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Food, Agriculture,
and the Environment
Discussion Paper 29

Prospects for India's Cereal Supply and Demand to 2020

G. S. Bhalla
Peter Hazell
John Kerr

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2020 VISION

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Prospects for India's Cereal Supply and Demand to 2020

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Foreword

IFPRI's "2020 Vision Initiative for Food, Agriculture, and the Environment" is intended to develop a shared vision on how to meet future world food needs while reducing poverty and protecting the environment. It brings together divergent schools of thought on these issues, working on the principle that divergent views can generate a constructive dialogue that will ultimately lead to a consensus for action.

The current paper on projected supply and demand for cereals in India, and the possibility of an emerging cereal gap of serious proportions by the year 2020, is a useful illustration of the kind of constructive dialogue IFPRI hopes to encourage. It responds to several quite recent developments, notably the rapid expansion of India's industrial and service sectors since the 1991 structural reforms, the improved prospects for continued growth over the next few decades, and the likelihood of rising per capita incomes that could generate substantially increased demand for livestock products. As demand for livestock products grows, livestock production could increasingly depend on cereals for feed—perhaps as much as 50 million tons by 2020, according to G.S. Bhalla, Peter Hazell, and John Kerr, authors of this 2020 discussion paper on *Prospects for Balancing Cereal Needs in India to 2020.*

These conclusions differ somewhat from other IFPRI studies, which have generally found that growth in demand for livestock products will be lower than the current study. This divergence of views is a useful signal to policymakers to pay careful attention to trends in demand for livestock products in India in the coming years. Notwithstanding these differences in modeling assumptions and projections, this study and the rest of IFPRI's 2020 research have consistently pointed to the vital link between agricultural policies and prospects for production growth in the next two decades.

If a cereal gap does develop by 2020, improved agricultural policies will give India's farmers an opportunity to respond to growing demand and fill the gap through greater domestic production. Increased domestic cereal and livestock production is also a way to generate greater employment and income in rural India, which still contains about three fourths of India's population; to restore the stalled momentum to alleviate poverty in rural areas; to improve food security at the national and household level; and to use growing rural prosperity to stimulate demand for India's industrial and service sectors. Such policies can help alleviate the most crucial gap of all—the growing gap in incomes, wealth, and opportunity between India's rural and urban areas.

Per Pinstrup-Andersen
Director General

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1. Estimating Demand for Cereals to 2020

Introduction

Although many Indians still do not have an adequate diet, the national food situation is dramatically better today than 30 years ago. In 1970, India's population was only two-thirds its current size, but cereal production was only half the current level and the country was critically dependent on food aid to prevent widespread famine, particularly in drought years. Today, India is self-sufficient in cereals. The nation produces and consumes about 170 million metric tons[1] of cereals each year (including seed and waste).

But will India continue to be self-sufficient in cereals in the years ahead? Over the next 20 years, will total cereal demand double again to over 340 million tons? Or will there be significant departures from past trends that may slow or increase growth in demand? And will national production of cereals continue to keep pace with demand, or will increasing resource scarcity and degradation—and already high use of high-yielding varieties (HYVs), fertilizers, and irrigation—limit future growth opportunities?

The answer depends on several factors: growth trends in population, per capita income, and urbanization; changes in taste as more people have better access to, and more information about, alternative foods; increased reliance on cereals for feed in response to rising consumption of meat products; and the impact of future economic growth on the poor.

Using 1993 as the base year, this paper presents projections of cereal demand and supply balances to 2020 under alternative scenarios for income growth, consumption behavior, and agricultural production strategies. A principal finding is that, as India's economy grows and per capita income rises over the next two decades, consumption of livestock products will increase dramatically. This, in turn, will drive a dramatic increase in the demand for cereals for livestock feed—50 million tons of cereal feed by 2020, or a twelvefold increase over 1993.

While some of the scenarios are based on speculative assumptions, the results show that there are plausible conditions under which India could have cereal deficits of 36 to 64 million tons per year by 2020. If deficits of this magnitude were to materialize, India's cereal needs would have significant impacts on world cereal markets, as well as on the country's trade balance. But such deficits can be avoided through appropriate policies that take advantage of this opportunity for poverty-alleviating agricultural growth.

Demand for Cereals

Growth in cereal demand in recent years has been somewhat slower than earlier forecasts suggested. In urban areas, per capita cereal consumption seems to have stabilized at about 130 kilograms per year, while it has actually declined in rural areas—from 185 kilograms in 1980 to 160 kilograms per year currently. Diets are more diversified, with increasing shares of the food budget allocated to milk, eggs, and livestock products. Consumption of milk and milk products, in particular, has grown rapidly, averaging about 6 percent per year. Cereal demand for livestock feed has also remained low, at about 5 million tons per year.

From the mid-1970s to the early 1990s, several studies predicted that total foodgrain (cereal plus pulses) demand in India would exceed 200 million tons by the year 2000 (e.g., Rao, 1975; Radhakrishna and Ravi 1990; Sarma and Gandhi 1990). But these

[1] Unless otherwise noted, all units of measure are metric.

demand projections have proved too high, as evidenced by total foodgrain demand of only 170 million tons in 1995, slowing population growth, and declining per capita cereal consumption. More recently, several studies have projected continued slow growth in India's cereal needs into the early decades of the next millennium (e.g. Rosegrant et al. 1995; Kumar 1998). Yet, if the Indian economy continues to grow at the high and unprecedented rates of recent years (Box 1), will growth in total cereal demand remain flat over the next two decades? Or could new patterns of consumption and cereals use emerge?

Assumptions for Demand Projections

Cereal demand projections are based on assumptions about growth in population size, urbanization, and national per capita income, as well as changes in consumption behavior, the distribution of income, and livestock production systems. These are discussed below.

Population Growth Rate

India's population, estimated at 880 million in 1993, has tripled since Independence in 1947 and doubled since 1980. The growth rate is slowing down, from 2.1 percent per year in the 1980s to 1.8 percent in the 1990s, and is expected to slow even further in the next century. Still, the population is projected to reach 1 billion by 2000 and 1.3 billion by 2020.

This report uses the latest population projections developed by the Registrar General of the Government of India (GOI 1996). Under these projections, total population is expected to reach 1.329 billion by 2020 (Table 1).

Box 1
India's Post-Reform Economic Trends

India today is facing a critical point in its history, enjoying at once a remarkable period of economic growth in many sectors, yet at the same time trying to cope with more than 300 million people living below the poverty line—the highest concentration of poverty of any country in the world and fully one-fourth of the world's poor.

In June 1991, faced with severe fiscal and trade imbalances and double-digit inflation, the government officially ended four decades of government-led growth and embarked on a new approach that emphasized stabilizing the economy; reforming the investment, trade, and tax regimes, the financial sector, and public enterprises; and giving the private sector a much greater role in India's development.

In the aggregate, the strategy is paying off handsomely. Gross domestic product grew at better than 7 percent annually during the 1994–96 period. During the 1999–2003 period, the World Bank is forecasting average annual GDP growth of 6 percent and per capita GNP growth of 4.7 percent. To date, however, India's economic progress has been concentrated in the industrial and service sectors. During the 1988–98 period, industry grew at 6.6 percent annually and services at 7.2 percent, while agriculture lagged behind at 3.7 percent.

Rural India, which includes about three-fourths of India's population, remains a critical part of India's development future. The rural sector and its employment opportunities are critical to sustained poverty reduction, food security at the national and household level, and the size of the market for industry and services. Agriculture—the main source of employment for 75 percent of the rural working population and accountable for 65 to 70 percent of rural income—is central to any hopes for sustained rural poverty reduction.

In the 1990s, while other sectors were growing rapidly, rural growth lost momentum and became much less effective in alleviating poverty. By 1997, the incidence of rural poverty was as high as it was prior to structural reforms. The Government of India is increasingly constrained in its spending for rural and social infrastructure, subsidies and technology dissemination, raising serious concerns about the future of India's rural economy and prospects for the further alleviation of rural poverty.

Table 1—Population projections for 2020, India

	Rural	Urban	Total
		(millions)	
1993	648.7	231.6	880.3
2020	863.5	465.6	1,329.1

Source: Government of India, 1996.

Rate of Urbanization

Assumptions about urbanization are based on the urbanization projections developed by the Government of India (GOI 1996). These projections indicate an urban population of 465.6 million by 2020 (up from 231.6 million in 1993), and a rural population of 863.5 million (up from 648.7 million in 1993). The urban share of the total population is projected to increase from 26 percent to 35 percent of the total population.

Growth in Per Capita Income

The baseline case for per capita income growth is assumed to average 3.7 percent per year over the 1993–2020 period, which is a little lower than the actual rate of growth achieved in recent years. For purposes of comparison, the report also includes a best-case scenario of 6.0 percent per year and a worst-case scenario of 2.0 percent per year. A 6.0 percent growth rate would be equivalent to India becoming a TIGER economy; that is, growth rates comparable to those experienced by several nations in East and Southeast Asia immediately prior to the recent financial crisis. The 2.0 percent rate corresponds to a regression back to the kind of growth rates experienced prior to the policy reforms of the early 1990s. The worst case might materialize if the world economy slips into a recession, if India is more seriously impacted by the Southeast Asian economic crisis than at present, or if there is serious back-peddling on economic reforms.

Changes in Consumption Behavior

Food consumption is affected by changes in per capita incomes, prices, and changes in taste. We assume that real food prices will change little over the next 25 years. This assumption is based on IFPRI's long-term food projections (Rosegrant et al. 1995).

Given the assumption that per capita incomes will continue to grow, we also need to assume values for expenditure elasticities so that projected increases in income can be translated into changes in per capita food demands. These elasticities measure the percentage change in expenditures on a particular food group, given a 1 percent increase in total expenditures. This study looks at three types of foods, which have been aggregated into three groups: cereals (rice, wheat, and coarse grains); meat and eggs; and milk and milk products (liquid milk and ghee). Within the cereals and meat and eggs groups, individual commodities are simply added together in kilogram units. All milk and milk products are first converted to their equivalent value of liquid milk. The elasticity assumptions for the 1993 base year are shown in Table 2. These estimates were made using data from the 50th Round of the Consumer Expenditure Survey (NSS 1996) and by regressing log-inverse expenditure functions across class-wise data for different commodity groups. The estimates were calculated separately for rural and urban areas. For

Table 2—Estimated expenditure elasticities

	Cereals	Meat and eggs	Milk and milk products
Authors' estimate			
Rural			
1972/73	0.41	0.65	1.54
1983	0.33	0.71	1.29
1987/88	0.33	1.04	1.47
1993	0.29	1.01	1.53
2020	0.1	1.25	1.53
Urban			
1972/73	0.27	0.76	1.00
1983	0.21	0.48	0.66
1987/88	0.18	0.75	1.01
1993	0.18	0.71	0.94
2020	0.1	0.74	1.05
Radhakrishna and Ravi, 1987/88			
Rural	0.38	0.93	1.15
Urban	0.20	0.89	1.09
IMPACT			
Rural and urban, 1993	0.17	0.59	0.88
Rural and urban, 2020	0.07	0.397	1.01
Kumar, 1993/94			
Rural	−0.007	0.848	0.458
Urban	−0.037	0.633	0.372

Sources: Radhakrishna and Ravi 1994, Rosegrant et al. 1995, and Kumar 1998.

comparative purposes, Table 2 also reports similar elasticity calculations for 1972/73, 1983, 1987/88, and 1993, also based on earlier rounds of the Consumer Expenditure Survey.

Cereal demand is very inelastic (0.29 for rural households and 0.18 for urban households). Expenditure elasticities for livestock products are much more elastic, averaging 1.53 and 0.94 for milk and milk products in rural and urban areas, respectively, and 1.01 and 0.71 for the eggs and meat group. As shown in Table 2, these elasticities have shown consistent trends since 1972/73. For cereals, demand elasticity has declined in both rural and urban areas. For meat and eggs, it has increased in rural areas but not in urban areas. For milk and milk products, it has remained much the same in both rural and urban areas.

These elasticities are quite consistent with the estimates provided by Radhakrishna and Ravi (1994) for 1987/88. However, other available estimates (reported in Table 2) differ. The IMPACT elasticities for 1993 estimated by Rosegrant et al. (1995) are similar for cereals, but are only two-thirds as large for livestock products. Using data from 1972/73 to 1987/88, Kumar (1998) estimates a negative elasticity for cereals and, like IMPACT, generally lower elasticities for livestock products. These wide variations in estimated demand elasticities are rather disconcerting, particularly as they are all estimated using the same NSS data source. Choice of time period and model specification is clearly crucial. The final choice of elasticities has to be judged in terms of the reasonableness of the resulting demand projections. This issue is discussed later in this report.

In projecting expenditure elasticities to 2020, two adjustments were made to the authors' 1993 values in Table 2. First, we had to make assumptions about how elasticities will change as per capita incomes rise in the future. We did this by extrapolating along the expenditure function.

Second, we had to make some allowance for possible changes in tastes as more Indians become wealthier, better connected to markets, and have greater access to and information about alternative foods (Huang and Bouis 1996). Ignoring changes in tastes may be a reasonable assumption for short-term projections, but it could prove very misleading for longer-term projections, particularly for a country that is experiencing unprecedented rates of growth in per capita income. India's per capita consumption of livestock products is also extremely low by international standards. This could change rapidly as the economy grows and modernizes, and as more people become exposed to a wider range of food types, including more processed products. There is already growing evidence that many more households are now consuming livestock products than a decade ago. In 1987/88, for example, the NSS reported that 78.9 percent of all urban households and 61.9 percent of all rural households consumed milk and milk products, but these shares increased to 84.3 and 69.6 percent, respectively, by 1993/94 (NSS 1990; 1996). Similarly, only 43.7 and 31.5 percent of urban and rural households, respectively, consumed meat in 1987/88, but more than half of both types of households consumed meat in 1993/94.

There is also growing evidence that the average budget shares for milk and meat are increasing over time in ways that are inconsistent with income and price changes. For example, the average budget shares for milk and meat increased by 24 and 19 percent, respectively, in rural areas between 1987/88 and 1993/94, even though per capita incomes changed hardly at all and the prices of these foods increased relative to the consumer price index for rural areas. Similar results hold for milk and meat consumption patterns in urban areas.[2] These changes can only be explained by structural shifts in consumer preferences.

Unfortunately, there is no precise way of forecasting these kinds of structural changes in consumption behavior. Table 2 contains the authors' "best guesses" of the likely 2020 elasticity values for cereals, milk, and meat and eggs. These estimates assume a continuing decline in the elasticities for cereals in rural and urban areas, but continuing strong or increasing elasticities for livestock products. The assumed demand elasticity for cereals in 2020 is almost the same as the elasticity projection used in IMPACT (Table 2), but elasticities for livestock products remain higher. For comparative purposes, demand projections based on the IMPACT model elasticities are also included.

Changes in the Distribution of Income

The baseline estimates assume that distribution of income is unlikely to change much within rural and urban areas, and that any redistribution in income will result from rural-urban migration. However, we also consider a scenario for 1993 in which poverty is eradicated in India, and another scenario in which everyone is well fed. The assumptions underlying these scenarios are described later. Projections to 2020 are not attempted for these scenarios because of the difficulties of forecasting changes in 2020 income distribution corresponding to different growth rates in per capita income.

Changes in Livestock Feed Requirements

Given income elastic demands for milk, eggs and meat, and accelerating growth in per capita incomes, demand for livestock products will continue to grow rapidly in India in the years ahead. This will place increasing pressure on livestock production systems. Traditional breeds and feeding practices are likely to give way to improved breeds and a greater reliance on cereal feeds.

Currently, India's livestock rely heavily on crop by-products, household waste, and open grazing areas as sources of feed. In fact, less than 5 million tons of cereals are currently fed to livestock each year, or about 3–4 percent of total cereal production. Further expansion of these traditional sources of feed to support a large increase in livestock production seems unlikely, particularly as available grazing areas are shrinking and are already seriously degraded (Repetto 1994).

Sarma and Gandhi (1990) suggest feed coefficients for more modern livestock production systems in India of 2 kilograms of feedgrains per kilogram of meat and eggs, and 0.2 kilogram of feedgrains per kilogram of milk. These levels are high by international standards. We assume more modest feed coefficients of 1.2 kilograms of cereals per kilogram of meat and eggs, and 0.12 kilogram of cereals per kilogram of milk. This is consistent with survey evidence of actual cereal use in broiler and egg production in Punjab, Haryana, and western Uttar Pradesh (Bansil 1985). It also allows for the use of other feedgrains besides cereals in dairy production, which are not included in this analysis. We assume that 1993 levels of livestock production can continue to be produced with the very low level of cereal feed observed that year (3.7 million tons). However, if livestock production is to increase beyond 1993 levels, then we assume that the additional output will have to be produced under more modern systems with the feed coefficients mentioned above.

Baseline Projections for Food Demand

The baseline projection assumes the rates of population growth for rural and urban areas shown in Table 1; initial expenditure levels for rural and urban households for 1993 as reported in the 50th round of the NSS consumer expenditure survey; no change in the distribution of income within rural and urban groups; and a 3.7 percent annual rate of growth in national per capita income. Since the NSS consumer survey is a sample-based approach, we calibrated the projections to actual 1993 national consumption using a ratio approach.

The baseline projection of cereal demand in 2020 for direct human consumption is 246.1 million tons—a 67 percent increase over 1993 demand of 147.1 million tons (Table 3). This estimate is similar to other demand projections that have been made for India using similar assumptions about the rate of growth in per capita income; for example,

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[2] It can be shown that the change over time in the average budget share for commodity i is related to changes in total household expenditure and prices in the following way:

$$\dot{A}_i = (\xi_E - 1)\dot{E} + \xi_P \dot{P}_i + R$$

where $\dot{A}_i$ denotes the average budget share for commodity *i*, ξ_E is the expenditure elasticity, ξ_P is the own price elasticity, *E* is total household expenditure, P_i is the price of commodity *i* relative to an appropriate cost of living index, *R* is a residual that captures any structural changes in demand, and dots denote percentage changes over time in a variable. If this formula is applied to observed changes between 1987/88 and 1993/94 in the average budget shares for milk and meat amongst rural and urban households in India (assuming the authors' estimates of the expenditure elasticities for 1987/88, and any reasonable own-price elasticities), then nearly all the increase in the average budget shares are explained by the residual term. This is because per capita expenditure did not increase very much, and the prices of milk and meat increased relative to the relevant rural and urban consumer price indices.

Table 3—Food demand projections for 2020, India

Scenario	Cereals Total	Cereals Per capita	Meat and eggs Total	Meat and eggs Per capita	Milk and milk products[a] Total	Milk and milk products[a] Per capita
	(million metric tons)	(kilograms/day)	(million metric tons)	(kilograms/day)	(million metric tons)	(kilograms/day)
1993[b]						
Actual	147.12	0.458	5.012	0.016	51.991	0.162
Poverty eradicated	153.68	0.478	5.534	0.017	58.007	0.181
Well-fed India	140.92	0.438	9.532	0.029	95.872	0.298
2020[b] (per capital income growth)						
2.0 percent	231.51	0.479	12.654	0.026	159.216	0.328
3.7 percent	246.08	0.509	19.918	0.041	289.591	0.597
6.0 percent	267.21	0.553	32.036	0.066	646.839	1.333
3.7 percent with IMPACT elasticities[b]	246.08	0.509	13.33	0.027	175.32	0.361
IMPACT Model[c]	223.57	0.461	10.91	0.022	159.92	0.330
Kumar[d]	237.6	0.489	7.8	0.016	142.7	0.294

[a] All milk products have been converted to liquid milk equivalents.
[b] Authors' own calculations.
[c] Rosegrant et al. (1995).
[d] Kumar (1998).

Rosegrant et al. (1995) used the IMPACT model to project a 2020 demand of 224 million tons, and Kumar (1998) projects a 2020 demand level of 237.6 million tons (Table 3). Per capita cereal consumption is estimated to be 0.51 kilogram per day, which is only 11 percent larger than in 1993, and quite comparable to 1993 consumption levels in Pakistan and China.

More dramatic increases are projected for the consumption of livestock products. The projected demand for meat and eggs in 2020 is 19.9 million tons, a fourfold increase over 1993 consumption of 5.0 million tons (Table 3). Consumption of milk and milk products is projected to increase more than five times, from 52.0 million tons in 1993 to 289.6 million tons in 2020. These projections also imply significant increases in daily per capita consumption, from 0.016 to 0.041 kilogram for meat and eggs and 0.162 to 0.597 kilogram for milk and milk products.

Our demand projections for livestock products are approximately twice as large as the 2020 projections from IMPACT by Rosegrant et al. (1995)[3] and by Kumar (1998) for similar increases in per capita incomes (Table 3). The difference is almost entirely due to the higher expenditure elasticities for livestock products that we assumed for 2020. Indeed, as shown at the bottom of Table 3, if we used the same demand elasticities as the IMPACT model, then projected demand for livestock products would be reduced by one-third from the baseline level and is quite close to the IMPACT forecasts. These other studies begin with lower estimates of the demand elasticities for livestock products and do not allow for any structural shift in tastes over time, except through rural-urban migration.

Are our projections reasonable? One test is to compare these projections with current trends in other Asian countries, as shown in Table 4. Pakistan's per capita consumption of meat and eggs was already 0.038 kilogram per day in 1993, which is similar to our 2020 projection of 0.041 kilogram per day for India. China consumed more than three

[3]IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) incorporates the effects of key factors on food supply and demand to 2020—population, income growth, urbanization, the rate of increase in food production due to technological change and productivity growth, prices of commodities, and the response of supply and demand to prices. The "baseline" results show an aggregate global food supply and demand picture that is fairly good, if rates of investment in agricultural research and development are maintained. The IMPACT projections used a base year of 1993, were developed in 1995, and were reported in Rosegrant et.al. (1995). The IMPACT model is annually reviewed and updated as new information becomes available. Results from later runs of the model may vary from those presented and described here.

Table 4—Food demand projections for 2020 for India, China, Pakistan, and the United States

	Per capita income	Cereals		Meat and eggs		Milk and milk products[a]	
		Total	Per capita	Total	Per capita	Total	Per capita
	(US$)	(million metric tons)	(kilograms/day)	(million metric tons)	(kilograms/day)	(million metric tons)	(kilograms/day)
India							
1993	250	147.1	0.458	5.0	0.016	52.0	0.162
2020	670	246.1	0.509	19.9	0.041	289.6	0.597
Pakistan							
1993	349	20.4	0.432	1.8	0.038	13.8	0.292
2020	595	42.4	0.469	4.2	0.046	33.4	0.369
China							
1993	356	251.2	0.577	49.7	0.114	8.0	0.018
2020	1,242	293.4	0.555	104.7	0.198	16.6	0.031
United States							
1993	24,257	34.8	0.253	34.5	0.361	66.3	0.694
2020	30,773	42.4	0.360	42.9	0.365	79.0	0.672

Notes: All 1993 figures and the 2020 projections for Pakistan, China and the United States are from Rosegrant et al. (1995). The 2020 projections for India are the authors' own calculations.
[a] All milk products have been converted to liquid milk equivalents.

times as much meat and eggs per person per day (0.114 kilogram) in 1993 than we are projecting for India in 2020. Our 2020 projection for consumption of milk and milk products in India is about twice as high as Pakistan's 1993 consumption and considerably higher than China's 1993 consumption (0.018 kilogram per person per day). This compensates to some extent for India's lower consumption of meat and eggs. By weighting meat and eggs at 1.0, but milk and milk products (already measured in liquid milk equivalents) at 0.1 to allow for its much higher water content (that is, a given amount of milk has about one-tenth the nutritional content of the same amount of meat), then India's consumption of livestock products in meat equivalents in 2020 would be 0.1 kilogram per person per day. This compares with 0.115 and 0.087 kilogram per person per day for China and Pakistan in 1993, respectively.

Alternative Scenarios for Food Demand

Poverty Removed

The first alternative scenario for 1993 assumes that all the poor are brought above the official 1991 poverty line as recently revised by the Planning Commission. Using the results of the 1987/88 NSS survey of consumer expenditure, we increased the consumption basket of all expenditure groups falling below the poverty line in 1993 to the consumption basket of the group lying just above the poverty line. This was done separately for the rural and urban populations.

If poverty had been eliminated in 1993, consumers would have demanded 153 million tons of cereals instead of 147 million tons (an increase of 4.4 percent), 5.5 million tons of meat and eggs instead of 5 million tons (an increase of 10 percent), and 58 million tons of milk and milk products instead of 52 million tons (an increase of 12 percent) (Table 3). These are not large increases, suggesting that on its own, redistribution of income in favor of the poor would not cause any major problems for India's food markets.

Well-Fed India

Over one-third of the people living above the official poverty line are still malnourished in India, particularly from protein deficiency (GOI 1993). Recognizing that fact, we considered a second poverty reduction scenario for 1993 in which everyone is assumed to become well fed. For this purpose, we took the food consumption basket recommended by the Indian Council of Medical Research (ICMR) as the desired minimum.[4] Again using the 1987/88 NSS consumer expenditure data for urban and rural people, we changed the consumption basket of all expenditure groups falling below the ICMR norm to match the ICMR dietary norm for balanced food, and then calculated revised averages for the expenditure bundles of the rural and urban populations for 1987/88. These figures were then projected to 1993 by using 1987/88 demand elasticities. These calculations reduced the intake of cereals for some expenditure groups, but invariably increased the consumption of livestock products.

Had the entire Indian population been fed to at least ICMR recommended dietary standards in 1993, total cereal consumption would have been 4.2 percent lower at 140.9 million tons, but consumption of milk, eggs, and meats would have doubled (Table 3). These results suggest that significant increases in the consumption of livestock products are needed in India for good nutrition, providing they are consumed by the needy.

Alternative Growth Rates in Per Capita Income

If India were to become a TIGER economy, then demand for cereals would likely increase by a further 8 percent over our baseline projection, but demand for livestock products would explode (Table 3). Demand for meat and eggs would increase 60 percent over our baseline projection, while demand for milk and milk products would increase by another 120 percent. Even at these high levels, the projected consumption of meat and eggs per person per day in India in 2020 would still be less than half the amount that the Chinese consumed in 1993.

If per capita income growth declined to 2.0 percent per year, then there would be a corresponding sharp decline in the growth of consumption of livestock products. Consumption of meat and eggs in 2020 would only be two-thirds of the baseline projection, while demand for milk and milk products would be half the baseline projection.

Table 5—Projected cereal feed requirements for 2020, India

	Kilograms of cereal per kilogram of meat equivalent	Total
		(million metric tons)
1993	0.36	3.712
2020 (per capita income growth)		
2.0 percent	0.90	25.749
3.7 percent	1.03	50.111
6.0 percent	1.11	107.522

Notes: Based on feed coefficients of 1.2 kilograms of cereals per kilogram of meat and eggs, and 0.12 kilogram of cereal per kilogram of milk, for all additional livestock output beyond 1993 levels. Meat equivalents are calculated as meat and eggs = 1.0, milk = 0.1.

Implications for Livestock Feed Demand

India used very little cereal for livestock feed in 1993— about 3.7 million tons. As discussed earlier, a significant increase in the production of meat, eggs, and milk would require a change in existing livestock production and feeding systems. We assume that any increase in livestock production beyond 1993 levels would require 1.2 kilograms of cereals per kilogram of meat equivalent (meat and eggs are weighted at 1.0, milk at 0.1). This leads to the 2020 feed projections in Table 5.

The baseline projection—50.1 million tons of cereal feed by 2020—is a more than twelvefold increase over 1993. This compares with projections of 13.7 million tons by Rosegrant et al. (1995) and 16.9 million tons by Kumar (1998), but their projections are based on livestock production levels that are only about half as large. Despite the size of our projection, the average feed ratio in 2020 would still be 1.025 kilograms of cereal per kilogram of meat equivalent, which is less than half the amount that China used in

[4]The relevant food intake recommended by ICMR is as follows (in grams per person per day): milk 227.0, beef 3.74, pig meat 1.71, sheep meat 2.57, poultry 1.35, total meat 11.42, eggs 7.21, soybeans 6.83, cereals 400, pulses 41.34. oils 16.83, sugar 43.06, and roots 55.58.

Table 6—Projected total cereal requirements for India for 2020 and comparison with other countries

Country/year/source	Food	Feed	Total	Kilograms per capita per day
		(million metric tons)		
India				
1993 (actual)	147.121	3.712	150.833	0.47
2020 (authors' projections) with per capita income growth of:				
2 percent	231.510	25.749	257.259	0.53
3.7 percent	246.080	50.111	296.191	0.61
6 percent	267.210	107.522	374.732	0.77
2020 (IMPACT)[a]	223.6	13.3	237.3	0.51
2020 (Kumar)[b]	237.6	16.9	254.5	0.55
China				
1993 (actual)	251.243	72.640	323.883	0.73
2020 (IMPACT)[a]	293.441	177.989	471.430	0.90
Pakistan				
1993 (actual)	20.361	1.313	21.674	0.47
2020 (IMPACT)[a]	42.406	2.826	45.232	0.49
United States				
1993 (actual)	34.822	158.200	193.022	2.03
2020 (IMPACT)[a]	42.390	202.101	244.491	2.08

[a] IMPACT model baseline results (Rosegrant et al,1995).
[b] Kumar's projections (Kumar, 1998).

1993. If India emerged as a TIGER economy, then cereal feed demand could reach 107.5 million tons by 2020. Even then, the average feed coefficient would still only be 1.112 kilograms of cereal per kilogram of meat equivalent.

Total Cereal Requirements

Table 6 summarizes projected food and feed requirements for cereals in 2020 under different scenarios. The baseline projection is for total cereal demand of 296.2 million tons, including 50.1 million tons (or 17 percent) for feed and 246.1 million tons (or 83 percent) for direct human consumption. This would mean a doubling of total cereal demand over 1993, which is the kind of increase that India experienced over the past 30 years. The total cereal requirement increases to 374.7 million tons if per capita income grows at 6 percent per year, including 107.5 million tons (or 28 percent) for feed. This level of total cereal demand seems quite reasonable when expressed in per capita terms (0.77 kilogram per capita per day), and would bring India more into line with the level demanded in China in 1993 (0.73 kilogram per capita per day). It is also only about one-third of the current level in the United States. If per capita income growth slows to 2.0 percent per year, then total cereal demand in 2020 is projected at 257.3 million tons, a modest 70 percent increase over 1993 demand.

Our projections for total cereal demand are higher than other projections. For rates of growth in per capita income comparable to our baseline (3–4 percent per year), the IMPACT model projects a total cereal demand of 237.3 million tons by 2020 (Rosegrant et al. 1995), while Kumar (1998) projects a figure of 254.5 million tons. The differences arise almost entirely from different assumptions about the livestock sector. Unlike other authors, we have assumed structural changes in the demand for livestock products that will lead to higher income elasticities. We have also assumed that rapid growth in livestock demand will have to be matched by a shift towards more cereal-intensive livestock feeding systems. These are controversial assumptions, but ones that are not implausible given the experience of many other countries, including neighboring countries in Asia.

2. Estimating Cereal Supply to 2020

India's total cereal production has averaged 2.7 percent annual growth since the mid-1960s. This was more than sufficient to keep pace with growth in market demand, and the country moved from severe food crises in the mid-1960s to aggregate food surpluses today. This remarkable increase in cereal production was largely the result of increases in yields; only 20 percent of the total production increase can be attributed to expansion of the net cropped area, and 80 percent to yield increases. The yield increases were attained from two major sources: an expansion of irrigated area from 24 million hectares in 1962–65 to 44.3 million hectares in 1990–93, and the spread of Green Revolution technologies, including improved seeds and intensive use of inorganic fertilizers.

The simplest method for projecting future production of cereals in India is to extrapolate past growth trends. Assuming that total cereal production will continue to grow at 2.7 percent per year, then by 2020 production will be 347 million tons, or more than twice the production level achieved in 1993. But such an extrapolation seems unrealistic, since the underlying sources of growth during the past quarter century have largely run their course and new sources of production growth must be found. Further expansion of the irrigated area will be more costly, and agriculture must increasingly compete with other water users (e.g. industry and urban households) for limited water resources. In addition, the Green Revolution technologies have already spread widely in the areas where they are most economic. There is now limited scope for further production gains from the greater use of improved varieties and fertilizers. Resource degradation is also impacting on productivity growth in irrigated and rainfed areas; unless corrected, it could become a significant constraint on future cereal production growth rates.

Given the constraints to traditional sources of growth, new sources of growth will have to be found. Projections of future cereals production need, therefore, to be based on more detailed analysis of the technology and economic options available for different types of areas.

Possibilities for Future Growth

Production prospects differ for irrigated and rainfed areas. They also differ for different types of rainfed areas, particularly between high-potential and low-potential rainfed areas. Virtually no productive land remains uncultivated in India today, so there is little scope for increasing the cultivated area in any of the three types of areas. Not only is the remaining land relatively unproductive, but bringing it under cultivation would entail high environmental costs, including deforestation and soil erosion. Future growth will therefore have to continue to depend on yield increases, and this will require the continued spread of yield-enhancing technologies, improved natural resource management, and greater technical efficiency. In some of the most productive areas, research is needed to boost potential yields in order to create a new source of yield growth. On the other hand, in many other areas there are still large yield gaps between farmers' yields and demonstration plots, suggesting that significant gains could be made just by spreading existing technology. Another imperative is to minimize natural resource degradation, which threatens to undermine the gains already made.

Irrigated Areas

The scope for further expansion of irrigated area is now limited, and production growth in irrigated areas will increasingly have to come from growth in the productivity of existing land and water resources. Unfortunately, there is increasing evidence to suggest that productivity growth is stagnating in many irrigated areas. There are two main reasons for this. First, the Green Revolution has already run its course in irrigated areas, and there is less scope than in the past for obtaining additional output from the greater use of improved varieties and fertilizers. Second, environmental stresses associated with intensive irrigated farming are reducing productivity growth in many high-yielding areas (Bhalla and Singh 1997). Salinity, alkalinity, and waterlogging of land are even leading to the degradation and loss of significant areas of irrigated land. More work is needed to understand the nature of these problems, how serious they are, and what is required to solve them (Hobbs and Morris 1996).

Possibilities for increasing production in irrigated areas include the following:

Genetic improvement. There is scope for continued development of new varieties. For rice, a recently introduced hybrid offers the possibility of a one-time yield increase of 15–20 percent. The International Rice Research Institute (IRRI) is in the process of developing a "super rice" that drastically modifies plant architecture and promises additional gains of up to 30 percent (Pingali et al. 1997). Other crops continue to enjoy modest advances through the development of second-generation modern varieties. Biotechnology holds some promise for significantly increasing productivity in the long term, but short-term gains will most likely arise by reducing susceptibility to pest and disease losses.

Crop management. There are significant opportunities to raise productivity by reducing the large technical efficiency gap in many irrigated areas. There has been widespread adoption of modern varieties, fertilizer, and irrigation, but much less adoption of improved management practices that could boost productivity and reduce environmental stress. Though often very knowledge-intensive, some incremental management changes—relating to site- and season-specific pest, water, and nutrient management—provide the potential for reducing this efficiency gap. As elsewhere, however, this type of "precision farming" will require greatly improved knowledge-transfer systems and skilled and educated farmers to be successful in India. This suggests a need for major changes in the agricultural research system to promote work that is more on-farm, more interdisciplinary, more focused on crop management in addition to plant genetics, and that promotes more feedback from farmers.

Spreading irrigation. Increasing the irrigated area, either by investing in new sources or by using existing irrigation facilities more efficiently, could also be a source of future growth. Irrigation now covers about 33 percent of gross cropped area, but the potential is as high as 50 percent. However, expanding irrigation facilities to the maximum potential area by the year 2020 is probably not feasible. There are several constraints. First, most of the "easy" options for increasing irrigated area have already been exploited. Remaining possibilities for large-scale canal irrigation involve higher financial, environmental, and social costs than previous projects, so progress in expanding irrigation potential is likely to be increasingly slow.

Second, water demand is rising in nonagricultural sectors, and agriculture's share in total water use is certain to drop during the period up to 2020. The World Bank estimates that agriculture's share in 2025 will be 73 percent, compared to 87 percent in 1985. This means a significant share of any expansion of irrigation facilities will simply go to maintaining existing potential.

Third, groundwater is now India's fastest growing source of irrigation, but well irrigation also faces limits to growth. In many dry areas, groundwater has been tapped so heavily that the water table has fallen precipitously over the years. In the dry areas, where irrigation can have its greatest impact, the prospects for additional well investment are the lowest.

Even without creating new irrigation potential, however, better management of existing water resources could have a large impact on output. Legal and administrative provisions leave irrigation water underpriced and poorly managed, causing widespread waste. In canal-irrigated areas, water tariffs are so low they do not even cover maintenance costs. Farmers on the upper end of distribution channels use scarce water for water-intensive crops, leading to waterlogging and salt problems and reducing water availability for farmers at the tail end. In many areas irrigated by wells, free or nearly free electricity causes over-pumping, which leads to ever lower water tables and widespread well failure. With more careful management, available water resources could go much farther, raising overall irrigated area and irrigated crop yields. The World Bank estimates that even a 10 percent increase in efficiency of existing irrigation facilities could add 7–8 million hectares of irrigated land in India without utilizing additional water resources (World Bank 1998).

Institutional reforms are needed to better coordinate irrigation management. Watershed management, groundwater development, canal irrigation, lift irrigation, and agriculture are all managed independently of each other, even though they are strongly linked and potentially complementary. Similarly, social and environmental externalities that cross the boundaries of narrowly organized government line departments receive inadequate attention in project planning (Repetto 1994). Irrigation development proceeds with inadequate attention to drainage or soil conservation, resulting in shortened project life spans due to soil salinity or sedimentation of reservoirs. As a result, reorganizing the irrigation administration is needed not only to increase productivity of existing irrigation capacity but to prevent its decline.

High-Potential Rainfed Areas

Agriculture in favorable rainfed areas has performed well in recent years. Production will probably never match that in the most productive irrigated areas due to inferior agroclimatic conditions, but some growth potential still exists. Projections of continued growth in these areas are based on two factors. First, for the past two decades these areas have consistently adopted improved varieties and other inputs, but with a lag compared to irrigated areas. This trend should continue. Second, additional growth is possible with improvements in crop management. In high-rainfall areas with deep black, water-retentive soils, for example, improved drainage practices will enable more area to be brought under double cropping even without irrigation. Adoption of such management practices depends largely on increased farmer knowledge and higher output prices. In some areas of eastern India, unraveling complicated tenure arrangements should encourage land-improving investments, such as irrigation and flood control, which are critical to further intensification (Repetto 1994).

On the whole, high-potential rainfed areas may represent India's "easiest" option for expanded production. Historical trends suggest that improved varieties and inputs will continue to spread to these areas. In addition, they are among the poorest, least-educated, and least-developed areas in the country. Continued improvements in infrastructure will raise the returns to agriculture in these areas, while increases in education may increase the scope for adoption of better management practices.

Low-Potential Rainfed Areas

Other rainfed areas lag behind in agricultural production and yield growth. In particular, semi-arid rainfed areas have seen only limited adoption of modern inputs. They produce mainly coarse grains like sorghum and millet, and in some places yield growth has been negligible over the last three decades. In recent years, there has been a shift to oilseeds, which have performed well in response to high output prices. But on the whole, progress has been limited in semi-arid regions. This is largely a result of unfavorable growing conditions, natural resource degradation, and farmers' unwillingness to invest in costly inputs due to the high risk of crop failure.

Technical solutions are less clear than in more favorable environments, and output growth is likely to be limited. Farmers in unfavorable environments pursue complex, risk-minimizing strategies for producing food and earning their livelihoods. This complicates the introduction of new production technologies, which may not be adopted if they are incompatible with some component of existing livelihood systems, thus imposing unacceptable opportunity costs. Some technical recommendations, such as watershed management, require collective action among farmers that is difficult to attain. So far, the promise of dryland watershed development in raising agricultural productivity has been fulfilled only in a few isolated cases. Researchers and development practitioners are increasingly realizing that developing and adapting technologies to meet complex, location-specific requirements in unfavorable areas will require greater participation of intended users. Encouraging such hands-on, participatory approaches is difficult where research or development systems traditionally work in a top-down manner.

On the bright side, the experience with oilseeds in recent years shows that favorable incentives can encourage productivity increases even in relatively unfavorable areas. High output prices for oilseeds have induced increases in both area and yield.

Another positive sign is that agricultural intensification in dry areas may be associated with environmental improvements, not degradation. Water harvesting and moisture concentration measures also bring soil conservation and application of organic matter and other nutrients. Where water becomes available, farmers often invest in improved livestock, which require stall-feeding rather than open grazing. Their manure can be saved for use both as fuel and as organic matter to be applied to crop lands. As a result, intensification can reduce the pressure on widely degraded rangelands and forests and contribute to improved soil fertility. Meanwhile, chemical inputs in low-potential rainfed areas will remain below polluting levels.

The Role of Fertilizer

Fertilizer can play an important role in increasing cereal production, either through increased fertilizer applications or improved efficiency. After expanding at a rapid pace since the early 1960s, fertilizer consumption averaged about 120 kilograms per hectare in 1990–91 in the major states of India. However, current use rates are still far below the amount that would maximize production, estimated at a national average of 334 kilograms per hectare of NPK fertilizer (Gandhi et al. 1998). Of course, this average figure reflects variations both within and across states. It represents the agronomic optimum, at which yields no longer increase with an additional unit of fertilizer applied. It is higher than the economic optimum, at which net returns (the value of output less the cost of fertilizer) no longer increase with an additional unit of fertilizer applied.

As with irrigation expansion, raising fertilizer use to maximum levels is also unrealistic, for at least four reasons. First, unless fertilizer prices plummet and food prices rise dramatically, the economically optimal quantity of fertilizer will not likely approach the agronomic optimum. Second, many fertilizers are petroleum-intensive, and tripling their use may have unmanageable foreign exchange implications. Third, high fertilizer application rates would lead to chemical pollution and impose unacceptable off-site costs, especially through leaching into groundwater. And fourth, as mentioned above, in drier rainfed areas fertilizer application will remain constrained by risk. To illustrate the difficulty of a three-fold increase in average fertilizer use, it is helpful to consider that the current average in highly intensive Punjab is about 210 kilograms per hectare, and there is some evidence that marginal returns are low at this rate. It is difficult to imagine the all-India figure exceeding the current Punjab level by the year 2020.

On the other hand, there are reasonable prospects for increasing the efficiency of existing fertilizer inputs, especially on rainfed lands. Studies suggest that the profitable use of fertilizer in many unirrigated areas will generally require greater fertilizer efficiency through a balanced dose, timely planting, improved time of application, and improved placement. In marginal areas, it is likely that fertilizer will only be profitable in some years and locations (Dvorak 1992). This suggests a movement away from general recommendations to more specific recommendations conditional on factors such as crop rotation, moisture availability, and time of planting. It implies that substantial increases in yield could be achieved through better management; the yield increases would exceed the increase in fertilizer application. Relaxing various supply constraints like marketing and access to credit can also help increase fertilizer use, particularly in many rainfed areas.

Meeting the Demand for Livestock Feed

If the demand for livestock products increases substantially, as projected in this paper, it is likely that the agricultural sector will be asked to produce more feed grains. This could induce a shift away from rice and wheat, which currently account for around 80 percent of total cereal production, toward maize, sorghum, and millet.

Direct human consumption of these coarse grains is falling in India (Singh and Morris 1997; ICRISAT and FAO 1996), while yields are rising. If these trends continue, then presumably these crops will be able to supply growing amounts of grain as livestock feed, even without growth in the area under cultivation. Given current annual coarse grain production of about 31 million tons, a diversion of about 20 million tons from the food to the feed sector seems possible.

Changes in tenure systems on pasture lands could also affect demand for livestock feed. Putting an end to uncontrolled grazing, whether through privatization of pastures or improved management under common property regimes, would mean a substantial reduction in the amount of fodder that farmers can obtain for free. At the same time, it would result in large increases in production of fodder grass due to better pasture management (Fernandez 1999). Most likely this would result in a reduction in the overall number of animals and a shift toward higher quality animals that consume more feed. Questions remain about how much of this would come from grain and how much from fodder.

Some Projections of Future Cereal Production

Trend Projection

As mentioned earlier, the simplest method for projecting future production of cereals is to extrapolate past growth trends, which produces an estimate of 347 million tons by 2020, or more than twice the 1993 production level (Table 7). However, for reasons discussed above, such a projection is probably too simplistic.

Table 7—Alternative cereal supply projections for 2020, India

Scenario/projection basis	Production	Seed and waste[a]	Available supply
		(million metric tons)	
1993			
Actual	168.6	12.6	156.0
2020			
Scenario 1			
1962/65–93 trend extrapolated (2.7 percent production growth per year)	347.1	26.0	321.1
Scenario 2			
IMPACT model (baseline)	256.2	19.2	237.0
Scenario 3			
1993 fertilizer use is tripled to an all-India average of 334 kilograms/hectare (to reach the agronomic optimum level)	287.5	21.6	265.9
Scenario 4			
50 percent of gross cultivated area is irrigated (100 percent irrigation potential is achieved)	236.3	17.7	218.6
Scenario 5			
Fertilizer use rises to 334 kilograms/hectare and 50 percent of gross cultivated area is irrigated (most optimistic fertilizer and irrigation scenario)	389.6	29.2	360.4
Scenario 6			
Fertilizer use doubles to 227 kilograms/hectare and 41.5 percent cultivated area is irrigated (half of the increased irrigation and fertilizer compared to scenario 5)	279.4	21.0	258.4
Scenario 7			
Fertilizer rises 50 percent to 173 kilograms/hectare and 41.5 percent cultivated area is irrigated (25 percent of the fertilizer rise and 50 percent of the irrigation rise compared to scenario 5)	251	18.8	232.2
Scenario 8			
Scenario 7 plus genetic and technical efficiency improvements	281	21.1	259.9

[a]According to Sarma and Gandhi, (1990), the Indian Ministry of Agriculture deducts 5 percent for the seed and 2.5 percent for waste when calculating available grain production. We have therefore deducted 7.5 percent from total production to obtain the available supply for food and feed. The gap between total production (plus net imports) and total demand is about 10 percent in the IMPACT model results.

IMPACT Model

IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) provides cereal supply projections to 2020 for India (see footnote 3 and Rosegrant et al. 1995). The area under cultivation is endogenously determined in the model, responding to price changes but constrained by available area. IMPACT shows annual increases in area under cereals of only 0.7 percent, consistent with figures over the last three decades, so production growth must come from yield growth.

Yield growth is based on exogenous and endogenous components. The exogenous component is based on various assumptions about future conditions in public and private research and extension, and the spread of markets, infrastructure, and irrigation. The endogenous yield growth component is based on price response, with prices set to clear markets. The growth contribution of modern inputs such as fertilizers is accounted for in price effects in the yield response function, and as a complementary input with irrigation and with the modern varieties generated by research (Evenson and Rosegrant 1995).

The projected annual yield growth rates to 2020 are 1.53 percent for wheat, 1.43 percent for rice, and 1.42 percent for all cereals. The rates for all cereals are brought down by the low rates for coarse grains. The projected growth rates would be sufficient to raise yields from 2.4 tons per hectare for wheat in 1993 to 3.6 tons per hectare in 2020, and 1.9 tons per hectare to 2.7 tons per hectare for rice. Total cereal production would grow from 168.6 million tons in 1993 to 256.2 million tons in 2020 (Table 7).

Kumar's Projections

Kumar (1998) developed a detailed econometric model of the cereal production system in India that simulates planted area, input use, and yields by cereal type. The model includes assumptions about changes in output prices, the price of fertilizer, wage rates, and trends in total factor productivity growth (TFP). He provides two supply scenarios for 2020, one with constant growth in TFP, and one with a decelerating rate of growth in TFP. In the first case, total cereal production in 2020 is estimated at 309 million tons. If growth in TFP slows down, then total production in 2020 will only be 269.9 million tons. The latter is remarkably close to the IMPACT forecast.

Expanding Irrigation and Fertilizer

Another way to examine future growth is to consider the prospects for increasing output simply by extending the use of inputs that have proven successful in raising output in the past. As mentioned above, sizeable yield gaps remain between national averages and those attained on experiment stations, suggesting that existing technology can go a long way toward meeting India's growing food requirements.

As previously discussed, the main sources of growth have been irrigation, modern varieties, and fertilizer. We examined possible increases in food grain production through further expansion in the use of these inputs. In the projections under the most optimistic scenario, all remaining irrigation potential is fully utilized and fertilizer use is raised to agronomically optimal levels in the year 2020.

The exercise requires comparing current irrigation and fertilizer levels with the ultimate potential, comparing yields with and without irrigation and with different levels of fertilizer, and then calculating additional production if these gaps were closed. These scenarios imply that irrigated land would spread from the current level of 33 percent of gross cropped area to 50 percent, and that fertilizer use would rise on average from 120 kilograms per hectare to 334 kilograms per hectare.

The results of this exercise are shown in Table 7 (scenarios 3–5). If fertilizer use is tripled, cereal production would increase from the 1993 level of 168.6 million tons to 287.5 million tons in 2020 (scenario 3). If irrigation were expanded to 50 percent of gross cropped area, the 2020 production figure would be 236.3 million tons (scenario 4). And if both fertilizer and irrigation were expanded to these levels, cereal production in 2020 would be 389.6 million tons (scenario 5), or 42.5 million tons above the trend projection (scenario 1).

It is important to note that these optimistic figures simply show what is theoretically possible given existing technology. But for reasons explained above, they are not realistic due to the high costs of completely closing the gaps in both irrigated area and fertilizer use. Accordingly, Table 7 also shows what would happen under more realistic and less optimistic assumptions about expansion of irrigation and fertilizer use. If the irrigation and fertilizer gaps are closed by 50 percent instead of 100 percent (scenario 6), irrigation would spread to about 41.5 percent of cultivated area, and average fertilizer use would rise to an all-India figure of about 227 kilograms per hectare (representing a doubling of current rates). This scenario assumes that the 50 percent shortfall below the most optimistic projection is spread evenly throughout the country. Under this scenario, cereal production would increase by 110.4 million tons to a total production level of 279 million tons in 2020.

This scenario is probably still questionable. The irrigation figures may be attainable through a modest increase in irrigated area coupled with significant improvements in irrigation efficiency. But fertilizer quantity probably remains an overestimate for the reasons given above. Under a still less optimistic projection, irrigation is assumed to increase to 41.5 percent as under the previous scenario, but fertilizer increases by 50 percent instead of doubling. In this case, additional cereal production would be 82 million tons, for a total production level of 251 million tons (scenario 7), which is similar to the IMPACT projections.

Other Sources of Growth

As discussed above, modern varieties still have a role to play in increasing yields. Introduction and diffusion of the hybrid and "super" rices mentioned earlier, combined with similar advances in wheat and other crops, could eventually lead to additional annual rice production of 10–30 million tons. Additional spread of the current generation of modern varieties will also continue to stimulate gains. Improvements in technical efficiency, principally through site-specific measures to reduce pests and raise soil fertility, will add 10–20 million tons as well. If genetic improvement and technical efficiency raise production by an additional 30 million tons, combining this with the estimates based on the spread of irrigation and fertilizer could bring total production to 281 million tons by 2020 (scenario 8).

Effects of Natural Resource Degradation Scenarios on Cereal Production

Several studies have estimated degraded land area in India. Sehgal and Abrol (1994), using the guidelines of the Global Assessment of Soil Degradation (GLASOD) (Oldeman 1988), estimated the national figures shown in Table 8. Sehgal and Abrol relied on several sources of information, including a

Table 8—Extent of soil degradation severity in India

Type of degradation	Severity of degradation: Low	Medium	High	Very high	Total area
			(million hectares)		
Water erosion	5.0	24.3	107.2	12.4	148.9
Wind erosion					
Loss of topsoil	. . .	. . .	6.2	. . .	6.2
Loss of topsoil or terrain deformation	. . .	. . .	4.6	. . .	4.6
Loss of soil due to terrain deformation or due to over-blowing	. . .	. . .	. . .	2.7	2.7
Chemical deterioration					
Loss of nutrients	. . .	. . .	3.7	. . .	3.7
Salinization	2.8	2.0	5.3	. . .	10.1
Physical deterioration					
Waterlogging	6.4	5.2	. . .	. . .	11.6
Total area	14.2	31.5	127.0	15.1	187.7

Source: Sehgal and Abrol, 1994.
Note: . . . is a nil or negligible amount.

generalized soil map of India, remote sensing data from selected areas, and published information on forestry and soil degradation problems. Unlike other studies, they also gave a rough estimate of the effects of land degradation on crop yields (Table 9).

The data presented in Tables 8 and 9 raise at least three interesting issues. First, the area under degradation is quite large, even after adjusting the figures to cover only agricultural land. If the numbers are correct, they may help explain the low yields found in many areas of the country. Second, continued spread of degradation could have a debilitating effect on food output growth. Third, if the current level of degradation were reduced through investments to improve soil conditions, then presumably yields could rise. Shortages of land and rising food prices often provide the needed incentive for farmers to invest in their land, reversing degradation and increasing productivity (Scherr and Hazell 1994). For example, by 1986–87, 42 percent of salt-affected land in Punjab had been reclaimed using soil amendments and other management practices (Joshi 1997), and reclamation has proceeded further since then. On rainfed lands, there is abundant evidence that farmers conserve soil, plant trees, and undertake other measures to protect natural resources where the net returns warrant them (Pender and Kerr 1996).

To consider the effects of changes in the level of degradation, we take a very simple look at what would happen to current levels of national food production if degradation levels were to either improve or deteriorate beyond the levels estimated by Sehgal and Abrol. We assume that current food production levels reflect the yield-reducing effects of degradation cited by Sehgal and Abrol, and then simulate the change in production that would be associated with a 50 percent reduction of degradation and a 50 percent increase in degradation on agricultural lands. This exercise is only intended to give a rough idea of the implications of changing natural resource management conditions. It is important to note that Sehgal and Abrol's estimates of the yield effects of degradation are very broad, so precision is impossible. Also, the exercise should really be done at a disaggregated level, matching local degradation conditions to crop yields to capture differences in yield effects of degradation across different types of agriculture, and then summing to the national level. But such an undertaking is beyond the scope of the present study.

Table 9—Yield implications of soil degradation

Severity	Yield implications
Low	Negligible loss (up to 15 percent), easily manageable
Medium	Moderate loss (15–33 percent), soils can be managed at farm level
High	Significant loss (33–67 percent), affected area not economical to cultivate, could have other uses such as agroforestry
Very high	Unmanageable and uneconomical to use

Source: Sehgal and Abrol, 1994.

The exercise is conducted separately for irrigated and rainfed lands because they are subject to different kinds of degradation problems. For example, rainfed lands are more prone to soil erosion, while irrigated lands are susceptible to salinity. In the scenario of reduced degradation, it is assumed that for each type of degradation, 50 percent of the area affected at different levels of severity shift to a reduced level of severity. For example, 50 percent of the slightly affected area becomes nondegraded, 50 percent of the "medium" area becomes "low," and so on. For the increasing degradation scenario, the same area of land shifts in the opposite direction. The base land area used in the calculations is the area that is subject to changes in yield as a result of degradation or improvement on different types of land.[5] Then the percentage of production change is calculated under the full range of yield changes in Table 9.

Under the scenario of an improved land degradation situation, and assuming a 50 percent increase in fertilizer use and that 41.5 percent of the cropped area is irrigated, projected 2020 food production would increase by 7.2 percent—from 251.0 million tons to 269.1 million tons (Table 10, scenarios 7 and 12). Varying the assumptions about the impact of degradation on food production to Sehgal and Abrol's high and low points, this percentage change

[5] The rough area figures were suggested by Abrol in a personal communication.

Table 10—Alternative cereal supply projections for 2020, with land degradation, India

Scenario[a]	Projection basis	Production	Seed and waste	Available supply
	1993			
	Actual	168.6	12.6	156.0
	2020			
2	IMPACT model (baseline)	256.2	19.2	237.0
9	With additional land degradation	235.8	17.7	218.1
10	With reduced land degradation	271.0	20.3	250.7
	Fertilizer rises 50 percent to 173 kilograms/ hectare and 41.5 percent cultivated area is irrigated			
7	Base calculation (scenario 7 in Table 7)	251.0	18.8	232.2
11	With additional land degradation	233.9	17.5	216.4
12	With reduced land degradation	269.1	20.2	248.9
	Plus genetic and technical efficiency improvements			
8	Base calculation (scenario 8 in Table 7)	281.0	21.1	259.9
13	With additional land degradation	261.7	19.6	242.1
14	With reduced land degradation	301.2	22.6	278.6

[a]According to Sarma and Gandhi, (1990), the Indian Ministry of Agriculture deducts 5 percent for the seed and 2.5 percent for waste when calculating available grain production. We have therefore deducted 7.5 percent from total production to obtain the available supply for food and feed. The gap between total production (plus net imports) and total demand is about 10 percent in the IMPACT model results.

ranges from 4.7 percent to 10 percent. If the degradation situation worsens by the same magnitude, the numbers are slightly smaller because there are some degraded areas that have prospects for raised production but no prospects for dropping any further (such as windblown areas of Rajasthan and waterlogged riverbank areas of eastern India). The average decline in production is 6.8 percent (with a range of 4.5 percent–9.5 percent), leading to a decline in total cereal production from 251 to 233.9 million tons (Table 10, scenario 11).

These figures are constant across all the 2020 food supply projections listed in the previous section, because it was assumed that the area under irrigated and rainfed conditions is roughly constant across projections. As a result, worsening degradation reduces the range of supply projections from 250–280 million tons by about 6.8 percent to 233–261 million tons, and reducing degradation increases the range by about 7.2 percent to 268–300 million tons. These results are generally consistent with simulations conducted with the IMPACT model (Rosegrant et al. 1995) (Table 10, scenarios 9 and 10). In this case, additional land degradation is projected to reduce cereal production by 8 percent, from 256.2 to 235.8 million tons. Reduced degradation leads to a 5.8 percent increase in production to 271 million tons.

To conclude, it seems unlikely that India can produce more than 280 million tons of cereals by 2020, or 260 million tons excluding seed and waste. But the amount could be lower if there is any significant slowdown in technological change, or if resource degradation is not contained. Discussions with several analysts and policymakers in Delhi revealed strong support for this figure.

3. Conclusion: Projected Cereal Gaps and Policy Implications

By combining the demand and supply projections from previous sections, we can now assess the likely cereal gaps for India in 2020. These gaps are reported in Table 11 for some of the more important demand and supply scenarios.

Our results show that whether India will have a manageable cereal demand in 2020 depends critically on what happens to the livestock sector. Rapid economic growth, particularly if it is accompanied by significant shifts in consumption patterns and reductions in malnutrition, could lead to escalating demands for milk, eggs, and meats. These in turn would require changes in livestock production methods, with increasing reliance on cereals for livestock feed. A distinguishing feature of our paper is that we look beyond the bounds of past patterns of consumption behavior and livestock feeding systems in India and consider the possibility of significant structural shifts in these variables as the Indian economy continues to grow rapidly and modernize and as more people become exposed to a wider range of food types, including more processed foods. The per capita consumption of livestock products is currently very low by international standards, and also falls well below the standards set by the Indian Council of Medical Research. Any significant correction of these abnormalities would quickly lead to larger cereal gaps than other forecasters have estimated.

Given plausible assumptions about how expenditure elasticities and livestock-feed coefficients will change over time, and per capita income growth of 3.7 percent or more per annum, India may need nearly 300 million tons of cereals by 2020. But short of significant changes in the agricultural sector, the country's production capacity is not likely to exceed 260 million tons (net of seed and waste). This implies a cereal gap (excess demand over domestic production) of 36 million tons or more per year by 2020. The cereal gap would be

Table 11—Matrix of projected cereal gaps for India in 2020 under alternative demand and supply scenarios (million metric tons)

Supply scenario	Total supply (net of seed and waste)	Demand (food + feed) scenario: Authors' projections with per capita income growth of 2 Percent	3.7 Percent	6 Percent
Total demand		**257.3**	**296.2**	**374.7**
		(supply minus demand)		
1962/65–93 Trend extrapolated	**321.1**	63.8	24.9	–53.6
Reasonable increase in fertilizer and irrigation use[a]	**232.2**	–25.1	–64.0	–142.5
Plus genetic and technical efficiency improvements[b]	**259.9**	2.6	–36.3	–114.8
With additional land degradation[c]	**242.1**	–15.2	–54.1	–132.6

[a] Scenario 7 in Table 7. Fertilizer use increases to 173 kilograms/hectare and half of remaining irrigation potential is exploited.
[b] Scenario 8 in Table 7.
[c] Scenario 14 in Table 10.

even larger if India were to become a TIGER economy. For example, with 6 percent growth in per capita income each year, the gap could reach 115–142 million tons by 2020. Even if the Indian economy slows down to more historical rates of growth, the cereal gap could grow to as much as 25 million tons by 2020.

These findings contrast sharply with results from several other studies, which are much more sanguine about the prospects for continued national self-sufficiency in cereals. The IMPACT model projects a market clearing situation in which domestic production and demand are almost in balance at 237 million tons in 2020. Kumar (1998) also projects small cereal gaps for 2020. In his case, projected demand is 265.8 million tons and production is either 286.1 or 245.9 million tons (both adjusted for seed and waste), depending on whether TFP growth continues unabated or whether it slows down. In the first case, India would have a cereal surplus of 20.3 million tons, but in the second case there would be a cereal gap of 19.9 million tons. Yet our higher figures for India involve less cereals (including feed grains) per person in 2020 than some other Asian countries are already using today.

Of course, large cereal gaps could never materialize in a market economy. There would be an inevitable upward pressure on prices, which would serve to close the gap by dampening demand, inducing new sources of supply, and encouraging more imports. Price increases would be particularly hard on the poor and, as in the past, it is likely that the government would give continuing priority to either keeping basic food prices at acceptable levels or targeting assistance to the needy. Either approach would help maintain cereal demand. The gaps would therefore have to be filled through increased domestic production or imports. Imports could take the form of rice and wheat for human consumption, livestock feeds (such as maize), or livestock products themselves.

Policy Implications

The likelihood of a rapidly growing demand for livestock products and feedgrains presents an important opportunity to increase incomes and employment and to reduce poverty in rural areas through additional investments in agricultural development. There is considerable scope for additional agricultural growth that is economically efficient, that would better exploit the country's comparative advantage, and that would contribute to the generation of rural employment and poverty alleviation. This would require additional policy reforms and market liberalization to bring price ratios more in line with world prices, and additional public investment in agriculture and rural areas.

The policy reforms begun in the early 1990s have yet to be fully completed for many domestic agricultural markets. Many farmers have been squeezed between the rising costs of key inputs (as subsidies have been removed) and declining farmgate prices. The latter have been aggravated by restrictions on exports, cheap imports, and excessive regulation of agro-industry (World Bank 1999). Completion of the reform process with full liberalization of domestic markets, foreign trade, and agro-industry would improve the terms of trade for many farmers and encourage greater cereal and livestock production. Such growth could include many of the poorer rainfed areas (Gulati and Sharma 1997).

As in the past, public investment in rural infrastructure, agricultural research and extension, and the education and health of rural people will continue to play a key role in determining the rate of agricultural growth (Fan et al. 1998). It will also require that rainfed areas receive a larger share of any additions to public investment. There is clear evidence that infrastructure investments have been biased towards irrigated areas, and this has compounded the natural advantage enjoyed by irrigated over rainfed areas (Binswanger et al. 1993). Recent evidence suggests that while in the past these investments have yielded the highest returns in irrigated areas, this has been less true in the post-Green Revolution era (Fan and Hazell 1999). In fact, the marginal returns to several infrastructure investments are now higher in many rainfed areas, and they also have a potentially greater impact on reducing rural poverty. This suggests the possibility that investment in infrastructure in rainfed areas can offer India a "win-win" strategy for addressing productivity and poverty problems.

The Indian government already spends more on agriculture than almost any other Asian country.

But the lion's share of this expenditure goes to subsidies for farm inputs, particularly fertilizers, credit, water, and electricity. While once important for helping to initiate the spread of the Green Revolution, these subsidies contribute very little to agricultural growth today (World Bank 1999; Gulati and Rao 1994). As such, there is considerable scope for achieving greater growth in agriculture simply by redirecting public funds that are already expended on the sector. There is also scope for reducing the cost of providing public goods in rural areas by a) forming new partnerships between the public, private, and NGO sectors to take better advantage of alternative and lower cost sources of supply of public goods; and b) improving the efficiency of public supply institutions through improved management, more transparent procurement and operational procedures, and greater accountability to end users (World Bank 1999).

Several of our supply-side scenarios for 2020 implicitly assume that the government will continue to invest in new technology and rural infrastructure. But a combination of greater productive investments plus more favorable terms of trade for agriculture could bring about an additional 20–30 million tons of cereals by 2020. With parallel increases in livestock productivity, the projected food gaps should be manageable.

The policy alternative would be to fill the cereal gap through increased imports. The importation of 36–64 million tons of cereals (or its equivalent in livestock feeds or livestock products) would place a heavy burden on the country's trade balance and divert funds from more economically productive investments. It would also do much less to alleviate the most crucial gap of all—the growing gap in incomes, wealth, and opportunity between India's rural and urban areas.

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