RESEARCH REPORT

119

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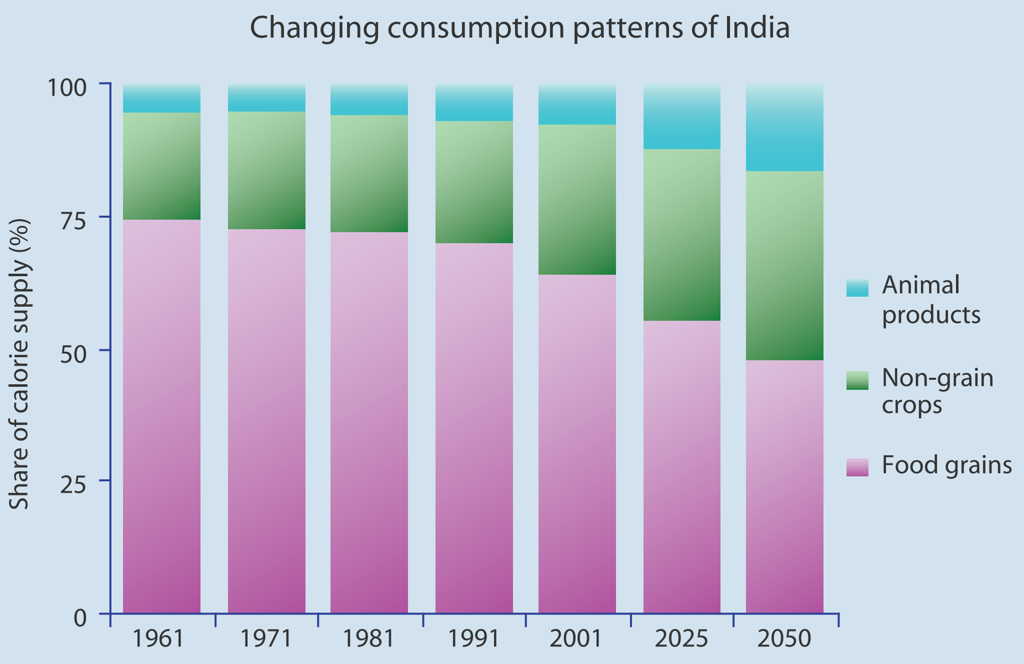

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Cover photograph shows changes in calorie supply per person from the three categories of food products: grains, non-grains and animal products in India. The data for the period from 1961-2001 are from the FAOSTAT database, and the projections for 2025 and 2050 are the authors' estimates given in this report.

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Contents

Summary

Increasing income and urbanization are triggering a rapid change in food consumption patterns in India. This report assesses India's changing food consumption patterns and their implications on future food and water demand. According to the projections made in this study, the total calorie supply would continue to increase, but the dominance of food grains in the consumption basket is likely to decrease by 2050, and the consumption of non-grain crops and animal products would increase to provide a major part of the daily calorie supply. Although, the total food grain demand will decrease, the total grain demand is likely to increase with the increasing feed demand for the livestock.

The implications of the changing consumption patterns are assessed through consumptive water use (CWU) under the assumptions of full or partial food self-sufficiency. Irrigated crops contributed to 54 percent of the total consumptive water use of the examined crop categories in 2000. The rain-fed portion—the effective rainfall—of the irrigated and rain-fed crops contribute to two-thirds of the CWU. If the growth in water productivity stagnates, the CWU demand exceeds the potentially utilizable water resources. However, a 1.0 percent annual growth in water productivity could eliminate the increase in CWU demand for grains. If the water productivity can be increased by 1.4 percent annually, or to an amount equivalent to doubling it by 2050, then the need for additional CWU can be eliminated.

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Introduction

Food grains dominate the vegetarian centered diet of the Indian people, although the composition of the diet varies across different regions. Grains provided 65 percent of the calorie supply in 2000, and this varied from 60 percent in the north to 74 percent in the south. Rice is the main food grain in the south and the east, and is followed by wheat in the east and coarse cereals in the south; wheat is the principal food grain in the north followed by rice; and wheat comprises half of the grain consumption in the west, followed equally by rice and other coarse cereals. The non-grain food crops and animal products provided 27 and 8 percent, respectively, of the remaining calorie supply in 2000. Due to cultural and religious reasons, the meat consumption in India is very low, and much of the calorie supply from animal products is obtained, at present, from milk and milk products. Milk consumption also varies significantly from 101 liters per person per year in the north to 26 liters in the south.

Thus, the question of how India should manage its water resources to meet food grain security for the increasing population was a paramount concern for Indian policymakers. This concern was the basis for the food and water demand projections of the National Commission of Integrated Water Resources Development (NCIWRD) in 1998 (GoI 1999). The commission has assumed adequate nutritional and livelihood security to all people by 2050. The commission has projected India's population to reach 1,500 million by 2050. The grain need, under well-fed scenarios, is projected to increase to 494 million metric tones (mmt) - more than a 150 percent increase from the present level. Accordingly, the NCIWRD has projected the irrigation water demand to increase from 594 billion cubic meters (BCM) in 1998 to 807 BCM by 2050. This projection in increase is important in two aspects.

First, the projection of the NCIWRD for grain demand was a key justification for the National River-Linking Project (NRLP) (NWDA 2006). The commission assumed that a major part of the additional grain demand by 2050 will be produced under irrigated conditions. For this purpose, according to the commission, the irrigated area needs to be increased to 140 million hectares (mha), from 68 mha in 1993. The estimated irrigation water demand under this growth scenario was one of the key justifications for the NRLP, where transfers of 178 cubic kilometers (km^3) of water were to be made through a proposed network of more than 12,000 kilometer (km) long canals. This increases the irrigated area by 30 mha from the present potential, while also easing the water scarcity in the south and west, and mitigating the flood-related problems in the east. However, the concept of the project is a major contentious issue of discourse in India today (Chopra 2003; Iyer 2003; Bandyopadhyay and Perveen 2003). It is argued that the basis for the projections in growth of irrigated area, in a way, is an over-estimate due to various factors, which include the changing food consumption patterns and food needs; the higher potential for an increase in the crop yield than as assumed by the commission, and the changing global food trade scenarios.

Second, the commission's projections on the total grain demand may not be in line with the changing food consumption patterns. A major part of the projections made by the NCIWRD for grain demand is for food. However, the global and the national consumption patterns indicate different trends (Delgado et al. 2005; Rosegrant et al. 2001; Bansil 1999; Bhalla et al. 1999; Rao 2000; Kumar 1998; Kumar and Mathur 1997; Radhakrishna and Ravi 1992). With increasing income and urbanization, consumption patterns shift from grain to non-grain products. Increasing consumption of animal products in the non-grain component results in major changes in the share of the demand for food and feed grains. This pattern can be clearly seen in the developed countries. The FAOSTAT database (FAO 2005a) shows that the share of the food grain of the total grain demand in the developed countries was only 23 percent in 2000; and much of the other demand for grain is for feeding livestock. It further indicates that the share of food grains in developing countries, although still high relative to developed countries (68% in 2000), is declining too. In India, while the food grain demand increased by only 1 percent, the feed grain demand for livestock increased by more than 9 percent annually in the 1990s. In fact, in many developing countries with fast-growing economies, the growth of feed grain demand (238%) is outpacing the growth of food grain demand (53%) by many times (Rosegrant et al. 2001).

However, the assumptions and the concerns of the projected total grain demand in some studies are not in line with the recent trends due to rapid economic growth. Food self-sufficiency may no longer be an important issue in the context of World Trade Agreements and the world's increasing food trade, but then, the extent of imports depends on the true nature of future grain and non-grain food and feed demand. The true nature of grain and non-grain demand depends on the changes in consumption patterns. Therefore, the major objectives of this report are the following:

- To incorporate the recent changes in consumption patterns when projecting the demand for grain and non-grain crops in India by 2025 and 2050
- To assess the implications of increasing crop demand on water demand

Many studies have illustrated the emerging shift in food consumption patterns in India from food grains to non-grain food crops and animal products (Chatterjee et al. 2006; Bansil 1999; Rao 2000; Kumar 1998; Kumar and Mathur 1997; Radhakrishna and Ravi 1992, Huang and David 1993). The per capita grain consumption has been decreasing since the 1980s. This decline is due to various facts, including income growth, urbanization and associated changes in lifestyles, changes in relative prices and the availability of non-grain foods, etc. The results of the survey carried out by the National Sample Survey Organization (NSSO) show that the average monthly per capita cereal consumption in the urban areas of India has dropped from 11.2 kilograms (kg) during 1973-1974 to 10.6 kg during 1993-1994. The corresponding decline in the rural areas is 15.3 kg and 13.4 kg, respectively, for the specified periods. Within the grain products, there is a shift from coarse cereals to superior cereals such as rice and wheat (Viswanathan 2001). Rath (2003) has suggested that the per capita grain consumption will decrease further due to the reduction in the physical labor requirement in rural areas.

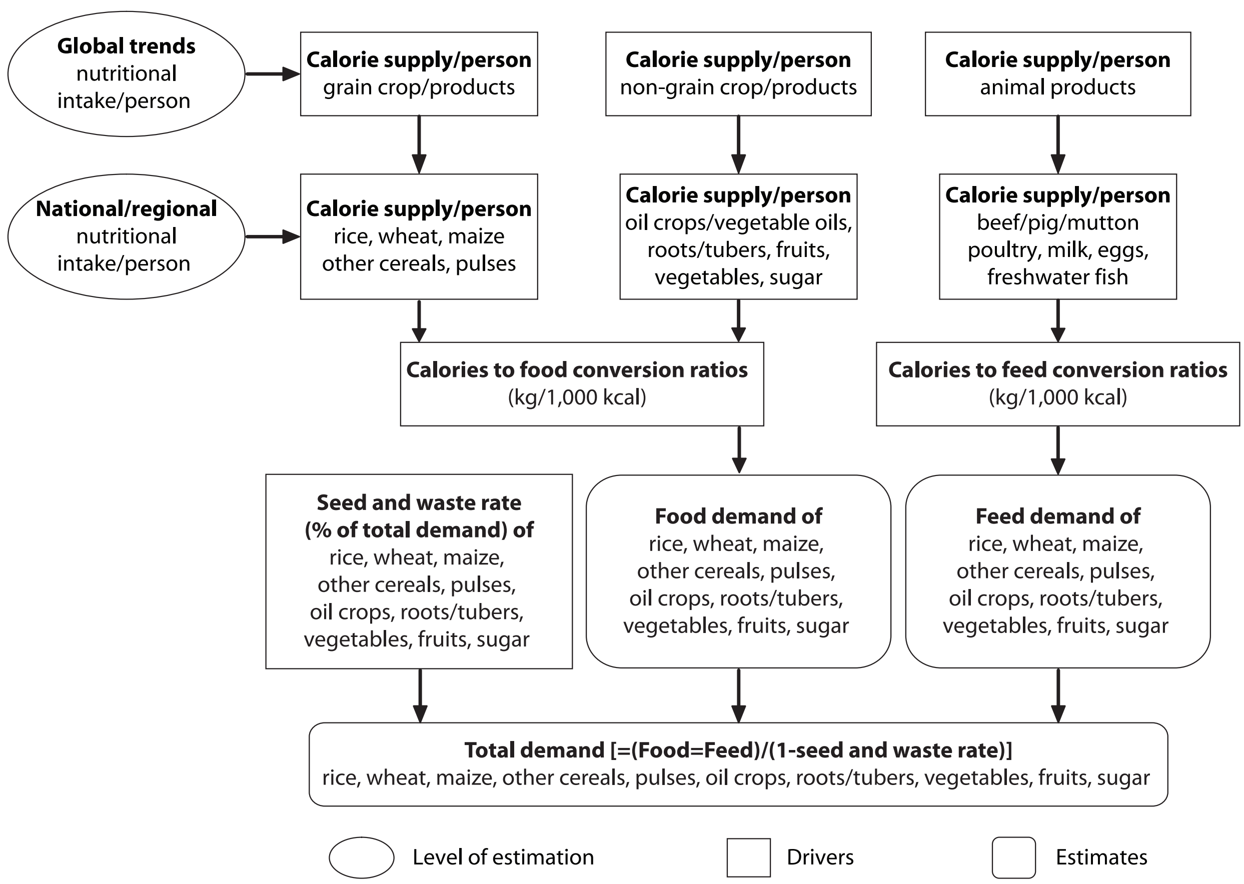
Several studies in the past have also projected India's food grain demand for 2020 (Bhalla et al. 1999; IWMI 2000; Kumar 1998; Rosegrant et al. 1995; Radhakrishna and Reddy 2004). These studies have, in varying degrees, accounted for the emerging trends of increasing animal product consumption and the resulting feed demand. However, most of the studies have concentrated only on the grain demand. Based on the spatial and temporal trends between 1987 and 1988 and between 1993 and 1994, Dyson and Hanchate (2000) have projected the demand for grain and non-grain crops at the state level to 2020.

This study extends the projections of crop demand to 2050, by using the global, national and regional level changes in consumption patterns in recent times. The rest of the report is divided into four sections. The next section explains the assumptions and the methodology adopted in this report. The third section presents the projections to 2025 and 2050, and compares these with the results of the projections made by the NCIWRD and other projections. The fourth section presents the implications of the projected increase in grain demand on water demand. We conclude the report by discussing the policy implications and further research requirements.

Methodology, Data and Assumptions

This study assesses the demand for 12 major crops or crop categories (called only ‘crops’ hereafter). They include the grain crops: rice (milled equivalent), wheat, maize, other cereals (such as jowar, bajra, ragi, barley, millet, etc.), and pulses; and the non-grain crops: oil crops

FIGURE 1.
Estimation of crop demand in India.



(including vegetable oils as oil crop equivalent), roots and tubers (dry equivalent), vegetables, fruits and sugar. The food balance sheets from the FAOSTAT database show that these crops accounted for 99 percent of the nutritional supply in the daily diets from 1991 to 2001, directly through food and indirectly through feed for the livestock (FAO 2005a). Hence, they were selected for the projection of demand in this study. We also keep an allocation for seeds and waste.

Figure 1 shows the approach that we used to estimate crop demand. First, we project the calorie intake of grain, non-grain and animal product food categories using the global trends. Second, we assess the level of consumption of different crops or animal products that provide the projected calorie supply in the Indian context. Here we account for the regional variations of consumption patterns in India. Details of these are discussed next.

Food Demand

First, we capture the changing consumption patterns of rural and urban India, for which we use the nutritional intake of three major food consumption categories—grain crops, non-grain crops and animal products. The total calorie availability per person per day is taken as an indicator for the nutritional intake.

It is generally recognized that income and urbanization are two major drivers of changing consumption patterns. Low income people increase their nutritional intake through easily accessible crops, such as cereals and pulses. Many of the developing countries are in this category, and they have a significantly high percentage of calorie supply that is obtained from grains (table 1). As income and also access to other foods increase, people diversify food habits by consuming more non-grain crops and animal products (Radhakrishna and Ravi 1992). As income increases, the animal products substitute the cereals in the diet.

Although, the composition within the three food categories depends on taste, culture, religion, access to markets and other regional factors, this global trend of total nutritional intake of the three food categories remains the same. We assume that India is no exception to this changing global pattern, but the level of consumption and hence the calorie intake of the individual crops or animal products within the three categories varies according to the specific regional consumption patterns in India. We use a sample of developing countries (with a gross domestic product (GDP) per person of less than US$10,000) to assess trends in calorie intake of the three food categories with respect to income and urbanization. The spatial variations of consumption patterns within India are used to assess the projections of consumption of the different commodities within the three food categories.

TABLE 1.
Calorie intake of food categories - grains (G), non-grains (NG) and animal products (AP).

Year	Developed countries				Developing countries				India			
	Total	G	NG	AP	Total	G	NG	AP	Total	G	NG	AP
	kcal	%	%	%	kcal	%	%	%	kcal	%	%	%
1980	3,217	32	40	28	2,308	64	27	9	2,082	71	22	6
1985	3,261	31	40	29	2,444	64	27	9	2,229	69	23	7
1990	3,289	31	40	28	2,520	62	27	10	2,366	69	23	7
1995	3,199	33	40	27	2,602	59	29	12	2,399	67	25	7
2000	3,275	32	42	26	2,654	56	31	13	2,413	63	28	8

Source: FAO 2005a

Note: G, NG and AP are calorie supply from grain (including pulses), non-grain and animal product (including freshwater fish), respectively, food categories as a percentage of total calorie supply.

Second, we assess the changing patterns of the composition within the two food categories. The rice, wheat, maize, other cereals and pulses among the grain crops, and oil crops, roots and tubers, and vegetables, fruits and sugar in the non-grain crops are the focus of analyses here. Tastes and a host of other factors determine the composition of different crops or animal products in the diet. Due to this fact, the composition of calorie supply varies between countries and also within countries. For example, in India, rice provides a major part of the calorie intake from grain crops whereas wheat is the major calorie provider in Pakistan; milk provides almost all the calorie supply from animal products in India, while meat, mainly pork, provides much of the calorie supply from animal products in China (table 2). Wheat is the staple diet in the northern and western states of India. Rice is the staple diet in the east and south. To capture the consumption patterns specifically for India, we first assess the national trends in the contribution of calorie supply from individual crops or animal products to the total calorie supply of the three broad categories. We then incorporate the regional differences within India by adjusting the national estimates according to the state level of differences in calorie supply in 2000.

Finally, the food demand for different crops is obtained by multiplying the calorie intake by the food conversion factors. The food conversion factor is the quantity (kg) of food required to generate 1,000 kilocalories (kcal) of calorie supply. Table 3 shows India's food conversion factors in 2000.

TABLE 2.
Composition of calorie supply of different food categories in 2000.

Countries	Grain crops				Non-grain crops					Animal products		
	Rice	Wheat	Other cereals	Pulses	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar	Meat	Milk	Fish
	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal
Developed	118	740	153	28	458	136	76	94	324	246	336	5
Developing	692	473	258	63	279	148	69	72	163	145	93	10
China	887	547	150	13	285	175	138	50	61	352	21	20
Pakistan	157	1,005	93	65	249	26	26	51	235	48	347	3
India	737	492	183	109	270	49	44	50	161	18	153	5

Source: FAO 2005a

TABLE 3.
India's food conversion factors in 2000.

Food conversion factor	Rice	Wheat	Maize	Other cereals	Pulses	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
kg/1,000 kcal	0.287	0.322	0.335	0.322	0.288	0.398	0.321	4.184	2.114	0.283

Source: Estimates based on FAOSTAT data of 1999, 2000 and 2001 (FAO 2005a).

Feed Demand

Feed conversion ratios along with the projected calorie intake from animal products - are used for projecting the feed demand. In India, milk and milk products provide 87 percent of the calorie supply from animal products (table 2), and maize is the major commercial livestock feed in 2000 (table 4). The feed conversion ratio is defined as the quantity (kg) of a crop used for generating 1,000 kcal of animal products in the diet. If grain is the only source of feeding, then it takes 3 to 6 kg to produce 1 kg of meat products (poultry to red meat). However, traditional grazing, crop residues, food waste, dry fodder and oil cakes are the main forms of feeding used for the livestock in the developing nations. According to the FAOSTAT database, the total feed grain consumption in India was only 8.1 mmt in 2000, and this is equivalent to a feed conversion ratio of 0.11 kg/1,000 kcal of animal products. The feed conversion ratio in India is very low compared to many other countries. However, the conversion ratio has been increasing by 2.0 percent annually between 1995 and 2003, as against the 1.6 percent annual growth of calorie supply from animal products (FAO 2005a). The future demand for direct feed grains may increase rapidly as land is a significant constraint for additional grazing and fodder production, and grain is the main feed for the poultry production.

Inadequate information on feed use for different animal husbandry activities is a considerable constraint for projecting feed demand. Many global and national databases provide information on total feed consumption. However, they do not provide the breakdown of the feed consumption for various livestock-rearing activities. Therefore, we only use the feed conversion factors (kg/1,000 kcal) of different crops with respect to the total calorie supply from animal products. Here we assume that changes in the feed conversion factor reflect the efficiency of meat production, changes in the consumption of animal products, and lack of grazing land and fodder for livestock feed. Table 4 shows that maize has the highest feed conversion factors for India. The recent trends in the feed conversion factors are assumed to be the indicators of future growth. The projected feed conversion factors are multiplied by the respective calorie supply from the animal products to estimate the feed demand.

TABLE 4.
Feed conversion ratios and the seed and waste share in the total crop consumption.

	Rice	Wheat	Maize	Other cereals	Pulses	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
Feed conversion factors (kg/1,000 kcal)	0.005	0.012	0.074	0.005	0.016	0.008	0.000	0.000	0.000	0.006
Seeds and waste - % of total demand	6.8	11.7	17.0	9.7	8.2	12.7	19.2	6.7	14.0	0.04

Source: Estimate based on FAOSTAT data of 1999, 2000, and 2001 (FAO 2005a).

Seeds and Waste

The share of seeds and waste in the total crop consumption, for which data is only available at the national level, are shown in table 4 as a percentage of the total demand for grain in India. The production efficiency of crops, in general, improved with better seed varieties and with improved post-harvest storage techniques. As the production efficiency increases, the share of seeds and waste in the total demand goes down. For example, seeds and waste as a percentage of the total grain supply in India has decreased from 10.2 to 9.5 percent over the period 1980-2000 (FAO 2005a). Using the past trends, we project the rates of seeds and waste as a percentage of total consumption at the national level.

Total Crop Demand

Finally, the total demand for each crop is estimated as

Total demand = (food demand + feed demand) / (1 - seeds and waste as a percentage of total demand)

Consumptive Water Use

This study uses the consumptive water use (CWU) - the quantity of water transpired by the crops and evaporated by the surface on which the crop grows during the crop growth period - as a means of assessing the implications of increasing food demand on water demand. We compare the increasing CWU demand with the CWU in 2000. Vaidyanathan and Sivasubramaniyan (2004) used the CWU to assess changes in water demand for crop production in Indian agriculture between 1966 and 1991. They estimated the CWU using the mean annual rainfall and evapotranspiration, and also identified several limitations in the estimation. Vaidyanathan and Sivasubramaniyan's study did not cover all states in India. Moreover, the average annual data in their study did not capture the significant spatial variations of the potential evapotranspiration (ET_p), the rainfall and the growth periods for different crops.

This study improves the assessments made by Vaidyanathan and Sivasubramaniyan in many ways. We use the mean monthly rainfall and the ET_p at district level, the crop coefficients (the ratio of potential to actual ET) at different periods of crop growth (initial, development, middle and late), and the crop calendar of different crops for four different regions to estimate the CWU (FAO 2005b).

The implications of an increase in food demand on CWU are assessed in three steps. First, we estimate the CWU of both irrigated and rain-fed crops in 2000. Second, we estimate the water productivity per unit of CWU for the irrigated and the rain-fed crops in 2000. Finally, we assess the consumptive water demand under different scenarios of increases in water productivity to meet the future crop demand.

The CWU of the rain-fed crops is the minimum effective rainfall or the actual evapotranspiration (ET_a); and for irrigated crops it is simply the ET_a. Our assumption that irrigation meets the full crop water requirement is a fairly strong one, especially for water scarce locations where only part of the crop water requirement is met. However, we do not have the information of these locations for inclusion in the estimation of ET_a.

This study uses a 75 percent exceedence probability of monthly rainfall for estimating the effective rainfall (Amarasinghe et al. 2005). The CWU for the l^{th} crop is estimated as:

$$CWU_l = \begin{cases} \sum_{k \in seasons} IRA_{lk} \sum_{j \in months} \sum_{i \in growth\ periods} kc_{ki}^{l} \times ETp_j \times \frac{d_{ij}}{n_j} & for\ irrigated\ crops \\ \sum_{k \in seasons} RFA_{lk} \sum_{j \in month} \sum_{i \in growth\ periods} \min\ (kc_{ki}^{l} \times ETp_j, Effrf_j) \times \frac{d_{ij}}{n_j} & for\ rain-fed\ crops \end{cases}$$

where IRA_{lk} and RFA_{lk} are irrigated and rain-fed areas, respectively, of the crop in the k^{th} season; lε 9 crops (rice, wheat, maize, other cereals, pulses, oil crops, vegetables, fruits, sugar), iε four growth periods (initial, development, middle and late), = number of days of j^{th} months in the i^{th} crop growth period, and = number of days of j^{th} month; is the crop coefficient of the crop in the i^{th} growth period in the k^{th} season.

Food and Feed Demand

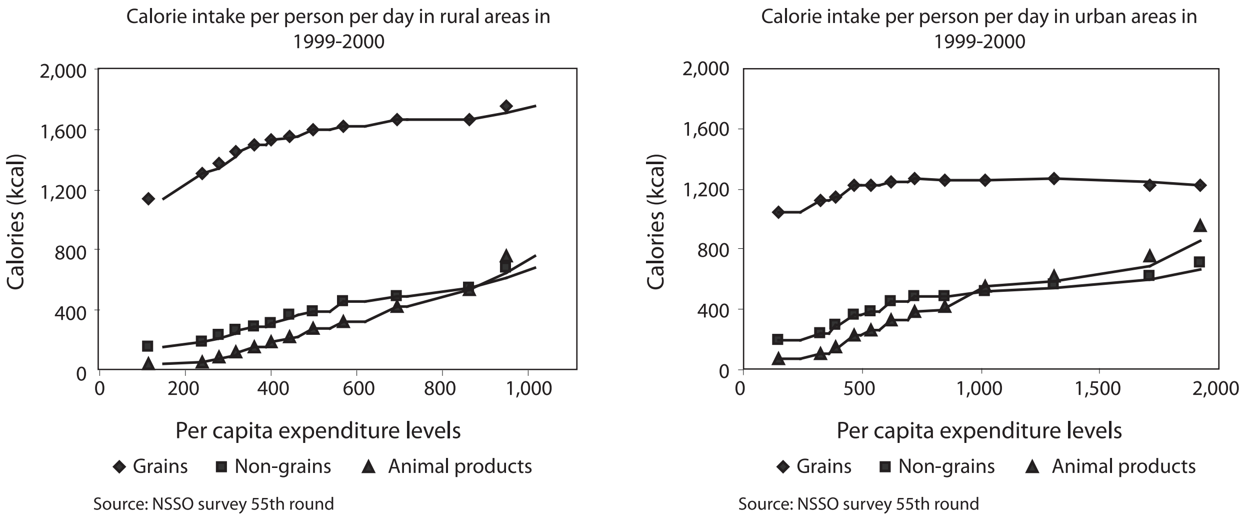
Nutritional Supply

A clear shift in the patterns of nutritional intake is taking place in India today. Although the calorie supply from all food categories (grains, non-grains and animal products) increased in the 1980s, the percentage obtained from grain products has decreased (table 1). In the 1990s, both the magnitude and the share of calorie supply obtained from food grains have decreased. However, thanks to the increasing consumption of non-grain food categories, the total calorie supply has increased.

The changing consumption patterns are also observed at varying scales of regional and demographic levels. The average calorie intake of rural India (2,437 kcal in 2000) is more than the calorie intake of urban India (2,367 kcal in 2000). The majority of the rural people are engaged in agriculture and many still depend on hard manual labor for their farm activities. This results in a higher energy requirement for the rural masses, and hence the rural people consume more food grains. However, the grain consumption in both the rural and urban sectors has been declining in recent years. The decline in grain consumption in the rural areas is mainly attributed to two reasons: the manual agricultural labor requirement in rural India is less today due to fast-spreading mechanization (Rath 2003). Hence, the rural people need less energy intake; increased income and improved infrastructure in the rural areas have increased access to non-grain foods. In urban areas, the changes in lifestyle with increasing income are associated with a shift to consuming more superior non-grain food products. Dyson and Hanchate (2000) have shown that consumption patterns changed in almost all the states in the late 1980s and early 1990s. In India, an increase in total calorie supply and the change in consumption patterns are expected to continue with increasing income and urbanization.

Income is a major driver of changing patterns of nutritional intake. Drewnowski and Popkin (1997), Popkin (2000, 2001), WHO (2003), and Knudsen and Scandizzo (1982) showed that the changes in consumption patterns exist extensively in the middle- to high-income countries. Subramanian and Deaton (1996), using the sample from the Maharashtra state of the 38th round of the National Sample Survey Organization (NSSO) survey, and Dawson and Tiffin (1998), using national consumption data, showed a statistically significant income elasticity (0.30%-0.40%) between income and consumption. Figure 2 shows the average calorie intake of the three food categories in the rural and urban populations in the 55th round of the NSSO survey. The consumption of non-grain crops and animal products are increasing from the lower to upper income groups in both the rural and urban areas. Huang and David (1993) have shown that urbanization has a significant effect in the changing patterns of cereal consumption. With increasing income and urbanization, people are switching to superior cereals. While the contribution of wheat to the total calories obtained from grain products has increased by 11 percent in the 1990s, the contribution from coarse grains has decreased by 25 percent.

FIGURE 2.
Changes in calorie supply of grains, non-grains and animal products across expenditure groups.



To assess the extent of diversification of consumption patterns, we project the calorie intake of grains, non-grain crops and animal products in the Indian diet. For this projection we use the global trends of energy intake of different food categories with respect to the changes in income and urbanization (see annex for details). We project India's calorie intake of grain, non-grain crops and animal products, with respect to the changes in income and urbanization from the levels of the base year 2000. The projections of calorie supply in 2025 and 2050 are given in table 5.

Our projections show that non-grain crop products will dominate the Indian diet by 2050. The total calorie supply is projected to further increase, 15 percent by 2025, and another 8 percent by 2050. Almost the entire increase in calorie intake after 2025 is due to the increased consumption of non-grain crops and animal products. Our projections show a slight decline in the calorie supply from grains (9%) by 2050, but significant increases in the non-grain crops (75%) and animal products (144%). The composition of calories supplied from grain, non-grain and animal products changes from 63, 29 and 8 percent in 2000 to 55, 33 and 12 percent by 2025, and 48, 36 and 16 percent by 2050, respectively.

TABLE 5.
Projections of calorie supply to 2025/2050.

Year	GDP (person/year)	Urban population (% of total)	Calorie supply/person/day			
			Grains	Non-grains	Animal products	Total
	$	%	kcal	kcal	kcal	kcal
1990	313	25	1,640	562	163	2,365
2000	463	27	1,579	673	183	2,435
2025	1,765	37	1,520	912	343	2,775
2050	6,731	53	1,440	1,083	477	3,000

Source: Mahmood and Kundu 2006 (for urban population projection).

Note: GDP in 1995 in constant dollars ($) (source for 1990 and 2000 is WRI 2005). In the projections, we assume a 5.5 percent annual growth rate of per capita GDP for 2025 and 2050.

Composition of Nutritional Intake of Grains

The composition of the diet in different food categories depends on the taste and preference of the people and, as previously mentioned, it varies significantly across regions. Thus, we need to take these differences into account in projecting individual crop demands. In India, there is a declining trend in the consumption of coarse cereals. In 2000, rice and wheat contributed to most of the calorie intake (47% and 31%, respectively) from grains, while maize, other cereals and pulses contributed to 5, 9 and 7 percent, respectively. Dyson and Hanchate (2000), using the trends between 1987-1988 and 1993-1994 in the National Sample Survey Organization (NSSO) rounds of surveys, observed that the per capita cereal consumption had declined in all the states except in Kerala and West Bengal. The consumption of rice and wheat remains stable and the decreasing consumption of coarse grains was the major contributor to the decline in cereal consumption.

Cereal consumption has declined further between 1993-1994 and 1999-2000 in the NSSO rounds of surveys, but the rate of decline had also decreased significantly. The cereal consumption/person/day before and after the 1993-1994 NSSO rounds of surveys has declined by 1.19 and 0.74 percent annually in the rural areas, and by 0.91 and 0.24 percent in the urban areas. Within the cereal category, wheat consumption has shown no significant change (table 6). However, a declining trend in rice consumption, especially in the rural areas, is seen in the post-1993-1994 NSSO rounds of surveys. The consumption of pulses remains unchanged at the 1987 level, though it had decreased before 1993-1994. In the urban areas, the consumption of other cereals has also declined further, but at a much slower rate than before. A notable trend, however, is the increasing rate of decline in the consumption of rice in the rural areas. Rural rice consumption per person has decreased 0.5 percent annually after the 1993-1994 NSSO rounds of surveys against only a 0.05 percent decline before the 1993-1994 NSSO rounds.

We project that the composition of grains in the diet will further change, but will soon reach a steady state in both rural and urban areas. As in Dyson and Hanchate (2000)[1], we use recent trends to project future demand, subject to the restriction that the total calorie supply/person/day

[1]Dyson and Hanchate (2000) project the cereal consumption/person/month in the rural and urban sectors to decrease from 15.1 and 12.3 kg in 1993-1994 to 12.7 and 10. 9 kg by 2020, respectively. Other studies based on expenditure elasticity have projected an increase in per capita cereal consumption by 2020 (Bhalla et al. 1999). However, many (Dyson and Hanchate 2000; Bansil 1999) argue that due to the complex nature of taste and preferences, and changes in lifestyles across states and across income classes, the estimated elasticity may also change in the future.

TABLE 6.
Consumption/person of grain crops.

Year	Rice		Wheat		Maize		Other cereals		Pulses	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Past trends (annual growth rates (%))										
1987-1993	-0.05	-0.42	-0.60	0.27	-4.97	-6.78	-4.97	-4.97	-2.40	-1.62
1993-1999	-0.50	-0.10	0.50	0.04	-5.03	-2.77	-5.03	-2.77	4.37	4.45
Projected annual growth (%)										
2000-2025	-0.04	-0.01	0.00	0.00	-0.40	-0.22	-0.40	-0.22	0.00	0.00
2000-2050	-0.11	-0.02	0.00	0.00	-1.06	-0.59	-1.06	-0.59	0.00	0.00
Consumption/person/month in India (kg)										
2000	6.78	5.15	4.80	4.89	1.10	0.09	1.72	0.67	0.93	1.04
2025	6.71	5.14	4.80	4.89	0.99	0.09	1.55	0.63	0.93	1.04
2050	6.43	5.10	4.80	4.89	0.64	0.07	1.01	0.50	0.93	1.04

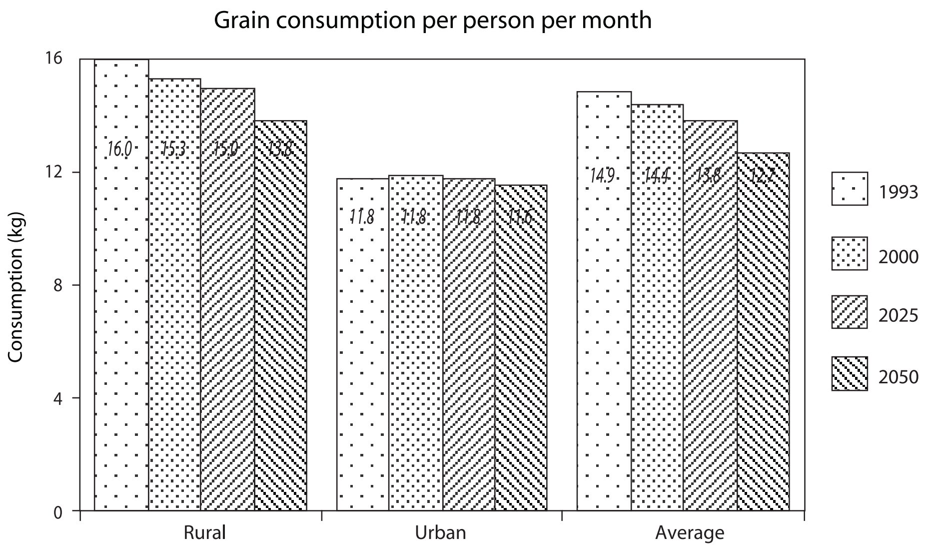
Sources: The trends are estimated from the data of the NSSO rounds of surveys in 1987-1988, 1993-1994, and 1999-2000 (NSSO 1996, 2001). The projections for 2025 and 2050 are the authors' estimates.

from grain products will be 1,520 kcal in 2025 and 1,440 kcal in 2050 (see table 5). As the long-term trends show no significant change, we assume that the per capita consumption of wheat and pulses remains the same in the rural and urban areas. The adjusted growth rates of per capita consumption are given in table 7. The rural rice consumption per person is projected to decrease from 6.78 kg per month in 2000 to 6.43 kg per month by 2050.

The final projections of grain consumption at the national level depend not only on the level of per capita consumption in rural and urban areas but also on the changes in population. A recent study projects that India's total population will increase from 1,027 million in 2001 to 1,383 million in 2025, and to 1,585 million by 2050 (Mahmood and Kundu 2006). It is further projected that the rural population, as a share of total population, will decrease from 72 percent in 2000, to 63 and 47 percent by 2025 and 2050, respectively. Thus, as a result of the increasing urban population, and also the differential patterns in consumption between rural and urban areas, the average grain consumption/person/month declines at a faster rate than the decline of grain consumption in rural and urban areas (figure 3). The composition of calorie supply from rice, wheat, maize, other cereals and pulses will change from 47, 31, 5, 9 and 7 percent in 2000 to 48, 33, 4, 8, 7 percent in 2025, and 49, 35, 3, 5 and 8 percent by 2050, respectively.

Declining rice consumption, especially in the rural areas, has a significant implication for irrigation water requirements. First, a rural Indian consumes, on average, about 1.63 kg more rice per month than the urban Indian. Due to the significantly higher rural population, even a slight decline in the percentage of per capita rice consumption will have a significant reduction in the total demand for rice. With the decreasing demand for rice and the increasing demand for non-grain crops, farmers may increase production of high-value crops. Second, irrigation contributes to the greater part of India's paddy production, and in 2000, nearly half the rice area was under irrigation. Finally, water diversions to paddy are mainly due to the requirements for higher evaporation and percolation. Thus, changes in the composition of grains, especially the quantity of rice, will have significant implications on the projections of future irrigation demand.

FIGURE 3.
Grain consumption/person/month.



Source: 1993, 2000 data from NSSO rounds.
2025 and 2050 are authors'estimates

Composition of Calorie Supply of Non-grains

The consumption of non-grain crops, such as fruits, vegetables and edible oils, will prominently feature in the future Indian diet. Chopra (2003) and Dyson and Hanchate (2000) have noted that fruit and vegetable consumption will increase significantly by 2020. Our projections in a previous section, indeed, show that the contribution of the non-grain crops to the total calorie supply is expected to increase from 29 percent in 2000 to 33 and 37 percent by 2025 and 2050, respectively. How is the composition of non-grain crops changing?

The oil crops (including edible oil) and sugar products provided 79 percent of the calorie supply of non-grain crop products (table 7). While the contribution of oil crops to the total calorie supply has increased over the years (34% in 1980 to 42% in 2000), the contribution from sugar products has decreased from 43 to 37 percent over the same time period. The contribution of roots and tubers, vegetables and fruits shows no major changes (9%, 7% and 7% in 1980 to 7%, 7% and 8% in 2000, respectively). Where the consumption per person is concerned, fruits, vegetables and oil crops have shown a substantial annual growth in the last decade.

Indeed, the calorie supply from oil crops and sugar in India (528 kcal/person), compared to other developing countries (273 kcal/person), is significantly higher now. However, this is much lower than the calorie supply in the developed countries (871 kcal/person). Fruit and vegetable consumption, which is highly income-elastic, provides 96 kcal/person, and this is much lower compared to that in other developing countries (170 kcal/person). However, with increasing income and urbanization, fruit and vegetable consumption is projected to increase rapidly. We use this information to project the composition of calorie supply from non-grain crops in the future.

As in the estimation of grain consumption, the annual growth rates of the consumption per person between the 1993-1994 and 1999-2000 NSSO rounds of surveys are used for the projection of consumption of non-grain crops (table 8). First, we project rural and urban consumption demand per person. The state-level consumptions are projected according to the differences of state-level growth rates. However, two adjustments to the growth rates are necessary before we can make future

TABLE 7.
Calorie supply from non-grain crops.

Year	Total	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
Calorie supply from non-grain crops (kcal/person/day)						
1980	449	152 (34)	41 (9)	32 (7)	31 (7)	193 (43)
1990	526	195 (37)	40 (8)	35 (7)	34 (7)	221 (42)
2000	673	281 (42)	49 (7)	45 (7)	51 (8)	247 (37)
2025	912	442 (49)	66 (7)	67 (7)	63 (7)	274 (30)
2050	1,083	500 (46)	105(10)	75 (7)	87 (8)	316 (29)
Annual growth (%)						
1980-1990	1.7	2.5	-0.3	0.9	1.0	1.4
1990-2000	2.5	3.7	2.0	2.4	4.1	1.1
2000-2025	1.2	2.2	0.9	1.6	1.9	0.6
2000-2050	0.9	1.3	1.4	1.0	1.6	0.6

Sources: 1980-2000 data are from FAO 2005a. The projections for 2025 and 2050 are the authors' estimates.

Note: Numbers within parentheses show the percentage of the total calorie supply.

projections. First, with annual growth rates between the 1993-1994 and 1999-2000 NSSO rounds, the projection of the total calorie supply from the non-grain products is much higher than the projected total in table 5. Therefore, we adjust the annual growth rates of rural and urban sectors so that the total calorie supply of non-grain products per person will be 940 kcal in 2025 and 1,140 kcal in 2050. Second, even with this adjustment, the calorie supplies of oil crops and vegetables in 2050 are unrealistically high, and they are even higher than the levels of the highest-consuming countries at present. Therefore, we set a ceiling for the per capita consumption of these crops, 500 kcal for oil crops, and 75 kcal for vegetables, by 2050, a level comparable to the highest consumption in the developing world.

The projections of the per capita consumption of vegetables and fruits for 2050 in our study are even lower than those of Dyson and Hanchate (2000) for 2020. They project that the rural and urban vegetable consumption per person increases to 162 and 140 kg/year by 2020, respectively, and that the fruit consumption increases to 39 and 78 kg/year by 2020, respectively. The calorie supply from this level of vegetable and fruit consumption (170 kcal/person) is even higher than the present-day calorie supply of the developed countries. The growth assumptions in our study, however, are less rigid, and we believe they will result in more realistic projections by 2025 and 2050.

Food Demand

The projections of total food demand for 2025 and 2050 are given in table 9. We use the state-level population projections of Mahmood and Kundu (2006) for estimating the total food demand. According to this demographic projection, the rural population will increase from 729 million in 2000 to 879 million in 2025 and then decrease to 776 million by 2050. The urban population will increase from 278 million in 2000 to 510 million in 2025 and to 810 million by 2050. Overall, the total population will reach a peak of about 1,580 million by 2050 and then start to decline thereafter. More than half (53%) the total population will be in urban areas by 2050.

TABLE 8.
Consumption of non-grain crops.

Year	Oil crops		Roots and tubers		Vegetables		Fruits		Sugar	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Past trends (annual growth rates (%))										
1987-1988	3.9	3.3	1.4	0.3	3.9	0.2	1.6	1.9	-1.3	-0.2
1993-1999	6.6	5.9	5.1	3.7	6.1	5.8	2.0	1.8	1.7	0.7
Projected annual growth (%)										
2000-2025	1.7	1.5	1.3	1.0	1.6	1.5	0.5	0.5	0.4	0.2
2000-2050	1.0	0.9	1.8	1.3	1.0	0.9	0.7	0.7	0.6	0.2
Consumption/person/year in India (kg)										
2000	37	53	6	5	68	72	31	64	25	29
2025	57	77	8	6	100	105	35	72	27	30
2050	62	83	15	10	111	116	44	89	33	32

Sources: The trends are estimated from the data of the NSSO rounds in 1987-1988, 1993-1994, and 1999-2000 (NSSO 1996, 2001). The projections for 2025 and 2050 are the authors' estimates.

TABLE 9.
Projections of total food demand in 2025 and 2050.

Year	Food demand (Mmt)										
	Grain	Rice	Wheat	Maize	Other cereals	Pulses	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
1990											
2000	173	76	58	10	17	12	42	6	70	40	26
2025	230	102	81	11	20	16	89	11	142	67	39
2050	241	109	92	7	14	19	115	19	180	106	52

Sources: 1990 and 2000 data are from FAO 2005a. Figures for 2025 and 2050 are authors' estimates.

Feed Demand

At present, India's feed grain demand is very low due to the low level of animal product consumption. In 2000, animal products contributed to only 7 percent of the daily calorie supply. Milk and milk products provided the bulk (91 percent) of this calorie supply. Much of the feed demand for producing this calorie supply at present is met through open grazing, crop residues, food waste, oil cakes, etc. The total feed grain use in 2000 was only 8 mmt, which is only 4 percent of the total grain use. However, feed demand is expected to increase much faster with increasing animal products in the diet.

Our projections indicate that the calorie supply from animal products will increase by 89 percent between 2000 and 2025; and a further 54 percent between 2025 and 2050. Recent trends show that the consumption of poultry products, eggs and freshwater fish is rapidly increasing (table 10). The consumption of meat products, especially beef and pork, is very low, mainly due to religious and cultural reasons, and has posted no significant growth in the last few decades. Milk consumption, 98 kg/person/year, which is relatively high compared to that in developing countries, increased at 0.8 annually in the 1990s.

TABLE 10.
Consumption of animal products

Year	Beef/pork/ mutton		Milk products		Poultry products		Eggs		Freshwater fish	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
Past trends (annual growth rates (%))										
1987-1988	1.8	-2.7	3.4	2.3	0.0	7.0	3.5	0.6	2.0	2.7
1993-1999	1.6	1.0	-0.5	0.8	12.2	12.2	9.3	5.7	2.6	1.6
Projected annual growth (%)										
2000-2025	1.5	0.9	0.7[1]	0.7	11.4	11.4	8.7	5.3	2.4	1.5
2000-2050	1.1	0.6	0.5[1]	0.5	8.2	8.2	6.3	3.8	1.8	1.1
Consumption/person/month (kg)										
2000	0.28	0.47	4.81	7.33	0.07	0.13	0.09	0.18	0.23	0.24
2025	0.46	0.63	6.14	9.36	0.42	0.85	1.56	1.07	0.53	0.40
2050	0.53	0.69	6.59	10.04	0.74	1.48	3.74	1.82	0.68	0.47

Source: Past trends estimated from the data of the NSSO rounds in 1987-1988, 1993-1994, and 1999-2000 reports (NSSO 1996, 2001). The consumption data of the NSSO rounds in 1999-2000 are adjusted to match the FAOSTAT totals of 2000. The projections are the authors' estimates.

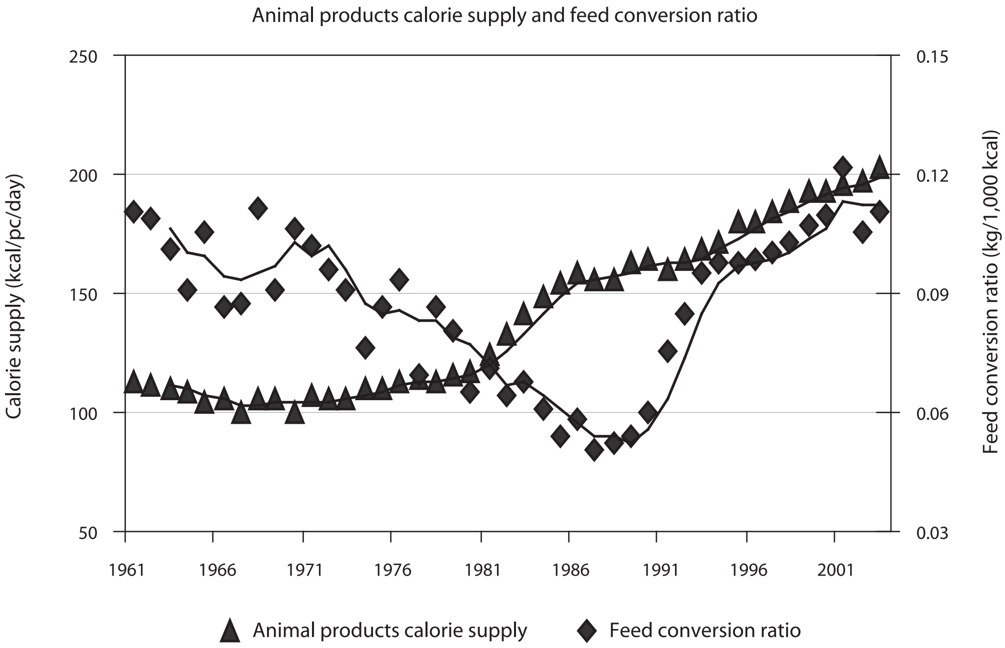
Notes: [1] The growth of milk consumption in the rural areas during 1993-1990 was negative. We assume that it would increase at the same rate as in the urban areas in the future.

If recent trends are indications of the future, then milk products will still dominate the animal product consumption. The share of poultry products will also increase substantially. We use the trends between 1993-1994 and 1999-2000 NSSO survey rounds for projecting the future demand for animal products. We subject the projections to the constraint that the total calorie supply from animal products does not exceed the projections of 341 and 478 kcal/person/day in 2025 and 2050, respectively. The projections show that milk products will still contribute to 66 percent of the calorie supply by 2050. However, the share of calorie supply from poultry products will increase from only 1 percent in 2000 to 20 percent by 2050. Since poultry farming mainly operates at a commercial level, the increase in consumption will have a substantial impact on the feed grain demand.

This paper uses the feed conversion ratio (FCR) to estimate the feed grain demand. FAOSTAT data show that the feed conversion ratio of grain was decreasing until the late 1980s (figure 4). During this period, the growth in feed use has not matched the pace of the increasing calorie supply from animal products. However, with the increasing use of grains, especially maize, for livestock, the FCR started moving upwards in the late 1980s. Between 1988 and 1995, the FCR increased at 9.3 percent annually. Over this period, the calorie supply from animal products increased at 1.6 percent, while the feed grain use increased at 13.2 percent. The growth in the FCR between 1995 and 2002 was 1.9 percent. During this period, the calorie supply from animal products increased annually at 1.6 percent while feed grain use increased at 5.3 percent annually.

We use the growth rates of feed conversion ratios between 1995 and 2002 to project feed use for 2025 and 2050. First, we project the feed conversion ratios of grains. The growth rate of the feed grain conversion ratio is adjusted according to the growth rates of the calorie supply from animal products. The calorie supply from animal products is projected to increase by 2.2 and 1.7 percent during the periods 2000-2025 and 2000-2050, respectively, while the feed conversion ratios are projected to increase by 2.7 and 2.0 percent in the corresponding periods. The projected FCR of grains by 2025 is 0.37 kg/1,000 kcal, and is slightly higher than the FCR of China

FIGURE 4.
Growth of calorie supply from animal products per person and the feed conversion ratio of grains.



in 2000 (0.34 kg/1,000 kcal), but still much lower than the developed countries (0.74 kg/1,000 kcal).

With the projected feed grain conversion ratios, the feed grain demand will increase 4.6 times by 2025; and 13.7 times by 2050, from the level of 8 mmt in 2000 (table 11). Next, we estimate the individual grain demand. Here, we adjusted the growth rates of feed conversion ratios of individual crops by a similar factor subject to the constraint that the total feed demand of individual crops is equal to the projected feed grain demand.

TABLE 11.
Feed consumption.

Factors	Grains	Rice	Wheat	Maize	Other cereals	Pulses	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
Feed conversion ratios in kg/1,000 kcal											
1995	0.098	0.005	0.012	0.054	0.007	0.020	0.013	0.000	0.000	0.000	0.007
2000	0.113	0.004	0.011	0.077	0.005	0.015	0.010	0.000	0.000	0.000	0.005
Annual growth rates of feed conversion ratios (%)											
1995-2002	2.0	-2.6	-1.7	5.4	-4.2	-4.2	-3.2	0.0	0.0	0.0	-2.7
2000-2025	2.7	-1.9	-1.3	4.0	-3.1	-3.2	-2.4	0.0	0.0	0.0	-2.7
2000-2050	2.1	-1.4	-1.0	3.0	-2.3	-2.3	-1.8	0.0	0.0	0.0	-2.7
Feed demand (Mmt)											
2000	8.1	0.4	0.9	5.3	0.4	1.2	0.6	0	0	0	0.4
2025	37.5	0.5	1.5	33.8	0.4	1.2	0.8	0	0	0	0.3
2050	111.2	0.6	1.8	107.4	0.3	1.0	0.8	0	0	0	0.1

Source: Authors' estimates based on FAOSTAT data.

The majority of the increase in feed demand is for maize. According to estimates of the United States Department of Agriculture (USDA), 42 percent of the maize production at present is for feed in the poultry sector. With the increasing consumption of poultry products, the demand for maize for feed will increase rapidly (Landes et al. 2004). Our projection shows that the consumption of poultry meat and eggs is likely to increase at 9 and 5 percent, respectively, annually over the next 50 years. Poultry production of this magnitude can only be sustained under commercial farming and much of the feed demand in this sector will be met from maize. We project that the demand for maize for feed will increase 6 percent annually over the next 50 years.

Total Crop Demand

The rates of seeds, waste and other uses (i.e., as a percentage of total domestic use) of many crops have decreased slightly over the last decade (table 12). However, the waste of maize, roots and tubers and fruits is still substantial. With improved post-harvest technologies and storage facilities, and with increased transport facilities and marketing in the rural areas, rates of waste of all crops are expected to decline. We use the trends between 1990 and 2000 to project future seed and waste rates subject to the following constraints. First, if the projected values of the combined seed and waste rates fall below the seed rates in 2000, then we assume the seed rates in 2000 for the projection. Second, if the growth rates of seeds and waste show an increasing trend in the 1980s and 1990s, then we assume the seed and waste rates in 2000 for the projection.

The seed and waste rates of all crops, except oil crops, roots and tubers, and fruits, are lower according to our projections. The share of the waste in the rates of seed, waste and other uses of roots and tubers, and fruits is high and has been increasing in the past. However, better storage, transport and marketing facilities would have a significant impact in reducing the waste in these two crops. However, the information available now is not sufficient to assess the extent of the reduction in waste of these crops. So, we assume the rates in 2000 for future projections. With the projected rates of seeds, waste and other uses, we are now set to estimate the total crop demand (last three rows of table 12).

The total grain demand is projected to increase by 45 and 88 percent in 2025 and 2050, respectively. The increasing demand for maize, especially for feed, contributes to much of the increase in the total grain demand. The total grain demand is projected to increase by 176 mmt between 2000 and 2050. The increase in the demand for maize, of 102 mmt, contributes to 57 percent of the additional grain demand. Although the increases in demand for rice and wheat are the same (35 mmt), the level of increase in the demand for wheat over the consumption level in 2000 is significantly higher. Another important observation is the increasing demand for non-grain crop products. The demand for non-grain crop products will more than double over the next 50 years.

TABLE 12.
Seed and waste rates and total crop demand.

Factors	Grains	Rice	Wheat	Maize	Other cereals	Pulses	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
Seed and waste rates of total consumption (%)											
1980	10.2	8.3	12.8	19.6	9.4	10.2	18.9	16.4	7.2	12.9	0.02
1990	10.1	7.6	12.1	19.3	9.4	9.0	11.3	18.9	7.0	13.2	0.03
2000	9.6	6.8	11.7	17.0	9.7	8.2	12.7	19.2	6.7	14.0	0.04
Projected seed and waste rates as a percentage of total consumption											
2025		5.9[b]	9.9	10.1	9.7[a]	5.9[b]	12.7[a]	19.2[a]	5.5	14.0[a]	0.04[a]
2050		5.9[b]	8.3	6.0	9.7[a]	5.9[b]	12.7[a]	19.2[a]	4.5	14.0[a]	0.04[a]
Total crop demand (Mmt)											
2000	201	82	67	18	20	14	49	7	75	47	26
2025	291	109	91	50	23	18	103	13	150	78	40
2050	377	117	102	121	16	21	133	24	189	123	52

Notes: [a]An increasing trend is seen in the growth of seed and waste rates from 1980 to 2000. For these crops, we project the seed and waste rates at the 2000 level.

[b]The decreasing trends are significant in that the projected seed and waste rates fall even below the seed rate in 2000. For these crops, we assume the seed rates at the 2000 level.

Comparison with Other Food Demand Projections

We started our projections analyses with a view to assessing the impacts of recent changes in consumption patterns on the projections of grain demand made by the NCIWRD. A part of the deviation of various demand projections is attributable to the different assumptions made on the total population projections. In order to make proper comparison, we standardized the projection to the same level of population as illustrated in Dyson and Hanchate (2000). Table 13 summarizes six demand projections. The latter four studies only estimate cereal demand. Therefore, the per capita demand of these studies is adjusted by adding the demand for pulses in the present study (12 kg for food and 13 kg for total). The totals are adjusted to the population of 1,315 million by 2025 as projected by Dyson and Hanchate (2000), and 1,581 million by 2050 as assumed by the NCIWRD.

The present study and the NCIWRD projections differ in both food and feed consumption demand. The commission assumed a substantially high consumption of food grains per person thereby assuming a well-fed scenario for India. For the well-fed scenario, the commission assumed a substantially high proportion of the nutritional intake from the food grains. However, as discussed in the introductory section, this assumption converts to a substantially higher calorie intake per person, which is not realistic with the present trends of grain consumption in India or even in other developing countries in the world. Our study results differ a great deal from the commission's projections with respect to the consumption of other non-grain crops and animal products. According to the present study, the consumption of non-grain food products will provide the majority of the calorie intake (53% in 2050, as

TABLE 13.
Grain demand projections of different studies.

Source of study	Demand/person (kg/year)				Total demand (Mmt)			
	2025		2050		2025		2050	
	Food	All	Food	All	Food	All	Food	All
Present study	166	210	152	238	218	276	241	377
NCIWRD	215	240	279	312	283	316	441	494
Dyson and Hanchate	159	182	-	-	209	239	-	-
Kumar	179	190	-	-	235	250	-	-
Bansil	180	202	-	-	237	266	-	-
Bhalla et al.	197	235	-	-	259	309	-	-

Sources: GoI 1999; Dyson and Hanchate 2000; Kumar 1998; Bansil 1999; Bhalla et al. 1999.

against 35% in 2000). The increased consumption of animal products, especially milk and poultry products, in the present study, is reflected in a substantially high difference in the total and food grain demand. The feed grain demand comprises much of this difference.

The food demand projection in this study (166 kg/year in 2025) is higher than that of Dyson and Hanchate (2000), but lower than the latter three projections. Contrary to the current trends, the studies carried out by Kumar (1998), Bansil (1999) and Bhalla et al. (1999) projected increasing per capita cereal consumption. The projection made by Dyson and Hanchate (2000) is compatible with the current trends, but it is based on the extrapolation of the trends between 1987-1988 and 1993-1994 NSSO rounds of surveys. However, the present study reflects the recent trends observed after the 1993-1994 NSSO rounds of surveys.

The projection of total grain demand in this report is much closer to the Bansil (1999) and Bhalla et al. (1999) projections, primarily due to the high feed demand for livestock. Is the nutritional supply of the projected consumption in the present study adequate for feeding all the people in India satisfactorily by 2050? This study projects the average calorie supply at 3,000 kcal/person/day by 2050, and according to David Seckler (IWMI 2000), the average daily calorie intake of 2,700 kcal at the national level is adequate for providing the minimum nutritional intake of even the lowest income strata of any country (the minimum nutritional requirement of India is estimated to be about 2,200 kcal/person/day). Indeed, the average calorie intake of the developed countries is 3,200 kcal/person/day, and nutritional poverty is almost nonexistent in these countries. However, barring any distributional difficulties, which will be much lower with better infrastructure in 50 years time, the projected food consumption will be adequate to provide the minimum nutritional supply for much of the Indian population.

Consumptive Water Use

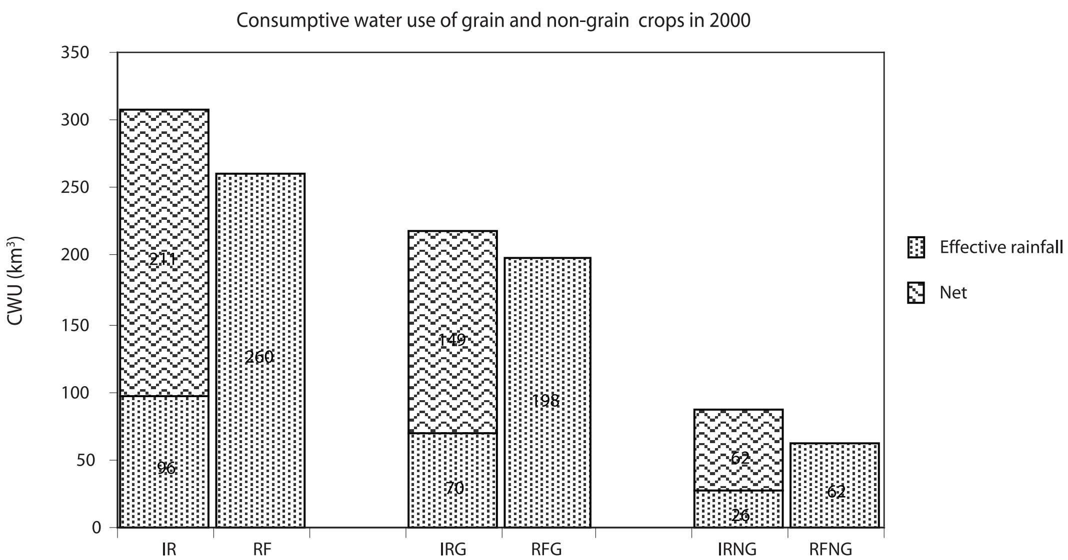
The implications of increasing food demand on water demand are assessed through the consumptive water use (CWU). The CWU is the actual evapotranspiration (ET_a)—the evaporation from the field and the transpiration from the crops—during the cropping period.

CWU in 2000

The estimates of CWU are only for rice, wheat, maize, other cereals, pulses, oil crops, roots and tubers, vegetables, fruits and sugarcane. In 2000, the estimated CWU of the examined crops was 567 km^3. The irrigated crops account for 54 percent of the total CWU (figure 5). These estimates are significantly different from those of the Vaidyanathan and Sivasubramaniyan (2004) study, which estimated the total, irrigated, and rain-fed CWU, of all crops from 1991-1993 as 660, 366, and 294 BCM, respectively, for the entire country. Declining rain-fed area explains part of the differences in the figure for rain-fed CWU. Part of the difference in irrigated CWU is due to the non-inclusion of cotton and fodder crops in this report. The rest of the differences may be due to the scale of estimation used in the two studies.

The rain-fed portion—the effective rainfall—of the irrigated crops (96 km^3) is 31 percent of the irrigated CWU. Overall, the rain-fed portion in both the irrigated and the rain-fed crops (96+260 km^3) accounted for two-thirds of the total CWU. This indicates that a substantial part of the crop water management at present is in the rainfall portion of the total water demand.

FIGURE 5.
CWU of irrigated and rain-fed crops.

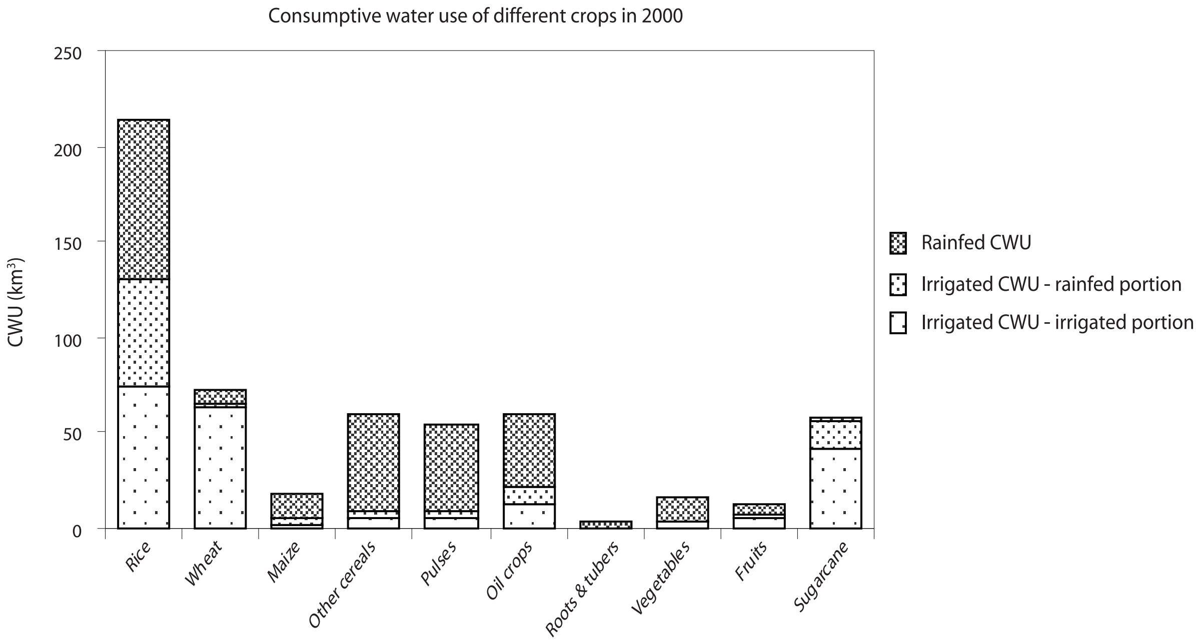


Note:. IR-irrigated crops; RF-rain-fed crops; IRG-irrigated grain crops; RFG-rain-fed grain crops; IRNG-irrigated nongrain crops; RFNG-rain-fed nongrain crops;

Source: Authors' estimates.

The grains dominate the CWU in both the irrigated and the rain-fed crops. The irrigated grain crops accounted for 71 percent of the irrigated CWU, while the rain-fed grain crops accounted for 76 percent of the rain-fed CWU. Overall, the grain crops contribute to 74 percent of the total CWU.

FIGURE 6.
CWU of different crops in 2000.



Source: Authors'estimate

Among the crops, rice and wheat consume a major portion of the total CWU (figure 6, table 14). In irrigated crops, 65 percent of the total irrigated CWU was for rice and wheat, and in rain-fed crops the corresponding proportion was 33 percent. Altogether, rice and wheat accounted for 55 percent of the total CWU. The coarse cereals, pulses, oil crops and sugarcane have the next highest CWU. Except for sugarcane, the rain-fed portion has a major share of the total CWU for the coarse cereals, pulses and oil crops. The irrigated sugarcane accounted for 96 percent of the total CWU of sugarcane.

It is interesting to note that, although the irrigated rice dominates the irrigated CWU, the rain-fed portion contributes to a major part of this CWU. Also, the rain-fed portion of the rice crop accounted for two-thirds of the total CWU of rice. This pattern is generally true for all crops except for wheat and sugarcane. Much of the wheat area is cultivated in the *rabi* season (winter season from November to March). The effective rainfall during this period is very small and the wheat crop requires substantial irrigation. Nonetheless, the significant contribution of the effective rainfall to the total CWU of all other crops indicates that vast opportunities exist in water management in the green water or the rainfall component of the CWU.

Water Productivity in 2000

Considerable differences in crop water productivities exist between irrigation and rain-fed crops, and also between different crops (table 14). Water productivity, in this report, is defined as the production (quantity in kg or the value in $ of 2000 export prices[2]) per unit of consumptive water use (Molden et al. 1998).

[2]The value of total crop production is estimated using the average export prices/kg of different crops in 1999, 2000 and 2001 (FAO 2005a). The average export prices of rice, wheat, maize, other cereals, pulses, oil crops (including vegetable oils), roots and tubers (dry equivalent), vegetables, fruits and sugar (refined) are 375, 107, 176, 203, 199, 559, 1631, 285, 776 and 268 US$/metric tonne, respectively).

TABLE 14.
Crop production, demand and CWU in 2000.

		Grain crops						Non-grain food crops					
	Units	Total	Rice	Wheat	Maize	Other cereals	Pulses	Total	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
Irrigated area	Mha	53.6	24.1	23.0	1.4	2.2	2.8	13.8	6.1	0.0	1.7	1.7	4.2
Rain-fed area	Mha	70.0	21.0	3.2	5.3	21.4	19.1	27.5	19.5	1.6	3.9	2.0	0.4
Total area	Mha	123.6	45.1	26.3	6.7	23.6	21.9	41.3	25.7	1.6	5.6	3.6	4.7
Irrigated production	Mmt	139.4	61.3	69.1	3.9	2.8	2.3	-	9.8	0.0	32.3	21.4	28.4
Rain-fed production	Mmt	67.2	28.1	3.3	8.3	16.6	10.9	-	21.5	7.0	41.7	24.6	1.8
Total production	Mmt	206.6	89.3	72.4	12.2	19.4	13.2	-	31.3	7.0	74.0	46.0	30.1
Total demand	Mmt	201.1	82.4	67.0	18.3	19.5	13.8	-	47.7	7.1	73.7	46.1	26.4
Production surplus/deficit in 2000 - % of demand	%	3	8	8	-33	0	-5	-	-34	-1	0	0	14
Value of total demand	Billion US$		2.7	0.6	-1.0	-0.1	-0.4	103.6	0.0	-0.3	-0.8	1.1	-9.9
Value of production surplus/deficit in 2000 - % of demand	%	3	9	8	-32	-3	-6	9	0	-1	-2	16	-36
Irrigation CWU	km^3	219.0	131.	65.4	5.6	8.6	8.5	88.0	21.5	0.0	3.0	7.1	56.3
Irrigated portion of ICWU[1]	km^3	149.4	73.5	63.8	1.5	5.1	5.6	61.6	12.6	0.0	2.8	5.2	41.0
Rain-fed portion of ICWU	km^3	69.5	57.4	1.5	4.2	3.5	2.9	26.4	8.9	0.0	0.2	1.9	15.4
Rain-fed CWU	km^3	198.3	83.2	7.8	12.0	50.4	45.0	61.9	37.9	3.7	13.4	5.4	1.5
Total CWU	km^3	417.3	214.	73.1	17.6	58.9	53.5	149.9	59.4	3.7	16.4	12.5	57.9
Water productivity of irrigated crops (weight/volume)	kg/m^3	0.64	0.47	1.06	0.70	0.33	0.27	-	0.45	0.00	10.61	2.99	0.50
Water productivity of rain-fed crops (weight/volume)	kg/m^3	0.34	0.34	0.43	0.69	0.33	0.24	-	0.57	1.91	3.12	4.56	1.14
Water productivity of irrigated crops (amount of money/volume)	$\$/m^3$	0.15	0.18	0.11	0.12	0.07	0.13	0.44	0.25	0.00	3.03	2.32	0.13
Water productivity of rain-fed crops (amount of money/volume)	$\$/m^3$	0.11	0.13	0.05	0.12	0.07	0.12	0.89	0.32	3.12	0.89	3.54	0.30

Notes: [1]The irrigated and rain-fed productivities of fruits are assumed to be the same.

ICWU is the irrigated consumptive water use

Source: Information on area and production is from the FAOSTAT database (FAO 2005a). Other data are the authors' estimates.

The water productivity of irrigated grain crops (0.64 kg/m^3) is 88 percent higher than that of rain-fed grain crops. Much of this difference, however, is due to the high water productivity of irrigated wheat crops. Most of the wheat area is irrigated, and the water productivity of irrigated wheat crop is 109 percent higher than that of the rain-fed wheat crop. The difference in water productivity between irrigated and rain-fed grain crops excluding wheat is only 33 percent.

In terms of monetary value, water productivity of irrigated grain crops ($0.15/$m^3$) is only 40 percent higher than that of rain-fed crops. This is mainly due to the low value of wheat and the low productivity differences of other grain crops under irrigated and rain-fed conditions. In fact, the values of the productivities of irrigated and rain-fed grain crops, excluding wheat (0.17 and 0.11 $/$m^3$), are very similar to the productivities of all the grain crops.

There is a substantial difference in water productivities between grain and non-grain crops. This difference is mainly due to price differences. While the grain crops generate $0.13/$m^3$ of CWU, the non-grain crops generate $0.63/$m^3$ of CWU.

Our analysis also revealed some interesting facts about the water productivity of non-grain crops. It turns out that the overall water productivity of the irrigated non-grain crops is lower than that of the rain-fed crops. The irrigated and rain-fed water productivities of the non-grain crops including sugar are 0.44 and 0.89 $/$m^3$ (i.e., lower and higher ratios), respectively. However, when sugar is excluded, the productivities are 0.99 and 0.90 $/$m^3$ (i.e., higher and lower ratios) for the irrigated and rain-fed crops, respectively. Low productivity of the irrigated sugar crops is the reason for this reversal. While the effective rainfall on the irrigated and the rain-fed areas of the sugar crop are similar (363 millimeters (mm) and 354 mm, respectively), the irrigated area of the sugar crop consumes an additional 996 mm, almost three times the effective rainfall, through irrigation. But the yield from irrigated sugar, 6,690 kg/ha, is only 66 percent higher than the yield from rain-fed sugar. Oil crops also have similar water productivity differences—$0.45/$m^3$ in irrigation and $0.57/$m^3$ in rain-fed. The irrigated and the rain-fed areas of oil crops have an effective rainfall of 145 and 194 mm, respectively. The irrigated area consumes an additional 205 mm through irrigation. However, the yield from the irrigated oil crop (1,590 kg/ha) is only 45 percent higher than the yield from the rain-fed oil crop.

Water productivity of grain crops in India, when compared to similar environments in other countries, is very low at present (Molden et al. 2001; Molden and Sakthivadivel 1999), and many argue that there is a vast scope for significant improvement in water productivity (various reports in Kijne et al. 2003). Our analyses also support these arguments. Due to the differences in productivity, a small reallocation of water from the grain crops to non-grain crops results in a significant increase in the value of production. The food and feed demand projections in the previous section showed that the value of food demand for non-grains will be three times more than the demand for grains by 2050 (table 15). Thus, there is considerable scope for reallocating water for higher-value crops and improving the value of production. We assess the increase in CWU for meeting the food demand projections in the next section.

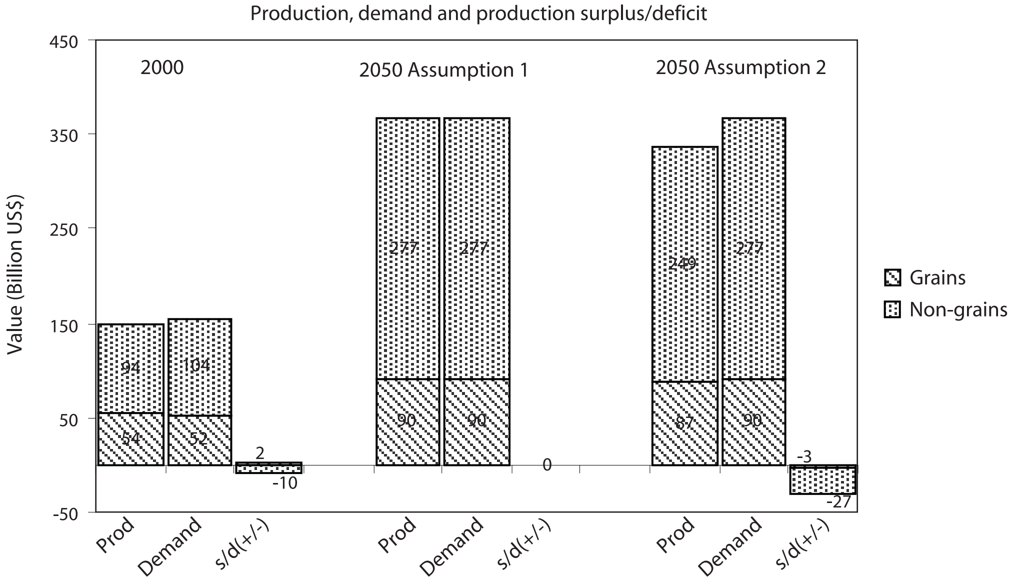
CWU Demand in 2050

The increase in the CWU demand by 2050 is assessed under two assumptions of self- sufficiency and three scenarios of water productivity growth. First, we state the two assumptions.

Assumption 1: Here we assume full self-sufficiency for food and feed crops by 2050. Under this assumption, the values for grain and non-grain crop production requirements increase by 67 percent (figure 7) and 195 percent, respectively.

Assumption 2: In the second assumption, the full self-sufficiency requirement is relaxed. Here, the self-sufficiency ratios of food and feed crops or the levels of production surplus or deficit as a percentage of total demand by 2050 are assumed to remain the same at the 2000 level (average of 1999-2001 in the FAOSTAT database). Under this assumption, the values for grain and non-grain crop production requirements increase by 61 and 167 percent, respectively, by 2050.

FIGURE 7.
Value of production, demand, and production surplus or deficit [s/d (+/-)] of grain and non-grain crops.



Source: Authors'estimates

With the same level of self-sufficiency ratios in 2000, grain crops show slight production deficits in 2050. In 2000, there were production surpluses of grains—3 percent more than the total demand. The rice and wheat production surpluses (9% and 8%) offset the production deficits of other grain crops, especially the maize deficits, and resulted in overall grain surpluses. The maize production deficit in 2000 was 32 percent of the total demand, but it was small in terms of the quantity (only 1.2 mt). But, the future demand for maize is considerably higher. We project maize demand to increase from 18 mt in 2000 to 121 mt by 2050. The maize production deficit in 2050, with a 68 percent self-sufficiency ratio, is about 40 mmt. However, the rice and wheat production surpluses offset the deficit of maize to some extent. In 2050, the total grain production deficit will be 21 mmt or 6 percent of the total demand. But, due to price differences, the value of this deficit is only 3 percent of the total demand. The second assumption is equivalent to an increase in grain trade in 2050—exporting a moderate quantity of rice and wheat while importing a substantial quantity of maize, primarily for meeting the feed demand.

Under the second assumption, there will be large production deficits of non-grain crops by 2050. The oil crops (including vegetable oil) are projected to contribute to this large deficit. In 2000, the oil crop production (39 mmt), was only 64 percent of the total demand. At this level of self-sufficiency, the oil crop demand will exceed the production by 85 mmt (mainly vegetable oils) in 2050. Overall, the value of non-grain crop production will be 10 percent less than the total demand.

The increases in CWU demand by 2050 under the above two assumptions are assessed with three scenarios that are related to different levels of water productivity improvements (table 15).

Scenario 1: Scenario 1 assumes no growth in water productivity in the irrigation or rain-fed crops. Indeed, this is rather a pessimistic scenario that we can model under the present trends of yield growth. The recent trends show that there are decreasing signs in the rates of yield growth. The grain crop yields in India

TABLE 15.

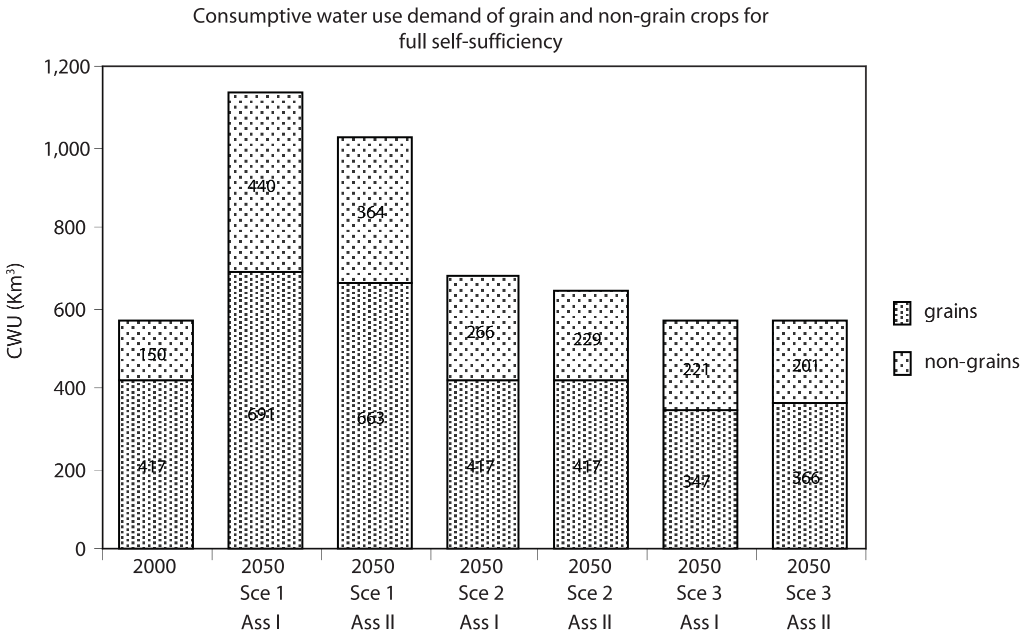
Crop demand and CWU demand in 2050.

		Grain crops						Non-grain food crops					
	Units	Total	Rice	Wheat	Maize	Other cereals	Pulses	Total	Oil crops	Roots and tubers	Vegetables	Fruits	Sugar
Crop demand	Mmt	377.0	117.0	102.0	121.0	16.0	21.0		133.0	24.0	189.0	123.0	52.0
Value of crop demand	Billion US$	89.8	43.9	10.9	21.3	3.2	10.5	276.6	74.4	39.2	53.9	95.4	13.9
Assumption 1 – Full self-sufficiency requirement													
CWU - Scenario 1	km^3	691.4	280.5	102.9	174.2	48.6	85.2	362.0	252.3	12.5	41.9	33.5	21.6
CWU - Scenario 2	km^3	417.3	169.3	62.2	105.1	29.3	51.4	265.7	152.2	7.6	25.3	20.2	60.4
CWU - Scenario 3	km^3	346.7	140.7	51.6	87.4	24.4	42.7	220.8	126.5	6.3	21.0	16.8	50.1
Assumption 2 – Partial self-sufficiency requirement													
Crop production requirement - % of total demand	%	97	109	108	68	93	94	90	64	100	99	98	116
CWU - Scenario 1	km^3	662.7	305.6	111.3	118.5	47.1	80.2	363.7	161.2	12.6	41.4	32.8	115.8
CWU - Scenario 2	km^3	417.3	192.4	70.1	74.6	29.7	50.5	229.0	101.5	7.9	26.1	20.6	72.9
CWU - Scenario 3	km^3	366.3	168.9	61.5	65.5	26.1	44.3	201.0	89.1	7.0	22.9	18.1	64.0

increased at 3.4 percent annually in the 1980s and at 1.9 percent annually in the 1990s. The growth of the average yield in the last decade, however, has closely followed the growth of the irrigated area. In the 1990s, the net irrigated area increased at a rate of 1.8 percent. There is no doubt that the increased irrigated area has contributed to a significant part of the growth in the crop yield, and it also increased the CWU. At present, we do not have any specific projections on the growth in water productivity in the past. However, scenario 1 shows how bleak the situation will be, if there is no growth in water productivity. This scenario shows that the CWU demand will increase considerably under both assumptions of self-sufficiency (figure 8). The CWU of the grain crops will increase by 66 and 59 percent under the first and second assumptions, respectively. For non-grain crops, the CWU increases are 246 and 161 percent under the first and second assumptions, respectively. Overall, the CWU demand under the two assumptions, will increase by 99 and 81 percent, respectively, and even exceed India's potentially utilizable water resource, a feat that cannot be realized easily.

Can India meet this increase in CWU demand? Indeed, the total CWU demand, even under the second assumption, is more than the total utilizable water supply (1,100 km^3) at present. To meet this CWU demand, India may require more than 1,800 km^3 (assuming a 55% overall irrigation efficiency), which indeed is not realistic considering the fact that India's average total renewable water resources are only 1,953 km^3 (CWC 2004). Thus, India definitely needs to increase water productivity to meet the future CWU demand.

FIGURE 8.
CWU under different scenarios.



Source: Authors'estimates

Scenario 2: This scenario assumes that the CWU of the grain crops will remain the same at the 2000 level. It estimates the required growth in water productivity, or essentially the growth in crop yield, for meeting the future grains demand. The increase in CWU of non-grain crops is assessed under the same levels of the growth in water productivity as for the grain crops.

To meet the production requirements of grain crops, grain yields have to increase by 1.02 percent annually under the first assumption (full self-sufficiency), and by 0.93 percent annually under the second assumption (partial self-sufficiency). If the non-grain crop water productivities of the irrigated and rain-fed crops increase at the same rates, the CWU demand for non-grain crops increases by 109 and 65 percent under the first and second assumptions, respectively. The overall CWU demand increases by 22 and 13 percent under the two assumptions, respectively.

Scenario 2 assumes reallocation of CWU between grain crops. For example, the CWU of rice crops was 214 km^3 in 2000 and the rice production was 89 mmt. By 2050, the CWU demand of rice crops decreases by 21 and 10 percent, respectively, according to the two assumptions; similarly, the production requirements increase by 31 and 43 percent. Also, while the production requirements of wheat and pulse are projected to increase, the CWU demand is projected to decrease. In the case of other coarse cereals, both the production requirement and the CWU demand decrease. The CWU savings of the rice, wheat, other cereals and pulses are consumed by the maize crops. The production requirement of maize is projected to increase by 889 and 572 percent, while the CWU demand is projected to increase by 496 and 369 percent under the first and second assumptions, respectively.

Both assumptions in Scenario 2 require the CWU demand of non-grain crops to increase. Among the non-grain crops, oil crops show the largest increase in CWU demand. Overall, the CWU demand of all the crops will increase by 20 and 14 percent under the first and second assumptions, respectively.

Can India meet this increase in CWU demand by 2050? The CWU demand under the first and second assumptions will increase by 115 and 78 km^3, respectively. At present, the total irrigation withdrawal of all the crops is estimated as 596 km^3, of which only 40 percent, or 240 km^3, are used beneficially (CWU). The remaining 356 km^3 are partly depleted through non-beneficial evaporation and the rest flows to internal or external sinks. Thus, the additional CWU demand can be met by transforming the non-beneficial use to beneficial use. The irrigation efficiency needs to be increased to 53 percent to meet the additional CWU of 78 km^3, and to 60 percent to meet the CWU of 115 km^3. Indeed, the increase could be higher if all irrigated crops are included in the analysis.

Scenario 3. This scenario assumes no increase in CWU by 2050. This is equivalent to further reallocation of CWU from the grain to non-grain crops. This scenario estimates the required increase in water productivity to meet both the grain and the non-grain requirements.

Under this scenario, the water productivity needs to be increased by 1.41 percent annually under the first assumption (full self-sufficiency) and by 1.18 percent under the second assumption (partial self-sufficiency). Accordingly, the CWU demand of grain crops will decrease by 18 and 12 percent under the first and second assumptions, respectively, and will result in CWU savings of 74 to 50 km^3. These savings are then allocated to non-grain crops. The CWU of non-grain crops will increase by 72 and 45 percent under the first and second assumptions, respectively. Given the present trends, increasing productivity at 1.4 percent annually, or doubling the productivity by 2050, especially in rain-fed agriculture, may not be a realistic scenario. However, it illustrates the implications of an increase in CWU demand if the water productivity can be increased between 1.0 and 1.4 percent annually over the next 50 years.

Conclusion

This report started assessing the recent shifts in food consumption patterns in India and their implications on total crop demand. The recent trends clearly show changing patterns of consumption. While direct grain consumption is decreasing, non-grain product consumption in the daily diet is increasing in both rural and urban areas. This study projects that, with increasing income and urbanization, the non-grain crops and the animal products (dairy and poultry) would dominate the consumption basket by 2050. The contribution of grain products to the total calorie supply is projected to decrease from 65 percent in 2000 to 55 and 48 percent by 2025 and 2050, respectively. However, the total calorie supply is projected to increase to about 2,770 and 3,000 kcal/person/day by 2025 and 2050, respectively. This level of average calorie supply is sufficient for providing adequate nutritional security to people even in the lowest income percentiles.

A major implication of the changing consumption patterns is the increasing feed grain demand. The total grain demand will increase from 201 mmt in 2000 to 291 and 377 mmt by 2025 and 2050, respectively. The feed demand is projected to increase many times, from a mere 8 mmt at present to 38 and 117 mmt by 2025 and 2050, respectively. The increasing feed grain demand is projected to consist of a major part of the increase in total grain demand, 33 and 83 percent, respectively, over the periods 2000-2025, and 2025-2050. The food demand projection in this study is significantly different from the projections made by the NCIWRD. According to the commission, food grains provide the bulk of the nutritional demand in the future. This study holds a diametrically opposite view. The total food grain demand of the present study is only 241 mmt in 2050, but the commission projects 441 mmt. The total grain demand of the present study is 117 mmt less than the projections made by the commission. Thus, as mentioned in the introduction, the reservations expressed by many on the NCIWRD's projected increase in irrigated area (by 30 mha), which is based on increased food grain demand, are justifiable. Thus, food grain demand cannot be a justification for large-scale water transfers such as India's river-linking project.

Another implication of the changing consumption patterns is the high level of consumption of non-grain crops. The demand for oil crops (including edible oil), vegetables and fruits increase several times from the present level. In fact, India's predominance of food grains in the consumption and production patterns of agriculture are changing. A major challenge for Indian agriculture, in the next few decades in this century, is how to meet the increasing demand for the feed grains. An even greater challenge in the future is how India meets the increasing demand for non-grain crops. The study shows the need for diversification of future agricultural production, especially to high-value non-grain crops. The increasing demand for non-grain crop products will outpace the increasing demand for grains. Where and to what extent crop diversification is possible depends on the access and availability of water resources and how they are consumed.

The study also assessed the implications of the changing food consumption patterns on CWU. The CWU of the selected crop categories in this study was 567 km^3. Nearly three-fourth of the CWU is for irrigated crops, where the rain-fed portion or the effective rainfall share of the CWU is 31 percent. Overall, the rain-fed portion or the effective rainfall of both rain-fed and irrigated crops share 63 percent of the total CWU. This indicates that a significant part of the present-day crop water management is in the rainfall or green water use.

Grain crops dominate the CWU at present. Overall, the grain crops accounted for 74 percent of the total CWU in 2000. Among the grain crops, rice and wheat crops share a major part of the total CWU. Among the non-grain crops, oil crops and sugarcane share 78 percent of the total CWU.

The study also finds a significant variability in crop water productivity between grain and non-grain crops and also between irrigated and rain-fed crops. The water productivity of grain crops is only $0.13/m^3, and in non-grain crops this is $0.63/m^3. The study uses the water productivity of irrigated and rain-fed crops to assess the increasing CWU demand of crops. In the absence of any growth in water productivity, the CWU demand will exceed the utilizable water resources in the country. To meet the future crop demand, India definitely needs to increase water productivity. If water productivity increases at 1.0 percent annually, India can meet full self-sufficiency of grains, while not increasing the consumptive water use. For partial self-sufficiency, the required growth in water productivity is only 0.93 percent. However, at this level of growth, the consumptive water demand of non-grain crops increases. The total CWU increases by 22 and 13 percent under full and partial self-sufficiency scenarios, respectively. This scenario shows significant reallocation of water resources between the grain crops.

If water productivity increases by 1.4 percent annually, then water demand in 2050 can be met without an increase in the CWU. For partial self-sufficiency, productivity needs to increase by 1.1 percent annually. This scenario shows no increase in total CWU, but shows a significant reallocation of water between grain and non-grain crops.

The national-level scenarios indeed show that India can meet most of its future water demand with a modest increase in water productivity. It is clear that increases in water productivity are required in both irrigated and rain-fed crops, and in both grain and non-grain crops. However, it is not clear where and how this can be achieved and to determine this further research is required. We suggest a few options here.

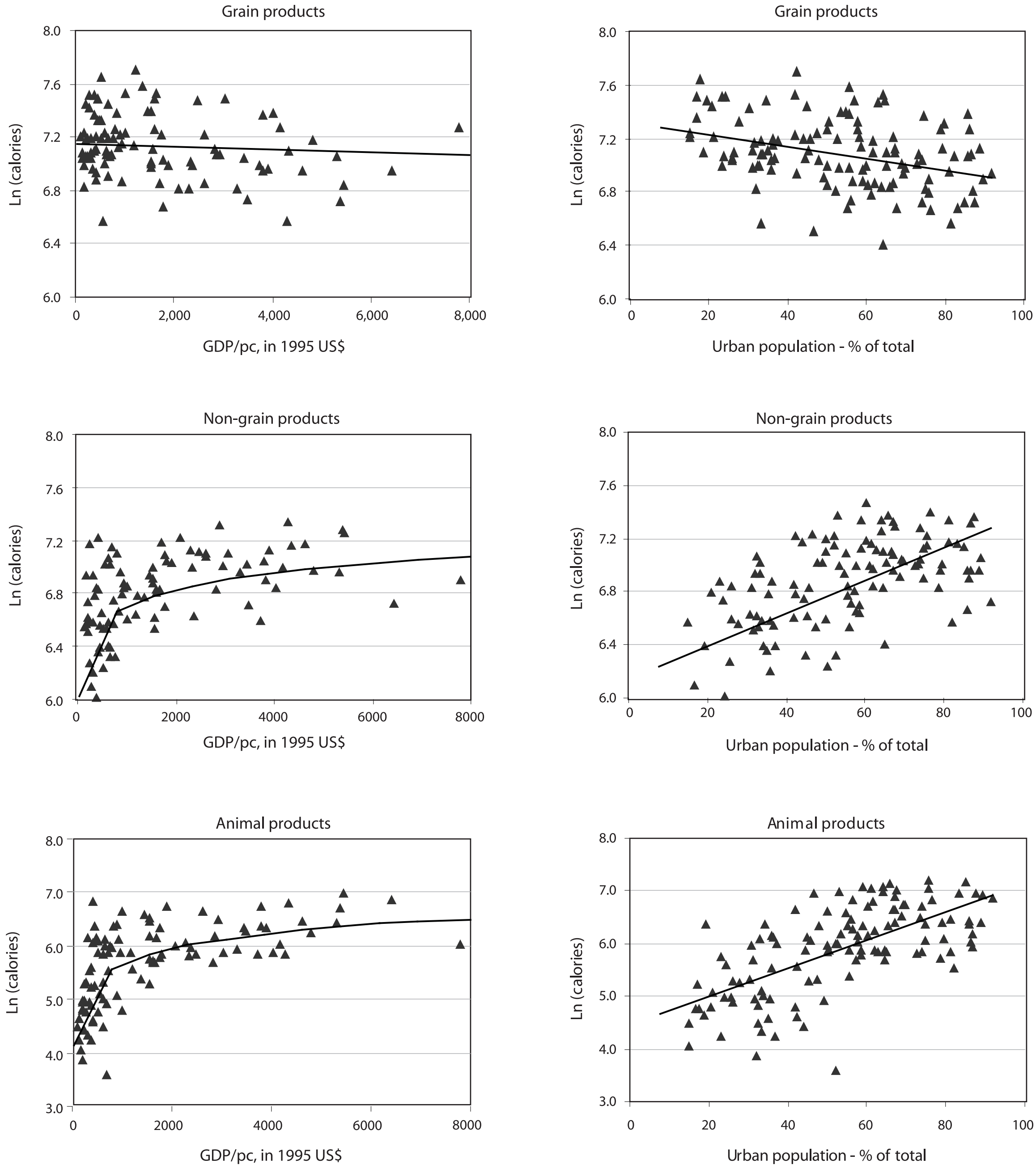
- Identify high productivity zones and high potential locations for increasing the water productivity of grain crops.
- Identify suitable cropping patterns, which generate higher value for every drop of water consumed.
- Encourage and increase the diversification of crops, from grain to non-grain crops, in locations where returns from water use are low at present.
- Import part of the demand for certain crops, or increase virtual water trade, where differences in irrigated and rain-fed water productivities are high or where water productivity is low under both conditions. Virtual trade is a better option than using scarce irrigation water resources inefficiently. An increase in trade is not necessarily between countries; it can be between states. The trade can be commodities where there is no significant gain by irrigating them within India. Maize and the oil seeds are good examples of such commodities.
- Increase the beneficial use of present irrigation diversions. Less than half of the irrigation withdrawals are beneficially consumed at present. Much of the additional CWU demand in the future can be met from the non-beneficial depletions at present. Indeed, this can be done only in basins where reuse of non-beneficial use may not have any significant impact on downstream or other uses. Appropriate water saving techniques could offer significant opportunities here.

Annex

Calorie Supply of Grains, Non-grains and Animal Products

Global consumption patterns show that, in general, food grains dominate the diets of the low-income categories (figure A1). As income and urbanization increases, the consumption of non-grain crops and animal products increases. A significant diversification of diets occurs when people move away from the low-income to middle and high income categories.

FIGURE A1.
Calorie supply/per person/per day from grain, non-grain and animal products of selected countries in the world.



Data Source: WRI 2005, FAO 2005

We use the global consumption patterns to assess the trends of future calorie intake of the three food categories. Our approach is similar to the study by Knudsen and Scandizzo (1982), except that we use a sample of low to middle income countries to represent the variation of income. As India would only become an upper-middle-income country by 2050, we restricted our analysis to a sample of countries with a GDP/ person of less than $10,000.

First, we establish econometric relationships of the calorie supply of different crop products with the income and urbanization. Our dependent variables are the daily calorie intake of grains, non-grains and animal products per person. The independent variables are the GDP per person and the urban population as a percentage of total population. Additionally, we test the substitution effect of animal products on the consumption of food grains. The data consist of 3-year averages between 1999 and 2001 of 85 countries. Due mainly to taste and cultural differences, the levels of grain consumption vary in the studied sample. To capture the effect of this variation on the coefficients, we identify four homogeneous clusters within the grain consumption cluster. We use the K-means cluster analysis[3] with 4 clusters. The cluster means for the variable are given in table A1.

TABLE A1.
Cluster means.

	Average calorie supply (kcal/person/day)		
	Grains	Non-grains	Animal products
Cluster 1	901	1,210	537
Cluster 2	1,130	926	372
Cluster 3	1,363	837	373
Cluster 4	1,769	718	311

After examination of the structural changes of the calorie supply from non-grain and animal products with respect to GDP, we have selected the US$1,000 threshold of per capita GDP to separate the studied countries into low and middle income groups. Further analysis shows that the substitution effect of the animal products on the grain consumption is not significant for the selected low to middle income countries. However, if the sample includes the developed countries, the substitution effect becomes statistically significant. Finally, we select the following model for estimating the relationship between calorie supply, income and urbanization.

$$\begin{Bmatrix} Ln(Cal^{G}) \\ Ln(Cal^{NG}) \\ Ln(Cal^{AP}) \end{Bmatrix} = \begin{cases} (\alpha_{01} + \alpha_{02} Clus_2 + \alpha_{03} Clus_2 + \alpha_{04} Clus_4) + \alpha_0 GDP + \\ \alpha_2 (GDP - 1000) I_{[GDP>1000]}) + \alpha_3 PCTUP \end{cases}$$

where,

$Clus_i$ = Cluster i, i=1,..,4.
Cal^{G} = Daily calorie supply from grains in 2000
Cal^{NG} = Daily calorie supply from non-grains in 2000
Cal^{AP} = Daily calorie supply from animal products in 2000
GDP = Gross domestic product per person in 2000
PCTUP = Percentage of urban population

[3]K-means clustering is a statistical technique for identifying k homogeneous groups using certain characteristics, where the group members are much closer to the group mean than to the mean of any other group (Chatfield and Collins 1980).

Next, we estimate the income elasticities for food consumption categories in India. Finally, we project India's calorie intake of grain, non-grain crops and animal products, with respect to the changes in income and urbanization from the levels of the base year 2000.

TABLE A2.
Estimated regression equations.

	Ln (Cal_i^G)		Ln (Cal_i^{NG})		Ln (Cal_i^{AP})	
Variables	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Constants						
α_{01}	6.85[a]	0.026	6.355[a]	0.116	4.30[a]	0.208
α_{02}	0.204	0.020	-0.115	0.085	-0.026	0.153
α_{03}	0.390	0.021	-0.206[a]	-0.092	0.172	0.165
α_{04}	0.636	0.022	-0.432[a]	-0.096	0.013	0.176
GDP						
α_1	-0.000002	-.000002	0.000478[a]	0.002	0.0012[a]	0.0001
GDP – middle income						
α_2	-	-	-0.000476[a]	0.0001	-0.0011[a]	0.0001
% Urban population						
α_3	-0.0035	.002	0.00430[a]	0.002	0.0094[a]	0.0040
R^2	0.92		0.53		0.59	

A significant part of the variation in the calorie supply from grain is explained by the differences of consumption levels of the four clusters (table A2). This shows that the calorie supply from grain products is very much regional or country specific, and primarily dependent on taste. The coefficients of income and urbanization in the grain calorie supply model are negative but not statistically significant. The negative but very low elasticities of income and urbanization (table A3) show that they also gradually contribute to the declining grain consumption in India. In fact, urbanization is contributing to about 97 percent of the decline in grain consumption.

However, the differences in both income and urban population are significant factors in explaining the variation in the calorie supply from non-grain and animals products. With increasing income and urbanization, calorie supply from non-grain and animal products increases, but the rate of growth decreases in the middle-income countries. The elasticity estimates show that while income growth contributes to a significant part (85% in 2000) of the change in calorie supply from non-grains between 2000-2025, urbanization contributes to the majority of this change after 2025. However, the income growth continued to be a significant factor for the growth in calorie supply from animal products in both periods.

TABLE A3.
Elasticity of calorie demand with respect to GDP and Urban population growth.

Sources of growth	Elasticity in 2000 (GDP=US$463,PCTUP=28%)			Elasticity in 2025 (GDP=US$1,765,PCTUP=38%)		
	Grains	Non-grains	Animal products	Grains	Non-grains	Animal products
GDP growth	-0.001	0.22	0.52	-0.004	0.11	0.32
Urbanization	-.097	0.12	0.26	-.133	0.16	0.36

Literature Cited

Amarasinghe, U. A.; Sharma, B. R.; Aloysius, N.; Scott, C.; Smakhtin, V.; de Fraiture, C. 2005. *Spatial variation in water supply and demand across river basins of India.* Research Report 83. Colombo, Sri Lanka: International Water Management Institute.

Bandyopadhyay, J.; Perveen, S. 2003. The interlinking of Indian rivers: Some questions on the scientific, economic and environmental dimensions of the proposal. Paper presented at the Seminar on Interlinking Indian Rivers: Bane or Boon? at IISWBM (Indian Institute of Social Welfare and Business Management), Kolkata, on June 17, 2003, SOAS (School of Oriental and African Studies, King's College, London) Water Issues Study Group, Occasional Report No. 60.

Bansil, P. C. 1999. *Demand for food grains by 2020 A. D.* New Delhi: Observer Research Foundation.

Bhalla, G. S.; Hazell, P.; Kerr, J. 1999. *Prospects of India's cereal supply and demand to 2020.* Food, Agriculture and the Environment Discussion Paper 29. Washington, D.C., USA: International Food Policy Research Institute (IFPRI).

Chatfield, C.; Collins, A. J. 1980. Introduction to multivariate analysis. London, UK: Chapman and Hall.

Chopra, K. 2003. Sustainable use of water: The next two decades. *Economic and Political Weekly* 38(32): 3359-3365.

Chatterjee, S.; Rae, A.; Ray, R. 2006. *Food consumption, trade reforms and trade patterns in contemporary India: How do Australia and NZ fit in?* Working Paper 2/06. New Zealand: Centre for Applied Economics and Policy Studies, Massey University.

CWC (Central Water Commission). 2004. *Water and related statistics.* New Delhi: Water Planning and Projects Wing, Central Water Commission.

Dawson, P. J.; Tiffin, R. 1998. Estimating the demand for calories in India. *American Journal of Agricultural Economics* 80(3): 474-481.

Delgado, C. L.; Rosegrant, M.; Steinfield, H.; Ehui, S.; Courbois, C. 2005. *The coming livestock revolution.* Background Paper No. 6. Rome: Food and Agriculture Organization of the United Nations (FAO).

Drewnowski, A.; Popkin, B. M. 1997. The nutrition transition: New trends in the global diet. *Nutritional Review* 55: 31-43.

Dyson, T.; Hanchate, A. 2000. India's demographic and food prospects: State level analysis. *Economic and Political Weekly* 11: 4021-4036 (November).

FAO (Food and Agriculture Organization of the United Nations). 2005a. FAOSTAT database. Available at http://faostat.fao.org/

FAO. 2005b. AQUASTAT database. Available at http://www.fao.org/nr/water/aquastat/main/index.stm

GoI (Government of India). 1999. *Report of the National Planning Commission: Integrated Water Resources Development.* India.

Huang, J.; David, C. C. 1993. Demand for cereals grains in Asia: The effect of urbanization. *Agricultural Economics* 8(2): 107-124.

Iyer, R. R. 2003. *Water: Perspectives, issues, concerns.* New Delhi: Sage Publications.

IWMI (International Water Management Institute). 2000. *World water supply and demand 1995 to 2025 (draft)*. Available at http://www.iwmi.cgiar.org/pubs/WWVisn/WWSDOpen.htm

Kijne, J. W.; Barker, R.; Molden, D. 2003. *Water productivity in agriculture: Limits and opportunities for improvements.* UK: CABI Publishing.

Knudsen, O. K.; Scandizzo, P. L. 1982. Demand for Calories in Developing Countries:. *American Journal of Agricultural Economics* (1982) 80-86.

Kumar, P. 1998. *Food demand and supply projection for India.* Agricultural Economics Policy Paper 98-01, New Delhi: Indian Agricultural Research Institute.

Kumar, P.; Mathur, V. C. 1997. Agriculture in future: Demand and supply prospective. In: *Agricultural development paradigm for the ninth plan under new economic development*, ed. B. M. Desai. New Delhi, India: Oxford and IBH Publishing.

Landes, M.; Persaud, S.; Dyck, J. 2004. *India's poultry sector: Development and prospects.* Agriculture and Trade Report No. WRS04-03. Washington, D.C., United States: Department of Agriculture.

Mahmood, A.; Kundu, A. 2006. Demographic projections for India 2006-2051: Regional variations. Draft prepared for the International Water Management Institute (IWMI)-CGIAR Challenge Program on Water and Food (CPWF) project on "Strategic Analysis of National River-Linking Project of India".

Molden, D. J.; Sakthivadivel, R. 1999. Water accounting to assess uses and productivity of water. *Water Resources Development* 155(1&2): 55-57.

Molden, D. J.; Sakthivadivel, R.; Perry, C. J.; de Fraiture, C.; Kloezen, W. H. 1998. *Indicators for comparing performance of irrigated agricultural systems*. Research Report 20. Colombo, Sri Lanka: International Water Management Institute.

Molden, D. J.; Sakthivadivel, R.; Habib, Z. 2001. *Basin-level use and productivity of water: Examples from South Asia.* Research Report 49. Colombo, Sri Lanka: International Water Management Institute.

NSSO (National Sample Survey Organization). 1996. *Key results on household consumer expenditure in 1993-94, 50th round.* Report No. 401. New Delhi: Department of Statistics, Government of India.

NSSO. 2001. *Key results on household consumer expenditure in 1999-2000, 55th round.* Report No. 461. New Delhi: Department of Statistics, Government of India.

NWDA (National Water Development Agency). 2006. *The need.* Available at http://www.nwda.gov.in

Popkin, B. M. 2000. *Urbanization and the nutrition transition*. 2020 Focus no. 03 – Brief 07. Washington, D.C.: International Food Policy Research Institute (IFPRI).

Popkin, B. M. 2001. Nutrition in transition: The changing global nutrition challenge. *Asia Pacific Journal of Clinical Nutrition* 10 (Suppl. 1): S13-S18.

Radhakrishna, R.; Ravi, C. 1992. Effects of growth, relative price and performances of food and nutrition. *The Indian Economic Review* 27: 303-23.

Radhakrishna, R.; Reddy, K. V. 2004. Food security and nutrition: Vision 2020. In: *India Vision 2020*. *The report of the committee on India Vision 2020.* New Delhi: Academic Foundation.

Rao, C. H. H. 2000. Declining demand for foodgrains in rural India: Census and implications. *Economic and Political Weekly* (January 22).

Rath, N. 2003. Linking rivers: Some elementary arithmetic. *Economic and Political Weekly* 38(29): 3032-3033.

Rosegrant, M. W.; Paisner, M. S.; Meijer, S.; Witcover, J. 2001. *Global food projections to 2020: Emerging trends and alternative futures.* Washington, D.C.: IFPRI.

Rosegrant, M. W.; Agcaoili-Sombilla, M.; Perez, N. D. 1995. *Global food projections to 2020: Implications for investment*. 2020 Discussion Paper 5. Washington, D.C.: IFPRI.

Subramanian, S.; Deaton, A. 1996. The demand for food and calories. *Journal of Political Economy* 104(1): 133-162.

Vaidyanathan, A.; Sivasubramaniyan, K. 2004. Efficiency of water use in agriculture. *Economic and Political Weekly* 39(27): 2989-2996.

Viswanathan, B. 2001. Structural breaks in consumption patterns: India 1952-1991. *Applied Economics* 33(9): 1187-1200.

WHO (World Health Organization). 2003. Diet, Nutrition and the Prevention of Chronic Diseases. Report of the Joint FAO/WHO Expert Consultations. WHO Technical Report Series 916. Geneva: World Health Organization.

WRI (World Resources Institute). 2005. *Earth trends*. Searchable database. Available at http://earthtrends.wri.org

Research Reports

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