account for about 85% of the total increase in foodgrain over the past three decades.

It is interesting to note that the large increase in production in 1984 came mainly from rice and other cereals, not from wheat, while the small decrease in 1985 came mainly from wheat--perhaps due to the troubles in the Punjab. But these jumps in rice and other cereals, which normally go together, were not unusually large, and are frequently followed by a corresponding

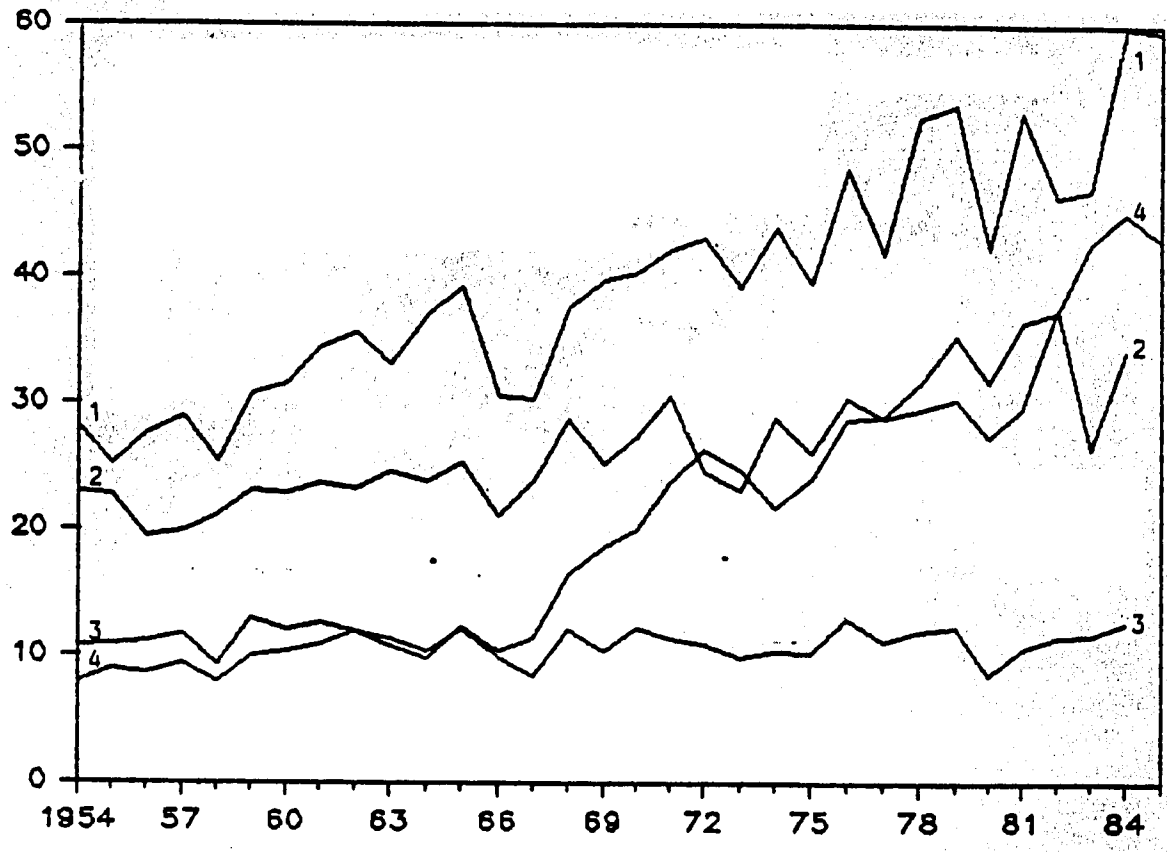


Figure 3c. Foodgrain Production by Crops (MT)

1. Rice
2. Other cereals
3. Pulses
4. Wheat

fall within a year or two. Inspection of the rice curve shows that it has become considerably choppier since the early 1970s--possibly because of extension of paddy area to rainfed and poorly irrigated/drained land, or because of increased short-term variability in rainfall.

Figure 3d places the crop production data on a per capita basis. While per capita wheat production has increased considerably, rice has remained at about the same level, other cereals have decreased, and pulses have substantially decreased.

A Hypothesis

It appears to us that perhaps the appropriate conceptual approach to understanding the remarkably constant trend rate of growth of foodgrain production over the past three decades is through a purposive, or cybernetic, model within a deterministic framework. GOI agricultural policies may have been chasing an effective demand curve that is shifting out at a trend rate of 2.7% pa, through a negative feedback response to fluctuations in surplus stocks. Thus the rate of growth of production could have been higher had effective demand called for it. On the other hand, the system is also constrained by restrictions on the pace of irrigation development and the lack of technology for dryland areas. In the next chapter, it is noted that there may be an autoregressive link between periods of foodgrain production every four years. This may be the consequence of a cybernetic system periodically under- and over shooting its target. It would be interesting to explore this hypothesis in greater detail than has been possible here.

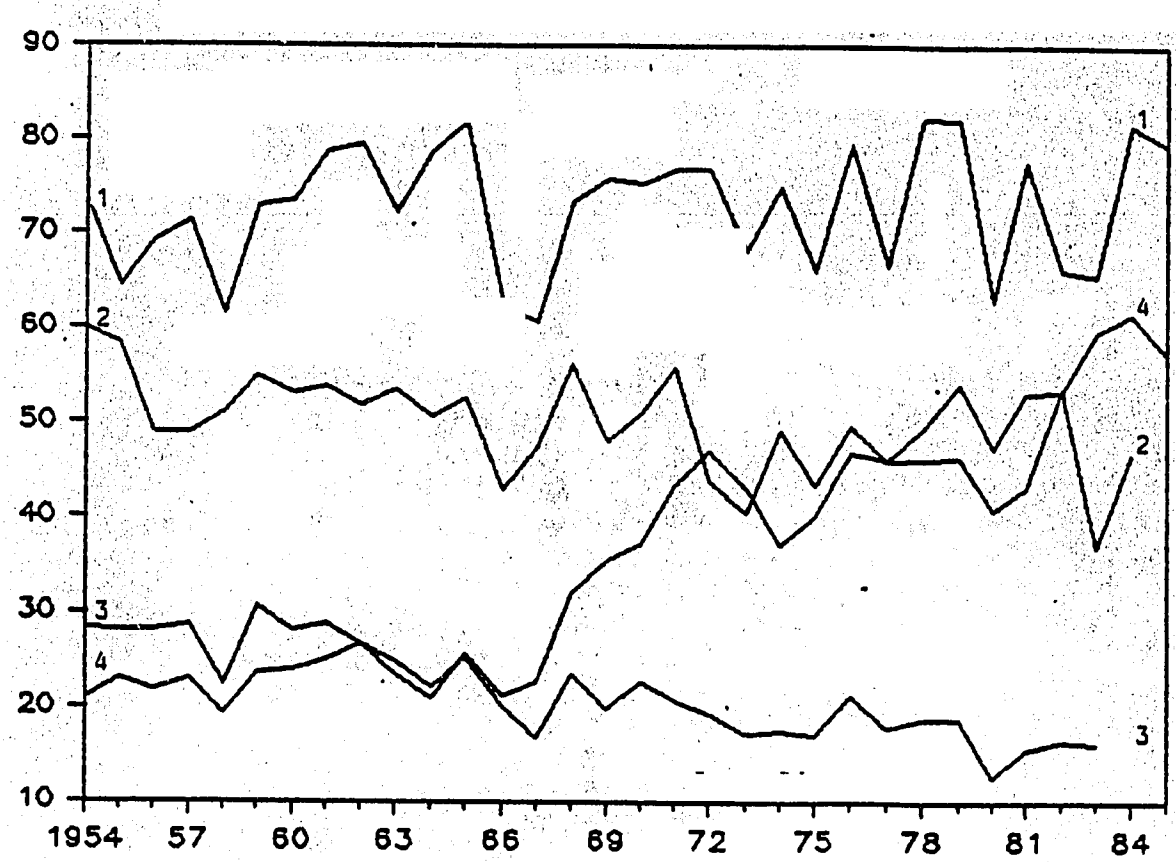


Figure 3d. Per Capita Foodgrain by Crops (MT)

1. Rice
2. Other cereals
3. Pulses
4. Wheat

Equation 3Ra
1954-1985

---------- REGRESSION ANALYSIS ----------

DEPENDENT VARIABLE: LNFG

VAR.	REGRESSION COEFFICIENT	STD. ERROR	F(1, 28)	PROB.	PARTIAL r²
YEAR	.0267	8.95997E-04	890.563	.00000	.969[illegible]
RAIN	3.6991	.7162	26.674	.00002	.487[illegible]
RAIN^2	-1.7425	.3705	22.117	.00006	.441[illegible]
CONSTANT	.7824				

STD. ERROR OF EST. = .0446

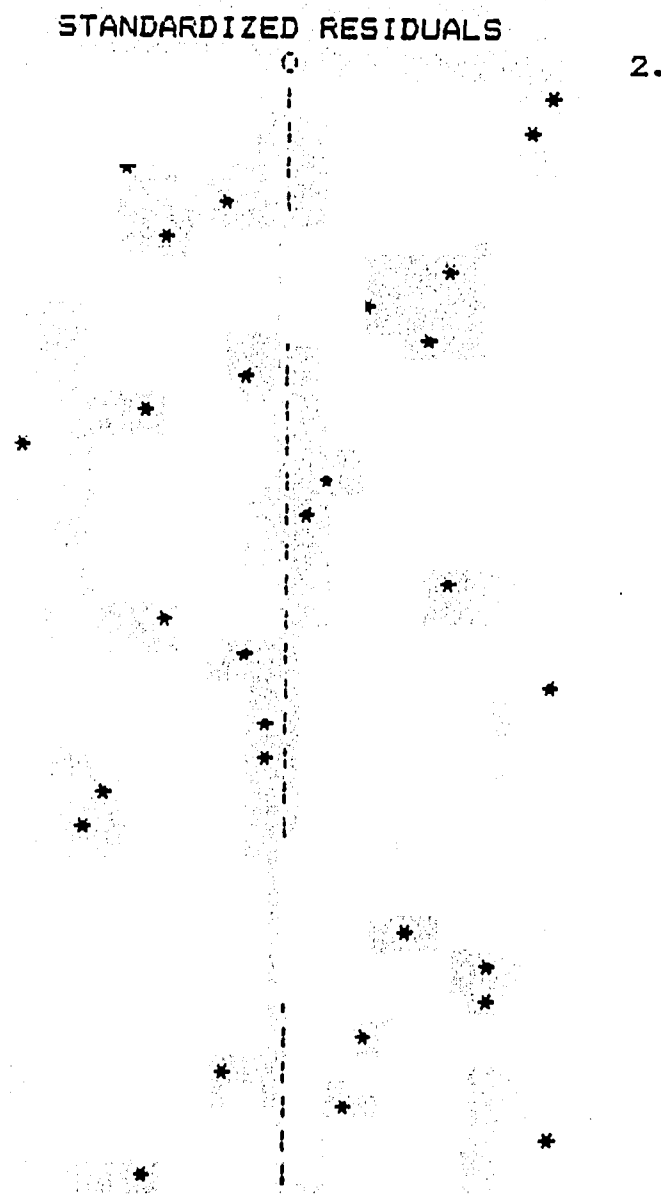
ADJUSTED R SQUARED = .9683
R SQUARED = .9714
MULTIPLE R = .9856

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	1.8872	3	.6291	316.491	5.000E-14
RESIDUAL	.0557	28	.0020		
TOTAL	1.9429	31			

	OBSERVED	CALCULATED	RESIDUAL
1	4.248	4.188	.0605
2	4.220	4.165	.0545
3	4.205	4.243	-.0380
4	4.248	4.264	-.0152
5	4.159	4.186	-.0274
6	4.344	4.309	.0352
7	4.344	4.324	.0196
8	4.407	4.374	.0327
9	4.419	4.427	-.0083
10	4.382	4.412	-.0301
11	4.394	4.455	-.0607
12	4.489	4.478	.0110
13	4.277	4.270	.0068
14	4.304	4.409	-.1046
15	4.554	4.518	.0355
16	4.543	4.569	-.0256
17	4.605	4.613	-.0075
18	4.682	4.622	.0598
19	4.654	4.657	-.0031
20	4.575	4.578	-.0037
21	4.654	4.695	-.0414
22	4.605	4.649	-.0442
23	4.796	4.772	.0241
24	4.710	4.802	-.0923
25	4.836	4.810	.0268
26	4.883	4.837	.0454
27	4.700	4.657	.0435
28	4.868	4.849	.0181
29	4.890	4.903	-.0129
30	4.852	4.836	.0155
31	5.024	4.966	.0580
32	4.984	5.016	-.0321

STANDARDIZED RESIDUALS



DURBIN-WATSON TEST = 2.0290

19b

Chapter 4. Sources of Growth in Indian Foodgrain Production with Projections to 2010

Introduction

The last chapter examined the trend in foodgrain production and the effect of rain on variations around the trend. This chapter undertakes the much more difficult task of quantitatively estimating the causal factors behind the growth of foodgrain production and projecting the effects of these factors in the future.

In principle, the major factors behind the growth of foodgrain production are clear. As shown before in Figure 1b, they are irrigation, HYVs, NPK, and changes in dryland area. Tables 4a and 4b provide additional information on these factors and related aspects of Indian agriculture.

Rice and wheat are the growth crops in Indian foodgrain production. Together, these two crops constitute 62% of total foodgrain production and account for over 85% of the increase in foodgrain production over the past three decades. Rice and wheat cover 85% of the total irrigated land, use about 80% of total HYVs, and consume about 80% of NPK.

Irrigation and Biochemical Technology

To properly understand the past performance of foodgrain production in India and to estimate its future, it is extremely important to distinguish between the two interrelated but separate components of the Green Revolution: irrigation and biochemical technology. In principle, biochemical technology can expand forever (although the rate of expansion is limited by diminishing returns), while irrigation is, for all practical purposes, an ultimately limited resource. However, as noted in Chapter 1, there are formidable statistical and data problems in attempting to estimate the separate effects of these two basic factors of production.

A very interesting study of NPK use by the National Council of Applied Economic Research (NCAER, 1978) and analysis of this and other data by Desai (1982) provides important insights into these relationships. Figure 4a, adapted from Desai's study, shows NPK use per ha for rice and wheat in relation to irrigation and HYVs. Unfortunately, the related yield data is not available, but perhaps NPK use provides a rough indicator of yield. It is interesting to see that the effects of changes in irrigation and HYVs are nearly the same, on the average, for rice, wheat, and all the major foodgrain crops. In the transition from NPK use under non-irrigated (NIR) and traditional varieties (TV), the increase in NPK is the same either for irrigation with traditional varieties or for improved varieties under non-irrigated conditions. Either of these changes cause an increase in NPK of about 67%. Then a transition from these two states to irrigation with improved varieties causes an additional

Table 4a

PROGRESS OF SELECTED PHYSICAL AGRICULTURAL DEVELOPMENT PROGRAMMES

Programme	Unit	1970-71	1975-76	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83	1983-84	1984-85 (Target)
1	2	3	4	5	6	7	8	9	10	11	12
High Yielding Varieties Programme :											
Paddy	Million hectares	5.59	12.44	16.12	16.88	15.99	18.23	19.69	18.84	22.18	25.00
Wheat	,,	6.48	13.46	15.80	15.89	15.03	16.10	16.75	17.84	18.55	19.00
Maize	,,	0.46	1.13	1.24	1.35	1.35	1.58	1.60	1.72	1.81	2.00
Jowar	,,	0.80	1.96	3.14	3.07	3.05	3.50	3.88	4.37	4.84	5.00
Bajra	,,	2.05	2.90	2.63	2.94	2.96	3.64	4.58	4.71	5.11	5.00
Total HYP	,,	15.38	31.89	38.93	40.13	38.38	43.05	46.50	47.48	52.49	56.00
Irrigated Area (cumulative utilisation)	,,	38.0	45.3	48.5	50.6	52.2	54.1	56.0	58.2	60.5	62.9
Through Major & Medium .	,,	17.3	20.1	21.2	22.0	22.2	22.7	23.2	24.0	24.9	25.8
Minor*	,,	20.7	25.2	27.3	28.6	30.0	31.4	32.8	34.2	35.6	37.1
Soil conservation (cumulative level at the end of the year)	,,	12.11	19.96	21.70	22.57	23.40	24.37	25.39	26.52	27.76	29.17
Consumption of Chemical Fertilisers :											
Nitrogenous	Million tonnes	1.49	2.15	2.91	3.42	3.50	3.68	4.07	4.22	5.22	5.66
Phosphatic	,,	0.46	0.46	0.87	1.11	1.15	1.21	1.32	1.44	1.73	1.88
Potassic	,,	0.23	0.28	0.51	0.59	0.61	0.62	0.67	0.73	0.77	0.86
Total NPK	,,	2.18	2.89	4.29	5.12	5.26	5.52	6.06	6.39	7.72	8.40

*The figures for minor irrigation indicate the net benefit after allowing for seepage.

Source: Ministry of Finance, 1984-85

Table 4b

IRRIGATED AREA UNDER DIFFERENT CROPS

(Million Hectares)

Group/Commodity	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
1	2	3	4	5	6	7	8	9	10	11
Rice	14.08 (37.2)	14.42 (39.1)	14.67 (38.4)	14.67 (38.8)	15.22 (38.7)	14.77 (38.4)	16.20 (40.2)	16.86 (41.6)	16.91 (42.8)	16.34 (40.5)
Jowar	0.73 (4.4)	0.55 (3.3)	0.68 (4.0)	0.75 (4.6)	0.79 (4.9)	0.80 (5.1)	0.66 (4.0)	0.77 (4.8)	0.63 (3.8)	0.63 (3.8)
Bajra	0.44 (3.7)	0.56 (4.5)	0.59 (4.2)	0.64 (5.5)	0.59 (5.1)	0.53 (4.9)	0.47 (4.2)	0.50 (4.4)	0.63 (5.9)	0.64 (5.4)
Maize	0.80 (14.3)	1.09 (18.8)	0.88 (14.7)	1.22 (21.0)	0.96 (16.2)	1.06 (17.7)	0.91 (15.9)	0.95 (16.3)	1.36 (23.5)	1.20 (19.7)
Wheat	10.40 (54.5)	10.77 (57.7)	10.76 (57.7)	11.08 (61.8)	12.56 (61.8)	13.59 (65.1)	13.72 (64.3)	14.87 (66.0)	15.03 (67.9)	15.52 (69.7)
Barley	1.20 (48.9)	1.20 (48.8)	1.36 (51.3)	1.65 (57.3)	1.53 (54.4)	1.25 (55.9)	1.08 (53.9)	0.95 (51.7)	0.90 (50.8)	0.91 (50.4)
Total Cereals	28.11 (28.0)	29.00 (29.1)	29.30 (28.3)	30.48 (30.7)	32.14 (31.0)	32.45 (32.0)	33.50 (32.1)	35.32 (33.5)	35.84 (34.7)	35.59 (33.8)
Total Pulses	1.97 (8.8)	1.76 (8.1)	1.87 (7.9)	1.82 (8.1)	1.95 (7.9)	1.77 (7.5)	1.70 (7.1)	1.89 (7.9)	1.95 (8.8)	2.02 (8.9)
Total Foodgrains	30.08 (24.5)	30.76 (25.4)	31.17 (24.5)	32.30 (26.5)	34.09 (26.5)	34.22 (27.4)	35.20 (27.5)	37.21 (28.8)	37.79 (30.1)	37.61 (29.4)
Oilseeds	1.22 (7.7)	1.07 (7.2)	1.36 (8.8)	1.48 (9.2)	1.20 (7.9)	1.10 (7.6)	1.59 (10.4)	1.70 (10.9)	1.93 (12.5)	2.28 (14.3)
Cotton	1.70 (26.7)	1.72 (21.0)	1.73 (22.1)	1.78 (22.9)	1.76 (23.5)	1.76 (24.6)	2.11 (26.2)	2.22 (27.2)	2.22 (27.4)	2.13 (27.1)
Sugarcane	1.73 (71.8)	1.88 (75.0)	2.19 (76.5)	2.31 (79.9)	2.23 (87.0)	2.39 (77.2)	2.62 (78.7)	2.60 (77.8)	2.14 (76.9)	2.29 (80.8)

Note : 1. Figures in parenthesis represent the percentage irrigated area to total area under the crop.

2. Irrigated area under oilseeds denote the area under groundnuts, rapeseed & mustard, linseed, sesamum, and others.

Source: Ministry of Finance, 1984-85

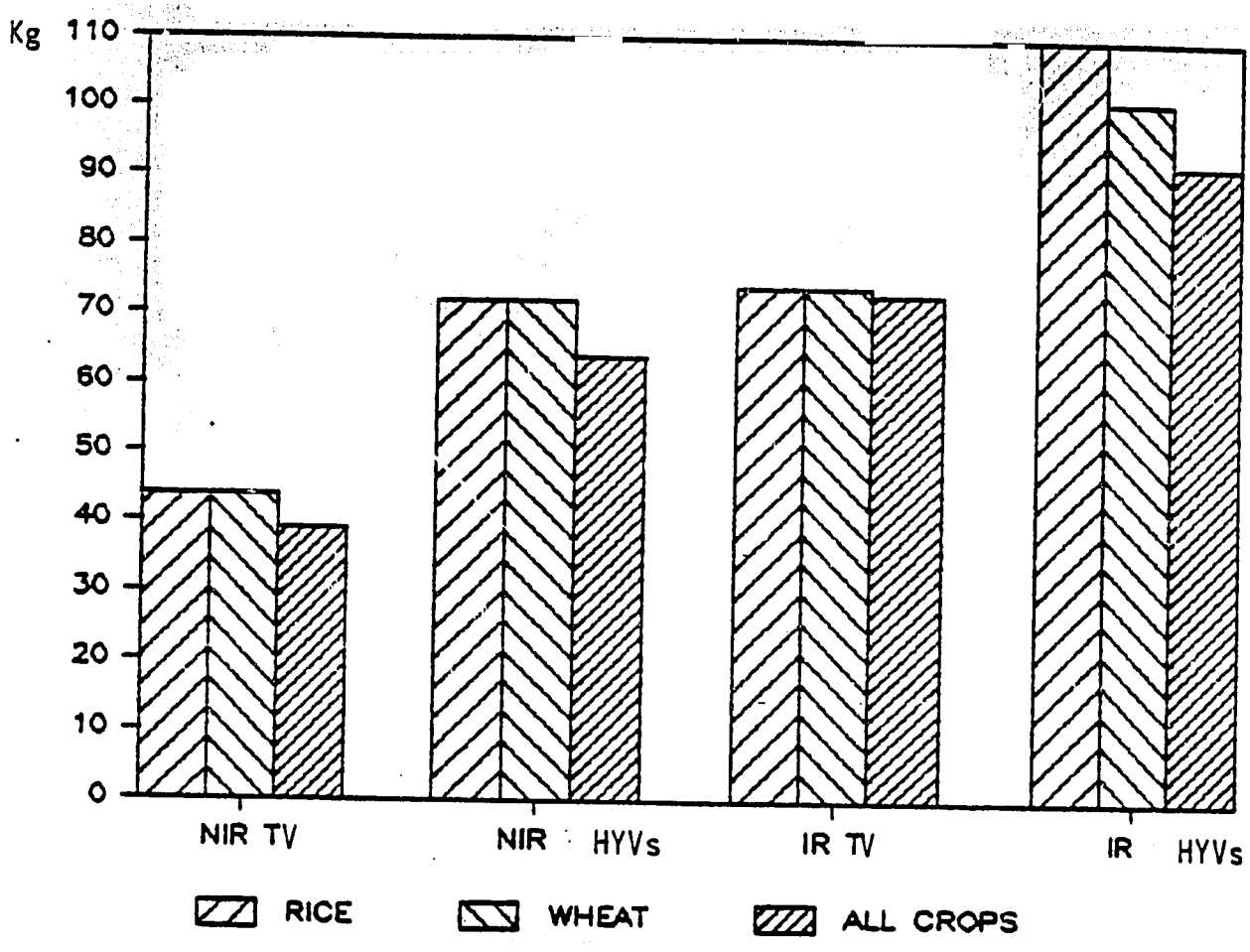


Figure 4a. NPK Per Ha, Irrigation and Improved Varieties

IR = Irrigated
NIR = Non-irrigated
TV = Traditional varieties
HYV = High-yield varieties

Source: adapted from Desai, 1982

increase in NPK use of about 40%. The total increase caused by irrigation and improved varieties is about 133%.

However, there is an important restriction on this generalization. The areas in which gains in NPK use occur under non-irrigated conditions, by improved varieties alone, is very limited. As shown in Desai's study, non-irrigated area with improved varieties accounts for only 4.8% of total NPK use. On the other hand, irrigated area accounts for 85% of total NPK use. Thus it may be concluded that irrigation is virtually a necessary condition to the use of NPK and HYVs in India.

Irrigation

There are two basic sets of data on irrigation in India. The first is the report on "Irrigation Development" (ID), as it will be called here, by the Ministry of Water Resources. This data is based on completion of irrigation projects and reports both the "potential", or designed, area to be irrigated and the "utilized" area--or what is thought to be actually irrigated. This latter figure is usually not based on empirical studies of actually irrigated area but on engineering rules of thumb. These figures are reported both in terms of net and gross irrigation, the difference being the intended number of crops irrigated each year. The second set of data is from the Ministry of Agriculture and arises out of the annual survey of areas under crops, yields, etc. This data is gathered through field observations by village officials. This agricultural data will be called "Gross (or net) Irrigated Area" (GIRA). Both data sources have their problems (Seckler, 1985), which will not be gone into here. However, a major point of relevance to this analysis is the increasing discrepancy between the two data sources over the past few years.

The two data sources and the discrepancy are shown in Table 4c. From 1979, ID has grown much faster than reported GIRA (GIRA RPT), so that in 1985, the (estimated) difference is 9.3 MH--compared to a difference of only 2.3 MH in 1979. If taken literally, this would imply that the new irrigation projects are only 43% effective in terms of the relation between ID potential and GIRA--a figure which is surprisingly close to an estimate made on other grounds (Seckler, 1985). However, the 1979-1981 GIRA figures are described as "preliminary" estimates that may be revised later. For lack of any better alternative concerning this vital data set, the GIRA figures shown for 1979-1985 are our own estimates based on extrapolating the 1978 figure at a growth rate of 2.6% pa. This still leaves a widening gap between ID and GIRA which we cannot go into further here. The extrapolated GIRA figures have been used in the statistical analysis below and elsewhere in the text.

Given the importance of irrigation to foodgrain production in India, the common practice of estimating yields on the basis of the total area under the crop is misleading. The best approach would be to estimate yields by crops per ha of irrigated area and per ha of non-irrigated area separately, but this cannot be done because the production data is not compiled separately for irrigated and non-irrigated areas. This, together with fur-

Table 4c
Comparison of Irrigation Data

YEAR	GROSS IRR A	GIRA. RPT	ID POTENT	ULTIL	ID UTIL-GIRA RPT
78	46				
79	47.5	48.3 P		50.6	2.3
80	48.7	49.2 P	56.5	52.2	3
81	50	49.6 P	58.7	54.1	4.5
82	51.3	50.3 PR	61	56	5.7
83	52.6	52.1 PR	63.3	58.2	6.1
84	54	52.9 PR	65.6	60.5	7.6
85	55.4	53.6 PR	68	62.9	9.3

P PRELIMINARY ESTIMATE MOA
PR PROJECTED BASED ON REPORTED

Table 4d

Development of Irrigation Potential and its Utilisation

(Cumulative Coverage)

(Million hectares)

Year	Major and medium schemes		Minor schemes		All schemes	
	Potential	Utilisation	Potential	Utilisation	Potential	Utilisation
1979-80	26.5	22.2	30.0	30.0	56.5	52.2
1980-81	27.3	22.7	31.4	31.4	58.7	54.1
1981-82	28.2	23.2	32.8	32.8	61.0	56.0
1982-83	29.1	24.0	34.2	34.2	63.3	58.2
1983-84	30.0	24.9	35.6	35.6	65.6	60.5
1984-85 (Target)	30.9	25.8	37.1	37.1	68.0	62.9
Ultimate Potential	58.5		55.0		113.5	

Source: Ministry of Finance, 1984-85

ther crop-wise studies of NPK such as those mentioned above, would contribute enormously to understanding the real dynamics of Indian agriculture. Strictly by way of illustration of the importance of such studies, Figure 4b is offered here.

Data are available (Table 4b) on irrigated area by crops for the period 1972-1981. If one takes total production of these crops and divides it by the irrigated area for each crop, the result is as shown in the lines over the relevant period in Figure 4b. The absolute level of the line does not matter since it is partly a function of the amount of production contributed by non-irrigated area for each crop. The interesting thing is that, with the possible exception of wheat, total production per ha of gross irrigated area over the period has apparently been constant. Further, if one takes total foodgrain production per ha of total GIRA over the entire period 1954-1985, as shown, it appears that there has been a systematic decrease in this irrigation-based yield figure. But it must be emphasized that there are many problems in this illustration, and no firm conclusions can be drawn from it. It is offered here only for suggestive purposes and to show the need for separate data on production under irrigated and non-irrigated conditions.

Last, given the importance of irrigation, it is important to see what its prospects for future development are. Table 4d shows the basic projections of the Ministry of Water Resources in terms of ultimate irrigation potential, which, to our knowledge, have not been seriously questioned. It is important to note that the category of "minor schemes" includes tubewell irrigation which has contributed the most to the Green Revolution, and is now up to 67% of its ultimate potential. Table 4e projects these figures, at present rates of growth, to the year 2010. On this basis, minor irrigation will reach its ultimate potential in 12 years, in 1997, and all irrigation development will end by 2010. The GIRA projection is based on the assumption that 88% of the ID "utilized" figures will be realized, or 74% of "potential", this may be much too optimistic.

Statistical Analysis and Projections to 2010

We have attempted to gather the above factors into a statistical model that would account for past changes in foodgrain production and provide a basis for projections into the future.

The best model, out of a set of very many we have tried, is shown in Equations 4Ra and 4Rb at the end of this chapter. Here, foodgrain production in millions of tonnes is the dependent variable, with gross irrigated area (MH), total dry area (MH), NPK (in thousands of tonnes), and the rainfall variables as predictive variables. With these variables, Equation 4Ra accounts for over 98% of the variance in foodgrain production over the 1954-85 period.

However, the Durbin-Watson test for this equation is in the indeterminate range for negatively autocorrelated residuals. We checked this by regressing the residuals in time "t" against the residuals in "t-1" and found that the coefficient was indeed significant at the 97% level. Accordingly, we used the "Generalized

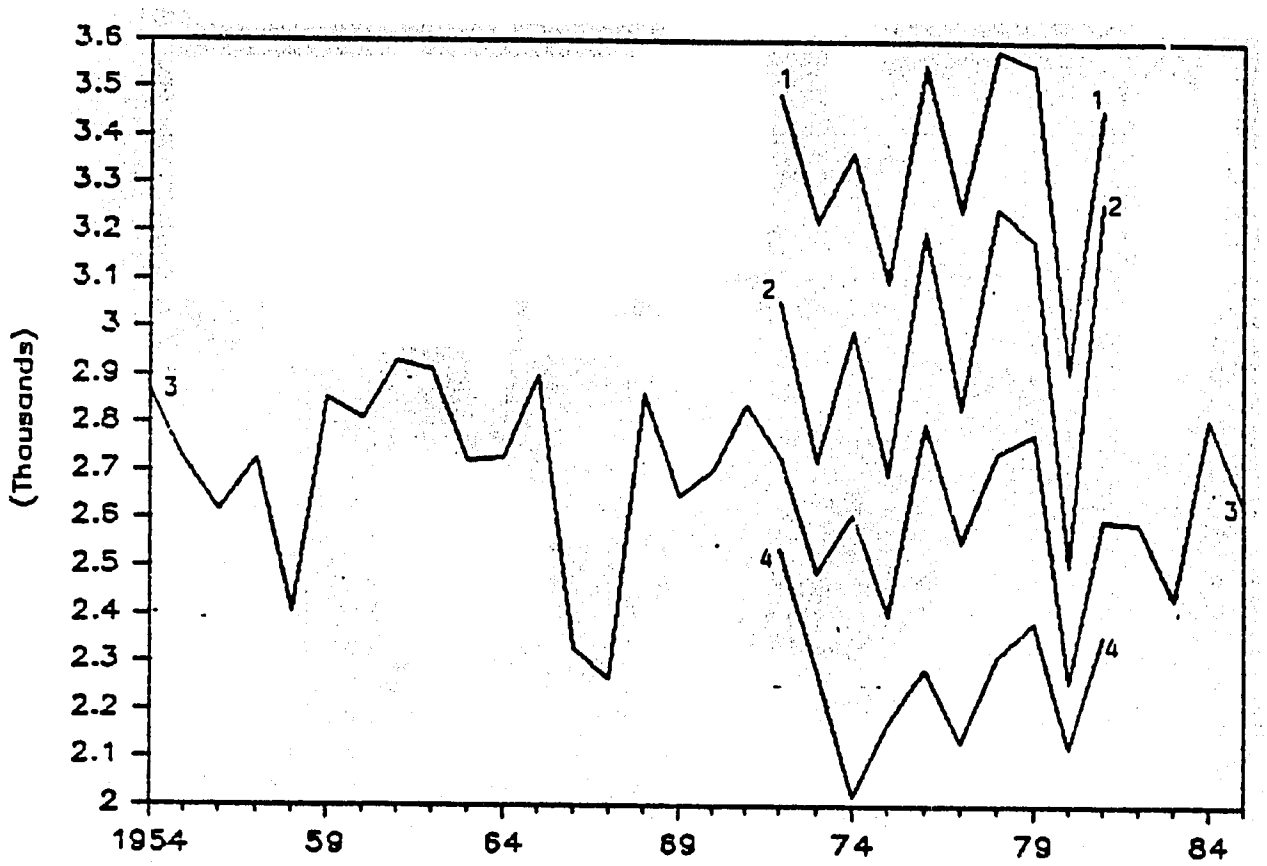


Figure 4b. Yields Per Ha of Gross Irrigated Area .

1. Total foodgrain production divided by net irrigated area in foodgrain
2. Total rice production divided by net irrigated rice area
3. Total foodgrain production divided by total gross irrigated area
4. Total wheat production divided by net irrigated wheat area

TABLE 4e DEVELOPMENT OF IRRIGATION POTENTIAL AND UTILIZATION TO 2010

YEAR	MAJOR & MEDIUM	MINOR	TOTAL POTENTIAL	UTILIZED (NOTE 1)	GIRA @ 88% UTITILIZED
1980	26.5	30	56.5	52.3	48.7
1981	27.3	31.4	58.7	54.3	50.0
1982	28.2	32.8	61	56.5	51.3
1983	29.1	34.2	63.3	58.6	52.6
1984	30	35.6	65.6	60.8	54.0
1985	30.9	37.1	68	63.1	55.4
1986	31.7	38.4	70.1	65.1	57.3
1987	32.5	39.8	72.3	67.1	59.1
1988	33.4	41.3	74.6	69.3	61.0
1989	34.2	42.7	77.0	71.5	62.9
1990	35.1	44.3	79.4	73.8	64.9
1991	36.0	45.9	81.9	76.1	67.0
1992	37.0	47.5	84.5	78.6	69.2
1993	37.9	49.2	87.2	81.1	71.4
1994	38.9	51.0	89.9	83.7	73.7
1995	39.9	52.8	92.8	86.4	76.0
1996	41.0	54.7	95.7	89.2	78.5
1997	42.0	55.0	97.0	90.3	79.5
1998	43.1	55.0	98.1	91.2	80.3
1999	44.3	55.0	99.3	92.2	81.1
2000	45.4	55.0	100.4	93.1	82.0
2001	46.6	55.0	101.6	94.1	82.8
2002	47.8	55.0	102.8	95.2	83.7
2003	49.0	55.0	104.0	96.2	84.7
2004	50.3	55.0	105.3	97.3	85.6
2005	51.6	55.0	106.6	98.4	86.6
2006	53.0	55.0	108.0	99.5	87.6
2007	54.4	55.0	109.4	100.7	88.6
2008	55.8	55.0	110.8	101.8	89.6
2009	57.2	55.0	112.2	103.1	90.7
2010	58.7	55.0	113.7	104.3	91.8

NOTE 1. UTILIZED ASSUMED TO BE 84% OF MAJOR AND MEDIUM PLUS 100% OF MINOR IRRIGATION

Least Squares" regression program, with the result shown in 4Rb. It appears that there is a rather mysterious autocorrelation between residuals every four years. Whether this is the result of a four-year weather cycle, or a cybernetic policy cycle as noted in Chapter 3, or something else, we do not know.

In any case, 4Rb accounts for fully 99% of the variance over the period with all of the major variables significant at well over 0.99 level. Of course, good regression results can be expected from any time series analysis of growing systems, but even so, these are quite remarkably good results. (For those with a time series-regression phobia, we refer to Ezekiel and Fox, 1961, Chapter 20, and Neter et al., 1983, Chapter 13, for comfort.)

Since 4Rb is a linear equation, it is very easy to interpret the results directly from the coefficients. The marginal productivities of GIRA, dry area, and NPK all are constant, with one more ha of gross irrigated area contributing 2,067 kg of foodgrain per ha to total production, compared to 1,217 kg of foodgrain per ha for dry area. Similarly, the productivity of fertilizer is 3.66 kg of foodgrain for each kilogram of fertilizer used. The equation indicates that the optimum rainfall is at 107% of normal. This equation also indicates that the contribution made by the net change in gross irrigated area (after subtracting the contribution made by the negative change in dry area) is 60% of the change in total foodgrain production between 1954 and 1985. The change in NPK (as an index of biochemical technology) contributes most of the remaining 40%.

This model could perhaps be improved with further research, but it is the best we have been able to find in terms of economic and statistical meaning to this point. With considerable trepidation, we have used this equation to project Indian foodgrain production out to the year 2010. The key assumptions behind this projection are: (a) that the growth in GIRA is as shown in Table 4e above; (b) that total foodgrain area will remain constant at 127 MH; and (c) that NPK per ha of GIRA will increase at a rate of 3% pa through the year 2010. The resulting projection is shown in Table 4f and Figure 4c.

In this scenario, total foodgrain production increases to 195 MT in 1996, the year in which the development of additional minor irrigation is projected to end. This represents a rate of growth of foodgrain production 2.7% pa, the same as the rate of the past three decades. Also in this year, per capita foodgrain production reaches a peak level of 203 kg, compared to 195 kg in 1985.

However, with minor irrigation at its plateau, the rate of growth of foodgrain production then decreases to only 1.9% pa over the period 1996-2010. This is less than the assumed rate of population growth, and per capita foodgrain production accordingly decreases to 192 kg in 2010, slightly below 1985 levels. The projection for 1996-2010 may be too optimistic because of the disproportionately high contribution of tubewell irrigation to foodgrain production in India.

In 2010, the development of major and medium irrigation also ends. Then, according to this equation, all future growth in foodgrain production would depend on growth of NPK (and associated HYVs). But NPK would already be at a very high level of

TABLE 4f PROJECTIONS TO THE YEAR 2010

YEAR	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
G IRR AREA	55.4	57.30	59.10	61.00	62.90	64.90	67.00	69.20	71.40	73.70	76.00	78.50	79.50	80.30	81.10	82.00	82.80	83.70	84.70	85.60	86.60	87.60	88.60	89.60	90.70	91.80
ANNUAL INCREASE		1.90	1.80	1.90	1.90	2.00	2.10	2.20	2.20	2.30	2.30	2.50	1.00	0.80	0.80	0.90	0.80	0.90	1.00	0.90	1.00	1.00	1.00	1.00	1.10	1.10
NPK @ 3% PA																										
PER HA GIRA	155	160	165	170	175	180	185	191	197	203	209	215	221	228	235	242	249	257	264	272	280	289	297	306	316	325
TOTAL NPK	8600	9162	9733	10347	10990	11679	12419	13212	14041	14928	15855	16868	17596	18306	19043	19832	20626	21476	22384	23301	24280	25297	26354	27451	28621	29837
ANNUAL INCREASE		562	571	614	642	690	740	793	829	887	928	1013	727	710	737	789	794	850	909	917	979	1017	1056	1097	1171	1216
DRY AREA MH	71.6	69.7	67.9	66.0	64.1	62.1	60.0	57.8	55.6	53.3	51.0	48.5	47.5	46.7	45.9	45.0	44.2	43.3	42.3	41.4	40.4	39.4	38.4	37.4	36.3	35.2
(127 MH FGA -GIRRA)																										
NPK/FG AREA	67.7	72.1	76.6	81.5	86.5	92.0	97.8	104.0	110.6	117.5	124.8	132.8	138.5	144.1	149.9	156.2	162.4	169.1	176.3	183.5	191.2	199.2	207.5	216.1	225.4	234.9
POPULATION @ 2.3 % PA	749	766	784	802	820	839	858	878	898	919	940	962	984	1007	1030	1053	1078	1102	1128	1154	1180	1207	1235	1264	1293	1322
PROJECTION																										
FG PROD MT	146.5	150.1	153.8	157.6	161.6	165.8	170.3	175.1	180.0	185.2	190.5	196.3	199.9	203.1	206.5	210.2	213.7	217.6	221.8	225.9	230.3	234.9	239.6	244.5	249.7	255.1
PER CAP FG	195.5	195.9	196.2	196.6	197.0	197.6	198.4	199.3	200.3	201.5	202.6	204.1	203.1	201.8	200.5	199.5	198.3	197.4	196.7	195.8	195.2	194.6	194.0	193.5	193.2	192.9

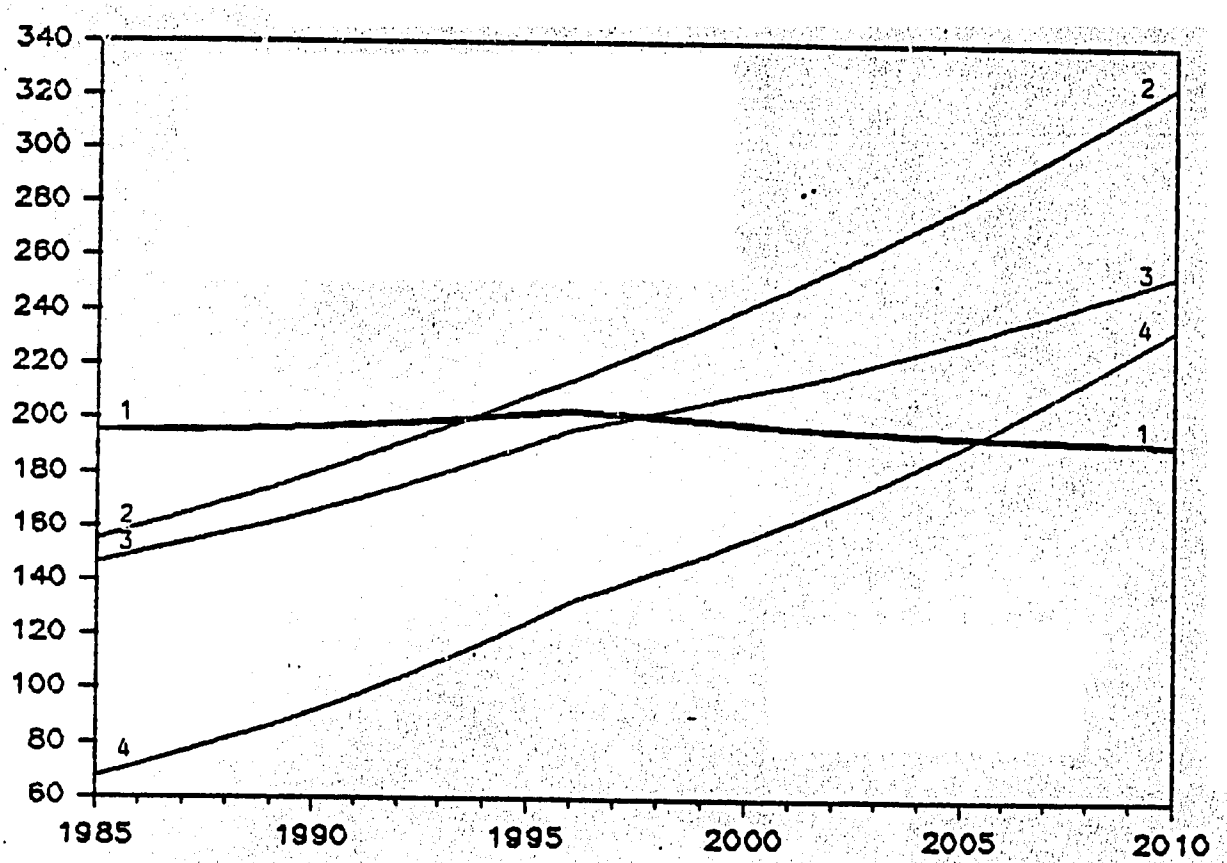


Figure 4c. Projected Foodgrain Production to 2010

1. Per capita foodgrain production
2. NPK per ha gross irrigated area
3. Total foodgrain production
4. NPK per ha of foodgrain area

use (325 kg/ha of irrigated land and 235 kg/ha of total foodgrain area; for increases of 210% and 346%, respectively, over 1985), and it will require rather spectacular progress in development of HYVs to keep the marginal product of NPK constant. This projection implies an increase of total foodgrain yield per ha of total foodgrain land of 74% over the 25-year period and, thus, further yield increases will have to be from an already high base.

As we have already emphasized in Chapter 1, we do not pretend to have a crystal ball to predict the future of Indian foodgrain production. As the old Chinese saying has it: "Prediction is extremely difficult, especially with respect to the future." Miracles, though rare, do occasionally happen.

But we do believe that both on conceptual and empirical grounds, this projection provides a rational basis for anticipating the nature of the problems India will be encountering as it approaches its third stage of agricultural development--the true Malthusian stage, where the land and water frontiers are basically closed. Of course, these frontiers could be reopened, and almost any amount of food produced in India if food prices were permitted to rise to sufficiently high levels. But without corresponding increases in the real income of the poor, poor people would be pushed below subsistence levels by these high food prices. After all, the Malthusian deluge is high food prices, a point apparently neglected by those who believe the market will solve these problems. As we argue in the next and final chapter of this report, there is very little possibility that the real income of the poor will increase over the foreseeable future, given current rates of growth of population.

Thus the conclusion of this chapter is clear. India simply must get the growth rate of her population down to around one-half the present level as soon as possible. Over the long run, this will solve her agricultural problem without miracles. On the other hand, if population continues to grow at present rates, it will require several large miracles to solve this problem.

Equation 4Ra

---------- REGRESSION ANALYSIS ----------

HEADER DATA FOR: C:INFGIRC LABEL: 11-7-85
NUMBER OF CASES: 32 NUMBER OF VARIABLES: 7

11-20-85

INDEX	NAME	MEAN	STD.DEV.
1	GIRRA	37.139375000	9.759139616
2	DRYAREA	83.216875000	4.367037408
3	RAIN	.980937500	.145033019
4	RAIN^2	.982615625	.280471499
5	NPK*GIRA	114508.885312500	132522.211213720
6	NPK	2474.843750000	2453.660611037
DEP. VAR.:	FG	98.343750000	24.934248211

DEPENDENT VARIABLE: FG

VAR.	REGRESSION COEFFICIENT	STD. ERROR	T(DF= 26)	PROB.	PARTIAL r^2
GIRRA	2.033252568	.295441417	6.882	.00000	.6456
DRYAREA	1.242341536	.334417761	3.715	.00098	.3467
RAIN	195.038891600	66.327907660	2.941	.00680	.2496
RAIN^2	-91.039950957	33.545051662	-2.714	.01164	.2206
NPK	.003740668	.001353463	2.764	.01036	.2271
CONSTANT	-191.675012396				

STD. ERROR OF EST. = 3.419244967

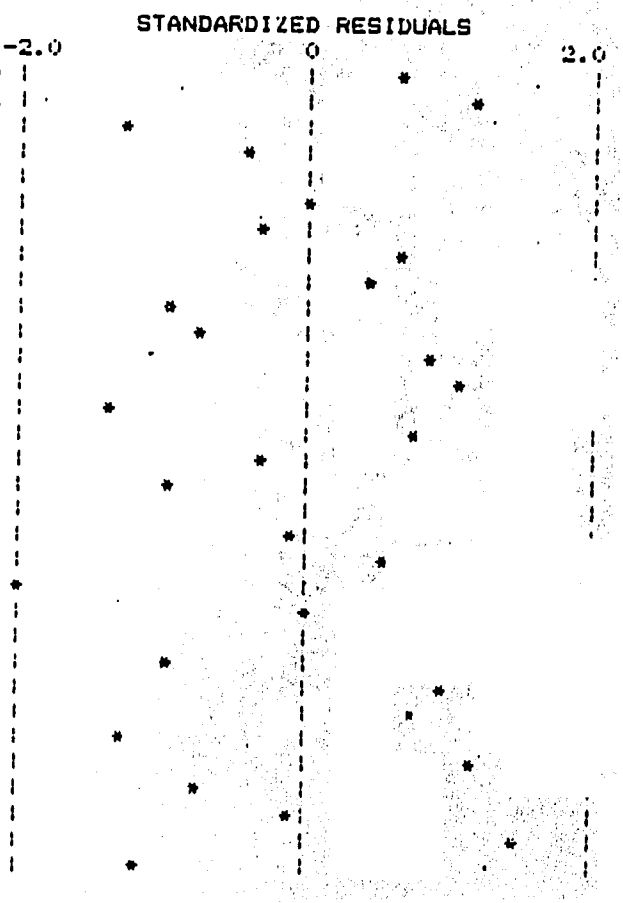
ADJUSTED R SQUARED = .981195237
R SQUARED = .984228263
MULTIPLE R = .992082790

ANALYSIS OF VARIANCE TABLE

SOURCE	SUM OF SQUARES	D.F.	MEAN SQUARE	F RATIO	PROB.
REGRESSION	18969.246610295	5	3793.849322059	324.504	.000E+00
RESIDUAL	303.972139705	26	11.691236143		
TOTAL	19273.218750000	31			

	OBSERVED	CALCULATED	RESIDUAL
1	70.000	67.859	2.140960
2	68.000	64.195	3.804862
3	67.000	71.382	-4.381538
4	70.000	71.370	-1.370419
5	64.000	63.717	.283078
6	77.000	76.915	.084993
7	77.000	78.182	-1.181675
8	82.000	79.864	2.135685
9	83.000	81.674	1.325675
10	80.000	83.239	-3.239318
11	81.000	83.510	-2.509703
12	89.000	86.337	2.663162
13	72.000	68.560	3.439788
14	74.000	78.438	-4.438221
15	95.000	92.456	2.543911
16	94.000	95.194	-1.194021
17	100.000	103.172	-3.172476
18	108.000	104.150	3.849523
19	105.000	105.337	-.337324
20	97.000	95.208	1.792035
21	105.000	111.770	-6.770439
22	100.000	99.971	.029330
23	121.000	116.735	4.264961
24	111.000	114.003	-3.002917
25	126.000	122.883	3.117495
26	132.000	129.500	2.500041
27	110.000	114.105	-4.105359
28	130.000	126.271	3.728578
29	133.000	135.477	-2.477320
30	128.000	128.353	-.353408
31	152.000	147.218	4.781634
32	146.000	149.952	-3.951572

STANDARDIZED RESIDUALS



DURBIN-WATSON TEST = 2.7059

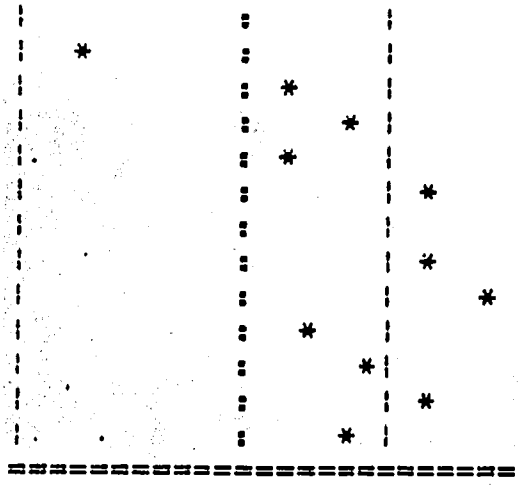
24a

SMPL 1958 - 1985 Equation 4Rb
28 Observations
LS // Dependent Variable is FG
Convergence achieved after 2 iterations

VARIABLE	COEFFICIENT	STD. ERROR	T-STAT.	2-TAIL SIG.
C	-191.41324	16.655073	-11.492789	0.000
GIRRA	2.0668041	0.1229690	16.807522	0.000
DRYARE	1.2166963	0.1846164	6.5904007	0.000
RAIN	197.35484	40.643918	4.8557041	0.000
RAIN2	-92.551497	21.020550	-4.4029056	0.000
NPK	0.0036578	0.0006636	5.5121728	0.000
AR(1)	-0.7212512	0.2147173	-3.3590742	0.003
AR(2)	-0.8060654	0.2604611	-3.0947636	0.006
AR(3)	-0.3572204	0.2558260	-1.3963412	0.180
AR(4)	-0.4835790	0.2066514	-2.3400707	0.031

R-squared	0.992088	Mean of dependent var	102.5714
Adjusted R-squared	0.988132	S.D. of dependent var	23.77585
S.E. of regression	2.590112	Sum of squared resid	120.7563
Durbin-Watson stat	2.141200	F-statistic	250.7878
Log likelihood	-60.19226		

Residual Plot



obs	RESIDUAL	ACTUAL	FITTED
1958	-0.98494	64.0000	64.9849
1959	0.30945	77.0000	76.6906
1960	-2.66404	77.0000	79.6640
1961	1.78705	82.0000	80.2130
1962	2.99458	83.0000	80.0054
1963	0.01830	80.0000	79.9817
1964	-2.68287	81.0000	83.6829
1965	0.69843	89.0000	88.3016
1966	3.48628	72.0000	68.5137
1967	-1.85292	74.0000	75.8529
1968	2.21092	95.0000	92.7891
1969	-0.16895	94.0000	94.1689
1970	-1.68311	100.000	101.683
1971	-0.51234	108.000	108.512
1972	1.02124	105.000	103.979
1973	2.93893	97.0000	94.0611
1974	-5.61962	105.000	110.620
1975	-1.87866	100.000	101.879
1976	-0.70944	121.000	121.709
1977	-1.80284	111.000	112.803
1978	0.87159	126.000	125.128
1979	3.47931	132.000	128.521
1980	0.57999	110.000	109.420
1981	1.96674	130.000	128.033
1982	-1.47289	133.000	134.473
1983	-0.30011	128.000	128.300
1984	0.79285	152.000	151.207
1985	-0.80359	146.000	146.804

Chapter 5. The Second Malthusian Race: Notes Toward a Theory of Poverty in India

Introduction

Compared to the wealth of data on agricultural production, reliable time series data on rural employment and poverty in India is virtually nonexistent. The best we can do is refer to the heroic struggles of Indian scholars with this problem and advance some hypotheses for future tests. Indeed, one of the concrete results of this study has been a recompilation of original data from farm management studies by Indian agricultural statisticians (S. K. Raheja and B. K. Bahel) to test the theory of employment elasticity explained below. Unfortunately, the results of this study are not available in time for this report. Thus this chapter is subtitled "Notes Toward..."--not out of modesty, but as a confession of inability to do more.

The Second Malthusian Race is a race between labor demand and supply curves over time. This race is conceptually illustrated in Figure 5a. Given a demand curve for labor, D_1, and a labor supply curve, S_1, the equilibrium level of employment may be at E_1, which is below the full employment level, E_f, for the given wage, W_1. This results in a temporary surplus of labor, or total underemployment, in the amount of $E_f - E_1$. This is the static situation, at a point in time. Now assume that the demand curve shifts out to the right, to D_2, because of increased national income or other effects. Then, if the supply curve remains the same, a shortage of labor develops in the amount $E_f - E_2$, and wages rise to W_2. However, if the supply curve also shifts to the right, to S_2, both wages and the degree of underemployment remain constant.

This analysis assumes a minimum wage floor (or annual income floor) below which labor will not work. This floor, which is near the "poverty line" discussed below, does, in fact, seem to exist in India. In Malthusian theory, this floor is maintained at subsistence levels by regulating population growth through variations in infant mortality on the margin of subsistence. Seckler (1980) has proposed a short-run equilibrating mechanism based on the relationships between labor productivity and the health and nutritional status of labor on the margin of subsistence. The immediate point of interest, however, is not the floor but the <u>race</u> between these demand and supply curves and the effects of this race on wages and poverty.

As noted in the first chapter, one of the striking facts about Indian economic development is that (insofar as it can be determined) the percentage of people below the poverty line has remained constant as a trend at 40% since data were first collected in the early 1950s. This means that the number of people below the poverty line has grown at the same rate as population. It also implies that the labor demand curve has been shifting out at the same rate as the labor supply curve: the second Malthusian race, in other words, has been "neck and neck".

In the next section, we do not attempt to explain these facts, only to document them. Then we advance a hypothesis about

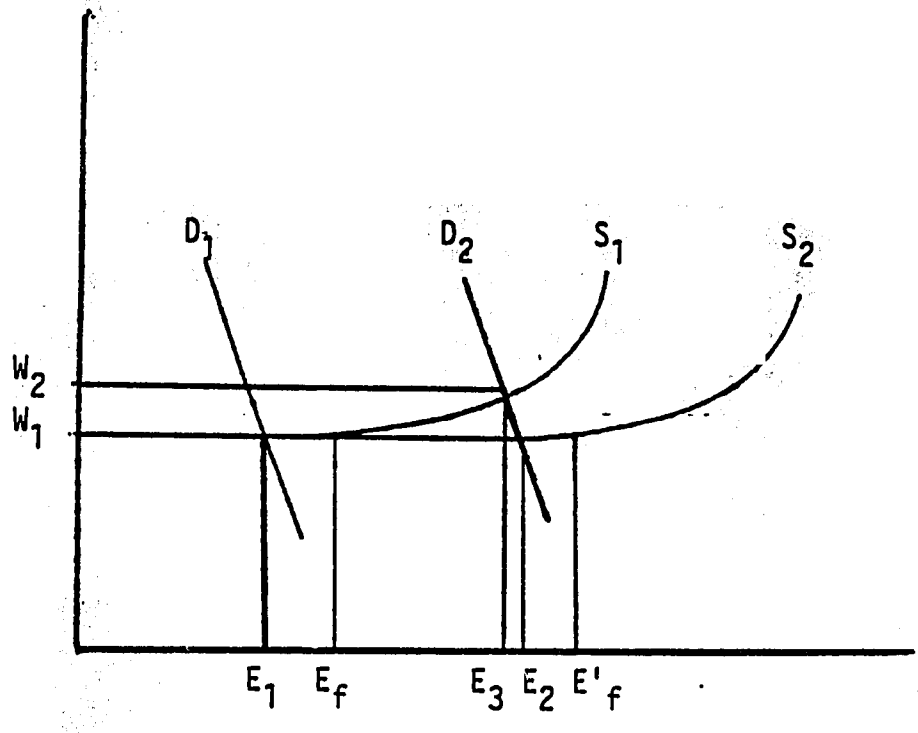


Figure 5a. Hypothetical Changes in Wages and Employment

the future outcome of this race. The hypothesis is that, regardless of what has kept this race in equilibrium in the past, the situation is likely to worsen in the future unless the rate of growth of population is reduced. The reason is that we expect the demand curve for agricultural labor to shift out at a decreasing rate as India shifts toward a biochemical mode of agricultural production while the supply curve for agricultural labor will shift out at about the same rate as in the past. Thus, as the demand for agricultural labor falls progressively behind the shifting labor supply curve, an increasing amount of surplus agricultural labor will be generated. In order to maintain the same rate of employment in the economy as a whole, the non-agricultural sectors must therefore grow faster than in the past. In the last section of this chapter, we estimate the required rates of growth of economic sectors for employment generation under various conditions and conclude that, with the present rate of popluation growth, perhaps the best that can be expected is that the state of employment and poverty in India will be about the same in the year 2000 as it is today.

Poverty in India

The title of this section refers to the classic work by Dandekar and Rath (1971), which was the first systematic study of poverty in India, and which has formed the basis of most subsequent studies.

Dandekar and Rath assumed an RDA of 2,400 calories per capita per day as the minimum nutritional requirement for the Indian population. They found through empirical studies that people consuming at this level spend 80% of their total income on food (60% on foodgrains), which leaves only 20% of their total income for all other necessities, such as shelter, clothing, cooking and heating fuel, and the like (also see Appendix C). In terms of per capita per month earnings in 1985, the poverty line in India is about Rs. 113 (U.S.$9.00) for urban areas and Rs. 98 (U.S.$7.80) for rural areas. However much one may question the RDA on which this poverty line is based, no rational person would disagree with the fact that people below this line are, indeed, "poor".

Montek Ahluwalia (1978) analyzed trends in India's rural poverty over the period 1956-1974. He concluded: "The major findings are that there has been no trend, up or down, in the incidence of absolute poverty over the period, but there has been considerable fluctuation, with the incidence of poverty inversely related to agricultural performance."

Ahluwalia's estimates of poverty in rural India are given in Table 5a. Estimate I in the table uses the all-India poverty line for various years of the NSS consumption distribution for rural India. Estimate II uses a weighted sum of the estimated percentages of poverty in individual states, obtained from the NSS distribution for individual states and the state-specific poverty line. As Ahluwalia argues, Estimate II is a better estimate of rural poverty in India than Estimate I because there

Table 5a

Percentage of Rural Population in Poverty

	Estimate I Based on All-India Poverty Line	Estimate II Based on State Specific Poverty Line	Size of the Poverty Population (Millions) Derived from Estimate I	Estimate II
1956-57	54.1	N.A	181.0	N.A.
1957-58	50.2	53.4	171.4	182.4
1958-59	46.5	N.A	161.8	N.A.
1959-60	44.4	48.7	157.6	172.8
1960-61	38.9	42.0	141.2	152.4
1961-62	39.4	42.3	145.9	156.6
1963-64	44.5	49.1	171.4	189.1
1964-65	46.8	50.4	183.8	197.9
1965-66	53.9	51.1	215.9	204.7
1966-67	56.6	57.4	231.2	234.5
1967-68	56.5	57.9	235.3	241.1
1968-69	51.0	53.5	216.6	227.2
1970-71	47.5	49.1	209.5	216.6
1973-74	N.A	47.6	N.A	221.3

Source: Ahluwalia (1978) adapted from Table 2, p. 15.

were substantial differences in prices in the base year and because inflation occurred at different rates across states.

A striking result from Ahluwalia's study is the large fluctuation over time in the incidence of rural poverty. It initially declined from over 50% in the mid-1950s to around 40% in 1960-61, rose sharply through the mid-1960s, reaching a peak in 1967-68, and then began to decline again.

Ahluwalia's analysis over this period clearly shows that there is no discernible trend in the incidence of poverty. The incidence of poverty falls in periods of good agricultural performance and rises in periods of poor performance. The analysis of the time pattern of poverty in individual states shows it follows the pattern of fluctuation described for India as a whole. The percentage of the rural population in poverty by states is given in Table 5b.

According to Ahluwalia, the evidence concerning the relationship between rural poverty and agricultural performance is somewhat mixed. As he says:

> Much depends upon the level of aggregation at which the analysis is conducted, with the all-India results presenting a somewhat different picture from that obtained at the level of individual states. At the all-India level, there is strong support for the hypothesis that the incidence of rural poverty is inversely related to agricultural performance....While this correlation does not establish the causal mechanisms involved in the process, it does suggest that faster agricultural growth might have led to a reduced incidence of poverty.
>
> The state-level analysis presents a somewhat different picture. On the one hand, we find a significant inverse relationship between growth and poverty in at least seven states accounting for three-fourths of the rural poor. On the other hand, the state-level analysis also shows that there may be processes at work in the rural economy which tend to increase poverty over time (pp. 39-40).

This last sentence is the subject of the next section.

Table 5b

PERCENTAGE OF RURAL POPULATION IN POVERTY BY STATES

	1957-58	1959-60	1960-61	1961-62	1963-64	1964-65	1965-66	1966-67	1967-68	1968-69	1970-71	1973-74
Andhra Pradesh	53.5	48.8	50.1	47.2	45.6	41.5	45.4	47.9	46.0	47.3	41.0	39.8
Assam	28.0	31.4	25.6	29.4	24.4	24.2	31.3	46.8	38.4	47.3	35.3	39.3
Bihar	59.7	55.7	41.5	49.9	52.3	54.3	59.4	74.4	70.9	59.4	59.0	58.4
Gujarat	1/	41.5	31.6	39.7	45.7	49.8	50.7	54.1	50.8	42.5	43.8	35.6
Karnataka	41.3	48.9	39.1	35.4	50.5	55.1	63.9	59.5	56.9	58.8	47.2	-6.9
Kerala	59.6	62.3	57.8	50.3	52.6	60.7	70.7	67.1	63.4	64.6	62.0	-9.3
Madhya Pradesh	57.7	46.4	43.8	40.0	43.6	42.1	47.2	58.3	62.3	56.0	52.9	52.3
Maharashtra	1/	54.5	48.4	43.6	48.2	59.1	57.8	61.2	57.2	54.8	46.6	49.8
Orissa	66.6	63.4	62.4	49.3	60.0	61.9	62.1	64.2	64.7	71.2	65.0	55.0
Punjab & Haryana 2/	28.0	24.2	18.8	22.3	29.4	26.5	26.5	29.5	33.9	24.0	23.6	23.0
Rajasthan	33.4	n.a.	32.3	33.0	32.6	31.8	30.8	37.1	35.9	41.4	41.8	29.8
Tamil Nadu	67.8	64.4	53.9	51.0	52.0	57.4	59.5	62.7	58.1	60.6	57.3	45.3
Uttar Pradesh	52.3	36.7	37.9	35.4	56.6	53.7	47.1	55.2	60.2	46.4	40.6	[illegible]
West Bengal	62.3	61.4	40.4	58.3	63.3	64.0	56.5	64.3	80.3	74.9	70.1	6[illegible].0
INDIA Estimate II (Weighted Averages)	53.4	41.7	42.0	42.3	49.1	50.4	51.1	57.4	57.9	53.5	49.1	4[illegible].6

1/ Figures for Gujarat and Maharashtra are not available separately for the year 1957-58 since NSS tabulations for that year refer to the old Bombay State including both Maharashtra and Gujarat. The poverty incidence for Bombay State is 66.2 and this figure has been used with the combined weights for Gujarat and Maharashtra to calculate the all-India weighted average.

2/ NSS data report a single distribution for the old Punjab State (including Haryana) up to 1963-64, after which separate distributions are reported for Punjab and Haryana. The poverty incidence for the years after 1963-64 is based on a pooling of the data for the two states using rural populations of Punjab and Haryana as recorded in the 1971 Census as weights. It should be noted, however, that parts of the old Punjab States were merged into Himachal Pradesh and the Union Territory of Delhi. Our procedure ignores this problem but the error is likely to be extremely small.

Source: Ahluwalia (1978)

A Hypothesis on Agricultural Employment Under Different Modes of Production

There are three distinct although interrelated modes of agricultural production, and each can have considerably different effects on employment.

First is the "resource-intensive mode", where production is increased through the application of more and better quality land and water resources. Land resources are increased through new cultivated area (net area) and multiple cropping (gross area). Water resource inputs are increased through irrigation and water conservation measures and technologies.

Second is the "biochemical mode". Here, yields increase through the application of improved seeds, fertilizers (including natural fertilizers), and pesticides to the same land and water resources. The biochemical mode can also contribute to the resources mode through shorter duration and more drought-resistant varieties of plants, and by bringing poor soils into production through fertilizers, more suitable varieties, and the like.

Third is the "mechanization mode". This mode should be divided into two submodes: labor-increasing mechanization and labor-saving mechanization. The distinction depends upon the total effect of mechanization on agricultural employment. An example of labor-increasing mechanization is pump irrigation, which induces high labor use in irrigated agriculture. An example of labor-saving mechanization is the use of tractors for shallow ploughing--a number of laborers with spades could do the same job, in the same time. An intermediate case is mechanical threshing. If it speeds harvesting activities so that a second crop can be planted, it is labor-increasing through its effect on employment in the second crop. If it does not, it may be purely labor-saving.

Agricultural systems tend to evolve through these three modes sequentially, as stages. Thus, as the costs of developing new land and irrigation facilities increase, investments are allocated more to yield-increasing biochemical inputs. As labor costs rise and increased yields justify the costs, investments are allocated to labor-saving forms of agriultural mechanization. But the sequential nature of these modes is more a matter of degree than of absolute stages. Thus irrigation, biochemical inputs, and mechanization may all combine to increase multiple cropping through improved water regimes in dry seasons, shorter duration and drought-resistant plant varieties, and rapid harvest and land preparation activities between crops.

Nevertheless, if information is available, it is possible to separate each of these modes, even if they overlap, and to estimate their differential impacts on agricultural employment. For this purpose, the essential concept is the employment elasticity of production: the percentage change in employment divided by the percentage change in production. For example, if employment elasticity is one, then a given percentage increase in production is accompanied by an equal percentage increase in employment. On the other hand, if the elasticity is only 0.20, then employment increases only 20% as rapidly as production.

Thus the concept of employment elasticity provides the bridge between the growth of employment and the growth of production over which most of the effects of interest here flow.

The subject of employment elasticity in Indian agriculture may first be approached analytically and then, with much more difficulty, empirically.

Analytically, the important distinction is between fixed and variable labor inputs in agricultural operations. For example, when new land is brought into production or non-irrigated land is irrigated, labor input may increase even more than proportionately to the increase in production, so that employment elasticity is above unity. But after this transformation is complete, most of the pre-harvest labor inputs involved in land preparation, interculture, and irrigation are essentially fixed costs that do not vary substantially with further increases in yield. On the other hand, in the absence of mechanization, harvest and post-harvest operations do vary roughly in proportion to yield. Much the same is true in the transition to more intensive use of biochemical inputs. At first, the farmer, encouraged by high yields, invests more labor in pre-harvest operations, but then as dimishing returns set in, labor input stabilizes. In this case, the effect is complicated by the fact that chemical fertilizers and pesticides may reduce pre-harvest labor input from that required by natural manures and hand weeding. Thus, on a per crop basis, the employment elasticity of pre-harvest operations would be expected first to increase in the transition stage to higher yields, but then to <u>decrease</u> as yields continue to increase. On the other hand, the employment elasticity of harvest and post-harvest operations would remain about the same without mechanization--or likely decrease with mechanization.

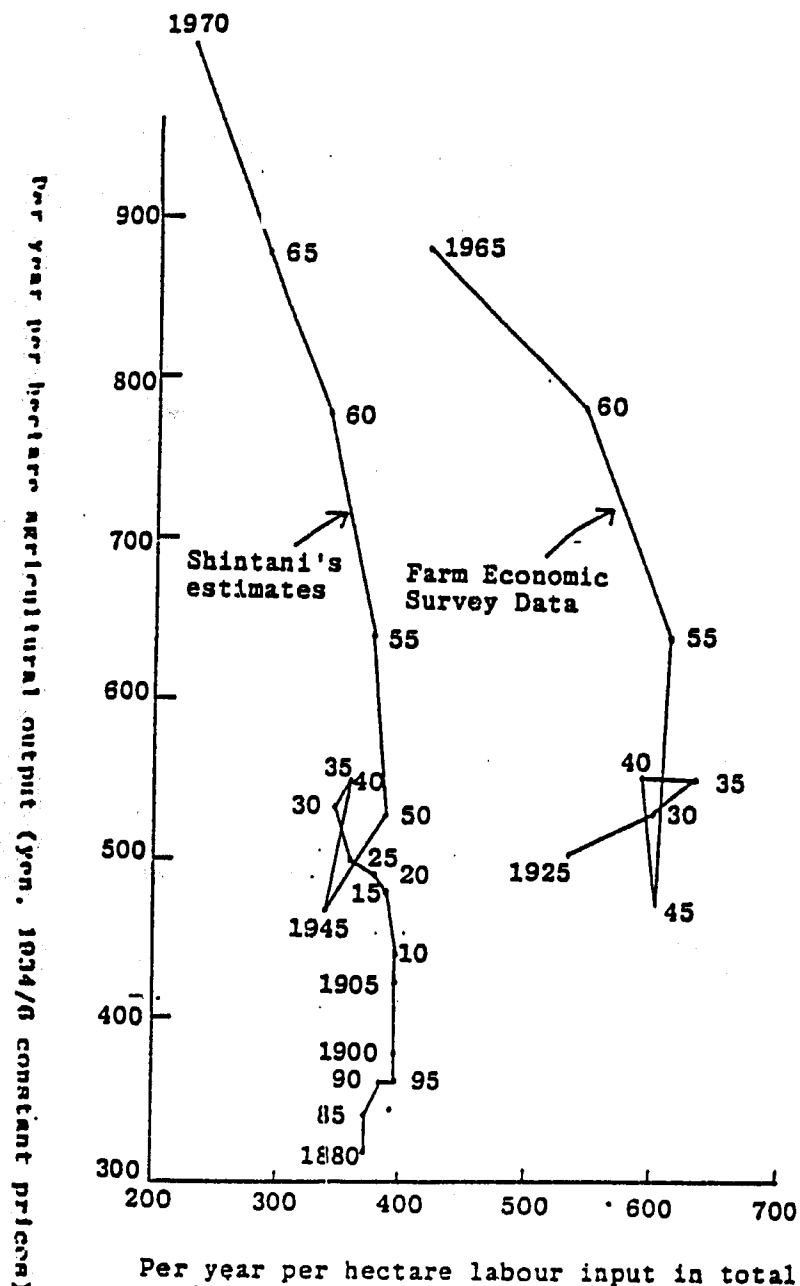
Since pre-harvest operations typically constitute about two-thirds of total labor input in agriculture, the prospect that employment elasticity would be expected to decrease as yield increases is a proposition of considerable significance to the prospects for the demand for agricultural labor. It means that as countries shift from the resource mode to the biochemical mode, the rate of growth of agricultural production must increase to compensate for decreasing employment eleasticity to maintain the same rate of growth of labor demand. As Alice says, "We must run faster and faster just to stay where we are."

Historical data on agriculture in Japan, shown in Figure 5b, illustrate the issues at stake. While the value of agricultural output per hectare doubled from 1880 to about 1955, labor input per ha hardly changed at all, resulting in an employment elasticity of zero. After 1955, output increased by about a third, while labor input substantially decreased, due to mechanization, resulting in negative employment elasticity.

Unfortunately, while there are innumerable studies of labor input per unit of land in the published literature on Indian agriculture, there are almost no published studies of labor input per unit of output at the farm level. And while there are many studies of labor input per unit of land or yield per unit of land, there are very few that give <u>both</u> input and yield under

Figure 5b

Path of Change in Per Year Per Hectare Labor Input in Total Agricultural Production -- Farm Economic Survey Data and Shintani's Estimates: 1880/1970



Per year per hectare labour input in total agricultural production (Working days)

Source: Hara's paper, Fig. 5.

varying conditions so that employment elasticities can be computed.

For this reason, before proceeding to the limited data available for India, some exceptionally interesting data on rice production and yield in Indonesia may be reviewed. This data has been gathered and compiled by Collier (1979). Table 5c shows a selection of Collier's data, selected mainly for these cases where yield data is provided.

First, there is the data from a study of a farm in East Java, in 1878. Unfortunately, yield is not reported. But it is interesting to see that total labor input per ha was as high on that farm, at that time, as in all but four of the more recent cases--and most of the recent cases were much lower.

The next set of data is from the period 1924-1930. Average labor input per ha per crop was 1540 hours, with 63% in pre-harvest operations and 37% in harvest and post-harvest (HAR) operations. The average for all of Collier's cases is also shown. The selection here appears to be reasonably representative of the total.

The last data set is for the same farms in 1969, divided between those using local and high-yield varieties (HYVs). It is clear that there is no significant change between periods or varieties in terms of total labor input per ha, or its division between pre-harvest and harvest and post-harvest operations. However, there were some changes within operational categories.

Finally, employment elasticities with respect to yields are calculated for the operations between the two periods and between local and HYVs. Between periods, employment elasticities were positive for all operations except harvest and transplanting. As Collier notes, the change from the traditional, razor-like ani-ani to scythes in crop harvesting resulted in some labor saving. This may have been supplemented by mechanical threshing. Why labor input per ha for transplanting decreased 46% is a mystery.

In the change from local to HYVs, elasticities are negative for all operations except weeding and harvesting. The positive elasticity for harvesting in this case, in light of the above, is again a mystery.

None of this evidence is conclusive in detail, but perhaps the grand total provides a reasonable basis for inference. If so, it appears that employment elasticities in Indonesia, both over time and with improved technology, are zero or negative even with rather small changes in labor-saving mechanization.

Lastly, the few bits of data that this study has been able to find for India are shown in Table 5d. First, the effects of the change from traditional to HYVs for wheat and rice are shown in Section A of the table. The employment elasticity varied from 0.58 to 0.18 for wheat; and, like the Javanese data, is zero for rice. In the case of the change from non-irrigated to irrigated wheat shown in Section B, the employment elasticities are, as would be expected, very high. Indeed, three of the five cases have an average elasticity of about 1.30, while the fourth is at 0.83. The very low elasticity of the fifth case makes it a decided outlier which probably should be rejected.

Thus it is clear even from this limited evidence that the effects of increased agricultural production on agricultural

TABLE 5c LABOR AND YIELDS IN JAVA (JAVALY)

VILLAGE	FARM HA	SEED-BED	FIELD PREP	TRANS-PLANTING	FERT & SPRAYING	WEEDING	HARVEST	DRYING & STORING	TOTAL PRE-HAR	TOTAL -HAR	GRAND TOTAL	YIELD TONNES/HA	KG PER HR
1878													
KIDIRI-		63	595	230		594	286	120	1482	406	1888		
1924-1930													
SAWO	0.56	21	230	314		10	444		575	444	1019	1.31	1.29
KARANG-	0.66	29	167	409		43	526		648	526	1174	1.53	1.30
JAHN	1.79	10	136	305		15	740		466	740	1206	2.5	2.07
DJATISARI	0.93	39	223	258		290	501	68	810	569	1379		
KUNINGAN		88	229	690		421	406		1428	406	1834	1.33	0.73
MAJA	1.1	74	381	673		124	277		1252	277	1529	1.6	1.05
KENEP A	0.41	26	413	484		459	876		1382	876	2258	1.8	0.80
KENEP B	0.33	92	447	412		254	713		1205	713	1918	1.6	0.83
AVERAGE	0.81	47	278	443		202	560	68	971	569	1540	1.67	1.15
% TOTAL		0.03	0.18	0.29		0.13	0.36	0.04	0.63	0.37			
COLLIER AVG		51	267	386		220	531	68	924	599	1523		
% TOTAL		0.03	0.18	0.25		0.14	0.35	0.04	0.61	0.39			
1969													
LOCAL VAR													
SENENG	0.45	44	241	242	16	264	475	21	807	496	1303	1.16	0.89
GEMARANG	0.22	69	393	303	53	597	647	49	1415	696	2111	1.39	0.66
SIDOMULYO	0.19	65	431	200	73	316	166	98	1085	264	1349	5	3.71
JANTI	0.58	63	370	208	59	310	195	126	1010	321	1331	2.76	2.07
HYV													
SENENG	0.19	51	328	270	50	573	475	47	1272	522	1794	3.2	1.78
GEMARANG	0.38	40	245	249	29	346	678	33	909	711	1620	2.33	1.44
SIDOMULYO	0.46	43	331	144	49	282	187	43	849	230	1079	5.27	4.88
AVERAGE													
LOCAL VAR	0.36	60	359	238	50	372	371	74	1079	444	1524	2.58	1.83
% TOTAL		0.04	0.24	0.16	0.03	0.24	0.24	0.05	0.71	0.29			
HYV	0.34	45	301	221	43	400	447	41	1010	488	1498	3.60	2.70
% TOTAL		0.03	0.20	0.15	0.03	0.27	0.30	0.03	0.67	0.33			
% CHANGE 1969/1924-1930		27	29	-46		84	-34	8	11	-22	-1	55	59
ELASTICITY		0.50	0.53	-0.85		1.54	-0.62	0.15	0.20	-0.40	-0.02		
% CHANGE HYV/LOCAL VARIETIES		-26	-16	-7	-15	8	20	-44	-6	10	-2	40	47
ELASTICITY		-0.65	-0.40	-0.18	-0.38	0.19	0.52	-1.11	-0.16	0.25	-0.04		

(NOTE: SIDOMULYO 1969 HARVEST LABOR REPORTED AS 87; CHANGED TO 187)
(Source, Collier 1979)

Table 5d

LABOR INPUTS IN AGRICULTURE

A. HYVS AND TRADITIONAL VARIETIES

CROP/CASE	MANDAYS HYV	MANDAYS TRAD	YIELD QUINTALS HYV	YIELD QUINTALS TRAD	% INCREASE MANDAYS	HYV/T YLD	EMP ELAST
WHEAT							
1	68.2	52.2	25.4	15.99	0.27	0.45	0.58
2	63.1	58	30.5	18.74	0.08	0.48	0.18
PADDY							
	91.9	91.8	41.41	27.14	.00	0.42	.00

B. IRRIGATED AND NONIRRIGATED

WHEAT	IRR	NIRR	IRR	NIRR			
1	40.5	16.8	6.9	3.4	0.83	0.68	1.22
2	53.9	13.3	5.9	2.1	1.21	0.95	1.27
3	34	28	11.4	6.4	0.19	0.56	0.34
4	26.6	14.4	10.3	6.7	0.60	0.42	1.41
5	27.8	12.9	12.9	5	0.73	0.88	0.83

SOURCE: S. MEHRA. 1976

employment very much depend on which of the three modes, or combination of modes, prevails. The resource-increasing mode generates a large amount of employment, with elasticities of over unity in the initial stages of development and continuing high labor inputs thereafter. The biochemical mode is subject to decreasing elasticities that perhaps approach a lower limit at around 0.30 set by harvest and post-harvest labor requirements. Last, the labor-saving submode of mechanization may create negative employment elasticities.

In conclusion, the future demand for agricultural labor in India will depend on the degree to which agricultural production proceeds along the three modes of resource development, biochemical inputs, and labor-saving mechanization. Given the lack of data on actual employment elasticities, it is impossible to make exact estimates. But as Indian agriculture develops progressively away from the resources mode to the biochemical mode, the direction of change in employment elasticities will almost certainly be downward--whether labor-saving mechanization develops or not. This, in turn, means either that the rate of growth of agricultural production must accelerate in compensation, or the other employment sectors must accelerate, or both, if the same rate of employment of agricultural labor is to be maintained in the future. This issue is the subject of the next and last section.

Prospects for Employment in India

In this brief concluding section we attempt a very rough estimatation of the employment situation to the year 2000. This is the approximate time through which the rate of growth of agricultural production is expected to be about 2.7%, according to the analysis of the preceding chapter, after which it decreases. We describe this as the employment "situation" rather than "outlook" or "projection" because the intent here is to attempt to define required rates of growth of the non-agricultural sector to maintain the existing employment situation without pretending to know exactly what this situation actually is. Thus this section is more a test of the sensitivity of possible future employment outcomes to specific conditions than a predictive effort.

The basic employment assumptions and their possible results are shown in Table 5e. Perhaps the best place to begin is with the forecast of labor supply, based on GOI estimates, in Row 6. It is seen that total labor supply is expected to rise from 224 million in 1980 to 376 million in 2000, an increase of 69%. Row 7 shows that the estimated amount of underemployment (including unemployment) in 1980 is 73 million standard person-years, an underemployment rate of 33%. Although this figure really is not known, it is assumed for the moment that it is valid. Given a 2.7% rate of growth for the agricultural sector and 7.2% for the non-agricultural sector, underemployment will rise to 106 million in 2000 with constant employment elasticities. If agricultural employment elasticity falls from 0.67 to 0.40, underemployment will rise to 121 million person-years. The rates of underemployment for these elasticities are

Table 5e

	Year 1979-80	Year 2000 Scenario I	Year 2000 Scenario II
Employment Elasticity*			
1. Agricultural	0.67	0.67	0.40
2. Non-Agricultural	0.56	0.56	0.56
Employment (In Million Standard Person-Years)			
3. Agricultural	80.33	114.97	99.58
4. Non-Agricultural	70.78	155.37	155.37
5. Total Employment (3&4)	151.1	270.37	254.95
6. Total Labor Supply**	224.06	375.81	375.81
7a. Underemployment	72.96	105.47	120.86
7b. Additional Under-Employment	---	32.51	47.90
8. Required Growth Rate of Non-Agricultural Sectors to Absorb All the Surplus Labor	---	12.03	12.58
9. Agricultural Employment as % of Total Employment	53.16	42.53	39.06
10. Required Growth Rate of Non-Agricultural Sectors to Absorb Only the Addition to Labor Surplus (i.e., Underemployment -72.96)	---	8.93	9.67
11. Row 10 minus the Planned Growth Rate in the Non-Agricultural Sector (7.16%)	---	1.77	2.51
12. Additional Investment Required in the Non-Agricultural Sectors (over the planned growth rate of 7.16% pa) (in Trillion Rupees)	---	2.16	3.18
13. Required Increase in Annual Investment in Non-Agricultural Sectors as % of Planned Investment for 7.16% Growth Rate	---	41.94	61.75

* Notes on the next page.

NOTES:

Sixth Plan projection of non-agricultural growth during 1980-85 is 7.16%.
Our estimate of long-range agricultural growth based on the analysis of last three decades of growth, 2.7%.

* Based on the Sixth Plan Document.
** Based on Agricultural Commission projection of participation rate of 35.9% in 2001.
*** Sixth Plan projection of investment in non-agricultural sectors during 1980-85 equals 1,287,280 million Rupees, for an average annual investment of 257,456 million Rupees.

28% and 32%, respectively, slightly lower than the assumed rate for 1980.

Row 9 shows the rate of growth of the non-agricultural sector that would be required to absorb all the assumed underemployment. These are very high rates, over 12% pa. Also, as shown in Row 9, the percentage of the work force employed in agriculture would decrease from 53% in 1980 to around 40% in 2000. This would break another remarkable constant in Indian economic history--namely, that the percentage employed in agriculture has been between 50% and 55% throughout this century.

But perhaps the above objective of full employment is too ambitious, especially since the present extent of underemployment in agriculture is really not known. Row 10 shows the relevant growth rates required to employ only the addition to the work force over the 1980-2000 period. The required rate of growth of around 9% is not impossibly high, although it is substantially above past rates of growth of the non-agricultural sector about 5.6% pa over the past decade.

Although it may at first seem odd, Row 11 shows that a decrease in agricultural employment elasticity from 0.67 to 0.40 can be compensated for by only a 0.74% increase in the rate of growth of the non-agricultural sector. This is because the growth of the agricultural sector is very low relative to the non-agricultural sector. However, this impression can also be deceptive in terms of investment requirements for the two sectors. The Planning Commission estimates that one million rupees invested in agriculture generates 45 standard person-years of employment compared to only 15 years for the non-agricultural sector. Thus, as shown in Row 13, the decrease in agriculture employment elasticity would require the amount of investment needed to employ the additional work force to rise by about one-third, or (Row 12) by about one trillion rupees (U.S.$80 billion), over the twenty-year period.

In conclusion, it must be emphasized again that these are only rough calculations designed primarily to provide a feel for the situation. Perhaps all that can be said here is that even under the best conditions it will be difficult for India to hold the line on employment and poverty, and the situation could get worse. On the other hand, if birth rates could be substantially reduced, labor shortages could develop in the next two decades and India would be well on the way to solving the problems of employment and poverty.

Appendix A. Historical Background

Table A1 shows the basic historical data referred to in Chapter 1. There are a great variety of estimates of percapita foodgrain production in early India, some of which are shown in Table A2. We have not been able to explore this problem in the depth we would like, but we do feel that these estimates are reasonably close to the truth and that the general pattern (if not precisely the absolute level) of per capita foodgrain production shown in Figure 1a of the text is accurate.

The statistics on foodgrain production from 1901-1950 are from Sen (1971, Annexure II, pp. 16-19). This data is based on "Studies Made by the Directorate of Economics and Statistics of the Ministry of Food, C.D., Cooperation and Agriculture and the Agro-economic Research Center, Delhi University" (Sen, 1971, p. 2). We are grateful to S. K. Ray for background information on this series.

The data is divided into two series. Series I is for "undivided India", 1901-1948. Series II is for the "Indian Union", 1937-1966. Because the objective here is to compile a continuous series for present-day India (which is assumed to be the same as for the "Indian Union"), Series I must be spliced into Series II. Why this was not done at the time is not known, but fortunately, the two series overlap for the period 1937-1949. On the average, Series II is 90% (±2%) of Series I over this period. This is also the percentage difference in the base year, 1945, used for compiling index numbers for Series I. Therefore, it is assumed that if Series I is reduced by 10% for the period 1901-1936, the resulting figures represent foodgrain production in that period in terms of the present Indian nation.

For the period 1950-1966, a special MOA-adjusted series has been used (MOA, Appendix E). This data corresponds reasonably well with Series II where it overlaps. Finally, for 1967-1985, routine MOA data is used.

Heston (1984) discusses various estimates of agricultural production in India, including his own, shown in Table A2. Blynn estimates net total foodgrain production in 1901 at 230 kg per capita for undivided India. If Blynn's net is about 10% of gross, this estimate is virtually the same as that used here for present India. Sivasubramonian's estimates do not include all foodgrains.

Heston's low estimates are based on the assumption that foodgrain yield did not increase in the period. In light of the large expansion of irrigation during the period, this is a most questionable assumption. Heston also argues that, while per capita foodgrain production did decrease from the early part of this century, it must not have decreased substantially because real prices did not rise. But demand is a function of income, not just need, and increasing prices of non-foodgrain necessities, discussed in Chapter 2, may have absorbed effective demand. This, together with lower wages from increased labor supply, may have prevented prices from rising.

TABLE A1. FOODGRAIN PRODUCTION AND POPULATION 1901-1985

YEAR	POPULATION 1000S	DECADAL RATE PA	INCREMENT 1000S	FOODGRAIN GROSS PROD MT	CHANGE PA	PER CAPITA GROSS KG	PER CAPITA NET KG
1891	236000	0.001011					
1901	238396	0.005602	2396	60		253	221
1902	239732			56	-0.07	233	204
1903	241075			65	0.16	269	235
1904	242425			64	-0.01	264	231
1905	243783			63	-0.01	258	226
1906	245149			59	-0.06	242	212
1907	246522			61	0.03	248	217
1908	247903			53	-0.13	214	187
1909	249292			55	0.03	220	193
1910	250689			72	0.31	287	251
1911	252093	-0.000307	13697	72	0.00	286	250
1912	252016			69	-0.04	275	241
1913	251938			64	-0.08	254	222
1914	251861			58	-0.10	229	200
1915	251784			62	0.08	247	216
1916	251707			68	0.10	272	238
1917	251630			73	0.07	290	253
1918	251552			71	-0.02	283	247
1919	251475			49	-0.32	193	169
1920	251398			69	0.43	276	241
1921	251321	0.010495	-772	53	-0.23	211	185
1922	253958			67	0.23	262	229
1923	256624			72	0.08	281	245
1924	259317			60	-0.16	233	203
1925	262038			62	0.03	237	207
1926	264788			59	-0.04	224	196
1927	267567			59	0.00	222	194
1928	270375			57	-0.05	210	183
1929	273212			61	0.08	224	196
1930	276080			62	0.01	225	197
1931	278977	0.013389	27656	63	0.01	226	198
1932	282712			64	0.01	226	198
1933	286497			61	-0.04	214	187
1934	290333			60	-0.01	208	182
1935	294220			60	0.00	205	179
1936	298160			57	-0.06	190	166
1937	302151			65	0.15	215	188
1938	306197			63	-0.03	206	180
1939	310296			59	-0.06	190	166
1940	314451			61	0.03	194	170

POPULATION OF THE FIRST YEAR OF THE DECADE ARE FROM THE CENSUS OF INDIA FOR PRESENT-DAY INDIA. ANNUAL POPULATION DATA IS EXTRAPOLATED FROM THE COMPOUND RATES SHOWN.
NET FOODGRAIN PRODUCTION IS ASSUMED TO BE 87.5% OF TOTAL.

CONTINUED

YEAR	POPULATION 1000S	DECADAL RATE PA	INCREMENT 1000S	FOODGRAIN GROSS PROD MT	CHANGE PA	PER CAPITA GROSS KG	PER CAPITA NET KG
1941	318661	0.012578	39684	59	-0.03	185	162
1942	322669			58	-0.02	180	157
1943	326728			64	0.10	196	171
1944	330837			65	0.02	196	172
1945	334998			63	-0.03	188	165
1946	339212			58	-0.08	171	150
1947	343478			57	-0.02	166	145
1948	347799			59	0.04	170	148
1949	352173			57	-0.03	162	142
1950	356603			55	-0.04	154	135
1951	361088	0.019784	42427	51	-0.07	141	124
1952	368232			52	0.02	141	124
1953	375517			59	0.13	157	137
1954	382947			70	0.19	183	160
1955	390523			68	-0.03	174	152
1956	398249			67	-0.01	168	147
1957	406128			70	0.04	172	151
1958	414163			64	-0.09	155	135
1959	422357			77	0.20	182	160
1960	430714			77	0.00	179	156
1961	439235	0.022400	78147	82	0.06	187	163
1962	449074			83	0.01	185	162
1963	459134			80	-0.04	174	152
1964	469418			81	0.01	173	151
1965	479934			89	0.10	185	162
1966	490684			72	-0.19	147	128
1967	501676			74	0.03	148	129
1968	512914			95	0.28	185	162
1969	524403			94	-0.01	179	157
1970	536150			100	0.06	187	163
1971	548160	0.022559	108925	108	0.08	197	172
1972	560526			105	-0.03	187	164
1973	573171			97	-0.08	169	148
1974	586101			105	0.08	179	157
1975	599323			100	-0.05	167	146
1976	612843			121	0.21	197	173
1977	626668			111	-0.08	177	155
1978	640805			126	0.14	197	172
1979	655261			132	0.05	201	176
1980	670043			110	-0.17	164	144
1981	685159	EXTRA-	136999	130	0.18	190	166
1982	700616	POLATED		133	0.02	190	166
1983	716421			127	-0.05	177	155
1984	732583			152	0.20	207	182
1985	749109			146	-0.04	195	171
1986	766008						
1987	783289						
1988	800959						
1989	819028						
1990	837504						
1991	856398		171239				

Table A2

Some social and economic indicators for India, and other countries (selected years, 1857–1946)

	1857	1871	1881	1891	1901	1911	1921	1931	1941	1946
(1) Population (mil)	242.6	255.2	257.4	282.1	285.3	303.3	305.7	338.2	389.0	412.3
(2) Per capita income (1946–7 prices)		133.6	140.3	144.1	155.6	175.8	173.4	184.8	174.8	177.4
Nutrition and health										
Net availability of foodgrains										
(3) Blyn–British India tons per/person/year				0.20	0.23	0.23	0.22	0.20	0.16	0.16
(4) Sivasubramonian India tons per/person/year					0.20	0.20	0.20	0.18	0.15	0.14
(5) Present study India tons per/person/year					0.17	0.18	0.18	0.17	0.15	0.16
(6) Expectation of life of male age 0			23.7	24.6	23.6	22.6	19.4	26.9	32.1	
(7) Expectation of life of male age 10			34.0	35.5	34.7	33.4	26.7	36.4	41.2	
(8) Infant mortality rate						205	198	179	160	
Education										
(9) Number of students – all levels (000)		189.5	264.4	385.7	441.7	678.0	838.1	945.4	1577.0	

Appendix B. Precipitation and Agricultural Production in India

Research in the relationships between precipitation and agricultural production in India was pioneered by Cummings and Ray (1968) and extended and refined by Ray (1983). Sanderson and Roy developed a separate index to 1977. These indices are very thorough and comprehensive aggregations of precipitation data for all the states, weighted by the contributions of each state to crop production by seasons. A disadvantage of these indices is their very thoroughness: they require a great deal of data and computation. For this study, we attempted to develop a simpler index that could easily be used for recent years, where the other indices are not available. We arrived at an even simpler index than we thought possible, and, as shown in the text, it has worked quite well in analysis of foodgrain production over the period 1954-1984.

Table B1 provides the relevant data for this appendix. Figure B1 compares the Ray index, the Sanderson-Ray (S-R) index, and the Seckler-Sampath (S-S) index. In general, the three indices move together, but the S-S index tends to be more volatile than the other two (except for 1957). The major reason for this is the much smaller number of states and seasons used in the S-S index, as explained below, thus reducing smoothing effects due to averaging over large numbers.

Figures B2, B3, and B4 show the residuals from the (log) trend analysis of foodgrain production of Chapter 3 expressed as a percentage of actual foodgrain production for the year, in relation to the three indices. It is difficult to interpret the S-S index directly because of the upside-down "U" function described in Chapter 3. However, a discrepancy occurs in 1977, where the foodgrain residuals are lower than would be indicated by the S-S index. In this case, the other indices would have been better, but it is not clear that this is true over all the observations.

In developing this index, we regressed a great variety of precipitation variables, defined in terms of states and seasons, against the residuals shown in Figure B2. Our first surprise was that the only significant seasonal precipitation variable (at this aggregate level of total foodgrain production) was the summer monsoon. Precipitation in the pre- or post-monsoon periods, or the winter season, was not significant. This does not mean that precipitation in these other seasons is not important. It only means that the summer monsoon: (a) determines a large part of the total variability in foodgrain production; (b) may serve as an indicator of precipitation conditions in other seasons; and (c) may influence soil moisture and irrigation conditions for later seasons. In the latter connection, it is important to note that most of the reservoir capacity of India, and, therefore, annual irrigation supply, is determined by the summer monsoon, which supplies about 70% of India's total precipitation. This effect, together with the effects on soil moisture conditions, gives the summer monsoon a good deal of influence on production in the post-monsoon period. If this finding is borne out by more

TABLE B1 RAIN AND FOODGRAIN RESIDUALS

SW MONSOON (JUNE 1 TO SEPT 30)

YEAR	GROUP I WB	ORRISA	BIHAR	GROUP II UP	PUNJAB	I AVG	II AVG	AVG S-S INDEX	RAY INDEX	S-R INDEX	FG RES MT	FG PROD MT	RES % FG PROD
1951									-11				
1952	-13	-8	-24	-23	-50	-15	-37	-26	-15	-12		52	
1953	2	0	5	-2	-3	2	-3	0	-17	-5		59	
1954	6	-5	6	15	16	2	16	9	4	3	5.83	70	8.33
1955	-13	-15	-7	-8	-12	-12	-10	-11	-5	-4	2.17	68	3.19
1956	-16	7	-8	17	14	-6	15	5	30	9	-0.53	67	-0.79
1957	18	28	11	8	2	19	5	12	53	19	0.72	70	1.03
1958	-7	-33	-26	-23	-8	-22	-16	-19	-23	-15	-7.07	64	-11.05
1959	-21	-16	-11	-1	21	-16	10	-3	6	1	4.09	77	5.31
1960	11	-17	-25	-19	16	-10	-2	-6	11	6	2.21	77	2.87
1961	-6	18	0	7	26	4	17	10	0	2	5.28	82	6.44
1962	-11	36	-19	-4	9	2	3	2	18	0	2.26	83	2.72
1963	-20	-12	-10	-13	23	-14	5	-4	-9	-6	-0.74	80	-0.93
1964	-8	2	-7	16	4	-4	10	3	-12	-4	-1.83	81	-2.26
1965	-13	-1	-1	6	50	-5	28	12	-6	5	4.03	89	4.53
1966	-10	-35	-17	-37	-46	-21	-41	-31	-31	-26	-15.17	72	-21.07
1967	-29	-30	-49	-19	6	-36	-6	-21	-21	-17	-15.42	74	-20.84
1968	-1	-2	-19	8	-33	-7	-13	-10	4	3	3.27	95	3.44
1969	16	-16	-9	-19	6	-3	-7	-5	-18	-11	-0.1	94	-0.11
1970	-2	-5	11	6	-3	2	1	1	4	-1	3.47	100	3.47
1971	13	-5	-8	-3	-15	0	-9	-5	1	4	8.97	108	8.31
1972	34	-4	7	25	12	12	19	15	1	4	3.41	105	3.25
1973	-4	-11	-40	-28	-14	-18	-21	-20	-12	-16	-7.21	97	-7.43
1974	83	20	12	22	-21	38	1	19	1	3	-1.91	105	-1.82
1975	5	-34	-7	-14	-35	-12	-24	-18	-20	-13	-9.67	100	-9.67
1976	2	-3	-22	21	44	-8	32	12	7	10	8.49	121	7.02
1977	-17	-16	1	1	60	-11	31	10	-9	-10	-4.41	111	-3.97
1978	-24	-2	-14	-20	27	-13	4	-5	13	0	7.6	126	6.03
1979	41	-8	3	18	26	12	22	17	12		10.54	132	7.98
1980	-9	-19	-19	-50	-38	-16	-44	-30	-16		-14.6	110	-13.27
1981	6	13	12	33	46	10	39	25			2.18	130	1.68
1982	28	-5	-5	-10	-34	6	-22	-8			1.88	133	1.41
1983	-16	-4	-30	-13	-40	-17	-26	-21			-6.51	128	-5.09
1984	-2	4	-25	9	-17	-8	-4	-6			14.01	152	9.22
1985								10			4.44	146	3.04

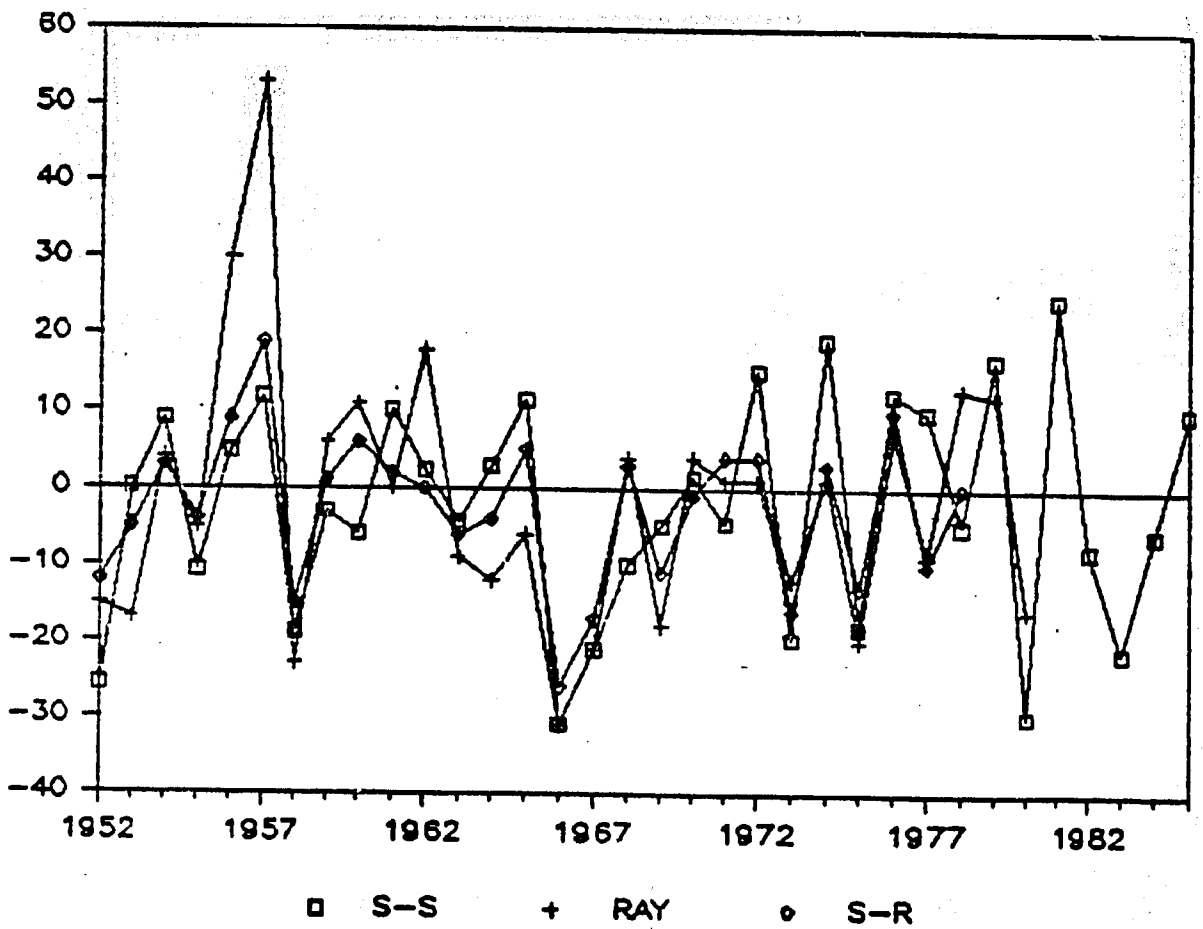


Figure B1. Comparison of Three Indices

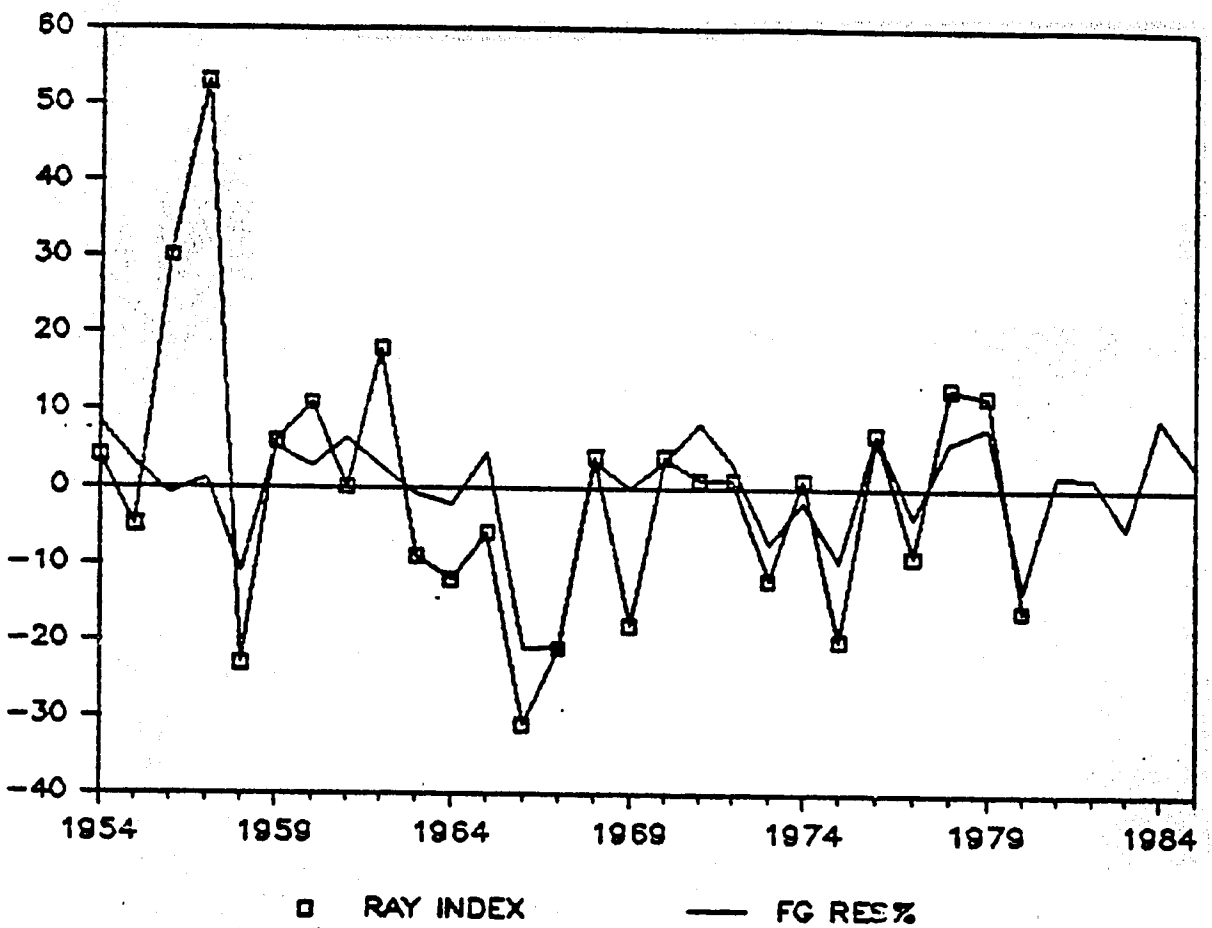


Figure B2. The Ray Index

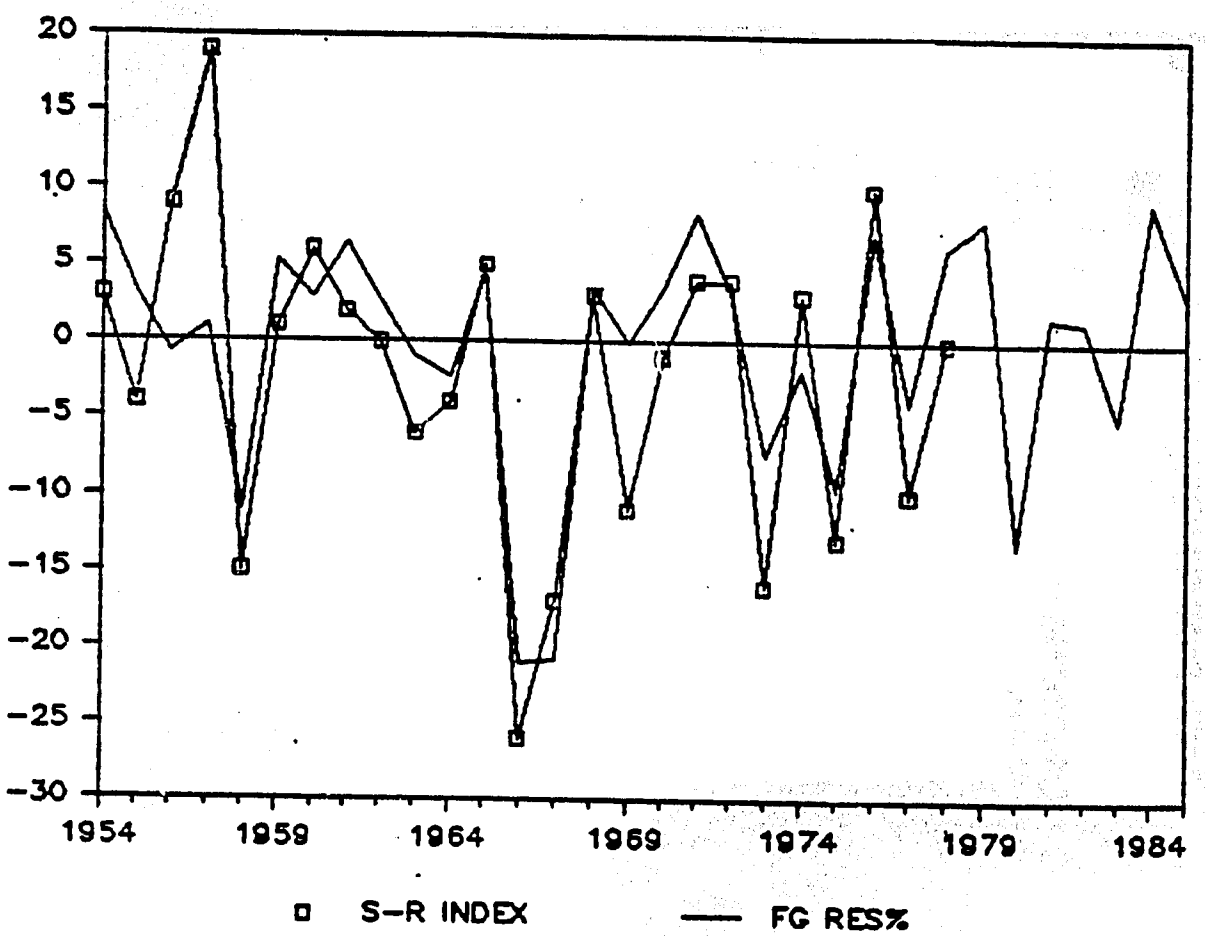


Figure B3. The Sanderson-Ray Index

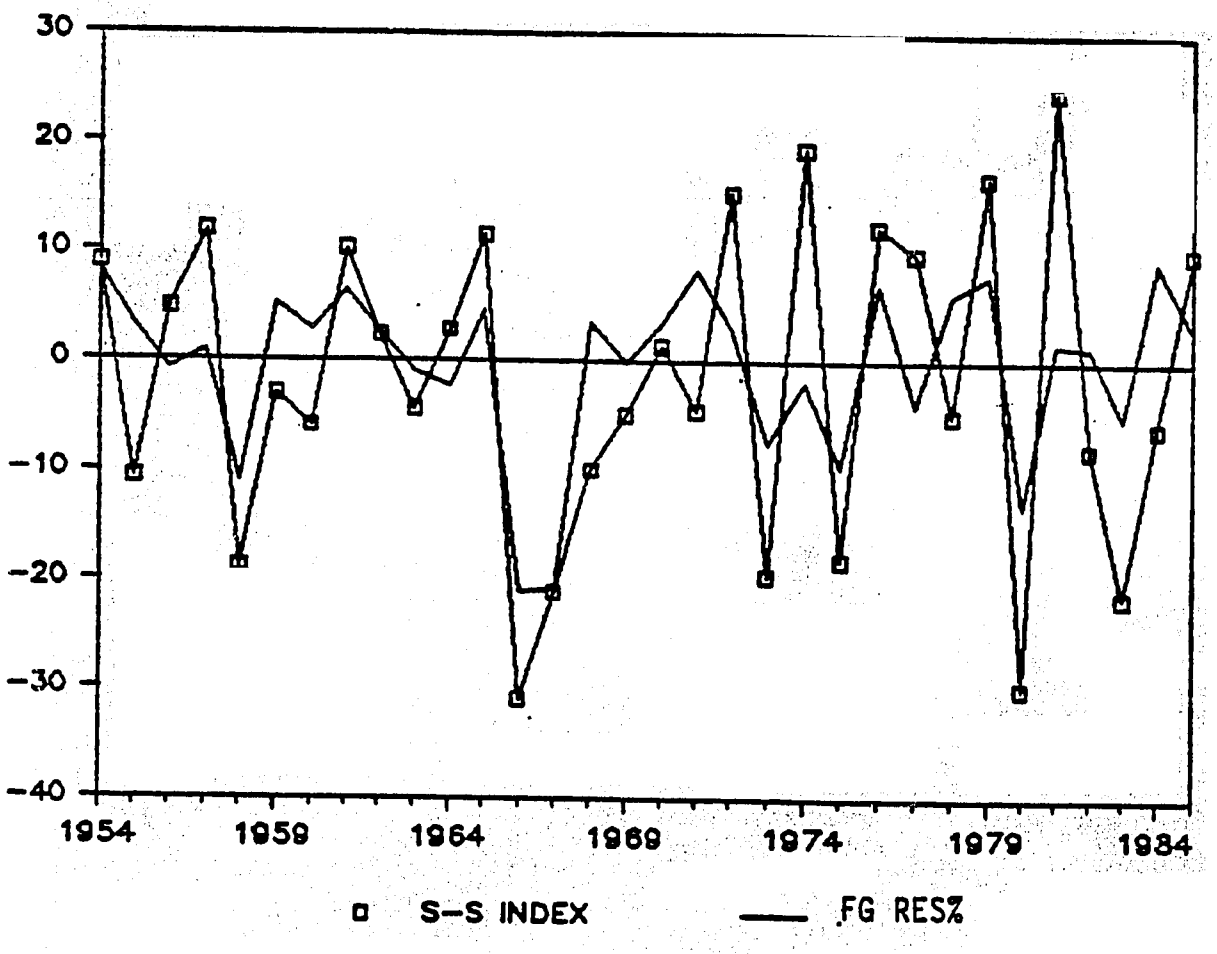


Figure B4. The Seckler-Sampath Index

detailed studies, it provides a means for an early warning system based on monsoon precipitation alone.

Second, we found that most of the variability in foodgrain production could be accounted for by variations in the summer monsoon in the five major foodgrain-producing states of the northern tier of India--namely, West Bengal, Orissa, Bihar, Uttar Pradesh, and Punjab. These five states account for about 50% of the rice production and 70% of the wheat production in India. It is reasonable to think, because of the problems of water management in the first four states, that a good part of the total variance in rice production in India is from these four states, although we have not investigated that question thoroughly.

Table B1 shows the method of computation of the S-S index. The index is based on the percent deviation from normal precipitation of the summer monsoon for these five states. The states are divided into groups I and II, as shown, and the average of each group is taken; then the average of these two averages becomes the index (a simple average would do as well). We have explored more sophisticated formulations (it is not difficult to come up with them!), but they do not yield better performance, so far as we can determine, variables at this level of aggregation.

Finally, we would like to call attention to a peculiarity in the precipitation data that could be of considerable significance, but is far beyond the scope of this study. It appears that the percent deviation from normal of precipitation in the post-monsoon season had a substantial downward bias from 1964 to 1972, and then either recovered to normal variations around the mean or has been trending upward. Such cyclical variations in the various seasons deserve more attention.

Appendix C. Poverty and the Foodgrain Surplus

The data used in this appendix is from the National Sample Survey (NSS). While there are major problems with this data (Minhas, 1974), it is all there is.

The NSS data on foodgrain and non-foodgrain consumptions expenditure in 1973-74 at 1973-74 prices is shown in Table C1 for rural and urban areas, by various expenditure classes. This data indicates that about 50% of the total population in both areas consumes less than the RDA, valued at Rs. 49.09 for rural areas and 56.64 for urban areas, for these years.

According to the 1973-74 NSS consumer expenditure study, roughly 56.5% of the total expenditure by the bottom half of the population was spent on cereals and about 5.4% on pulses, resulting in more than 60% of total expenditure on foodgrains. The expenditure elasticity of demand for foodgrain is 0.97. In other words, when the expenditure for this bottom 50% of the population goes up by 1%, the demand for foodgrains from this group goes up almost proportionally (to be exact, by .97%). Using the NSS estimates of total foodgrain consumption for 1973-74, the share of the bottom 50% of the population is estimated to be 42.48%.

The Sixth Plan document states (on the basis of consumer expenditure data made available from the 32nd NSS rural rounds conducted in 1977-78) that there had been virtually no change in the percentage of people below the poverty line. By assuming that the distribution has remained constant in 1984-85, we have worked out the demand for cereals if the income of all the people below the poverty line were increased to poverty line in the year 1984-85. These estimates are shown in Table C1.

Using the NSS data (Tables 1.27R and 1.27U from the 28th NSS round on consumer expenditures in rural and urban areas), we estimated the total number of persons in each expenditure class for rural and urban areas. Then by multiplying the average quantity of cereals consumed in each expenditure class by the number of persons in that class, we get the total cereals consumed by each class. Summing across all the classes gives the total consumption of cereals in rural or urban areas; their sum gives the total cereal consumption in the country.

We then calculated the extent of deficit in cereals consumption in each expenditure class below the poverty line in terms of percentage deviation from the minimum. Because, as already mentioned, the expenditure elasticity for cereals is found to be near unity in these groups, increases in per capita expenditure for each class to raise it to the minimum poverty level will result in a proportional increase in expenditure and demand for cereals. Thus, for example, for the Rs. 0-13 expenditure class, whose consumption expenditure is 85.1% below the poverty line, an 85.1% increase in expenditure to raise it to the poverty line will increase its demand for cereals by 85.1% from the current level of consumption of 0.129 million tons to 0.330 million tons. Thus, removing the deficit in the level of consumption expenditure for each class below the poverty line will result in a total increase in the demand for cereals by about 13.188 million tons in rural areas and by about 3.111 million tons in urban areas,

for a total increase of 16.3 million tons. This is 1.3 MT more than the current surplus available. The detailed computations pertaining to this discussion are given in Table C1.

TABLE C1 POVERTY AND CEREALS REQUIREMENTS, 1973-74

	EXPENDITURE CLASS RS PER MONTH PER CAPITA															
	0-13	15	18	21	24	28	34	43	55	75	100	150	200	200+	TOTAL <RP55	TOTAL >RP55
NO. HOUSHOLDS SAMPLED																
RURAL	55	49	145	272	412	749	1593	2760	3113	3168	1704	1025	255	167		15467
URBAN	9	10	20	26	62	168	415	940	1283	1647	1250	1169	467	413		7881
TOTAL	64	59	165	298	474	917	2008	3700	4398	4815	2954	2194	722	580		23348
HOUSEHOLD SIZE																
RURAL	4.95	5.87	6.03	6.08	5.82	6.05	8.81	5.6	5.4	5.15	4.7	4.19	3.72	3.15		
URBAN	1.86	3.77	5.21	7.17	7.55	6.56	6.5	6.01	5.74	5.21	4.36	3.29	2.74	2.4		
NUMBER PERSONS SAMPLED																
RURAL	272	288	874	1654	2398	4531	14034	15456	16810	16315	8009	4285	949	526		
URBAN	17	38	104	186	468	1102	2698	5649	7376	8581	5450	3846	1280	991		
TOTAL	289	325	979	1840	2866	5634	16732	21105	24186	24896	13459	8131	2228	1517		
POPULATION (MILL)																
RURAL	1.89	2	6.12	11.61	16.82	31.75	64.86	108.3	117.7	114.3	56.11	30.03	6.64	3.72		
URBAN	0.07	0.18	0.5	0.88	2.23	5.26	12.85	26.91	35.14	40.88	25.96	18.32	6.1	4.72		
TOTAL	1.96	2.18	6.62	12.49	19.05	37.01	77.71	135.2	152.9	155.2	82.07	48.35	12.74	8.44		
PER CAP CONS CERALS (KG) PER ANNUM																
RURAL	68.4	76.9	102.6	121.4	132.9	145.6	161.4	177.9	203.4	215.2	243.8	259.3	273.6	337.8		
URBAN	31.2	63.8	83.8	94.3	96.7	114.5	121.9	133.5	141.3	151.2	154	143.4	139.7	145.5		
PER CAP CONS EXPEND																
RURAL	10.6	14	16.8	19.7	22.4	26	31	38.4	48.6	69.6	85.3	119.4	169.8	284.7		
URBAN	8.5	13.5	17	19.6	22.8	26.2	31.2	38.5	48.9	64	85.9	107.6	171.8	287.8		
EXP DEFICIT																
RURAL	0.78	0.71	0.66	0.60	0.54	0.47	0.37	0.22	0.01	-0.42	-0.74	-1.43	-2.46	-4.80		
URBAN	0.85	0.76	0.70	0.65	0.60	0.54	0.45	0.32	0.14	-0.13	-0.52	-0.90	-2.03	-4.08		
TOTAL CONS CERALS (MT)																
RURAL	0.129	0.153	0.627	1.409	2.235	4.622	10.46	19.27	23.95	24.60	13.67	7.786	1.816	1.256	62.88	49.14
URBAN	0.002	0.011	0.041	0.082	0.215	0.602	1.566	3.592	4.965	6.191	3.997	2.627	0.852	0.686	11.08	14.34
TOTAL	0.131	0.165	0.669	1.492	2.451	5.225	12.03	22.86	28.91	30.78	17.67	10.41	2.668	1.943	73.96	63.49
TOTAL ADDITIONAL CEREALS REQUIRED																
RURAL	0.101	0.109	0.413	0.843	1.215	2.174	3.857	4.197	0.239	-10.2	-10.0	-11.1	-4.46	-6.03	13.15	-42.0
URBAN	0.001	0.008	0.029	0.054	0.128	0.323	0.703	1.150	0.678	-0.80	-2.06	-2.36	-1.73	-2.80	3.08	-9.76
TOTAL	0.103	0.118	0.442	0.898	1.344	2.498	4.561	5.347	0.917	-11.0	-12.1	-13.5	-6.19	-8.83	16.23	-51.7

Appendix D. Data Sheet for the Study

YEAR	POP (1,000	FOODGRAIN FGPROD	FGAREA	FGYLD	RICE RAREA	IRRA	RPROD	RYLD	R PC	WHEAT WAREA	IRRA	WPROD	WYLD	W PC
1954	382947	70	109	642	31.3		28.2	901	74	10.7		8	748	21
55	390523	68	108	630	30.8		25.2	818	65	11.2		9	804	23
56	398249	67	111	604	31.5		27.6	876	69	12.4		8.7	702	22
57	406128	70	111	631	32.3		29	898	71	13.5		9.4	696	23
58	414163	64	109	587	32.3		25.5	789	62	11.7		8	684	19
59	422356	77	115	670	33.1		30.8	931	73	12.6		10	794	24
60	430712	77	116	664	33.8		31.7	938	74	13.4		10.3	769	24
61	439235	82	116	707	34.1		34.6	1015	79	12.9		11	853	25
62	449073	83	117	709	34.7		35.7	1029	79	13.6		12	882	27
63	459133	80	118	678	35.7		33.2	930	72	13.6		10.8	794	24
64	469417	81	117	692	35.8		37	1034	79	13.5		9.8	726	21
65	479932	89	118	754	36.5		39.3	1077	82	13.4		12.3	918	26
66	490683	72	114	632	35.5		30.6	862	62	12.6		10.4	825	21
67	501674	74	115	643	35.2		30.4	864	61	12.8		11.4	891	23
68	512911	95	121	785	36.4		37.6	1033	73	15		16.5	1100	32
69	524401	94	120	783	36.9		39.8	1079	76	16		18.6	1163	35
70	536147	100	124	806	37.7		40.4	1072	75	16.6		20	1205	37
71	548160	108	124	871	37.6		42.2	1122	77	18.2		23.8	1308	43
72	560525	105	123	854	37.8	14.1	43.1	1140	77	19.1	10.4	26.4	1382	47
73	573170	97	119	815	36.7	14.4	39.2	1068	68	19.5	10.8	24.7	1267	43
74	586101	105	127	827	38.3	14.7	44	1149	75	18.6	10.8	21.8	1172	37
75	599322	100	121	826	37.9	14.7	39.6	1045	66	18	11.1	24.1	1339	40
76	612842	121	128	945	39.5	15.2	48.7	1233	79	20.4	12.6	28.8	1412	47
77	626668	111	124	895	38.5	14.8	41.9	1088	67	20.9	13.6	29	1388	46
78	640805	126	128	984	40.3	16.2	52.7	1308	82	21.5	13.7	31.7	1474	49
79	655261	132	129	1023	40.5	16.9	53.8	1328	82	22.6	14.9	35.5	1571	54
80	670043	110	125	880	39.4	16.9	42.3	1074	63	22.2	15	31.8	1432	47
81	685158	130	126	1032	39.8	16.3	53.2	1337	78	22.1	15.5	36.5	1652	53
82	700615	133	129	1031	37.8		46.5	1230	66	22.1		37.4	1692	53
83	716420	128	125	1024	38.3		47.1	1230	66	23.6		42.8	1814	60
84	732581	152	130	1169	41		59.8	1459	82	24.4		45.2	1852	62
85	749108	146	127	1150	41		59.5	1451	79	24.3		43	1770	57

1985 FG PROD PRELIMINARY
1985 FG AREA ESTIMATED
1980 ONE OF WORST DROUGHTS; 1983, SERIOUS DROUGHT
1979-85 GROSS IRR AREA EST AT 1.026% PA GROWTH; REPORTED FIGURES SHOWN
1985 RICE AREA, YIELD ESTIMATED

YEAR	TOTAL CERALS CAREA	CPROD	OTHER CERALS PROD	AREA	YLD	PULSES PC	PULSP	PULSA	PU YLD	PC	GROSS IRR A	GIRA RPT T	IRR/ AREA	DRYA	NPK 1000 T	NPK/ FGA	NPK/ GIRRA
1954	87.3	59.2	23.0	45.3	508	60	10.8	21.70	498	28	24.4		22	84.6	105	1.0	4.3
55	85.9	57	22.8	43.9	519	58	11	22.10	498	28	25		23	83	121	1.1	4.8
56	87.3	55.8	19.5	43.4	449	49	11.2	23.70	473	28	25.6		23	85.4	131	1.2	5.1
57	87.8	58.3	19.9	42	474	49	11.7	23.20	504	29	25.7		23	85.3	154	1.4	6.0
58	86.9	54.7	21.2	42.9	494	51	9.3	22.10	421	22	26.6		24	82.4	184	1.7	6.9
59	90.4	64	23.2	44.7	519	55	13	24.60	528	31	27		23	88	224	1.9	8.3
60	91	64.9	22.9	43.8	523	53	12.1	25.00	484	28	27.4		24	88.6	305	2.6	11.1
61	92	69.3	23.7	45	527	54	12.7	24.00	529	29	28		24	88	240	2.1	8.6
62	93	71	23.3	44.7	521	52	12	24.00	500	27	28.5		24	88.5	338	2.9	11.9
63	93.6	68.6	24.6	44.3	555	54	11.4	24.40	467	25	29.4		25	88.6	452	3.8	15.4
64	93.2	70.6	23.8	43.9	542	51	10.4	23.80	437	22	29.7		25	87.3	544	4.6	18.3
65	94.2	76.9	25.3	44.3	571	53	12.1	23.80	508	25	30.7		26	87.3	773	6.6	25.2
66			21.1	44.2	477	43	9.9	21.7	456	20	30.9		27	83.1	785	6.9	25.4
67			23.8	50.8	469	47	8.4	22.2	378	17	32.7		28	82.3	1101	9.6	33.7
68	98.8	82.9	28.8	47.4	608	56	12.1	21.20	571	24	33.2		27	87.8	1539	12.7	46.4
69	99.2	83.6	25.2	46.3	544	48	10.4	24.80	419	20	35.5		30	84.5	1761	14.7	49.6
70	101.5	87.8	27.4	47.2	581	51	12.2	22.50	542	23	37		30	87	1982	16.0	53.6
71	101.8	96.6	30.6	46	665	56	11.4	21.20	538	21	38		31	86	2256	18.2	59.4
72	100.5	94.1	24.6	43.6	564	44	10.9	18.50	589	19	38.4		31	84.6	2657	21.6	69.2
73	98.4	87.1	23.2	42.2	550	40	9.9	28.60	346	17	39		33	80	2768	23.3	71.0
74	103.1	94.7	28.9	46.2	626	49	10.3	17.90	575	18	40.2		32	86.8	2839	22.4	70.6
75	99	89.8	26.1	43.1	606	44	10.2	29.00	352	17	41.7		34	79.3	2573	21.3	61.7
76	103.7	108	30.5	43.8	696	50	13	20.30	640	21	43.2		34	84.8	2893	22.6	67.0
77	101.4	99.8	28.9	42	688	46	11.2	26.60	421	18	43.5		35	80.5	3411	27.5	78.4
78	104	114.4	29.6	42.2	701	46	12	25.00	480	19	46		36	82	4286	33.5	93.2
79	105.3	119.7	30.4	42.2	720	46	12.3	19.70	624	19	47.5	48.3	37	81.5	5117	39.7	107.7
80	103	101.1	27.4	41.4	662	41	8.5	23.00	370	13	48.7	49.2	39	76.3	5255	42.0	107.9
81	103.2	118.7	29.7	44.6	666	43	10.6	22.50	471	15	50	49.6	40	76	5516	43.8	110.3
82			37.6	41.3	910	54	11.5	23.8	483	16	51.3	50.3	40	77.7	6067	47.0	118.3
83			26.5	45.7	580	37	11.6	22.4	518	16	52.6	52.1	42	72.4	6418	51.3	123.3
84			34.3			47	12.7				54	52.9	42	76	7800	60.0	147.6
85											55.4	53.6	44	71.6	8600	67.7	160.3

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