Meeting India's Water Future: Some Policy Options

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Introduction

The best course for managing and further developing India's water resources is a hotly debated subject, with some of the more contentious arguments centered on the large scale interbasin transfers planned as part of the National River Linking Project (NRLP). As part of a broader study to examine the NRLP and potential alternatives, this paper seeks to identify some of the more promising policy options which could be part of a strategic and holistic effort to address India's future water challenges.

Accounting for the characteristics of recent water resources development and management, the paper considers the future water needs should the country continue along this business as usual (BaU) path. In addition to the developments proposed under the NRLP, the other considered policy options , which could serve to replace or remove the need for elements of the NRLP, or which compliment elements of the NRLP, include increased emphasis on recharging groundwater to offset the over abstraction; adoption of water saving technologies for increasing water use efficiency[1]; formal or informal water markets; provision of more reliable yet rationed rural electricity supply to reduce uncontrolled groundwater abstraction; and increasing research and extension for enhancing agriculture water productivity.

As in many countries, agriculture is the largest user of water in India, and as such has and will continue to be a major driver of water resources management and development in the country. The dominance of food grains and the prominence of surface irrigation in India's agricultural production are gradually changing. In fact groundwater is already the dominant water source for agriculture, and recent trends show that agriculture is diversifying to cater to the changing domestic consumption patterns and increasing export opportunities. Groundwater irrigation is continuing to expand to meet the increasing demand of water in agriculture. Generally the agricultural diversification is to higher value crops and livestock, which in most cases requires costlier inputs, and necessitates a relatively reliable water supply. Until now, the inherent reliability of groundwater has made it the source of choice.

[1] However, in many cases while such technologies may reduce the amount of water pumped, it may not result in water savings at the basin scale.

The unplanned development of the resource, and the difficulties of managing it thereafter means that an increasing number of aquifers are over exploited, resulting in high social and environmental cost, and jeopardizing the reliability of the supply. Groundwater resources within many river basins will soon reach this critical stage with continuing groundwater expansion (Amarasinghe et al. 2007). Without appropriate management strategies and interventions, these unsustainable practices will lead to serious crises, perhaps in the near future and most certainly within the next four to five decades for some regions. We discuss the pending water crisis in the next section.

However, there are a number of policy options which could avert such a crisis. Artificial groundwater recharge, increasing efficiency of groundwater use, reducing uncontrolled groundwater pumping can sustain the groundwater expansion. Among others, increasing productivity and diversifying with proper cropping patterns can also offer a significant leverage. We discuss these policy options in detail in the third section.

In spite of these options, there are situations where major interbasin transfers may still be inevitable, especially over the long term. The justification and necessary support for such investments is unlikely to come from the development of new irrigated areas, at least not as a significant part of the investments, but is more likely from a combination of increased domestic and industrial water demand, providing a reliable water supply for high-value crops, growing pressure on the groundwater systems, escalating energy prices, and from increased efforts to account for environmental needs. We discuss them in the final section.

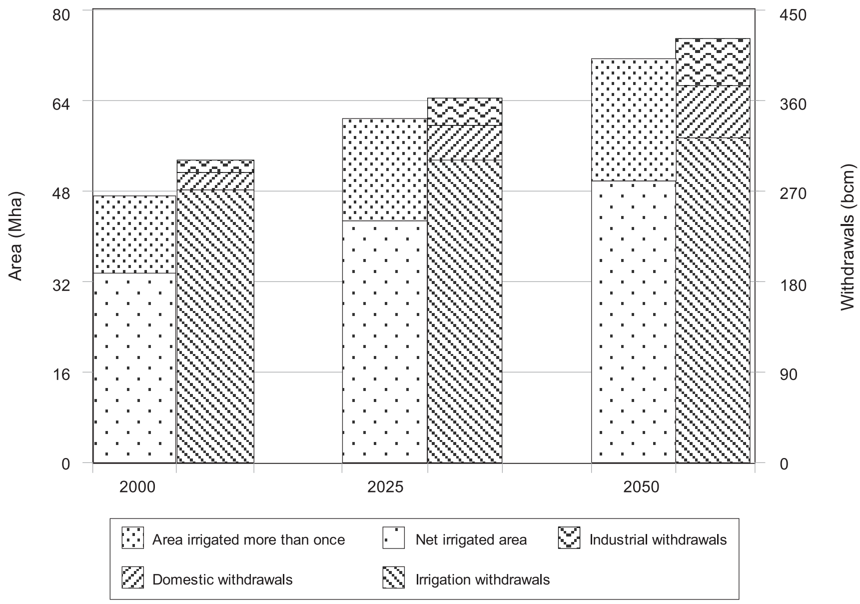
Pending Water Crisis

India already withdraws about 273 cubic kilometer (km^3) of groundwater per annum, which is estimated to be around 60 % of the sustainable yield (Amarasinghe et al. 2007). Given that most of the groundwater is abstracted for agriculture and that most has been developed by the private sector, it is anticipated that groundwater will continue to be the major source for future growth in irrigated areas.

Projections based on the most recent trends estimate that a further 14 million ha of land will be brought under irrigation by 2025 (Figure 1), and an additional 10 million ha by 2050 (Amarasinghe et al. 2007). Consequently, the Business as Usual Scenario projects that 31 km^3 of additional groundwater withdrawals will occur by 2025, and a further 22 km^3 by 2050. The result will be that by 2025 and 2050 India would be withdrawing 75 % and 85 % of the sustainable groundwater supply, respectively, accounting for both natural and return flow recharge. With this, several river basins would become water scarce and the rate of use would be unsustainable. In fact, 10 basins will withdraw more than 75 % of their available groundwater supply, and these 10 basins account for 69 % of the total groundwater supply in India.

On the other hand, if groundwater withdrawals are to remain at the 2000 level, then the additional surface withdrawal requirement will need to increase further by 65 km^3 by 2025, in part because surface water systems are less efficient than groundwater based systems. The peninsular basins, some of which are already water scarce, will require more than half of the total additional surface water withdrawals projected for the country, which is more than 35 km^3. Given the past investment trends and the slow growth of canal irrigation in recent decades, it is difficult to envisage adding this quantity of surface water in the next 25 years. Furthermore, such demands cannot be met in the peninsular rivers without diverting from elsewhere.

Figure 1. Groundwater irrigated area and withdrawal projections.



Source: Irrgated area data of 2000 are from GDI 2005.

In either case, whether through rapid expansion or an unexpected slowdown of further groundwater use, a major water crisis in the water sector is pending unless immediate solutions are sought. Next, we discuss some policy options that can avert a crisis in the short to medium term.

Policy Options

From overall economic investment perspective groundwater has been a much cheaper option than surface water development, although if sustaining and further development of the resource requires major investments in recharge and perhaps even large-scale transfers of water to where the recharge is required. Also with rising energy prices, the cost of groundwater abstraction will increase. At present, the development of one ha of surface irrigated area costs more than three times the cost required for developing one ha of groundwater irrigated area (GOI 2006). Groundwater development has been generally undertaken by the private sector with users sharing a significant part of the cost. Moreover, groundwater irrigation also generates higher crop production benefits, provided that adequate groundwater stocks are available to ensure reliability.

Sustaining Groundwater Irrigation

Artificial groundwater recharge could enhance the groundwater stocks, have positive impacts, and generate various social and environmental benefits. As has been practiced in some developed countries, India can start to actively manage its aquifers. Presently it depletes its groundwater stocks before the monsoon months and then recharges these with the monsoon run-off (Shah 2007). Existing small tanks and ponds, numbering more than 500,000 throughout

India, which are already augmenting the natural groundwater recharge, can be modified to further increase recharge, while meeting the drinking water demand for the human beings and livestock (Sakthivadivel 2007). Also, new small tanks and ponds need to be designed and constructed with a view to optimizing groundwater recharge, where appropriate. However, we need to know more about the negative impacts of groundwater recharge on downstream users before embarking on large-scale recharging programs, especially in water scarce river basins. Also the underlying hydrogeology will dictate whether recharge will result in improved supplies of groundwater in a form which can be appropriately utilized.

Rainwater harvesting programs, such as *johads* in Alawr district in Rajasthan (Sakthivadivel 2007) and also groundwater recharge movements in Saurashtra and Kutch (Shah and Desai 2002), have proven to rejuvenate the groundwater resources available for irrigation. However, some interventions, such as rain water harvesting in the upstream catchments, have been shown to reduce the inflows to existing reservoirs downstream (Kumar et al. 2006a), and can incur more cost than the benefits they generate.

The existing knowledge on surface and groundwater interaction across river basins in India is generally site-specific and neither sufficient to identify the locations where such negative impacts can occur nor, in fact, to determine where and how to improve groundwater recharge. Further research is required to identify the locations where artificial groundwater recharge harnesses water; the quantity of water that can be harnessed and the extent to which it meets the additional demand; and the net social benefits that these programs generate.

Increasing groundwater irrigation efficiency by an additional 5 % from the level assumed under the BaU scenario (70 %) can reduce the additional groundwater demand in 2025 by about 20 km^3 or two-thirds, assuming that these savings result in savings at the basin scale. Recent research shows that modern irrigation technologies — sprinklers and drip irrigation — are operating at 70-85 % efficiency in some irrigation systems in India (Kumar et al. 2006b, Narayanmoorthy 2006). Modern irrigation technologies also improve the uniform distribution of the irrigation water, reduce non-beneficial transpiration, and in general have higher productivity than the traditional flood irrigation methods. However, adoption of these technologies in India has been very slow. And these technologies were mainly adopted for a few crops, such as fruits and vegetables, in the groundwater irrigated areas (Narayanamoorthy 2006; Kumar et al. 2006b). Further research and extension are needed to determine the potential of such irrigation technologies in the Indian context, their net economic benefits and practical modalities to scale them up where appropriate. In addition, it is imperative that it be determined that these interventions would result in actual water savings, and not result in the transfer of water from other users further down the basin, as has been the case elsewhere.

Reducing uncontrolled groundwater pumping could mitigate over abstraction in many basins. In 2000, India withdrew about 273 km^3 of groundwater to meet only 151 km^3 of crop consumptive water-use demand. Indeed, proper policy and institutional interventions can reduce over abstraction even when traditional irrigation methods are utilized. Formal or informal water markets (Somanathan and Ravindranath 2006; Banerji et al. 2006), and regulating and/or providing a reliable rural electricity supply (Shah and Verma 2000) have been shown to have some effect on controlling unnecessary pumping and increasing water-use efficiency. Replicating these interventions, with adjustments to satisfy local socioeconomy, could help arrest the uncontrolled groundwater pumping in many water-stressed river basins.

Improving Crop Productivity

Improving crop productivity presents the greatest opportunity for reducing the additional irrigation requirement. If water productivity stagnates at 2000 levels, India will require 1,029 km^3 by 2050 to meet the agricultural consumptive water use demand, which is in effect the same as the estimates of total potentially utilizable water resources of India, and simply unattainable. Therefore, it is imperative that the productivity of water be continuously increased. India's grain crop water productivity - 0.64 and 0.34 kg/m^3 of consumptive water use for irrigated and rain-fed areas, respectively - is, in comparison with other countries, stubbornly low. The water productivity of non-grain crops under irrigated and rain-fed conditions is also low, and vary significantly across districts (Table 1).

Table 1. Irrigated, rain-fed and total water productivity of grain and non-grain crops.

State	Water productivity (WP) of grain and non-grain crops								
	Irrigation			Rain-fed			Total		
	Grain area as a fraction of total	WP of grains	WP of non-grains	Grain area as a fraction of total	WP of grains	WP of non-grains	Grain area as a fraction of total	WP of grains	WP of non-grains
	#	$\$^*/m^3$	$\$/m^3$	#	$\$/m^3$	$\$/m^3$	#	$\$/m^3$	$\$/m^3$
Andhra Pradesh	0.76	0.17	0.41	0.45	0.11	0.72	0.59	0.16	0.56
Assam	0.99	0.22	0.19	0.78	0.10	0.72	0.79	0.11	0.72
Bihar	0.93	0.13	1.66	0.86	0.14	1.43	0.90	0.13	1.55
Chattisgarh	0.95	0.10	1.47	0.91	0.10	0.50	0.92	0.10	0.69
Gujarat	0.37	0.08	0.23	0.45	0.12	0.57	0.42	0.10	0.31
Haryana	0.76	0.17	0.16	0.84	0.12	1.37	0.77	0.17	0.19
Himachal Pradesh	0.89	0.13	2.28	0.85	0.13	1.99	0.86	0.13	2.03
Jammu and Kashmir	0.81	0.13	1.34	0.88	0.14	4.10	0.85	0.14	2.43
Jharkhand	0.71	0.11	2.18	0.91	0.11	0.83	0.89	0.11	1.17
Karnataka	0.60	0.15	0.34	0.69	0.12	0.63	0.66	0.13	0.44
Kerala	0.50	0.16	0.39	0.09	0.16	0.83	0.17	0.16	0.78
Madhya Pradesh	0.87	0.07	0.36	0.56	0.10	0.40	0.64	0.09	0.39
Maharashta	0.56	0.07	0.51	0.67	0.08	0.21	0.65	0.07	0.34
Orissa	0.83	0.11	1.44	0.75	0.07	0.72	0.77	0.09	0.89
Punjab	0.87	0.25	0.24	0.57	0.13	4.21	0.86	0.24	0.39
Rajasthan	0.59	0.07	0.20	0.84	0.07	0.36	0.75	0.07	0.24
Tamil Nadu	0.64	0.20	0.49	0.55	0.22	1.09	0.60	0.20	0.64
Uttar Pradesh	0.83	0.15	0.26	0.80	0.14	2.12	0.82	0.14	0.44
Uttaranchal	0.73	0.20	0.25	0.91	0.11	1.26	0.83	0.15	0.35
West Bengal	0.85	0.21	1.23	0.66	0.17	1.17	0.73	0.19	1.18
India	0.76	0.15	0.36	0.68	0.11	0.69	0.71	0.13	0.50

Source: Authors' estimates are based on PODIUMSIM methodology.

Note: * - Values of crop production, estimated using the average (1999-2000) of the unit export prices of crops in the FAOSTAT Database (FAO 2005) are used to make comparison between the grain and non-grain crops.

By increasing grain crop water productivity by 1.0 % per annum, the respective CWU could be maintained at present day levels while meeting the increased demands for grain. Increasing the productivity a little further, to 1.4 % annually, would even account for the CWU demand for all crops (Amarasinghe et al. 2007). These scenarios demonstrate a significant opportunity to avoid a future agriculture-driven, water crisis. The latter scenario is equivalent to doubling the yield over the next 50 years, which given the past trends in India, is setting a very high goal. On the other hand, given the remarkable achievements of other countries over the last few decades, India does have the potential.

India's research and technological capacities are increasing. Knowledge generation in new commodity research, remote sensing, geographic information systems, and advances in water management systems are second to none in developing countries. India also has a sound agricultural research system spread across all regions. The immediate focus then should be how to combine these rich resources with proper extension systems to promote rapid growth in crop productivity. India needs to effectively use the advances in research and technology to identify opportunities for high productivity and also high potential zones for different crop and livestock production systems. As the value of water is increasing, agricultural production systems should be promoted in zones where they have a high value for each drop of consumptive water use and where there is adequate water supply for irrigation, such as in the lower part of the Ganga Basin. The recent trends of agricultural diversification, which are associated with changing consumption patterns, should also facilitate this revolution.

Agriculture Diversification

Agricultural diversification**,** if properly planned, could also help reduce additional irrigation demand. The BaU scenario projections, as discussed in the previous two chapters, show that the increasing consumption of animal products is transforming the demand and the production patterns of cereals (Table 2). Over the period (2000-2025), maize, primarily for livestock feeding, will contribute to more than one-third of the total grain demand increase (45 %). Between 2025 and 2050, this contribution is expected to be 83 % of the total grain demand increase. Also, food demand for high value non-grain crops, such as oilseeds, vegetables and fruits, is also increasing. The share of the value of non-grain crop production is expected to increase, from 51 % in 2000, to 63 and 69 % by 2025 and 2050, respectively.

As a result of the changing consumption patterns, food production patterns will change. The production of irrigated non-grain crops, as compared with irrigated grain crops, will increase much faster. According to the BaU scenario, as much as half the irrigated area will be under non-grain crops by 2050, compared with only 29 % in 2000; 71 % of the crop production (grains and non-grain crops) will be produced under irrigation by 2050, compared with 67 % and 51 % in 2000. Major implications of this agricultural diversification are that

- the consumptive water use demand of grain crops, in comparison to non-grain crops, increases very slowly;
- with increasing reliance on groundwater and increasing water-use efficiency of groundwater, the irrigation demand for grain crops will decrease from the 2000 levels (Figure 2); and
- almost all additional irrigation demand will be for non-grain crops, and much of that will be from groundwater (Figure 3).

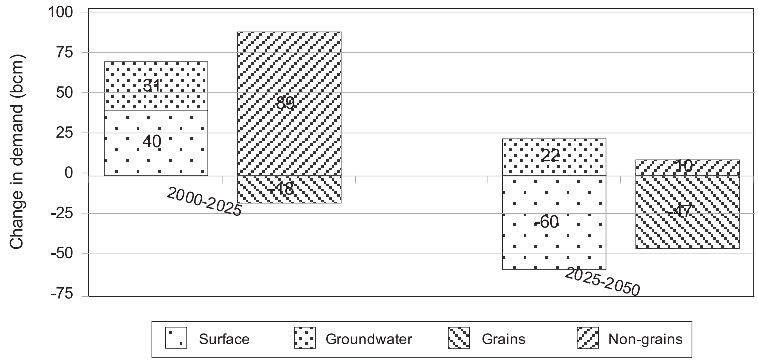
Table 2. The demand and production of grain and non-grain crops with their irrigation requirements.

Crop	Crop demand[i] (million tonnes)			Crop production Total[i] (million tonnes)			Crop production Share from irrigation (%)			Irrigated crop area (million ha)			Irrigation requirement[ii] (net-evapotranspiration) (km³)			Irrigation withdrawals (km³)		
	2000	2025	2050	2000	2025	2050	2000	2025	2050	2000	2025	2050	2000	2025	2050	2000	2025	2050
Grain crops																		
Rice	82	109	117	89	117	143	69	70	71	24.1	25.0	26.0	74	73	72	261	239	207
Wheat	67	91	102	72	108	145	95	99	99	23.0	25.0	26.3	64	72	76	132	135	122
Maize	16	50	121	12	28	65	32	51	38	1.4	4.0	5.1	1	3	3	3	5	6
Other cereals	21	23	16	19	21	13	14	19	38	2.2	2.4	2.7	5	5	6	10	9	9
Total cereals	187	273	357	193	274	365	71	76	75	50.8	56.4	60.1	144	153	158	406	388	344
Pulses	14	18	21	13	18	19	17	17	18	2.8	2.9	2.8	6	6	5	11	10	8
Non-grain crops																		
Oilcrops	48	103	133	31	73	97	31	56	68	6.1	18.7	25.2	13	37	49	25	66	76
Vegetables	75	150	189	74	149	227	44	64	69	1.7	3.3	3.8	3	5	6	6	10	10
Fruits	47	78	123	46	83	106	46	60	63	1.7	3.0	4.0	5	9	12	10	16	18
Sugar	26	42	55	30	46	60	94	93	100	4.2	5.1	6.6	41	48	60	80	87	95
Cotton	2	4	6	2	4	6	50	65	71	3.0	5.9	7.9	16	28	38	31	50	59
Other crops	-	-	-	-	-	-	-	-	-	5.6	11.3	7.3	18	26	18	36	48	28
Total grains	52[i]	73[i]	90[i]	54[i]	74[i]	93[i]	67	72	72	53.6	59.3	62.9	149	159	163	417	398	352
Total non-grains	106[i]	198[i]	284[i]	96[i]	187[i]	266[i]	51	65	71	22.3	47.2	54.8	95	154	183	188	277	286
Total	158[i]	272[i]	374[i]	150[i]	261[i]	359[i]	57	67	71	75.9	106	117	245	313	346	605	675	638

Source: Authors' estimates based on PODIUMSIM

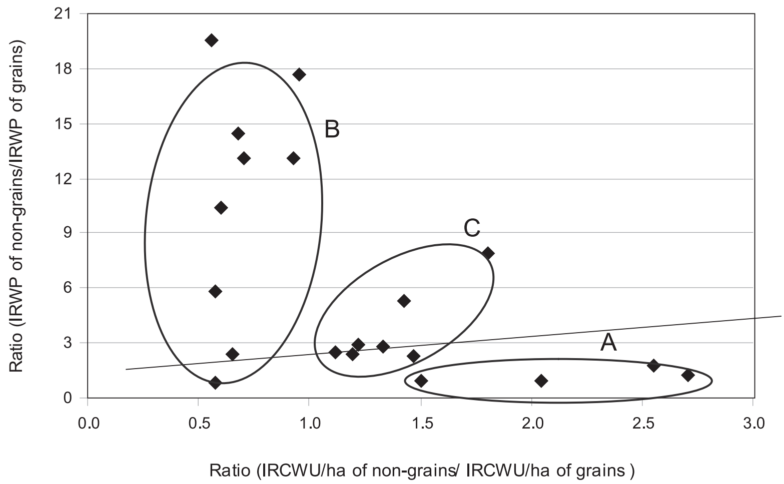
Notes: [i] Total demand and production for grain and non-grain crops are estimated using the average 1990-2000 export prices.
[ii] Irrigation requirement or net evaporation is the difference between evapotranspiration and effective rainfall.

Figure 2. Change in demand in surface and groundwater irrigation for grain and non-grain crops.



Source: Authors estimates

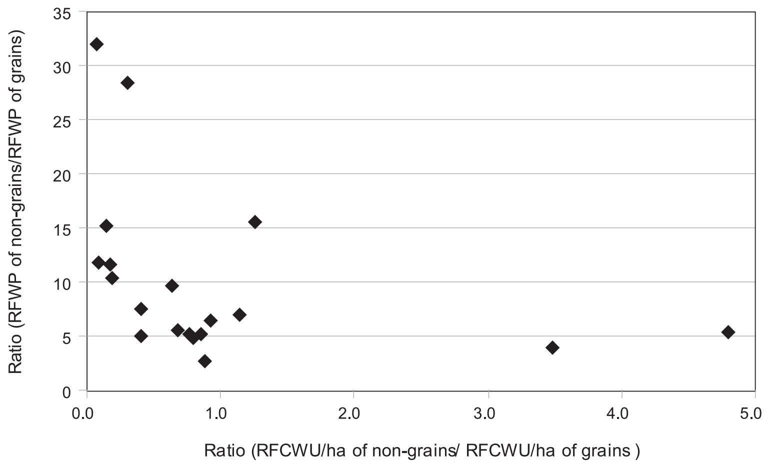
Figure 3. Consumptive water use/ha and water productivity differences between grain and non-grain crops in irrigated areas of different states.



Most of the non-grain crops, usually produced for urban markets or for export, can bring in high returns. However, in order to reap these benefits, high-value crops require the timely application of expensive inputs. A reliable irrigation supply is a critical prerequisite for timely input application, and also, it is an input by itself in water- stressed crop growth periods. More recently, groundwater has been the major source of this reliable irrigation supply in the context of diversifying agricultural production. It is likely that this trend will continue, at least into the near future. Therefore, an immediate challenge is to identify the cost-effective physical and institutional interventions for sustaining the groundwater irrigation growth.

Agricultural diversification could also be promoted in conjunction with improvement in water productivity. Figure 4 shows a glimpse of where this can be done at the state level. For the case of irrigated crops, the X-axis in Figure 3 is the ratio of the CWU (m^3/ha) for non-grain and grain crops, and the Y-axis is the ratio of the water productivity (US$/$m^3$ of CWU) for non-grain and grain crops. Figure 4 shows the same ratios for rain-fed production.

Figure 4. Consumptive water use/ha and water productivity differences between grain and non-grain crops in rain-fed areas of different states.



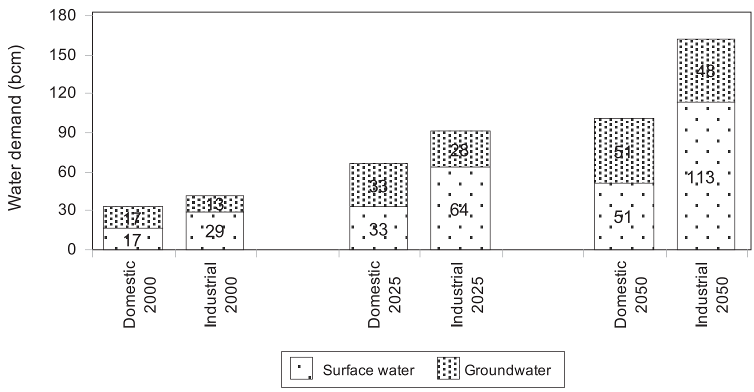
For the irrigated conditions there are three distinct clusters (Figure 4). The states in cluster A, that is Punjab, Haryana, Uttar Pradesh and Uttaranchal are those areas where irrigation is dominant and yields of grain crops are generally high. Also the CWU/ha for non-grain crops in these areas is significantly higher than for grain crops, but have lower productivity in terms of value per cubic meter of water. The difference between the water productivities of irrigated grain and non-grain crops is relatively small. Crop diversification in states in this cluster according to the current cropping patterns may yield little or no benefits. These states can continue to grow grains, increase the yields and trade the production surplus with other states as has been the case in the past. The benefit of that per every cubic meter of water depleted could be as high as the benefits that non-grain crops generate.

The states in cluster B are mainly in the east, namely Assam, Orissa, West Bengal, Bihar, Chhattisgarh, Jharkhand and also Jammu and Kashmir in the north and Kerala in the south. These states have significantly high irrigated areas under grain crops and a substantial part of that is rice. However, the rice crop has low yields and higher CWU than the irrigated non-grain crops in the state. Thus, this group has the highest potential for improvements in water productivity in grain crops. Many states in this group are also relatively water abundant, and they can continue to grow water intensive grain crops and increase water productivity through growth in the yield. On the other hand, due to limited land resources many small to medium land holders are poor in these states. So, crop diversification can also generate substantial benefit to these farmers. Cluster B states should have a combined strategy, increase the yields of grain crops while diversifying cropping patterns in small to medium land holdings with low productivity. The production surpluses of non-grain crops in this cluster can meet the production deficits of the states in cluster A.

In cluster C, states like Tamil Nadu, Andra Pradesh, Karnataka, Maharashtra, Madhya Pradesh and Gujarat, and Rajasthan, are relatively water scarce than those in cluster B. Irrigated non-grain crops in these states consume more water than the grain crops, but generate significantly more benefits. Crop diversification can benefit these states the most. It should be promoted as a solution in medium-term to meet the increasing agricultural water demand and also to meet the increasing demand for non-grain food crops and feed grains.

Rain-fed non-grain crops in all states have significantly higher water productivity than rain-fed grain crops (Figure 5), and many areas will benefit from crop diversification. On the other hand, major rain-fed states also have very low productivity compared to irrigated crops. These states have a significant scope for increasing crop yields. A small quantity of supplemental irrigation in the critical period of the crops' growth could even double the rain-fed yield (Sharma et al. 2006).

Figure 5. Domestic and industrial water demand projections of India.



Source: Authors estimates

Though the above analysis is constrained by the fact that the analysis was done at the state level, it demonstrates that there is a scope for improvements in productivity and crop diversification. An analysis at a smaller spatial unit, such as district or sub-basins, should provide a better picture where these improvements can de done and what interventions required. A preliminary analysis shows that a significant variation of water productivity exists across districts and also across different land-use patterns. A more detailed analysis at the district level, combining information on climate, physical and institutional factors, and geo-hydrological variation should provide a more rigorous estimate of the likely extent of crop diversification and growth in water productivity.

Contingencies for Large Interbasin Water Transfers

As discussed elsewhere in this paper, there are a number of policy options which could serve to replace, supplement or compliment aspects of the NRLP while addressing India's future water needs for food production and the other sectors. That said, there are situations where major interbasin transfers will be inevitable, especially over the long term. The justification and necessary support for such investments is unlikely to come from the development of new irrigated areas, at least not as a significant part of the investments, but more likely from a combination of increased domestic and industrial water demand, providing a reliable water supply for high-value crops, growing pressure on the groundwater systems, escalating energy prices, and from increased efforts to account for environmental needs. In each case, the characteristics and timing of such developments will depend on socioeconomic, environmental, and agricultural conditions within the given basin and locality.

Domestic and Industrial Water Demand

The demand of water in domestic and industrial sectors, according to the BaU scenario, will increase several fold over the period 2000-2050 (Figure 5). Domestic water demand is projected to increase by 204 % over the period 2000-2050, and the industrial water demand will increase by 234 % over the same period. It is expected that these sectors will generally secure their water from surface water sources, and given the expected increasing affluence of both sectors, the users will be able to pay for a reliable and high quality surface water resource. Some of this may result from reallocating from the agriculture sector. However, increasing the demand for surface water of both the sectors (118 km^3 over the period 2000-2050) is expected to outpace the reallocation from the irrigation sector. Over this period, surface irrigation demand is expected to decrease by 20 km^3, according to the BaU scenario, but this would still require that a further 100 km^3 of surface water supply be developed for domestic and industrial sectors. A substantial part of this additional surface water supply is projected to be for states that are already on the physical water scarcity threshold. These states are Andra Pradesh, Tamil Nadu, Gujarat, Maharashtra and Karnataka, where water availability for further development is a severe constraint or the cost of further development is prohibitively expensive if it has to be conveyed from distant locations. So these states, even under the BaU growth patterns, may require some intra - or inter - basin water transfers to meet the demands of domestic and industrial sectors. In addition, groundwater depletion in most of these states is already high, and further development of this resource for irrigation will exacerbate this situation, and increase the tension between agriculture and other sectors.

It is also likely that India's industrial and service sectors could shift gear and grow much faster than envisaged in the BaU scenario. The BaU scenario assumed that the per capita gross domestic product (GDP) will, on an average, grow at 5.5 % annually, and the contribution from the industrial and service sectors will further increase. Given the present economic growth patterns (9 to 10 % GDP growth), these assumptions are conservative. Many of the well to do states, with better industrial infrastructure now, will inevitably contribute more to a scenario of high industrial and service sector growth. And, many of the water scarce rich states may be willing to pay water rich poor states to meet their future water requirements, thus creating the conditions to both finance and develop large interbasin water transfers, similar to the situation with the Lesotho Water Highlands Project (Shah et al. 2007).

Agricultural Diversification

It is imperative that India needs to diversify its agriculture to meet future food demands. Much of the diversification will be towards high-value agricultural products. Returns from surface irrigation systems at present are very low because much of the command areas grow food grains, while high-value crops are grown outside the command areas using groundwater. Crop diversification could change the chronic low productivity of these systems, but only if a reliable water supply can be secured. There are already movements of growing high-value crops with a reliable water supply for urban markets or export. Should this gather momentum, water scarce southern and western India, with their increasing income from high-value agriculture, may be willing to invest for interbasin water transfers. However, if low productivity of these surface irrigation systems persists, and further irrigation sources have to be developed, including interbasin transfers to meet the demands for high-value crops it will be a significantly more expensive solution both in terms of economics and water resources.

Rising Cost of Energy

Irrigation expansion in India in the last two decades was primarily due to small-scale lift irrigation systems using mostly groundwater, but also surface water. These systems are highly flexible and provide reliable irrigation supply on demand. Yet, this mode of irrigation development is, in most cases, highly energy intensive. So far, the energy supplies of many states are highly subsidized. But the cost of energy, whether it be in the form of electricity or diesel, has been rapidly increasing in recent times. States can no longer continue to provide subsidies on electricity as they are an impediment to economic growth in other sectors. As energy prices increase, the farmers may opt for direct surface water for irrigation or reduce their pumping costs by groundwater recharge. Thus, rising energy cost could be another condition from the agriculture sector that supports, to some extent, the development of large-scale interbasin water transfers. Conceivably there could also be an indirect argument for interbasin transfers where concurrent development of hydropower could provide increased supplies of electricity, however, from an economic perspective this new power source would be better utilized in the industrial and service sectors.

Conclusion

Increasing agricultural water productivity offers one of the greatest opportunities to reduce the demand for additional irrigation. By doubling the water productivity over the next five decades, no additional irrigation would be required, at least on-balance. The achievement of this will require major investments in research, development, extension on better management of other inputs, and infrastructure particularly to improve the reliability of water supply.

Crop diversification offers opportunities to increase the value produced by the same amount of water, which would be particularly important in the water scarce basins in peninsular India. Crop diversification in already high water productivity areas, such as in north and north west, will need further understanding as the water productivity is already high for grain crops. In the water abundant east there is considerable scope to increase the productivity of grain crops, yet crop diversification would help the poor small farmers increase their returns from their land.

Based on recent trends, groundwater will continue to be the source of choice for further development of irrigation for the foreseeable future. However, in an increasing number of basins, aquifers are becoming over exploited. Continuing along this business as usual pathway means that India is heading for an increasing number of regional water crises. Depending on the specific conditions, artificial recharge could significantly enhance groundwater supplies. Such interventions should include renewed efforts for small scale water recharge systems, but also carefully consider large scale facilities, including as components of inter - basin transfer projects. The implementation of any large scale programs or interventions must determine, among other things, the hydrogeological suitability, the likely negative implications on the downstream water users, and the relative economic viability. Increasing groundwater irrigation efficiency and other demand management strategies will also be helpful for reducing the groundwater over-abstraction.

While it is acknowledged that the interactions between the surface and groundwater resources will be different for a given basin and the dynamics will very much depend on how these resources are developed, the important point to emphasize is that the policy environment for water resources management in India must take into account the present realities, and allow for not only the realistic future demands, but the real constraints of the availability of the resource. Specifically, much more emphasis needs to be placed on effective management of the groundwater resources through enhancing the supply by artificial recharge and conservation. Also, revived efforts should be made to improve the existing surface irrigation systems, in particular to reconfigure the systems to provide more reliable water supply and allow effective community level management, where appropriate. To achieve this requires a level of study and investigation beyond what has been hither to done in most situations.

Further development of groundwater, and water savings and reallocation of water from the agricultural sector will not be sufficient to meet the water requirements of other sectors. The increasing capacity and willingness of the domestic and industrial sectors to pay for clean and reliable water supply would increase the pressure for further surface water resources development. Such conditions are likely to emerge soon in states with high economic growth, particularly in the basins that are water scarce. Most of these are located in peninsular India, and meeting the additional surface water demand in these basins may require large intra - or interbasin water transfers.

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