Irrigation Demand Projections of India: Recent Changes in Key Underlying Assumptions

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Introduction

Coping with annual floods and droughts has been a major concern for India's agriculture in the past several decades. Concerns are more acute today as much of India's billion plus population depend on agriculture for their livelihood. Also, the slow growth of the agriculture sector, usually the hardest hit from floods and droughts, is a major constraint on the efforts to reduce rural poverty and also diversify and sustain the present economic boom. Annual floods on average affect more than 3 million ha of cropping area and 34 million people, mostly in the east, and inflict damage amounting to well over US$220 million. Droughts affect 19 % of the country, 68 % of the cropped area and 12 % of the population. Concerned on this twin menace, and responding to public interest litigation, the Supreme Court of India ordered the Government of India to expedite the interlinking of rivers plan, a series of large-scale interbasin transfers aimed at moving water from surplus basins to water short basins, before the first quarter of this century. A major factor in the 'National River Linking Project' (NRLP) as originally conceived is that it would ease water scarcities, especially for irrigation, due to droughts in the southern and western parts of India and mitigate the floods in the eastern parts of India and Bangladesh. However, although there has been some renewed efforts to implement components of the NRLP since the Supreme Court Decision, the NRLP is a very contentious issue today both within India and outside.

The significant irrigation water demand increases projected by the National Commission of Integrated Water Resources Development (NCIWRD) were a major facet of the initial justification of the NRLP (GOI 1999). The most prominent drivers of the NCIWRD irrigation demand projections were national self-sufficiency; nutritional security for all people; and rural livelihood security. However, even at that time the commission recognized that their projections were only a first approximation and would need periodic updating with the rapidly changing economic growth patterns.

The primary purpose of the paper is to re-examine the assumptions of irrigation demand estimation upon which the plans for the NRLP have been fashioned. The paper consists of three sections. Following this introduction, the second section investigates the recent trends of drivers affecting irrigated agriculture and assesses possible deviations from the NCIWRD assumptions. We conclude the paper by highlighting the key drivers which influence the short- to medium-term policy options for meeting the future irrigation demand.

Assumptions of Irrigation Demand Projections - A Re-examination

The National Water Development Agency (NWDA), the government agency responsible for implementing the NRLP project, states that "… for meeting the requirement of about 450 million metric tonnes of food grains the irrigation potential has to be increased to 160 million ha for all crops by 2050, and one of the most effective ways to increase the irrigation potential for increasing the food grain production, mitigate floods and droughts and reduce regional imbalances in the availability of water is the interlinking of rivers to transfer water from the surplus rivers to deficit areas..." (NWDA 2006). The NWDA message primarily summarized the implications of NCIWRD food and water demand projections, where the irrigation demand projections would expect to add another 34 million ha of surface irrigated area.

The NCIWRD projected water demand under high and low population projection scenarios (Paper 2). The plans for the NRLP were based on the 'high' population growth scenario. A major part, 68 %, of the NCIWRD high water demand projection (1,180 km^3), is for irrigation (GOI 1999). Key assumptions leading to the irrigation demand estimation are as follows:

- Food grain demand increase from 155 to 450 million tonnes. The total demand projection, including feed, seeds and waste, increases from 177 to 494 million tonnes. The Commission has assumed food grain self-sufficiency, and expected that food grain production would generate adequate income for the rural people.
- Irrigated and rain-fed grain yields, to grow 0.95 % and 0.71 % annually. Accordingly, irrigated and rain-fed yields are to increase from 2.3 to 4.0, and 1.0 to 1.5 tonnes/ha, respectively.
- The net irrigated area or the irrigable area increases from about 50 to 91 million ha; gross irrigated area from 68 to 146 million ha, and irrigation coverage of grain crops remains the same at 70 %.
- Surface to groundwater irrigated area ratio changes from 45:55 to 55:45.
- Net sown area remains the same at 142 million ha; gross crop area increases from 186 to 232 million ha; and grain crops cover 69 % of gross crop area. The latter assumption, an increase of 2 % from the 1993/94 level, basically maintains the dominance of grain production in Indian agriculture and a very slow growth of crop diversification.
- Surface irrigation efficiency increases from 35-40 % to 60 %; and groundwater irrigation efficiency from 65 to 75 %.

However, many of the above assumptions are either not in line with the trends since the time of the projections, or now seem to be rather conservative given the increasing scope for technology use in the Indian agriculture. Therefore, we re-examine the NCIWRD assumptions in line with the trends of the key-drivers observed in the 1990s, in what we refer to as the business-as-usual scenario. That is, what we expect to happen in the future, based on recent trends, past conditions, and no major changes in the policy environment.

Food Demand

The NCIWRD projection for food grain demand, which is equivalent to 778 g/person/day by 2050, is no longer valid on two points. First, this level of grain consumption provides a calorie supply of 4,000 kcal/person/day, which is even higher than the calorie intake in the developed countries with animal product dominated diet. For example, the USA ranked highest in calorie intake among the developed countries, consuming only 3,800 kcal/person/day. It is highly unlikely that, with a vegetarian centered diet, India will ever reach this level of calorie intake in the future.

Second, recent trends show, non-grain food crops and animal products in the diet are increasing (Table 1). The food-grain consumption per capita in both the rural and urban areas (Amarasinghe et al. 2007a) and in both upper and lower income groups (Joshi et al. 2007) is decreasing. The share of food grains in total calorie supply in India itself has decreased from 70 to 63 % between 1990 and 2000 (FAO 2005). Based on recent trends, it is estimated that total calorie supply will increase to 3,000 kcal/person/day by 2050, from 2,345 kcal/person/day in 2000 (Amarasinghe et al. 2007a). However, the share of calories met by food grains, non-grain food crops, and animal products will change from 65:28:8 % in 2000, to 48:36:16 % by 2050. In fact non-grain food crops and animal products will dominate the consumption pattern in the middle of this century.

Table 1. Changing food consumption and calorie supply pattern.

Crop or livestock product	Consumption (kg/person/year)			Annual growth (%)		Calorie supply (Kcal/person/day)			Annual growth (%)	
	1980	1990	2000	1980-1990	1990-2000	1980	1990	2000	1980-1990	1990-2000
Grain crops										
Rice	68	79	74	1.5	-0.6	670	780	737	1.5	-0.6
Wheat	46	55	58	1.8	0.5	390	467	491	1.8	0.5
Maize	7.4	7.7	4.8	0.4	-4.7	61	64	39	0.5	-4.7
Other cereals	28.9	23.3	16.8	-2.1	-3.2	248	200	144	-2.1	-3.3
Total cereals	150	164	154	1.0	-0.7	1368	1510	1412	1.0	-0.7
Pulses	13	14	12	1.1	-1.9	120	132	109	1.0	-1.9
Total grains	162	178	165	1.0	-0.8	1487	1643	1521	1.0	-0.8
Non grain crops										
Oil crops	22	28	40	2.6	3.6	152	195	273	2.5	3.4
Roots & tubers	4.9	4.6	5.4	-0.5	1.6	41	40	47	-0.3	1.7
Vegetables	48	53	67	1.0	2.4	32	35	44	0.9	2.3
Fruits	26	28	37	0.8	2.8	31	34	47	1.0	3.4
Sugar	20	23	25	1.3	0.8	193	221	240	1.4	0.8
Total non-grains						450	525	651	1.6	2.2
Livestock products										
Beef	2.4	2.7	2.6	1.2	-0.4	8.1	9.5	9.0	1.5	-0.5

(Continued)

Table 1. Changing food consumption and calorie supply pattern. *(Continued)*

Crop or livestock product	Consumption (kg/person/year)			Annual growth (%)		Calorie supply (Kcal/person/day)			Annual growth (%)	
	1980	1990	2000	1980-1990	1990-2000	1980	1990	2000	1980-1990	1990-2000
Pig meat	0.4	0.5	0.6	2.3	1.8	3.7	4.8	5.6	2.5	1.6
Goat/sheep	0.7	0.7	0.7	0.5	0.0	3.0	3.2	3.1	0.9	-0.4
Chicken	0.2	0.4	1.0	8.0	9.1	0.8	1.6	3.9	7.0	9.5
Milk/butter/ghee	40	55	66	3.2	1.9	93	129	153	3.4	1.7
Eggs	1	1	1	5.5	1.8	3	5	6	5.1	2.1
Fresh water fish	1	2	3	3.4	4.1	3	4	5	3.3	4.3
Total animal products						119	162	192	3.2	1.7
Total all items						2082	2366	2413	1.3	0.2

Source: FAOSTAT Database (FAO 2005).

Recent trends also indicate a diversifying consumption pattern. Among grain crops, preference for coarse cereals is decreasing fast. The consumption of maize and other coarse cereals declined from 4.7 and 3.7 % annually in the 1990s. Most importantly, the consumption of rice, a major staple food in the south and east, also declined, by 0.6 % annually in the 1990s. It is projected that per capita food grain consumption will further decrease in the future, from 472 kg/person/day in 2000 to 454 and 417 kg/person/day by 2025 and 2050, respectively.

Among non-grain crops, the consumption of fruits, vegetables and vegetable oils has increased significantly in the 1990s (Table 1). Combining the trends of increasing calorie supply of non-grain food crops and also the composition of the consumption of different crops, it is estimated that the consumption of vegetables, fruits, oil crops and roots and tubers per person has increased by 64 %, 68 %, 75 % and 112 %, respectively. In fact, non-grain crops are also expected to form a major part of the nutritional intake in the future.

Milk and milk products provide a major part of the animal product calorie supply at present. During the 1990s the consumption of milk has increased at a steady pace (1.7 % annually), and it has increased for chicken, eggs and freshwater fish significantly. It is expected that increasing income and urbanization will push the demand for animal products even further, increasing the consumption of milk by 51 % and fresh water fish by 142 % (Amarasinghe et al. 2007a). The consumption of chicken and eggs is expected to increase significantly, from only 1.0 and 1.4 kg/person/year respectively in 2000, to 13.4 and 34.1 kg/person/year, respectively over the period of 2000-2050.

Feed Demand

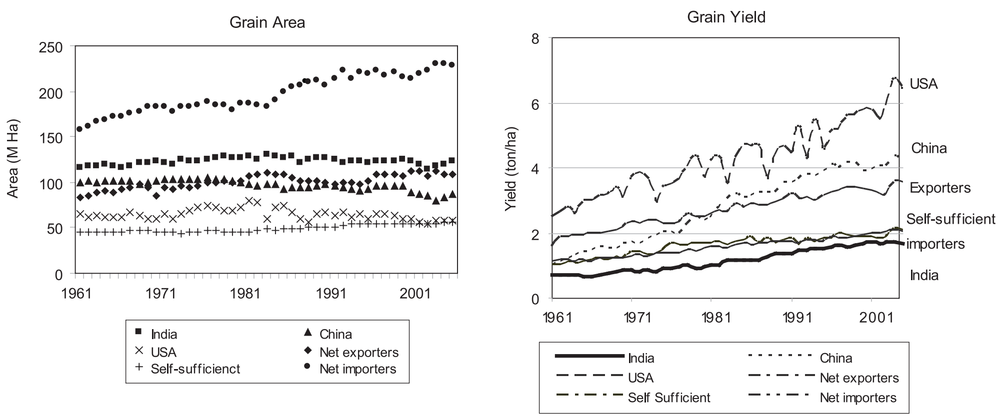
With the increasing consumption of animal products, especially of chicken and eggs, the demand of feed grains, mainly of maize, will increase significantly over the period of 2000 to 2050. The demand for feed grains is projected to increase, from 8 million tonnes in 2000 to 38 and 111 million tonnes by 2025 and 2050, respectively.

For feed demand, the commission projected 48 million tonnes, which significantly underestimates the present and future needs of livestock. Despite this, the total overall grain demand projections of the NCIWRD of 494 million tonnes is higher than the 377 million tonnes projected based on recent trends. The demand-driven, diversified agriculture pattern is transforming Indian agriculture (Joshi et al. 2007). This transformation will create numerous opportunities for increasing agricultural production, marketing, food processing, and retailing in the rural sector. The direct and indirect impact through agricultural diversification will not only help alleviate rural poverty, but also help increase the sustainable agricultural production systems in India (Barghouti et al. 2007; Pingali and Rosegrant 1995).

Crop Yields

The expected increase in yield is a major driver of additional irrigation demand. In fact, the NCIWRD assumption of annual growth in grain yields, 1.2 % and 0.7 % between 2000 and 2025, and 2025 and 2050, respectively, is a major point of contention in the recent discourse. The data indicate that India can be self sufficient in food grains without any additional irrigation if it doubles the crop yield in 50 years (Amarasinghe et al. 2007a). Many people argue that a great potential exists for doubling the crop yield (1.7 tonnes/ha in 2000), given what other large countries with similar irrigation growth have achieved over the last four decades (Figure 1). In fact, Figure 1 seems to suggest in general, those countries with a focus on exporting have given greater emphasis on yield growth to achieve production increase, whereas countries with policies aimed at self-sufficiency and net importers have emphasized more on expanding their area. Today, India has the world's largest area under grains with the largest irrigated area, but has one of the lowest yields among major crop-producing countries.

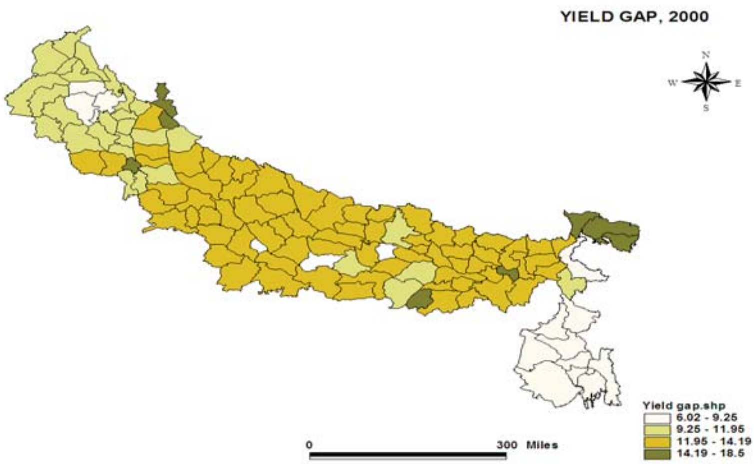
Figure 1. Growth patterns of grain area and yield in different countries or country groups.



Source: FAO 2005

Given the expansion of irrigated agriculture, it is puzzling that India was not able to match other countries in yield growth. According to official data, India has the largest irrigated area in the world (GOI 2005). However, studies show that crop yields vary in plots in the same farm, across farms in the same irrigation system, and across irrigation systems in similar agroclimatic zones etc (Kumar et al. 2006a, 2006b; Palanisami et al. 2006). Similarly, a significant gap exists between the actual and the potential yield in different agroclimatic zones (Figure 2, Aggarwal et al. 2000). The actual rice-wheat yields of 7.5, 6.1, 4.5, 4.4 t/ha, of Punjab, Haryana, Uttar Pradesh, Bihar and the West Bengal, are much below the potential yield of 12-19 tonnes/ha. Thus, studies claim that with proper water and nutrient management and advanced technology-use yield potential could be increased significantly.

Figure 2. The gap between the actual and potential yield of rice + wheat system in the Indo-Gangetic plain.



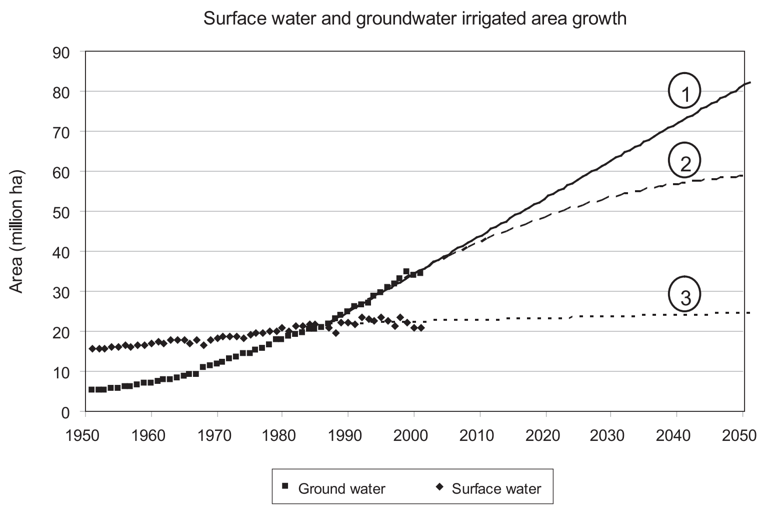
India also has the largest rain-fed crop area in the world with one of the lowest levels of rain-fed crop productivity. India's rain-fed grain yields (0.95 tonnes/ha) in 1995, is only one-fifth of the rain-fed yield in USA, one-third of China, and less than one-half of Argentina, Brazil and Australia (IWMI 2000). While favorable rainfall conditions were a major factor of high yields in other countries, low yield in rain-fed agriculture in India is mainly attributed to frequent occurrences of mid-season and terminal droughts (Sharma et al. 2006). The occurrence of mid-season or terminal droughts in 1-3 weeks of consecutive duration during the main cropping season causes either crop failure or low yield. However, a supplemental irrigation during the mid-season and terminal drought periods has the potential to improve the yields by 29 to 114 % for different crops. A district level analysis shows that as much as 25 million ha of rain-fed area (excluding extreme arid and wet areas) could benefit from supplemental irrigation during the water stress periods of the main season. This same area has approximately 99 km^3 of surface runoff that could be captured by rainwater harvesting, but requires only about 18-20 km^3 for supplemental irrigation. The supplementing of one critical irrigation to 18.75 m ha during a drought year and 22.75 million ha during a normal year could boost total rain-fed production by more than 50 %. Of course, the viability of implementing such a scheme on a landscape scale needs to be more closely examined.

In spite of the scope for improvements, the rate of growth in grain yield decreased in recent decades, from an all time high of 3.8 % annually in the 1980s to 2.1 % in 1990s. However, using conservative assumptions with regard to advanced irrigation technology, small-scale irrigation, groundwater use, enhanced water conservation, proper nutrient management, and investments in research and extension, Amarasinghe et al. 2007b concluded that irrigated crop yields could be increased at the rate of 1.4 % for 2000 to 2025, and 1.1 % annually from 2025 to 2050 in contrast with the 1.2 % and 0.7 % projected by NCIWRD for the same two periods.

Land Use Patterns

Groundwater has been the primary source of the growth in India's net irrigated area (NIA) in the last two decades, adding 8.4 and 8.6 million ha, respectively in 1980s and 1990s. In fact, the expansion in groundwater irrigated area has more than offset the decline of the surface irrigated area during the 1990s. The net surface irrigated area shrank by 0.9 million ha: from 22.0 million ha in 1989 to 21.1 million ha in 1999 (Figure 3). Given the present day investment patterns, groundwater development will most likely continue to drive the irrigation expansion in the near future.

Figure 3. Growth patterns of net surface and groundwater irrigated area.



Source: GOI 2004

Note: Lines 1 and 2 show the linear and quadratic extrapolation of net groundwater irrigated area using data from 1985-2003. Line 3 shows the linear extrapolation of the net surface irrigated area using the data over the same period.

[1] The Government of India sets targets for increasing irrigated area in successive 5-year planning periods. The IX[th] 5-year plan, which covers 2002 to 2007, envisages adding 9.8 million ha through major and medium irrigation projects to the existing irrigation potential. The total net surface irrigated area created before the IX[th] plan is 21 million ha.

If net groundwater irrigated area continues to expand at the same rate as in the recent past, it would reach 80 million ha by 2050, and with a slowing rate of increase (quadratic growth), the net area irrigated by groundwater would reach 60 million ha. However, it is likely that the pace of expansion will slow down further due to constraints on the availability of the resource and the over-abstraction in many regions. Thus, given the recent trends and the constraints due to over-abstraction in some regions and the opportunities that exist in other regions, net groundwater irrigated area would increase from 34 million ha in 2000 to 50 million ha in 2050. It is also likely that most of the ongoing major and medium canal irrigation projects will be completed before 2025. In fact, the IXth irrigation plan[1] aimed at adding another 10 million ha to the net surface irrigated area between 2002 and 2007. Overall, the net surface irrigated area is projected to increase from 21 million ha in 2000 to 31 million ha by 2025, and remains at that level there after.

The projected increase in net groundwater irrigated area to 50 million ha and net surface (canal and tank) irrigated area to 31 million ha by 2050 will mean that the NIA supplied by ground and surface water will increase from 56 to 81 million ha. As a result of this expansion, the gross irrigated area (GIA) is projected to increase from 76 to 117 million ha and gross crop area (GCA) is projected to increase from 189 to 209 million ha between 2000 and 2050 (Amarasinghe et al. 2007b). These estimates are significantly lower than the assumption of NCIWRD scenario, which assumed that GIA and GCA would increase to 146 and 232 million ha respectively by 2050.

Another striking difference is that the business as usual trends project the surface to groundwater irrigated area ratio to reach 39:62 % by 2050, whereas the earlier NCIWRD estimates determine this to be 55:45 %. Under the NCIWRD surface water is the source of choice for 60 % of the additional GIA, whereas under the prevailing trends the business as usual scenario determines that groundwater will be a dominant source for 61 % of the additional irrigated area. In the latter case, the essentially private-sector driven groundwater sector would continue to play the dominant role in India’s irrigation futures. However, this scenario would lead to severe groundwater depletion in many regions (Amarasinghe et al. 2007b). The major challenge facing the water sector in India today and over the long term is how to increase the groundwater stocks (supply enhancement) to arrest the declining groundwater tables, and how to sustain water use by minimizing uncontrolled groundwater pumping (demand management).

Crop Diversification

The decreasing share of grain crops, 74-65 % of GCA, and 77-71 % of GIA, between 1980 and 2000, shows that Indian agriculture is diversifying to cater to the increasing internal and global demand for non-grain crop products. Interestingly, perhaps as a response to the declining dominance of grains in the diet and also prices, the total grain harvested area also declined during the last two decades (Table 2). The only exception here is the area under maize, which has in fact increased due to rapidly increasing demand of livestock feed.

Among high-value non-grain crops, the area under fruits, vegetables, and roots and tubers experienced increasing growth rates over the last two decades (Table 2). It is most likely that this agricultural diversification trend will continue with the projected shift of consumption patterns. Given the recent trends, Amarasinghe et al. 2007a projects that harvested grain area

Table 2. Crop area, irrigated area and livestock population growth.

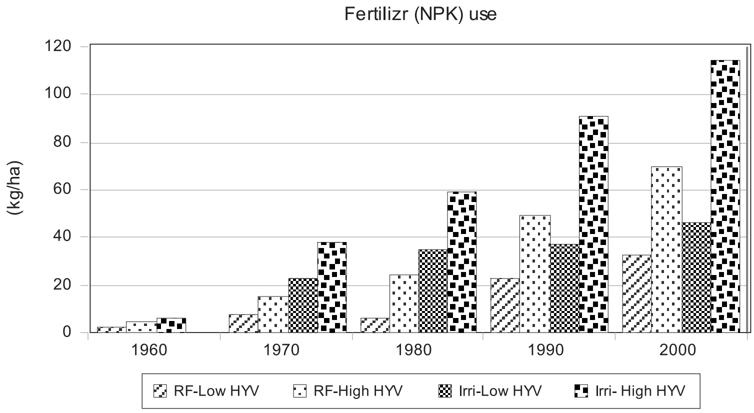
Crop or livestock item	Crop harvested area (mha)			Annual growth (%)		Crop irrigated area (mha)			Annual growth (%)	
	1980	1990	2000	1980-1990	1990-2000	1980	1990	2000	1980-1990	1990-2000
Grain crops										
Rice	40	43	45	0.6	0.5	17	19	25	1.5	2.4
Wheat	22	24	27	0.7	1.2	16	19	23	2.0	2.0
Maize	6	6	7	0.0	1.0	1.2	1.2	1.4	0.2	1.7
Other cereals	36	30	23	-1.8	-2.5	2.2	2.3	1.5	0.5	-4.3
Total cereals	104	102	101	-0.2	-0.1	36	42	51	1.6	1.9
Pulses	23	24	22	0.4	-1.0	2	2	3	2.0	1.8
Total grains	127	126	123	-0.1	-0.2	38	45	54	1.7	1.9
Non grain crops										
Oil crops	27	33	34	2.2	0.4	3	6	6	6.7	0.4
Roots and tubers	1	1	2	0.3	2.3	0	0	1	2.9	3.3
Vegetables	4	5	6	1.1	1.5	1	1	2	3.6	2.5
Fruits	2	3	4	1.6	3.4	0	1	1	4.2	4.5
Sugar	3	3	4	2.3	1.9	2	3	4	3.2	3.5
Cotton	8	8	9	-0.5	1.5	6	7	9	0.5	2.8
Livestock population (millions)										
Cows	187	203	193	0.8	-0.5					
Buffaloes	66	81	93	2.0	1.5					
Goats/sheep/pigs	141	174	195	2.1	1.1					
Chickens	0.2	0.3	0.4	4.6	2.1					

Source: FAOSTAT Database (FAO 2005)

will decrease further and consist of only 57 % of the total crop area by 2050, compared with 69 % of the NCIWRD projection. These trends project a slight increase (10 million ha) in irrigated grain area, compared with 44 million ha increase projected under the NCIWRD scenario. Thus, the irrigated grain area as a percentage of GIA based on the recent trends will be only 52 % in 2050 compared with 70 % in the NCIWRD projections. However, with the recent volatility in global grain markets and what appears to be long term increases in grain prices, these trends could change.

The projections based on recent trends show that a major part (77 %) of the additional irrigated area in the future will produce non-grain crops (Amarasinghe et al. 2007b). These are generally high-value crops, requiring timely application of expensive inputs. Although no data are available to illustrate the trends in the non-grain sector, we hypothesize that the efficacy of high value inputs very much depends on a reliable water supply during the critical periods of crop growth. This is clearly evident in the input use in the grain sector (Figure 4).

Figure 4. Fertilizer use in different land-use patterns in India.



A critical input for higher productivity, fertilizer use in irrigated areas with high-yielding varieties is much higher than in irrigated areas growing traditional varieties. Similar differences in fertilizer application exist in rain-fed areas with the use of high-yielding and traditional varieties. Indeed, a reliable water supply is a critical prerequisite for many of the other expensive inputs required for high value crop production. Groundwater, with its generally more reliable water supplies, has been a major source for meeting this irrigation demand in the recent past. But falling groundwater tables, and increasingly unreliable electricity supply and emerging energy crisis threaten this advantage and may have a significant impact on further crop diversification. How India will overcome these constraints will determine the pace of non-grain crop expansion in the future.

Irrigation Efficiency

The available information on irrigation efficiency improvement is very scanty, but that which is available suggests that the surface project irrigation efficiency has not increased much over the last decade. Although the project irrigation efficiency may be low, in water scarce river basins that are approaching a high degree of closure, the overall basin efficiency is generally much higher, that is the water lost from one project is used as supply by a project downstream. In such basins, increasing efficiency would only benefit downstream users, as has been observed in the Krishna (Venot et al. 2007). Thus, increasing surface project irrigation efficiency to the level suggested by the NCIWRD projections, i.e., 60 % will have limited effect on total water savings within these drier basins. Thus, it is important to know more about the interaction between surface and groundwater irrigation to make firm statements on utilizing water more effectively.

That said, recent studies suggest that the project efficiency of many groundwater systems is already higher than the 70 % projected by the commission for 2050. This is especially true in areas where micro-irrigation is in use, formal or informal water markets are functioning, and free electricity is not available for uncontrolled pumping. The estimates of the extent of uptake of the above interventions in different regions vary. Further research is needed to identify areas where such interventions can be practically implemented and the benefits of interventions exceed the cost.

Self-sufficiency in Grains

Can national self-sufficiency goals in food grains be a realistic assumption any more for projecting India's irrigation demand? This was so when the agricultural output in general, and grain production in particular, was a major part of the gross domestic product (GDP). The contribution of the agricultural sector to the GDP decreased from 46-25 % during 1961-2000, and will decrease further with rapidly growing services and industrial sector outputs. Moreover, the value of grain production, in comparison with total agricultural production is very small now, and is also declining, and demand for food grains is declining too. Thus, in purely economic terms, although it was a constraint for the Indian economy to import part of the grain demand now, it will be insignificant for a trillion dollar economy in a few years from now.

However, the recent volatility in the global grain markets, partly induced by significant production shortfalls in grain exporting countries and aggressive plans for developing bio-fuels, has significantly affected the price and supply of grains in a number of countries, including India. In the future, large importations of grain from populous countries like India and China could further add to the volatility. The increased costs for imports could hurt the very consumers that the imports are expected to help. In India, the major grain production deficit in the future will be for feed grains, especially for maize (Amarasinghe et al. 2007b). However, production surpluses of rice and wheat are expected to offset the production deficits of maize. Thus, in spite of price increase concerns, India's food trade will increase, and self-sufficiency of all grains need not be a rigid formula (more on this subject is discussed by R.P.S. Malik in Paper 9).

Agriculture Dependent Livelihoods

The high dependency of rural livelihoods on agriculture was a further component of the overall rationale for the commission's projections for future irrigation demand. The recent trends suggest that the agriculture demography is fast changing with increasing non-agricultural employment. Although it is not expected to see the general depopulation of all rural areas in India, as has happened in parts of South-East Asia, there are already indications that this is happening in parts of rural India. Over the last four decades, the agriculture depended population has decreased from 86-74 %. A quadratic extrapolation of the present trends (R^2=98 %) show this percentage will decline to about 58 % by 2025 and 40 % by 2050. This projected trend is more or less compatible with the present agricultural population of countries with similar economic conditions as projected for India by 2050. This means that although agriculture dependent population will increase in the short-term, it will start to decline after the next decade. And in 50 years from now, India will even have a less populace who depend on agriculture than they do now.

In fact, trends of rural population moving out of agriculture is already happening and will likely accelerate in the future with increasing employment opportunities in the non-agriculture sector (Sharma et al. 2006). There is a high probability that young rural farmers will move out of agriculture for various reasons particularly where non-agriculture employment opportunities are accessible, and the youth have better skills and education. Certainly, these conditions are increasingly apparent in many areas as urban centers continue to expand with booming industrial and service sectors.

Implications on Irrigation Demand

The above discussion shows that the key determinants of irrigation water demand of the NCIWRD projections, upon which the requirements for the NRLP have been based, are no longer consistent with the present-day trends. The NCIWRD assumed,

- increasing demand for food grains, whereas while the demand for food grains will continue to increase in the short term it will be at a declining rate, and the more significant actual trend is the increasing demand for non-food grain products;
- the grain production to dominate the future of Indian agriculture, whereas crop diversification is the actual and expected trend;
- the surface irrigation to dominate the land-use patterns, yet groundwater has been the engine of irrigation growth, and is expected to continue to be so, despite localized constraints of sustainability;
- a rather low crop yield growth, although substantial scope exists for yield improvements in both irrigated and rain-fed areas; and
- a high level of surface project irrigation efficiency, although many river basins rely on the recharge from surface return flows for groundwater irrigation and surface irrigation downstream and in these systems, surface irrigation efficiency is still as low as 30-35 %.

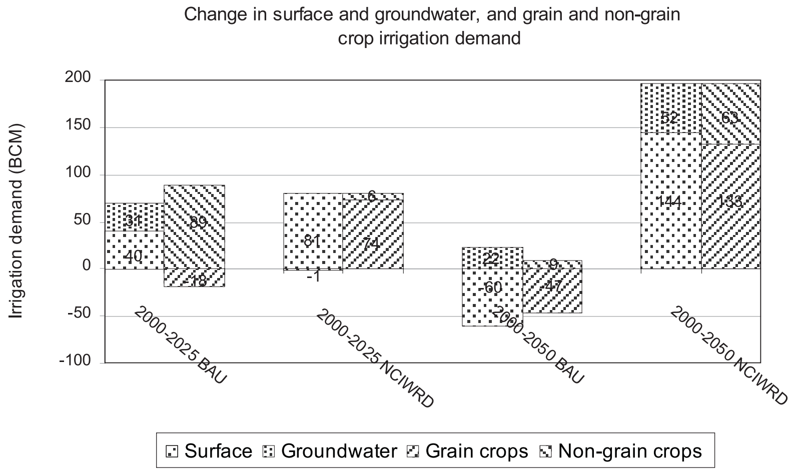
On the other hand, the recent trends suggest:

- consumption patterns will shift towards a non-food grain product dominated diet;
- agriculture will continue to expand, but it will diversify to meet the increasing demand for non food grain crops and animal products;
- groundwater irrigation will continue to expand in spite of the severe depletions in some regions;
- advanced irrigation and other water-saving technologies will spread to increase crop yields and water-use efficiency;
- better water and nutrient management will reverse the recent decline in the rate of crop yield increases, to some extent; and
- self-sufficiency in all grain crops will no longer be a concrete goal, and the production surpluses of some crops will pay for the production deficits of other crops.

Thus, irrigation water demand according to the Business as Usual (BaU) scenario trends, which is mostly based on the recent changes in key drivers as discussed above (Amarasinghe et al. 2007b), differs in many key aspects from the irrigation water demand projections of the NCIWRD report (Fgure 5).

- The BaU scenario results in a slightly lower additional irrigation demand (by about 10 billion m^3) between 2000 and 2025, and a much lower additional irrigation demand

Figure 5. Change in surface and groundwater irrigation demand and grain and non-grain in crop irrigation demand.



between 2025 and 2050. In fact, between 2025 and 2050, the irrigation demand under the BaU scenario is 38 billion m^3 less than previously predicted.

- Groundwater contributes to 44 % of BaU scenario additional irrigation demand between 2000 and 2025. And, between 2025 and 2050, the BaU scenario groundwater irrigation demand increases although the overall demand decreases. In contrast, surface irrigation dominates the NCIWRD additional water demand in both periods. The BaU scenario projects groundwater irrigation to increase by 31 km^3 between 2000 and 2025, while the NCIWRD projects it to decline by 1 billion m^3. Over the same period, additional surface irrigation water demand projection of NCIWRD is twice the projection of the BaU scenario. The differences of additional irrigation demand, both of surface and groundwater, of the two scenarios widen between 2025 and 2050.
- Non-grain crops consume a major part of the irrigation withdrawals under BaU scenario. In fact, the BaU projects decreasing irrigation demand for grain crops in both periods. However, grain crops consume a major part of the NCIWRD demand projections.

Conclusion

The major challenge facing the water sector in India today and over the long term is how to increase the groundwater stocks (supply enhancement) to arrest the declining groundwater tables, and how to sustain water use by minimizing uncontrolled groundwater pumping (demand management).

The most recent trends of the key drivers affecting water demand suggest that the required characteristics of water for agriculture will be significantly different in terms of quantity and source than those projected by the NCIWRD, upon which much of the proposed National River Linking Project has been based. However, it is also clear that if India continues along a business-as-usual path and follows these recent trends without timely and informed interventions it will lead to severe regional water crises.

Excessive groundwater exploitation will be a major component of the challenge to be tackled. In the medium-term, this will have major repercussion on changing cropping patterns, because groundwater is and will continue to be the main source of water for successful crop diversification. The challenges for the irrigation sector in India in the medium-term are,

- how to promote crop diversification to increase the benefits for every drop of consumptive water use, and
- how to promote sustainable groundwater expansion to reap the benefits of changing cropping patterns.

While it is clear from the above that the water requirements of the agricultural sector of the future will be quite different from those underpinning the NRLP as presently conceived, India does need to further develop its water resources to meet the needs of the people and the economy. Conditions will dictate that this will include large scale developments that incorporate intra - or inter-basin water transfers with surface storage. This is particularly true where increasing domestic and industrial water requirements are the dominant water consumptive factors in a relatively dry basin, and also other factors such as increasing crop diversification to high-value crops which will require a more reliable water supply and areas with declining groundwater tables which may demand better surface water supply for sustainable production and profits.

Also, there are likely to be other contingencies under which large scale inter-basin water transfers as envisioned under the NRLP are required for meeting India's future water demand. The foremost among the contingencies is that the economic growth is even more rapid than that assumed here. In such a case the domestic and industrial sector demand will be greater and will have the capacity to pay for a good quality and reliable surface water supply for their daily water needs.

Finally, the demand for biofuels will have a significant impact on water-use patterns, especially on groundwater use and may also have a significant impact on prices. Further, the climate change could have a significant impact on overall water demand and supply in many river basins. Climate change is expected to accelerate the seasonal melting of the snow pack from the Himalayas, affect the overall volume of precipitation and increase the frequency and magnitude of extreme rainfall events, which all may require large storage facilities for water use in the dry seasons (Sharma and McCornick 2006). Further research is necessary to assess the implications of these on future surface water demand.

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