MEETING INDIA'S FUTURE WATER NEEDS: POLICY OPTIONS

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Abstract

This paper discusses emerging water crisis in India with the business as usual water use patterns and ways of averting it. Increasing reliance on groundwater has been contributing to pockets of unsustainable water use in many basins. This trend is likely to continue and many river basins will face severe regional water crisis in the next half century. However, proper understanding of the negative impacts of downstream water users, artificial recharge of groundwater could facilitate sustainable water use. Increasing water use efficiency, reducing uncontrolable pumping, increasing water productivity and crop diversification could help in mitigating the groundwater related water crisis. Growth in industrial, services and domestic sectors, water demand in the future shall outpace additional irrigation. This, coupled with increasing desire for a clean and reliable water supply in these sectors, and increasing focuses on environmental water needs shall demand large intra-or inter-basin water transfers.

1. INTRODUCTION

The dominance of foodgrains and the prominence of surface irrigation in India's agricultural production are gradually changing. Recent trends show that agriculture is diversifying to cater to the changing domestic consumption patterns and increasing export opportunities; and groundwater irrigation is expanding, even outside the irrigation command areas, to meet the increasing demand of water in agriculture. The agricultural diversification, often to high value crops and livestock, generally requires costly inputs. Application of many of these inputs depends very much on a reliable water supply. So far, groundwater was the primary source that provided the required reliability in the irrigation sector. However, uncontrolled groundwater exploitation is bringing high social and environmental cost to some regions, and jeopardizing the reliability of the supply. Substantial part of many river basins will soon reach this category with continuing groundwater expansion (Amarasinghe et al., 2007). However, proper water management strategies and interventions can avoid unsustainable water use patterns in many basins. Otherwise India will face a severe water crisis, perhaps in the near future for some regions and most certainly within the next 4-5 decades for many regions.

This paper discusses the magnitude of India's looming water crisis and the short to mediumterm solutions that could mitigate it. It highlights longterm water demand situations under the business as usual trends and other contingencies that may require largescale water transfers as proposed under the National River Linking Project (NRLP) of India. And it also highlights recharging groundwater to increase the groundwater stocks; promoting water saving technologies for increasing water use efficiency; formal or informal water markets and providing reliable rural electricity supply for reducing uncontrolled groundwater pumping; and increasing research and extension for enhancing agricultural water productivity, i.e., more crop and dollar for every drop of consumptive water use, as short to medium term goals.

In longterm, surface water shall still play a prominent role. The depth to the groundwater in some regions has fallen drastically. But the groundwater is still being pumped out, even at elevated costs, to meet various needs. With increasing disposable income, people and industries located in the groundwater-stressed areas, may be ready and also can afford to pay for what would now be the more reliable supply, surface water.

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Even farmers' willingness to pay for a reliable surface water supply may increase with improved incomes from agricultural diversification. This may already be true in some areas where stress for fast depleting groundwater resources is high. At the rate of the present economic growth, the transfer projects of a magnitude to those proposed under the NRLP in purely financial terms may not be a serious concern in a few decades, provided that they address the environmental and social concerns.

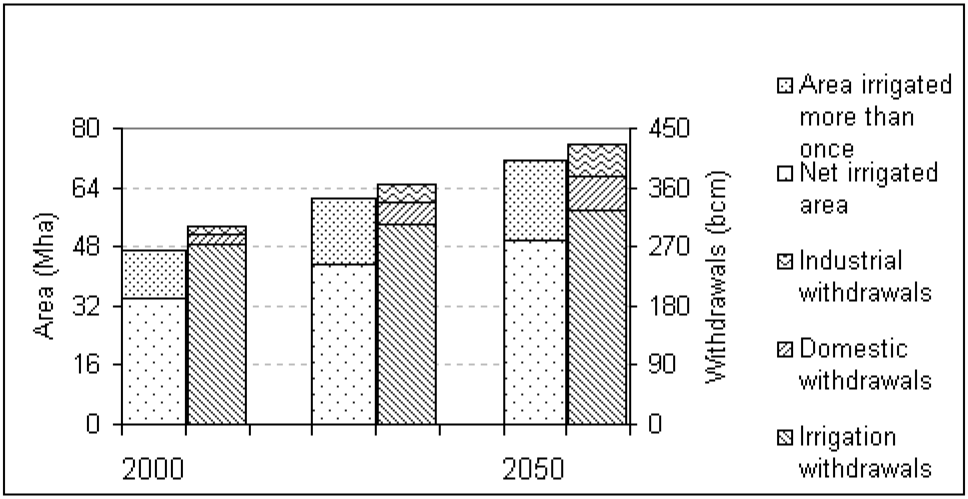
This paper is organized into three sections. In addition to the introduction above, the next section discusses the impending water crisis, and offer short- to medium- term solutions to avert the crisis. In the final section, we discuss the conditions that may necessitate large-scale water transfers between river basins.

2. REGIONAL WATER CRISIS AND MEDIUM-TERM OPTIONS

India already withdraws about 273 cubic kilometer (km^3) or 61% of the total available groundwater per annum (Amarasinghe et al., 2007). The recent trends show that groundwater irrigation will continue to be the major source for future growth in irrigated areas. The business as usual scenario (BAU) irrigation demand, which was based on recent trends of land-use patterns, projects that groundwater irrigation is expected to add at least 14 mha of additional irrigated area between 2000 and 2025 (Figure 1), and a further 10 mha by 2050 (Amarasinghe et al., 2007). The BAU scenario projection determines that 31 km^3 of additional groundwater withdrawals or a 13% increase will be required by 2025, and a further 22 km^3 by 2050.

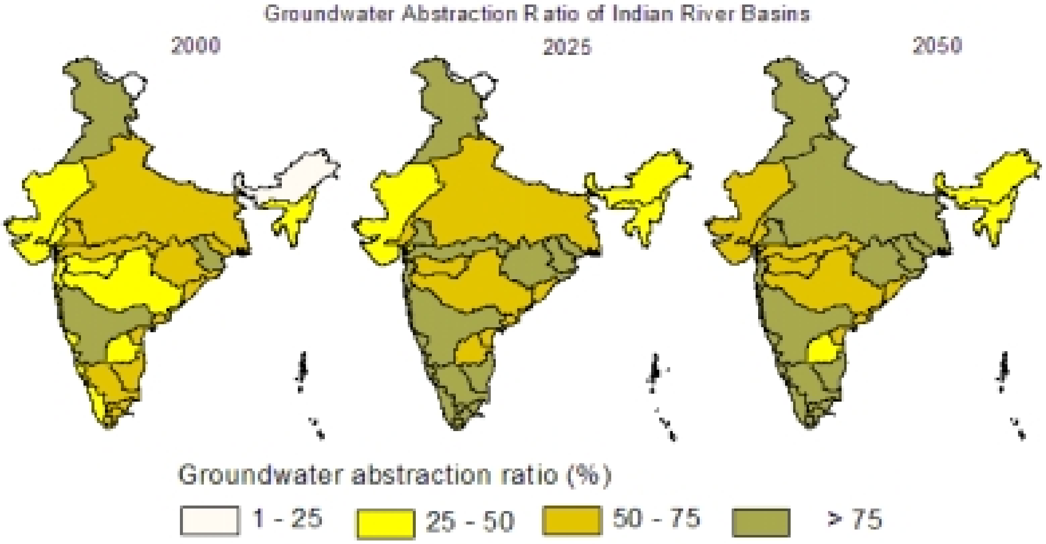
If these trends continue, India will be withdrawing more than three-quarters of the available sustainable groundwater resources (both natural recharge from rainfall and recharge from return flows) by 2025, and about 85% by 2050. This, indeed, will push several river basins into physical water scarcity and unsustainable water use category (Figure 2). If the BAU trends continue, four basins will have over abstracted and another six basins will have withdrawn more than three-fourths of the total available groundwater. And many other basins will have large pockets of unsustainable ground water use.

Figure 1: Groundwater irrigated area and withdrawal projections



On the other hand, if groundwater withdrawals are to remain at the 2000 level, then the additional surface withdrawal requirement will increase further by 65 km^3 by 2025. 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, that is more than 35 km^3. Given the past investment trends and the growth of canal irrigation, it is difficult to envisage adding this quantity of surface water in the next 25 years. And given the extent of

Figure 2: Groundwater abstraction ratios of Indian river basins



already committed surface water resources, such demands may also not be met in the peninsular rivers without diverting from elsewhere.

From overall economic investment perspective groundwater is a much cheaper option than surface water development. On an average, 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 with private sector and or 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. However, given the critical nature of groundwater depletion and the related issues, can this resource underpin further development of the agriculture sector in the near future, and also prevent a water crisis? These are pertinent questions to be answered, at least addressing the long-term water needs.

3. MEDIUM TERM OPTIONS FOR SUSTAINING GROUNDWATER IRRIGATION

Artificial groundwater recharge could enhance the groundwater stocks, have positive impacts, and generate various social and environmental benefits. As has been practised 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 5,00,000 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 humanbeings and livestock (Sakthivadivel 2007). Also, new small tanks and ponds need to be designed and constructed with a view towards optimizing groundwater recharge, where appropriate. We need to know more about the negative impacts of groundwater recharge on downstream users before embarking on large-scale recharging programmes, especially in water scarce river basins.

Rainwater harvesting programmes, 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 not 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 harness water; the quantity of water that can be harnessed and extent to which it meets the additional demand; and the net social benefits that these programmes bring out.

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 can be made 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 transfer 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 socio-economy, could help arrest the uncontrolled groundwater pumping in many water-stressed river basins.

Improving Crop Productivity presents the greatest opportunity for reducing the additional irrigation requirement. If water productivity stagnates at 2000 levels, India will require 1029 km^3 by 2050 to meet the agricultural consumptive water use demand, which is in effect the same as the estimates of potentially utilizable water resources of India, and simply unattainable. Therefore, it is imperative that the productivity of water be continuously increased. India's crop water productivity of grains of consumptive water use for irrigated and rainfed areas (0.64 and 0.34 kg/m^3 respectively) is, in comparison with other countries, stubbornly low. The water productivity of non-grain crops under irrigated and rainfed conditions is also low, and vary significantly across districts (Table 1).

By increasing grain crop water productivity by 1% 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 agricultural-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 commodities research, remote sensing, geographic information systems, and advances in water management systems are second to none in the 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

Table 1: Irrigated, rainfed and total water productivity of grain and non-grain crops

State	Water productivity (WP) of grains and non-grain crops								
	Irrigation			Rainfed			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
* - Values of crop production, estimated using the average (1999-00) 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.

agricultural diversification, which are associated with changing consumption patterns, should also facilitate this revolution.

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 (2000-25), 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

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

Crop	Crop demand[i] (million tonnes)			Crop production						Irrigation requirement[ii] (net-evapotranspiration) (km^3)			Total[i] (million tonnes)			Irrigation withdrawals (km^3)		
				Total[i] (million tonnes)			Share from Irrigation (%)											
	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

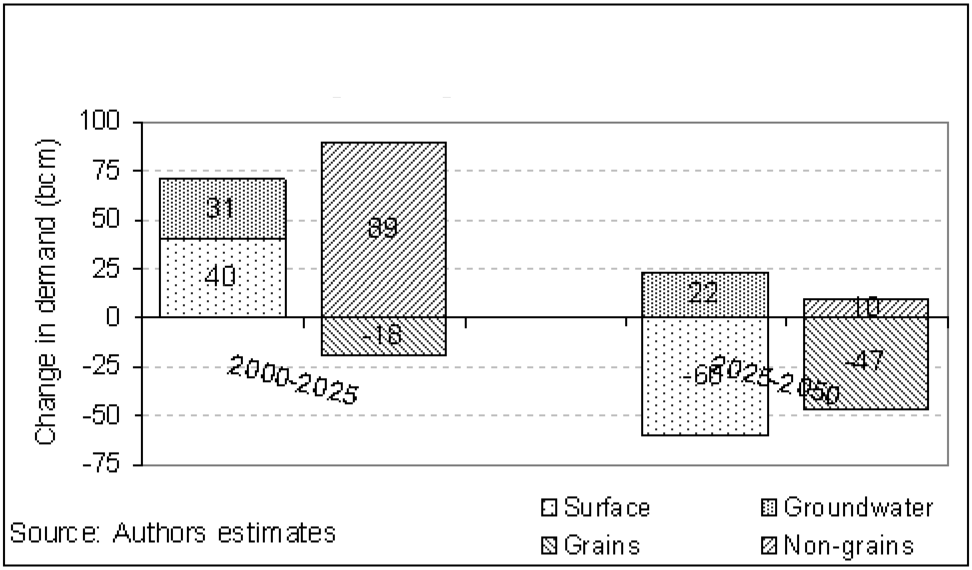
i – Total demand and production for grain and non-grain crops are estimated using the average 1990-2000 export prices.
ii – Irrigation requirement or net evaporation is the difference between evapotranspiration and effective rainfall
Source: Authors' estimates based on PODIUMSim

also increasing. The share of 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 to only 29% in 2000; 71% of the crop production (grains and non-grain crops) will be produced under irrigation by 2050, compared to 67 and 51% in 2000. Major implications of this agricultural diversification are:

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

Figure 3: Change in demand in surface and groundwater irrigation for grain and non-grain crops

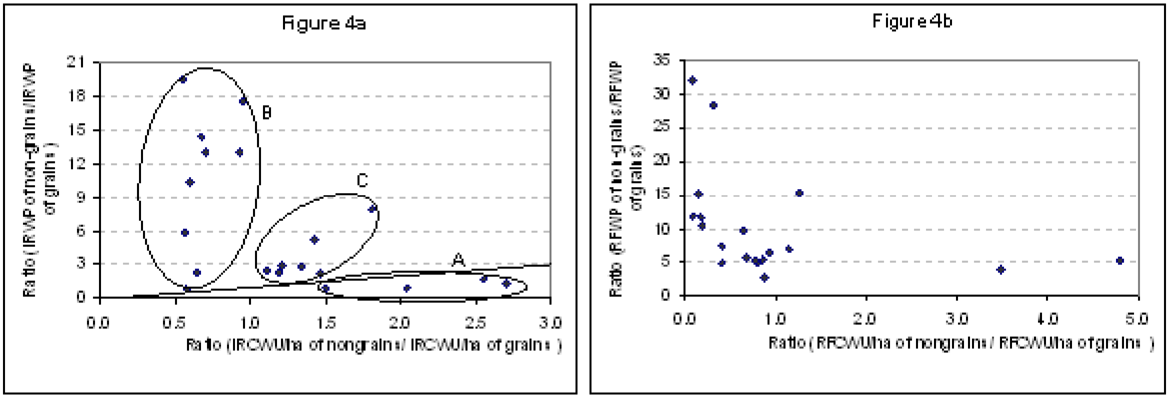


Source: Authors estimates

Most of the non-grain crops, usually produced for urban markets or for exports, 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 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. The X-axis in figure 4a is the ratio of the CWU (m^3/ha) for non-grain and grain crops produced under irrigation, and the Y-axis is the ratio of the water productivity (kg/m^3 of CWU) for non-grain and grain crops grown under irrigated conditions. Figure 4b shows the same ratios for rainfed production.

Figure 4: Consumptive water use/ha and water productivity differences between grain and non-grain crops in irrigated and rainfed areas of different states



For the irrigated conditions there are three distinct clusters (Figure 4a). The states in cluster A, that is Punjab, Haryana, Uttar Pradesh and Uttaranchal, have substantially higher CWU/ha for non-grain crops than grain crops, but lower productivity for every drop of CWU. These states have high irrigated grain area and irrigated yield. Thus, the difference between the water productivities of irrigated grain and non-grain crops is lower. 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 to other states as has been the case in the past. The benefit of that per every cubic meter of water depleted is 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 area under grain crops and a substantial part of that is rice. Moreover, 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 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.

Rainfed non-grain crops in all states have significantly higher water productivity than rainfed grain crops (Figure 4b), and many areas will benefit from crop diversification. On the other hand, major rainfed states also have very low productivity compared to irrigated crops. These states have a significant scope for increasing crop yields. Small quantity of supplemental irrigation in the critical period of crops growth could even double the rainfed yield (Bharat et el., 2006).

Recognizing that 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 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.

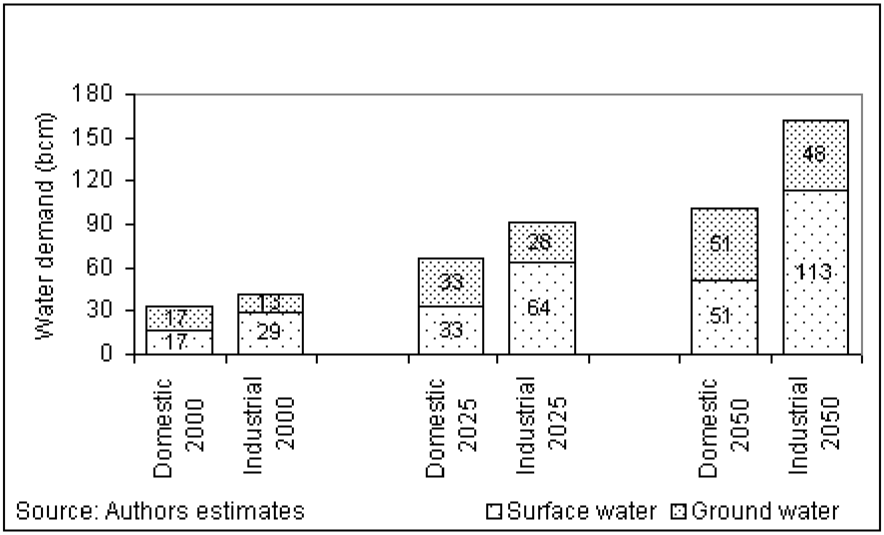
4. CONTINGENCIES FOR LARGE INTE-BASIN WATER TRANSFERS

As presented above, there are a number of physical and institutional interventions which, if given due attention and support, can assist India to meet its water demand for food production in the short- to medium-term. Also, over the long term, combined with the expected demographic changes and shifts in consumption patterns, the need for investments in large-scale infrastructure for irrigation needs to be planned and developed. That said, there are situations even under the business as usual scenario water demand projections and also under other contingencies, which may justify water transfers of the magnitude proposed under NRLP or water transfers of even larger scale. Increasing groundwater stocks, improving crop productivity, and diversifying for less water consumptive crops could mitigate the short- to medium-term water crisis in India. However, there appear situations that justify large inter-basin water transfers, such as some of those proposed under the NRLP over the long-term. Such conditions include: increasing domestic and industrial water demand, providing a reliable water supply for high-value crops, growing pressure on the groundwater systems, escalating energy prices, and allocating minimum river flows for protecting the environment. In each case, the characteristics and timing of such developments will depend on socio-economic, environmental, and agricultural conditions within the given basin and locality.

4.1 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 come by reallocating from the agriculture sector. However, the 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

Figure 5: Domestic and industrial water demand projections of India



Source: Authors estimates

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 inter-basin water transfers, similar to the situation with the Lesotho Water Highlands Project (Shah et al., 2006).

4.2 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 compared to rainfed lands, because much of the command areas grow foodgrain, 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 inter-basin water transfers. However, if low productivity of these surface irrigation systems persists, and further irrigation sources have to be developed, including inter-basin 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.

4.3 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 electricity or diesel, has been rapidly increasing in recent times. States can no longer continue to provide these subsidies 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 inter-basin water transfers. Conceivably there could also be an indirect argument for inter-basin transfers where concurrent development of hydropower could provide increased supplies of electricity, however, from an economic perspective this resource would be better utilized in the industrial and service sectors.

4.4 Environmental Water Demand

As a result of increasing economic activities, the quality and quantity of water in some rivers are at a threatening low level. As a result, water demand for the environment could become a priority. At least, a minimum flow requirement (MFR) provision could be established in most river basins.

Smakhtin and Anputhas (2006) provided a methodology for assessing the MFR of Indian river basins. This methodology depends on hydrological variability and environmental management class that rivers ought to maintain. Table 3 shows the estimated MFR for the environmental management class "C." The class "C" classifies rivers as "moderately disturbed". Many river basins in India are in the class C category, where the habitats and biota of rivers have already been disturbed, but the basic ecosystem functions are intact. The management perspective in these basins is to preserve the ecosystem to such an extent that disturbances associated with socio-economic development are still possible.

Table 3: Environmental water demand to be met from the potentially utilizable surface flows :

River basin	Potentially utilizable surface water resources[1] (PUSWR)	Un-utilizable surface water resources[2]	Minimum flow requirement (MFR)[3]	MFR to meet from PUSWR[4]
	km³	km³	km³	km³
Brahmaputra	22	607	287	0
Cauvery	19	2	4	2
Ganga 250	275	152	0	
Godavari	76	34	18	0
Krishna 58	20	14	0	
Mahanadi	50	17	12	0
Mahi 3	8	1	0	
Narmada	35	11	6	0
Pennar 6	0	1	1	
Sabarmati	2	2	0.5	0
Subernarekha	7	6	2	0
Tapi	15	0.4	2	2

1 - PUWR is from CWC 2004; 2 – Un-utilizable water resources – TRWR-PUSWR;
3 – MFR is from Amarasinghe et al., 2006.; 4 – The difference between the third or fourth column.

Environmental management class "C", in general, proposes an MFR in the range of 12-30% of the mean annual run-off. Particularly, the Brahmaputra river basin's MFR is estimated as 46%, and for the Mahi river it is 7%. According to these estimates, the estimated unutilized part of the water resources in many basins is higher than the required MRF. Only three basins, the Cauvery, Pennar and Tapi, are at levels that require re-allocation of potentially utilizable water resources to meet this relatively low environmental water demand. But the interpretation of these results require some caution.

The MFR, presented in this report, is based on annual river flows. However, due to monsoonal rainfall patterns, the monthly flows of Indian rivers vary significantly. If the demand is estimated at a monthly basis, the environmental water demand of some basins could be more, and the PUWR will have to meet part of this demand. As a result, the effective water supply available for other sectors could diminish in many basins. This would be another instance where inter-basin transfers could be required to satisfying the water demands of all sectors.

5. CONCLUSION

According to the business as usual water-use patterns, India is heading for a severe regional water crisis. Groundwater over-abstraction is the main cause for this. Many basins will have large pockets with unsustainable groundwater use. In the absence of major surface water development projects, reliance of groundwater in the long- to medium- term will increase. Artificial groundwater recharge can greatly enhance the groundwater stocks and shall facilitate the groundwater abstraction and sustainable water use. However, the negative implications of groundwater recharge on the downstream water users require further understanding. Increasing groundwater irrigation efficiency and other demand management strategies shall also be helpful for reducing the groundwater over-abstraction.

The increase in water productivity offers the greatest opportunities for reducing the additional irrigation demand. Impact of this on unsustainable water use will be significant as groundwater will be the major source of water for crop production. Doubling the water productivity over the next five decades shall require no additional irrigation requirement. However, given the direct and indirect contribution of irrigation to crop yield growth over the past decades, it shall require major investments in research, development, and extension on better management of other inputs. Crop diversification could also offer opportunities for increasing the value of water use. Many peninsular river basins, which are already water scare, can benefit from crop diversification. Crop diversification in already high water productivity areas, such as in north and north-west, shall need further understanding as the water productivity of grain crops in these areas are as high as the water productivity of no-grain crops. However, crop diversification would help the poor small farm holders in the east, although they have the water resources for meeting the requirements of water intensive crops.

Increasing dependency on groundwater, and water savings and reallocation of irrigation water shall still not meet all water requirements of other sectors. Increasing willingness and also affordability to pay for clean and reliable water supply would increase the pressure for surface water resources. Such scenarios will likely to emerge soon in states with high economic growth, and also water scarce. Most of them are located in peninsular India. And meeting additional surface water demand in these basins may require large intra- or inter-basin water transfers.

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REFERENCE

Amarasinghe, U. A.; Shah, T.; Turral, H. and Anand B. (2007), India’s Water Futures to 2025-2050: Business as Usual Scenario and Deviations. IWMI Research Report 123.International Water Management Institute, Colombo, Sri Lanka.

Banerji, A.; Khanna, G.; and Meenakshi, J.V. (2006), Markets, Institutions and Efficiency: Groundwater Irrigation in North India, Working Paper 152. New Delhi, India: Department of Economics, Delhi School of Economics, New Delhi.

GOI (2006), Report of the Working Group on Water Resources For the XI Five Year Plan (2002-2007). Ministry of Water Resources, Government of India, New Delhi.

Kumar, M.Dinesh; A. Patel and O. P. Singh (2006a.), Rainwater Harvesting in Water-Scarce Regions of India. Draft, IWMI-CPWF Project on Strategic Analyses of India’s National River-Linking, International Water Management Institute, Colombo, Sri Lanka.

Kumar, M. Dinesh; M. Samad; U. A. Amarasinghe and O. P. Singh (2006b.), Water saving and yield enhancing technologies: How far can they contribute to water productivity enhancement in Indian agriculture? Draft, IWMI-CPWF Project on Strategic Analyses of India's National River-Linking Project, International Water Management Institute, Colombo, Sri Lanka.

Narayanamoorthy, A (2006), Potential for drip and sprinkler irrigation in India. Draft, IWMI-CPWF Project on Strategic Analyses of India's National River-Linking Project, International Water Management Institute, Colombo, Sri Lanka.

Sakthivadivel, R (2007), The Groundwater Recharge Movements in India. In: Giordano, M. and Villholth (Eds.),The Agricultural Groundwater Revolution: Opportunities and Threats to Development. CAB International, Wallingford, UK, pp. 191-210.

Shah, Tushar (2000), Mobilizing social energy against environmental challenge: understanding the groundwater recharge movement in western India. Natural Resources Forum 24(3): 197-209.

Shah, Tushar (2007), The Groundwater Economy of South Asia: And Assessment of Size, Significance and Socio-ecological Impacts. In: Giordano, M. and Villholth (Eds.), The Agricultural Groundwater Revolution: Opportunities and Threats to Development. CAB International, Wallingford, UK pp. 7-36.

Shah, Tushar and R. Desai (2002), Decentralized water harvesting and groundwater recharge: can these save Saurashtra and Kutch from desiccation? Paper presented at the First IWMI-TATA Annual Water Policy Workshop held at Anand, India during 13-14 February 2002.

Shah, Tushar; U. Amarasinghe and P. McCornick (2007), India's River Linking Project: The state of the debate. Draft, IWMI-CPWF Project on Strategic Analyses of India's National River-Linking Project, International Water Management Institute, Colombo, Sri Lanka.

Smakhtin, V; Anputhas, M (2006), An Assessment of Environmental Flow Requirements of Indian River Basins. Research Report 107. International Water Management Institute, Colombo, Sri Lanka.

Somanathan, E and R. Ravindranath (2006), Measuring the Marginal Value of Water and Elasticity of Demand for Water in Agriculture. Economic and Political Weekly, 30 June 2006