India's Water Future 2050: Potential Deviations from 'Business-as-Usual'[1]

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Background

India has for long been toying with the idea of having a national water grid to overcome the spatial inconsistencies in demand and availability of fresh water resources. The idea of transferring the flood waters of the Ganga-Brahamaputra-Meghna (GBM) basin to the water-starved basins in western and peninsular India has been in existence for long[2]. More recently, the idea acquired a new life when, based on a public interest petition, the Supreme Court of India issued an order directing the government to implement the plan prepared by the NWDA[3] in 10 years. The government, in response to the court directive, set up a (now disbanded) high-powered task-force with the mandate to complete an analysis of how the project will unfold by December 31, 2006 and subsequently to complete, by 2016, the project in this respect that will cost roughly US$120 billion and link 37 Himalayan and peninsular rivers. The project (National River Linking Project – NRLP) "will form a gigantic South Asian water grid which will handle 178 km^3 of inter-basin water transfer/year, build 12,500 kms of canals, generate 35 gigawatts of hydropower and add 35 mha to India's irrigated areas" (IWMI 2003).

[1] This paper is a modified and updated version of a paper by the same authors and with the same title published in the 'International Journal of Rural Management', Sage Publications (Verma and Phansalkar 2007).

[2] It started in late nineteenth century when Sir Arthur Cotton thought of a plan to link rivers in southern India for inland navigation. The idea was partially implemented but was abandoned with time as inland navigation lost ground to railways. In 1972, the then Union Minister for Irrigation, Dr. K.L. Rao, proposed the Ganga-Cauvery link and again, in 1977, Captain Dinshaw Dastur coined the phrase 'Garland Canal' and while his plan was later rejected, the catchy phrase caught the imagination of people and continues to be popular.

[3] The National Water Development Agency (NWDA) was set-up by the Government of India (GOI) in 1982 to work out basin-wise surpluses and deficits and to study the possibilities of storage, links and transfers. It proposed two components of a mega river-linking plan – Himalayan and Peninsular – envisaging 14 and 16 links, respectively.

The 'task force' repeatedly cited projections made by the National Commission for Integrated Water Resource Development (NCIWRD 1999) of the increased irrigated area required to feed the growing population as the key justification for NRLP. In this paper, we try to identify grey areas and points of discontinuity with the aim of evolving a research agenda that will lead to a refined, textured and nuanced understanding of India's water future 2050. The paper is organized as follows. First, we present an overview of India's water resources; second, we provide a summary of the projections made by the NCIWRD; third, we review other projections for water availability and demand made at global and regional scale with special reference to India; fourth, we discuss potential deviations from the commission's projections; and, finally, we conclude with a framework for 'water future' research.

Setting the Stage: India's Water Resources

How much water do we have? How much of it is currently being used? How far can it be stretched further? Ironically, even the best estimates on these basic questions are often confusing, inaccurate or inconsistent. In this section, we address these questions in a simple and coherent manner to provide the reader a backdrop for NCIWRD's estimates[4].

Water Resource Accounting

India has a geographical area of a little over 329 million hectares (MHa), and a mean annual rainfall of 1,170 mm. This mean annual rainfall is added to the snow-melt in glaciers and net cross-border river-inflow (river-flow originating from outside India and coming into India MINUS river-flow originating in India and draining to a neighboring country) to calculate average annual precipitation. This amounts to around 4,000 BCM[5]. Of this, less than half is 'accounted-for' while the rest constitutes what may be called the 'unaccounted' water resources of India. This 'unaccounted' water is primarily used-up in four processes:

(1) Evaporation: A major portion of this 'unaccounted' water is lost to the atmosphere in the form of evaporation. As the rain falls, a good amount of it is first intercepted by the foliage and this amount returns to the atmosphere without ever reaching the ground. This 'deduction-at-source' takes place in every spell of rainfall. However, this rain does get measured by the rain gauges which are always kept in open areas, and is thus included in the above 4,000 BCM. Besides the evaporation of rainwater, the evaporation taking place from land area and water bodies accounts for a large amount of the 'loss'.

[4] All figures quoted in this section are with reference to the NCIWRD 1999 report, unless otherwise stated. The authors would like to acknowledge the help of Mr. Chetan Pandit, Mr. A.D. Mohile, Dr. Christopher Scott and Dr. M. Dinesh Kumar for their inputs and useful comments on previous versions of this paper.

[5] BCM = Billion Cubic Meters; 1 BCM = 1 x 10^9 m^3
While this figure is calculated at mean annual rainfall on 329 MHa, there may be variations in this on at least two counts: (1) 1,170 mm is a gross average for a continent-sized country and rainfall has huge inter-year variability; and (2) there are bound to be carry-overs and overdrafts between two consecutive years.

(2) Non-crop and Rain-fed Evapotranspiration (ET): As much as 19.25 % (63.34 MHa) of India's geographical area is covered by forests. Trees, shrubs and other vegetative growth in these forests, as well as elsewhere, require water for evapotranspiration (ET) throughout the year, unlike in the case of agricultural vegetation, which requires water only during specific and intermittent periods. This nonagricultural ET also contributes significantly to the use of 'unaccounted' water resources of the country. A large portion of India's cultivated area (roughly two-thirds) continues to be rain-fed. Evopotranspiration from the rain-fed crops, not included in the blue-water accounting, also forms part of the 'unaccounted' water.

(3) Deep Percolation: The 'unaccounted' water resources of India include percolation to very deep aquifers from where lifting water is either technically not feasible or economically viable. However, it is important to note that in certain areas (such as in north Gujarat), farmers have already started using even some of this 'unaccounted' water by using deep tubewells and submersible pumps. The total groundwater draft in such cases exceeds the annual replenishable recharge of the region and the phenomenon is, therefore, termed as 'groundwater mining'.

(4) Sub-surface flows to Oceans: India has a 7,000 km. long coast line where, beneath the surface, fresh water meets saline water to form an aquifer-ocean interface. It is important to maintain a higher hydraulic head at this interface to prevent saline-water ingress into the sweet groundwater aquifer. This means that, at all times, there should be a continuous flow towards the lower hydraulic head and into the ocean beneath the ground. This accounts for the remaining 'unaccounted' water.

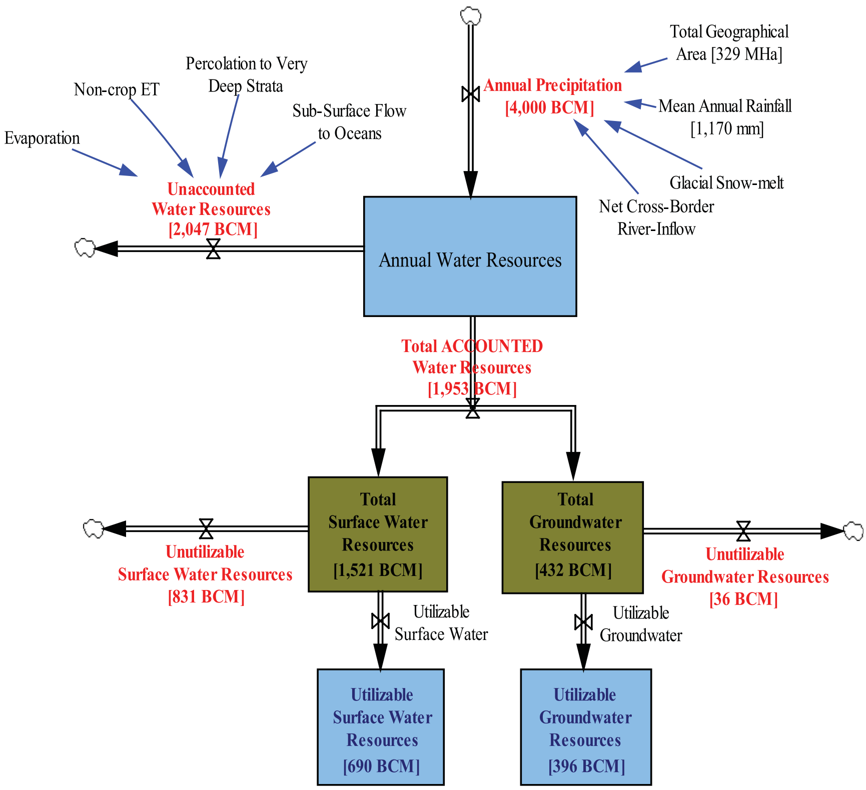
Utilizable Water Resources

Out of the 1,953 BCM, only about 1,086 BCM is actually usable. This 'second deduction' is because of the spatiotemporal variations in the water's availability. The Ganga-Brahmaputra-Meghna (GBM) basin, which covers 33 % of the land area, accounts for more than 60 % of India's water resources. Similarly, catchments of west flowing rivers, which cover only 3 % of the land area, account for 11 % of water resources. Thus, 71 % of India's water resources are available to only 36 % of the area (at a comfortable 24 BCM /Mha[6]) while the balance 64 % area gets the remaining 29 % of the water resources (at 5 BCM /Mha). Moreover, about 80 % of the Himalayan river flows and 90 % of the peninsular river flows occur during the 4 monsoon months. While some of this gets used 'online', what remains needs to be stored 'offline' for use in the remaining 8 months.

After taking into account these variations, the 'utilizable' water resources of the country add up to 1,086 BCM; of which 690 BCM is the utilizable surface water potential and 396 BCM is the utilizable groundwater potential (Figure1) In a nutshell, therefore, if we look at the hydrological cycle as a system, the purpose of all water resource development interventions (large or small) is to use through the creation of 'artificial delays,' the water (at least once and as many times as possible) from the time it falls as rainfall to the time it flows into the oceans and comes back in the form of rain in the next cycle. Unless such delays are introduced into the hydrological cycle, our capacity to utilize our water resources will remain significantly diminished.

[6] Mha = Million Hectares

Figure 1. India's water resources.



NCIWRD's Vision of India in 2050

Water Provision for Irrigation

For estimating agriculture water use the projected requirement has been broken down into four key determining variables: (1) requirement for food production; (2) requirement for non-food production; (3) water use efficiency; and (4) land productivity.

The key assumption in estimating the irrigation requirement for food production has been that India will continue its policy of attaining self-sufficiency in food production. The commission also assumes that the present ratio of the area under food and non-food production (70:30 for irrigated areas; 66:34 for unirrigated areas) will remain constant. Interestingly, a comparison of projections made under a special study commissioned by the NCIWRD (Ravi 1998) with those by Bhalla and Hazel 1998 shows that even at 5 % growth rate of expenditure, the food and feed demand projected by the commission is less than that estimated by Bhalla and Hazel. Moreover, Bhalla and Hazel estimate that 42 % of India's population will be living in urban areas as early as 2020. Ravi's prognosis, however, estimates a much lower proportion of urban population for the same time period and has generated three scenarios of food demand under 4.0 %, 4.5 % and 5.0 % growth rates in expenditure. The commission has accepted the projections made by Ravi with the assumption of 4.5 % growth in expenditure to estimate their food and feed demand in 2010, 2025 and 2050.

Based on these, the commission has calculated the total water requirement for irrigation in 2010, 2025 and 2050 under low as well as high population growth scenarios as shown in Table 1.

Table 1. Water requirement for irrigation 2010, 2025, 2050 (BCM).

Variable	Remarks and Assumptions	Units	2010	2025	2050
Population	Low growth scenario*	Million	1,156.60	1,286.30	1,345.90
	High growth scenario**	Million	1,146.00	1,333.00	1,581.00
Urbanization	Low growth scenario	%	32	37	48
	High growth scenario	%	34	45	61
Per capita food demand	at 4.5 % expenditure growth	Kg/Cap/Yr.	194	218	284
Food plus demand	Low growth scenario	MT	245	308	420
	High growth scenario	MT	247	320	494
NSA	Marginal increase	Mha	143	144	145
GIA/GSA	Low growth scenario	%	40	45	52
	High growth scenario	%	41	48	63
Cropping intensity	20 % growth assumed over 50 years	%	135	140-142	150-160
% Food crops	Rain-fed areas (no change)	%	66	66	66
	Irrigated areas (no change)	%	70	70	70
Food crop yields	Rain-fed areas (modest increase)	T/Ha	1.10	1.25	1.50
	Irrigated areas (modest increase)	T/Ha	3.00	3.50	4.00
Food plus production	Low growth scenario	MT	246	307	422
	High growth scenario	MT	249	322	494
Irrigation efficiency	Surface water irrigation	%	40	50	60
	Ground water irrigation	%	70	72	75
GIR [NIR = 0.36]	Surface water irrigation		0.91	0.73	0.61
	Ground water irrigation		0.52	0.51	0.49
SW dependence	Growing dependence on SW assumed	%	47	49-51	54.3
Total water required	Low growth scenario	BCM	543	561	628
	High growth scenario	BCM	557	611	807

Source: Adapted from various tables (NCIWRD 1999)

Notes: * Based on United Nations 1995 projections
** Based on Visaria and Visaria 1996

Water Provision for Domestic Use

The commission has reviewed various norms suggested for water requirement for human use and has suggested a target of providing 220 liters per capita per day (LPCD) for urban areas and 150 LPCD for rural areas by 2050. On the basis of these targets, it has estimated the water requirement for domestic use under high and low population growth scenarios. It has further assumed that roughly 55-60 % of the water requirement for domestic use will be met from surface water sources. The total bovine water requirement for 2010, 2025 and 2050 has been estimated assuming a 0.5 % annual growth rate of bovine population and water requirement of 18-30 LPCD (Table 2).

Table 2. Estimation of domestic and municipal use and bovine requirements in 2010, 2025 and 2050.

Population type	2010	2025	2050
Targets for domestic and municipal use (LPCD)			
Class I cities	220	220	220
Class II-VI cities	150	165	220
Rural areas	55	70	150
Low and high projections (BCM)	42-43	55-62	90-111
% from surface sources (approx.)	55	57	60
Bovine water requirements (BCM)	4.8	5.2	5.9

Source: Adapted from Tables 3.26 and 3.27 (NCIWRD 1999)

Water Provision for Industrial Use

The commission, on its own admission, is tentative about its projections for water use in industries. It notes that there is a serious dearth of information and analysis on both present water requirement and future growth of industries in India. In such a scenario, it uses data available with the Central Pollution Control Board (CPCB) and the classification of industries into 17 sub-sectors done by the Planning Commission to arrive at its estimates. The estimates for the years 2010, 2025 and 2050 are 37, 67 and 81-103 BCM, respectively. These estimates are based on a 'sliding scale' with the lower estimate of 81 BCM arrived at by assuming significant breakthroughs in the development and adoption of water saving technologies for industrial production. It has further assumed that 70 % of these requirements will be met from surface water sources.

Water Provision for All Other Uses

In addition to the above, the commission has estimated water requirements for power generation, development for inland navigation, compensating evaporation losses from reservoirs, floods and environment and ecology. We briefly enumerate these below:

(A) Power Generation: While recognizing the growing importance of nonthermal sources, specifically hydropower, the commission contends that, in view of the economies in power generation from coal and the high initial investment and long gestation period in the construction of hydro-schemes, thermal power will continue to be the mainstay of India's power sector in the foreseeable future. Based on estimates collected from various sources for thermal power and by using lump-sum provisions based on 9 % annual growth assumption for hydropower, it has used a water requirement norm of 0.001 BCM/100 MW power generation capacity. Based on this ballpark number and projections about India's growing power generation capacities, the commission has arrived at its final results (Table 3).

Table 3. Water requirement for power development 2010, 2025 and 2050 (BCM).

Category	Norm for water requirement (0.001 BCM/100 MW)					
	2010		2025		2050	
	Low	High	Low	High	Low	High
Thermal	2.81	3.43	7.85	9.59	28.71	35.07
Hydropower*	15.00	15.00	22.00	22.00	30.00	30.00
Nuclear	0.29	0.36	1.13	1.38	3.68	4.50
Solar/wind	0.00	0.00	0.01	0.01	0.04	0.04
Gas-based	0.02	0.02	0.06	0.07	0.18	0.22
TOTAL	18.10	18.80	31.10	33.10	62.60	69.80

Source: Adapted from Table 3.28 (NCIWRD 1999)

Note: * Lump-sum based on 9 % annual growth assumption.

(B) Development of Inland Navigation: Of the 900 billion tonnes km per annum of the total inland cargo, only one billion tonnes is currently moved by inland waterway transport. The flow requirements in water channels are mostly expected to be met by seasonal flows in various river systems and canals. However, in the event of the damming of entire river flow, some water would be required to be released from upstream reservoirs for keeping the waterways navigable, especially during the lean season. In view of this, the commission has projected 7, 10 and 15 BCM surface water requirements for 2010, 2025 and 2050, respectively, for navigational purposes.

(C) Compensating Evaporation Losses: The loss due to evaporation from surface water reservoirs would depend on the reservoir geometry (surface area), water available in the reservoir and potential evaporation. For all practical purposes, evaporation from a water body is generally expressed as a percentage of the reservoir capacity[7]. However, such calculations would require reasonably accurate withdrawal data from all reservoirs. In the absence of such information, the commission has adopted an alternative method which is based on the live storage capacity. It has estimated national average values of evaporation losses from reservoirs as 15 % of the live storage capacity for major and medium irrigation reservoirs and 25 % for the minor irrigation reservoirs (Table 4).

[7] The technical advisory committee of the NWDA has prescribed a norm for estimation of evaporation losses as 20 % of total withdrawals from the reservoir.

Table 4. Estimates of evaporation losses in 2010, 2025 and 2050.

Particulars	1997	2010	2025	2050
Live capacity (major storages)	173.73	211.44	249.15	381.50
Evaporation (at 15 %)	26.10	31.70	37.40	57.20
Live capacity (minor storages)	34.70	42.30	49.80	76.30
Evaporation (at 25 %)	8.70	10.60	12.50	19.10
Total evaporation loss (rounded-off)	35.00	42.00	50.00	76.00

Source: Adapted from Table 3.29 (NCIWRD 1999).

(D) Floods, Environment and Ecology: This is perhaps the most intriguing section of the entire chapter on water requirement projections. The commission makes a case for setting aside some water capacity for moderating the releases from dams in the event of high floods. However, it concludes that since such situations are ‘casual’ in nature, there is no provision made for such purpose. In any case, the requirement for flood control is for water storage capacity and not for additional water *per se*.

The commission report also talks at length about the poor state of the environment in the country, citing indiscriminate depletion of forest cover. It also mentions that India’s forests can sustainably provide only about 0.041 BCM of fuel wood every year compared with the current demand for 0.240 BCM. Further, it adds that the industrial wood requirements are more than twice the current silvicultural productivity; and also that while the carrying capacity of forests is only 31 million head of cattle, currently about 90 million graze in forests. The report, however, concludes that most of the water requirements for aforestation would be met from precipitation and soil moisture (green water) and that there is no need for any specific earmarking for this purpose.

The commission notes the alarming levels of water pollution in India’s rivers, giving examples of cities such as Delhi which produces nearly 2 billion liters of sewage, most of which is dumped untreated into the Yamuna River. It points out that for the treatment of sewage and for maintaining the river ecology (environmental flow releases – EFR), Delhi alone, would require about 3 BCM of fresh water to restore the quality of water to a safe limit. And yet, at the end, it makes ‘a token provision’ of 5, 10 and 20 BCM for water for all the purposes listed above for 2010, 2025 and 2050, respectively.

Total Water Requirement

Based on all the assumptions and projections above, the commission has estimated total water requirements under low and high demand scenarios as 629–694, 710–784 and 843–973 BCM for 2010, 2025 and 2050, respectively (Table 5).

As the maximum utilizable surface water resource amounts to only 690 BCM, the requirement in 2050, under high population projections, will exceed the availability according to the commission’s projections. The same will be the situation in the case of groundwater resources where the maximum utilizable resource is 396 BCM and the projected requirement is

Table 5. Total water requirement 2010, 2025 and 2050 (BCM).

Uses of water	1997-98	Scenario	2010	2025	2050	%SW**
Irrigation	524	High	557	611	807	57-61
		Low	543	561	628	
Domestic and municipal	30	High	43	62	111	53-59
		Low	42	55	90	
Industries	30	High	37	67	108	70-71
		Low	37	67	81	
Power	9	High	19	33	70	77-81
		Low	18	31	63	
Inland navigation	-	High	7	10	15	100
		Low	7	10	15	
Environment	-	High	5	10	20	100
		Low	5	10	20	
Evaporation losses	36	High	42	50	76	100
		Low	42	50	76	
Grand Total	629	High	710	843	1,180	63-65
		Low	694	784	973	

Source: Adapted from Table 3.30 (NCIWRD 1999)

Note: **Proportion of requirement proposed to be met from surface water sources

428 BCM. The situation will be even worse when we take into account the spatial variation in demand and availability at the basin level.

Other Projections for Water Future 2050

Besides the NCIWRD projections, there are several other attempted projections regarding global and regional water availability and demand. A neat summary of several of these can be found in Strzepek 2001. While these efforts provide a sound body of knowledge to use as a sounding board for methodologies and approaches, the results are of a global nature and not specific for India. Seckler et al. 2000 and Rosegrant et al. 2002 have made global scenario building for water future 2025 where they have fairly specific forecasts and comments about India. We compare the three projections up to the year 2025 to provide the reader an overview of approaches, assumptions and broad results (Table 6). The broad conclusions of the three exercises are not remarkably different. Thus, irrespective of what one may wish to do about India's water requirements, deny its size one cannot.

Table 6. Approaches, assumptions and broad results.

Aspects	NCIWRD (up to 2025)	Seckler et al. (BaU*)	Rosegrant et al. (BaU*)
Approaches			
Basic approach	Building blocks approach	Integrated, multi-year model	IMPACT-WATER model
Number of basins considered	24	Not specified	13
Whether trade considered?	No	Yes	Yes
Calculation of irrigation water requirement	Delta of 0.51 and 0.72 for ground and surface water, respectively	1cumt per kg grain	ET ratios for crops as per FAO.
Scenario building exercise	Not done except for high and low population growth	Subsequently tried out; Model permits scenario building exercise	Policy and lifestyle variables used to make 3 scenarios
Broad picture of India 2025	Tight overall balance; significant gaps and mismatches in several basins	Economic water scarcity: Investment needed for expanding primary water supply is unaffordable	Withdrawals will be 36 % of the renewable water resource; difficult to manage
Assumptions			
Annual available water resources	1,953 BCM	2,037 BCM	1,721 BCM
Efficiency assumption	0.50 for SW; 0.72 for GW	Basin efficiency gains assumed	Basin efficiency assumed to increase at specific rate
Domestic water requirement estimation	220 LPCD urban (Class I); 165 LPCD urban (Class II-VI); 70 LPCD rural	World Resources Institute (WRI) data used	(based on rural % and % HH with piped supply, income and prices of water) 41 BCM
Industrial water use	CPCB norms estimation	WRI data used very tentative	Water use intensity used along with estimates GDP growth
Livestock water requirement estimates	24 LPCD	WRI data used	FAO estimates used
Broad Results			
Population	1,286-1,333 million	1,216 million	1,352 million
% Rural	55-63 %	64 %	57 %
Projected irrigated area	67.00 MHa	63.10 Mha	76.00 MHa
Projected rain-fed area	77.00 MHa	81.00 Mha	68.00 MHa
Food grain requirement	308-320 MT	259 MT	275 MT

(Continued)

Table 6. Approaches, assumptions and broad results. *(Continued)*

Aspects	NCIWRD (up to 2025)	Seckler et al. (BaU*)	Rosegrant et al. (BaU*)
Approaches			
Water required for food production	561-611 BCM	702 BCM	332 BCM consumptive; much higher withdrawals
Assumed total water supply	SW: 382 BCM GW: 432 BCM Total: 824 BCM	1,263 BCM	Not specified
Total Water Demand 2025	784-843 BCM	811 BCM	815 BCM

Source: NCIWRD 1999, Seckler et al. 2000, Rosegrant 2002

Note: * BaU = 'Business as Usual' scenario

Potential Deviations from Business-as-Usual

The commission's report presents a rare case when issues of such diverse nature, requiring such diverse expertise, have all been dealt together, and thus making it compelling reading for any concerned individual. Having said that, we believe that the estimates represent ultra-conservative 'Business-as-Usual' scenarios which, among other things, fail to take into account two things: (1) coping mechanisms of the people and demand responses to policy triggers; and (2) technological and social breakthroughs on the horizon. Several autonomous and induced changes, which will profoundly influence the course of India's food agricultural sector over the coming 50 years do not find a place in the data and projections made by the NCIWRD (at least in the part available in the public domain). We discuss some such potential deviations here.

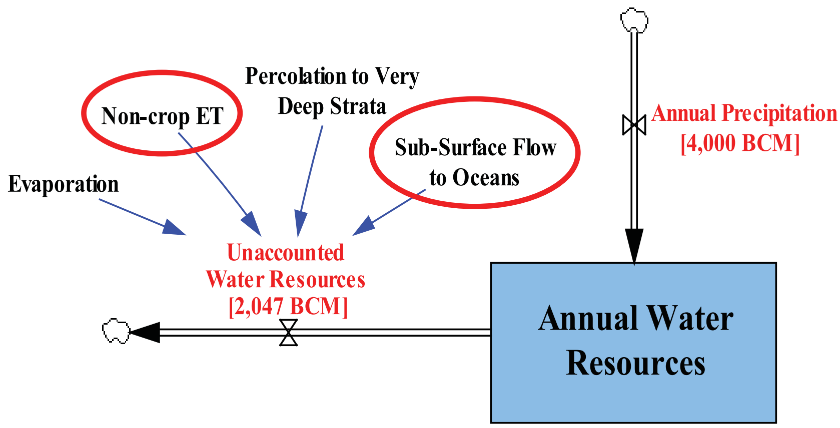
Rethinking Water Availability and Demand

(a) Accounting for Deductions at Source

The NCIWRD projections start with the assumption that the volume of water which can be put to use in India on a reasonably sustainable basis is 1,086 BCM (690 BCM of surface water and 396 BCM of annually replenished groundwater). As we have already explained above, the reduction from 4,000 BCM to 1,953 BCM is caused primarily due to four 'deductions-at-source': (1) Evaporation; (2) Non-crop and rain-fed ET; (3) Deep percolation; and (4) Sub-surface flows to the oceans. While little can be done to check evaporation and deep percolation, the other two 'deductions' can be seen as variables which are easily influenced by public policy and human actions (Figure 2).

Non-crop ET largely involves the water requirement by trees in the forests and naturally growing vegetation including grasslands, shrubs and weeds. While hardly anyone will want to suggest a policy to deplete forests to expand our utilizable water resource, how this will change in the coming 50 years needs to be looked at carefully. If our forests continue to deplete and degrade as they have in the recent past, much more of this water

Figure 2. Human influence on 'deductions-at-source'.



will be available for alternate uses, though at huge ecological costs. If, on the other hand, effective forest protection policies and laws coupled with efforts towards large-scale aforestation are going to move the country towards the universally preferred norm of 33 % forest cover (from the existing 20 %), much less water might actually remain utilizable. Both these scenarios need to be built into a realistic projection of India in 2050. The current projections made by the commission conveniently assume away any additional allocation for aforestation efforts citing that such requirements would be met by natural precipitation (green water). However, the fact that these might impact total blue water availability itself, is ignored[v].

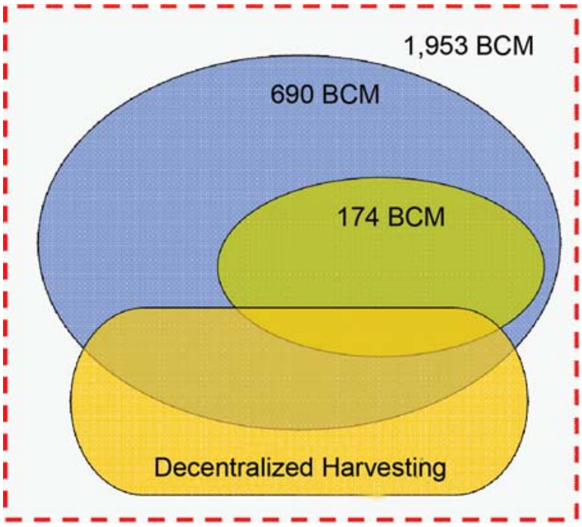
(b) Which Water to Harvest Where?

Decentralized rainwater harvesting and groundwater recharge movements have become a contentious issue in India. The Rajasthan Government took strong exception to Tarun Bharat Sangh's *Laava ka Baas* dam, arguing that it was capturing the water which would normally have flowed down to Bharatpur. There are also reports about how 'indiscriminate' rainwater harvesting in the upper catchment is preventing the Jayakwadi Reservoir in Maharashtra from filling (Pandit 2004). Even in Saurashtra, home to what is perhaps the largest people's movement of its kind in the world, doubts have been raised that the popular water harvesting and groundwater recharge movement might have affected the storage in reservoirs downstream.

As the battle of wits between the 'bare-foot' and the 'suited-booted' engineers assumes alarming proportions, it is critical to make an objective assessment of the potential of such practices. The first question, of course, is – what water do these movements harvest

[8] While the importance of forests can hardly be overemphasized, there is a striving for better understanding of the relationship between forests and water in order to give forests their due place in water resource planning. Our argument here is not for or against forests but that water requirements of forests, and other ecological and environmental needs, must be given their due share in water resource planning.

Figure 3. Decentralized water harvesting: Which water? Where?



(Figure 3)? If the water captured and harvested by these movements is part of the 2,147 BCM which was anyway 'unaccounted', such conflicts should not arise. If we assume that the capture is from the 1,953 BCM 'accounted' water, then, can decentralized water harvesting and recharge contribute to increasing the utilizable surface water potential beyond 690 BCM? If only a maximum of 177 of the 1,869 BCM of water is so far stored in large, medium and minor dams (existing storage capacity), one would tend to believe that there's a lot of scope for decentralized structures to capture more, provided they are sited at the right places and are not built to capture the same water which would have been captured downstream anyway. What can we do to ensure this? Further, if the water harvested upstream is the same as would have been gathered by the existing storage facilities, there is a need to make a critical evaluation of the benefits derived from the water harvested upstream. Is the efficiency of water use higher in the decentralized water harvesting systems or would the same water have produced greater welfare if captured downstream by existing storage facilities (Verma 2008; Verma et al. 2008b)? Answers to these questions can also significantly change our prognosis of India 2050.

(c) Desalination: How Much Freshwater Can It Add (and at What Cost)?

The problems of drinking water in class I cities are quite common around the country. These have perhaps been most severe in Chennai where inspite of municipal supplies, a portion of the population have shifted to local private players for meeting their drinking water and domestic water requirements. A 20-liter *jerry can* of potable water costs around Rs. 10-12 and is commonly home delivered throughout the city. In 2004, the Finance Minister announced the setting up of a 1,000 crore desalination plant in Chennai which would have the capacity to supply 300 million liters of water in the city. Does this mark the beginning of a series of such projects dotted all along the 7,000 km long coastline of India? How much will these add to India's freshwater resources (and at what cost)? Alternately, what kind and level of inter-basin transfers will be required to meet the growing needs of cities and towns in the future[9]? Such questions also need to be addressed for a more nuanced prognosis.

(d) Re-use of Wastewater for Agriculture: Boon or Bane?

Domestic and industrial wastewater in most Indian towns and cities is disposed of without any treatment. Increasingly, farmers in peri-urban areas have taken to using untreated wastewater for irrigation. In some of the class I cities in India, the peri-urban water economy may approach the size of a mid-scale irrigation system, helping peri-urban farmers to improve their incomes and livelihoods (Bhamoriya 2004; Buechler and Devi 2003). However, using untreated wastewater can produce adverse health effects – direct, through farmers handling untreated wastewater, and indirect, through the consumption of food stuff irrigated with wastewater. The critical questions to address are (1) by how much can the re-use of domestic and industrial wastewater multiply India's fresh water resources?; (2) how quickly will these economies grow?; and (3) what would be the implications of agriculture wastewater on public health?

(e) Water Requirements vs. Water Demand

The commission's approach ignores the impact of two key variables on demand – the price at which water is supplied; and the quality of the supply. The commission's estimates of 'water demand' are built on the basis of minimum norms set down by various agencies. For example, the commission's estimates of water demand are based on the 220 LPCD and 150 LPCD norms. However, these can hardly be termed as 'demand'. In textbook economics, we find a definition of demand very different from the one assumed here.

Demand is defined as the desire to possess a commodity or make use of a service, combined with the ability to acquire it. In other words, it is the amount of a commodity or service that people are ready to buy for a given price. The commission's definition of demand, however, completely misses the ability and price aspects of demand. Certainly, if the assumption of the commission is that domestic water will be supplied at zero (or almost zero) price, the estimates are perhaps correct. However, such a policy is likely to lead to wastes of the order which an economy facing water scarcity cannot afford. If, on the other hand, the assumption is that 220 LPCD will be actually 'demanded' at a reasonably high price and at a given level of

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[9] There already exist examples of canal projects (near Mumbai, Ahmedabad and several cities) which, under pressure of growing metropolitans have been forced to divert water (initially planned to be used for irrigation) to meet domestic and municipal requirements. While the priority accorded to domestic use is hardly debatable, it indicates that the growing needs of cities were not taken into account while planning the command area of irrigation projects. Recent studies suggest that within the next 3 years, half the world's population will be living in cities. The NCIWRD projections based on Ravi 1998 estimate that such a situation will not happen in India even in the year 2050.

quality of supply, the issues become completely different[10]. Price and scarcity also prompt people to make adjustments in their consumption patterns. The same happens in irrigation water demand through changes in cropping patterns (shift in favor of less water intensive crops) and cropping systems (adoption of water saving irrigation practices and technologies). None of these things have been factored into the commission's building block approach.

A refined prognosis of India's water future must, therefore, account for two critical variables missed by the commission: (1) water demand (as against water requirement) as a function of price, availability and quality of supply; and (2) coping mechanisms of the users of water.

India's Demography 2050

(a) Incorporating the Possible Impact of HIV/AIDS

The commission reviewed some of the existing demographic estimates (Table 7) and chose, for reasons not clearly specified, to follow Visaria and Visaria 1996 estimate as 'high variant' (1,581.00 million) and the United Nation's 1994 estimate (UN 1995) as 'low variant' (1,345.90 million). Interestingly even the UN has, since then, revised its own estimates and their latest (2002) projections for India in 2050 are 5-8 % lower than those in 1994. There is a strong

Table 7. Projections of India's population growth.

Reference	All India population (in million)				
	2000	2010	2020	2025	2050
Natarajan 1993	1,020.50	1,183.10	1,301.00		
United Nations 1994					
(a) Low variant	1,013.50	1,156.60	1,249.70	1,286.30	1,345.90
(b) Middle variant	1,022.00	1,189.00	1,327.10	1,392.00	1,640.00
(c) High variant	1,030.50	1,221.70	1,406.10	1,501.50	1,980.00
Registrar General 1996	997.00	1,162.00			
Visaria and Visaria 1996	995.00	1,146.00		1,333.00	1,581.00
United Nations 2002					
(a) Low variant	1,016.94	1,145.90	1,236.09	1,265.61	1,241.56
(b) Middle variant		1,173.81	1,312.21	1,369.28	1,531.44
(c) High variant		1,201.71	1,388.48	1,474.48	1,870.06

Source: NCIWRD 1999, UN 2002

[10] At a prominent gathering of water sector experts, Sunita Narain, head of the Centre for Science and Environment (CSE), made a strong pitch against the 220 LPCD norm. She argued that countries in the 'West' are targeting 125 – 150 LPCD for their cities by cutting losses and reducing wastage. Much of the 220 LPCD that gets delivered in Delhi (for instance) never reaches the consumers. Improving the quality of supply and the distribution system would bring down this requirement significantly.

possibility, therefore, that the reality in 2050 might significantly deviate from the commission's estimates. One of the reasons for such a deviation could be the potential impact of HIV/AIDS, which most population projections in India have so far ignored. Back in 1999, when the commission was preparing its estimates, the Government of India (GOI) had not officially recognized the emerging threat of HIV/AIDS. Today, not only has the situation perhaps somewhat degenerated but the GOI too has admitted that there are more than 5 million HIV/AIDS affected persons in the country[11].

Dyson and Hanchate 2000 are among the few who have attempted with and without AIDS projections. They argue that because the disease has a very long incubation period, the population known to be suffering from AIDS at any point of time represents only the tip of the iceberg. Further, they assert that while the effect in India might not be as dramatic as in some African countries such as South Africa, to make no allowance for its impact is no longer tenable. India must be looked at as a continent (like Africa) where there might be pockets (like South Africa and Botswana), which will be severely affected by the epidemic as well as pockets (like North Africa) where the level of infection will be low. Even in such large and diverse populations, the impact of HIV/AIDS on mortality rates and life expectancy can be significant. Between 1980 and 2005, it is believed that Africa's life expectancy will remain constant at around 51 years. However, in a 'without AIDS' scenario, it would have been roughly 5 years higher (UN 1999a; UN 1999b). In the light of the above, a closer re-examination of India's demography in 2050 is in order.

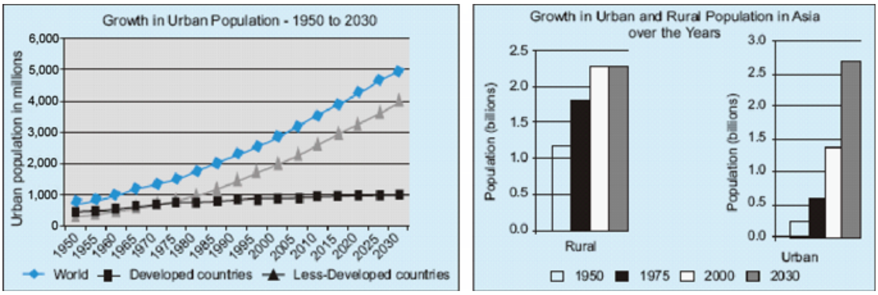
(b) Water Resources Planning in the 'Urban Century'

Even as the share of agriculture in the GDP of developing countries is continuously falling, the majority of their populations continue to depend on agriculture. This means that the water intensity of rural livelihoods has remained high and much of the planning for water resources has remained significantly agriculture-centric. However, recent trends in urbanization indicate that this is going to change sharply over the next half-century. Based on an analysis of the United Nation's latest demographic projections (UN 2002), Mohan and Dasgupta 2004 assert that the twenty-first century is going to be the 'Asian urban century' (Figure 4).

For India, this would imply that, by 2030, more than 40 % of her population will live in urban settings resulting in a further intensification of the already evident conflicts between towns and their hinterland for water. While urban water requirements total up to a small share in total fresh water use, and will perhaps continue to remain that way, year after year, knee-jerk policy action is taken to avert urban water crises. These annual bouts of crises and the fact that numerous irrigation systems are today unable to serve rural areas as their water gets diverted to cities illustrate that the growing needs of urban centers were not adequately considered at the time of planning the irrigation systems. Scenarios of urban water needs, which are backed by policy priority, much higher ability to pay, and often a stronger political pull, therefore must be developed and built into the planning process.

[11] Health Minister's reply to a question raised in Parliament on August 18, 2004.

Figure 4. Asia in the 'urban century'



Source: UN 2002; Mohan and Dasguptha (2004)

Liberalization and Food Crop Preferences

The commission's projections about water requirements assume that the share of food crops in irrigated as well as unirrigated lands will remain constant at 70 % and 66 %, respectively. However, this needs to be re-looked in the context of recent and possible future changes. Changes currently underway in the international trade policy environment and India's policy response to these will have wide-ranging consequences for the agriculture sector and for food security in the short and long terms. Along with China, India is one of the biggest players in the world food market; not by virtue of the size of their current trade, but on account of the potential havoc these countries can create by entering the world food market either as significant importers or exporters. If either of them decides to export or import in large numbers, world food prices could soar or crash in no time. With liberalization in trade, such situations will bring different incentives and signals to the Indian farmer. If world food prices are lower than the costs of production in India (assuming that China adopts a food export policy), free trade and Chinese farmers could potentially crowd Indian farmers away from food-farming.

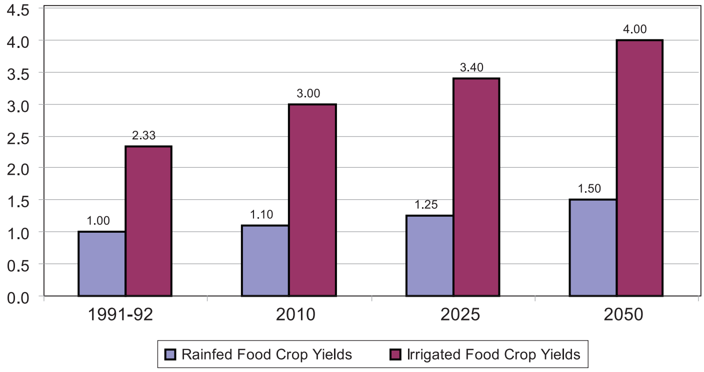
Three things will determine farmers' preference for food crops: (1) India and China's foray into the world food market and the resultant impact on food prices; (2) the degree of freedom and liberalization (conversely, support and protection) in international food trade; and (3) farm-level food surplus/deficit (it is not uncommon to see farmers being averse to buying food for self-consumption). While most people tend to agree that India will not give up its food self-sufficiency policy, individual farmers' decision to produce food crops will depend on price signals and market surplus/deficit conditions operating at the micro and meso level.

Modernization of Indian Agriculture

The commission has assumed a very modest increase in the productivity of irrigated and rain-fed food farming systems (Figure 5). If these assumptions hold, and given that total cropped area is unlikely to increase significantly, India would certainly need much more land under irrigation to feed the growing population. However, certain recent and potential future developments incline us to rethink.

Drip irrigation technologies promise 30–70 % improvement in water-use efficiency, besides offering significantly higher yields and several other benefits (Narayanamoorthy 1996; Narayanamoorthy 1997; INCID 1994; Magar et al. 1988; Kulkarni 1987). However, ever since

Figure 5. NCIWRD's projected yield growth.



Source: NCIWRD 1999

they were first introduced (some three decades ago), the area under drip irrigation has expanded rather sluggishly from 1,500 ha in 1985 to a little over 70,000 ha in 1992 (Chakravarty and Singh 1994) and rapid growth has only been seen in recent years as the area spread to 2, 25,000 ha in 1998 (Polak and Sivanappan 1998). However, this is still miniscule when compared with the estimated potential of 10.50 million ha (Sivanappan 1994). Despite active promotion by a growing private irrigation equipment industry and subsidies (up to 90 %) offered by the government, the appeal of these technologies has remained confined only to 'gentlemen farmers' (Shah and Keller 2002). Recent research suggests that when faced with groundwater stress; the same farmers who have rejected the capital intensive subsidized drip systems have innovated and embraced low-cost grassroots innovations such as *Pepsee* drips[12] which act as stepping-stone technologies. How quickly and to what scale will these technologies expand? What would be the net impact of 'more crop per drop'?

The impact of GM technologies, which for obvious reasons was not taken into account, could be another significant factor. So far, much of the debate on GM technologies in India has been concentrated around cotton rather than food crops. How the GM revolution can change the paradigms of food security needs to be studied in detail. Will future technologies offer seed varieties which will produce much more food grain for the same amount of water? What could be the implications of such technologies for the poor and for under-developed and developing countries? What kind of global system of governance will evolve to govern the GM revolution? Will intellectual property rights (IPRs) and patents play a big role in determining dominance in the global food business? What would all this mean for India?

Then, there are certain 'horizon' technologies like the system of rice intensification (SRI) which promise to improve water use efficiency. SRI is drawing attention world-wide as a compact of paddy cultivation practices that boost paddy yield while reducing water use and cost of

[12] *Pepsee* systems are low-cost substitutes for drip irrigation systems made up of low density polythene ranging from 65 to 130 microns. At less than half the price of conventional drip systems, this grassroots innovation promises comparable results and has become very popular among cotton farmers in the Maikaal region of central India (Verma et al. 2004).

cultivation. Developed after over two decades of experimentation in Madagascar, under conditions not very different from those in India, SRI promises a significant increase in rice yields without the introduction of new varieties of HYV seeds or increase in external chemical inputs and, most importantly, with much reduced water use. This technology has been successfully tried with farmers in Sri Lanka, Tamil Nadu, Karnataka and Andhra Pradesh and by PRADAN with poor farmers in Purulia. In regions where paddy cultivation is central to rural livelihood systems, such as tribal Orissa, Jharkhand and Chattisgarh, SRI holds out a big promise that needs to be vigorously explored (Verma and Phansalkar 2004). Though there is little empirical data on SRI in India, data from other countries suggests it might become the mainstream practice in the years to come and could well be the ‘next-big-thing’ in rice cultivation. In Madagascar, average paddy yields among adopter farmers rose from 2 to 8 tonnes/ha. Is the promise offered by SRI too good to be true? Can such high yields be sustained in the long-run without affecting soil fertility?

Efficiency and Productivity Gains

(a) The Surface Irrigation Challenge

The efficiency levels at which surface irrigation projects work in most parts of the country does not require great elaboration. The Planning Commission contends that a mere 10 % increase in the efficiency of the existing irrigation infrastructure would lead to water supply to 14 million additional hectares of agricultural land[13].

The commission has projected that India’s surface irrigation systems will work at 40, 50 and 60 % efficiency levels in 2010, 2025 and 2050, respectively. How these incredible efficiency gains will be achieved is mostly left to the readers’ imagination. The commission has suggested that “all state irrigation acts have to be amended to incorporate provision for the formation of

[13] In a series of exchanges between noted water sector stalwarts Ramaswamy R. Iyer and Radha Singh, in the Economic and Political Weekly, the latter remarked (Singh 2003):

> *“Conceding that the efficiencies of our water systems, especially irrigation, must be improved, the efficiencies within the major and medium sector (irrigation) are around 40 %, while in the minor and groundwater sectors it is above 60 %. With a delta of 0.95 m, total water use in major and medium irrigation sectors would be 37 MHa × 0.95 = 351 BCM. Improvements in efficiencies within this sector would render an additional availability of approximately 52 BCM which, though significant, is hardly enough to counter the widespread scarcity prevalent in numerous basins of our country.”*

It is not clear as to how the figure of 52 BCM has been arrived at. If 351 BCM is taken to be a correct estimate, and assuming that surface irrigation projects do operate at 40 % efficiency level (which is the level that the commission projects India’s surface irrigation projects will achieve by 2010), it would mean that the amount of water which actually reaches the farmers’ fields would be 351*0.40 = 140.40 BCM. Assuming that no additional surface irrigation projects are commissioned, with improvement in efficiency from 40 % to 60 %, this should change to 351*0.60 = 210.60 BCM. The additional availability, therefore, can be calculated as 210.60 - 140.40 = 70.20 BCM. Again using the commission’s own assumptions of water required to grow food grains, this additional 18.20 BCM water (which we just now discovered; 70.20-52) would amount to an additional food production of roughly 12 million tonnes!

farmers' bodies." It then proceeds to review performance of user managed irrigation systems in nine major states and concludes that their performance is far from satisfactory. Irrespective of the above, it hails the fact that over 25,000 water users' associations (WUAs), covering 5.8 Mha, have been created in various states.

Initiating a program for the user management of irrigation systems or the mere formation of irrigation communities will not automatically lead to improved efficiency in surface irrigation systems. One school of thought argues that even when successful, participatory irrigation management (PIM) only can help improve distribution efficiency, which, in any case, is only a small part of the overall efficiency[14]. Proponents of this school argue that the main culprit in poor efficiencies is the poor 'Main System Management'. Factors such as lower water availability, untimely and unreliable supply, lower storage capacity and higher conveyance losses vis-à-vis those assumed at the planning stage, are responsible for poor efficiencies. The pertinent questions, therefore, are: what kind of efficiency improvements (CE or DE or AE) can we achieve by 2050?; How, how much, and at what cost? To what extent will PIM or irrigation management transfer (IMT) salvage India's public irrigation systems? Is there a need to think of and experiment with alternative strategies and institutional arrangements for vitalizing this important sector?

(b) Relative Dependence on Surface and Groundwater

To us, there seems to be a distinct 'surface water bias' in the commission's estimates. It assumes that surface water will be used to meet 57–61 % agricultural; 53-59 % domestic and municipal; 70–71 % industrial; 77–81 % power generation; and 100 % of all other requirements. Recent studies, however, indicate that groundwater might be contributing much more than is commonly understood. While the commission estimates that the total groundwater use in 2010 will only be around 230 BCM, recent estimates of present groundwater use already exceed this number. According to the Central Ground Water Board (CGWB 1995), the groundwater provision for domestic, industrial and other (nonagricultural) uses totals to 71 BCM. If we add to this, the estimate for groundwater use in agriculture by Shah et al. 2003, 210 BCM, the total groundwater use in India can be estimated as 281 BCM. Thus, in all, anywhere between 250 and 300 BCM of groundwater is currently being used[15]. Compared to this, the commission estimates that total groundwater use in 2010 will be around 230 BCM.

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[14] According to the International Commission on Irrigation and Drainage (ICID), Overall Efficiency (E) = CE * DE * AE where,
CE = Volume of water delivered to the distribution system / Volume of water delivered at the canal head;
DE = Volume of water delivered to the field / Volume of water drawn from the distribution system;
AE = Volume of water made available to crops / Volume of water drawn at the field head.

[15] Here, it is important to note that a part of the groundwater use is caused not directly by rainfall recharge but by the return flows from irrigation caused by the inefficiencies in irrigation. However, the degree of this overlap is difficult to measure and quantify.

Other Macro Variables

(a) Changes in India's Macro Hydrology

With a predominantly agrarian economy and a 7,000 km long, densely populated, and low lying coast-line, the impact of climate change in India can be expected to be significantly higher than that suggested by the 'token provisions' made for by the commission. The most immediate impact of higher temperatures on India's water resources would be in the form of higher rates of evaporation. Potential changes in temperature and precipitation might also have a dramatic impact on soil moisture and aridity levels of hydrological zones, besides changing evapotranspiration, runoff coefficients, river flows and groundwater recharge.

Research carried out by the Hadley Centre[16] indicates that the mean annual runoff in Brahamaputra would decline by 14 % by the year 2050. The Intergovernmental Panel on Climate Change has predicted a likely increase in the frequency of heavy rainfall in South Asia (IPCC 1998) and notes that the impacts of climate change in India will be felt more directly in the western Himalayas as the contribution of snow to the runoff of major rivers on the western side is about 60 % compared with 10 % on the eastern side (IPCC 2001).

How real and how significant will be the impact of climate change in the context of water resource availability and use? These potential implications need to be brought into the prognoses for India 2050.

(b) Virtual Water Trade and Food Policy

Much of the projections made by the commission are based on the assumption that India will continue to pursue its policy of food self-sufficiency. At present, much of India's foodgrains are produced in a handful of states, all of which are facing water shortages and groundwater depletion. On the other hand, India's water rich regions, such as states in eastern India, are importing food from these states since they are unable to produce enough to meet their requirements. If we view this inter-state food trade within India as trade in 'Virtual Water'[17], we see that water-scarce regions in India are exporting virtual water to water rich regions, thereby exacerbating the water crisis. In part, this is due to the food procurement policies of the Government of India, which encourage states like Punjab and Haryana to grow foodgrains by offering them assured markets, lucrative prices and several input subsidies including those for electricity and fertilizers. On the other hand, farmers in water rich states are facing higher

[16] www.metoffice.com/research/hadleycentre

[17] 'Virtual Water' refers to the volume of water needed to produce agricultural commodities. When a commodity (or service) is traded, the buyer essentially imports (virtual) water used in the production of the commodity. In the context of international (food) trade, this concept has been applied with a view to optimizing the flow of commodities considering the water endowments of nations. Using the principles of international trade, it suggests that water-rich countries should produce and export water intensive commodities (which indirectly carry embedded water needed for producing them) to water-scarce countries, thereby enabling the water-scarce countries to divert their precious water resources to alternative, higher valued uses (Allan 1998, Hoekstra 2003, Wichelns 2004).

input costs and are able to derive lower market prices for their produce. This has lead to a stagnant, low-input agriculture, resulting in sustained poverty. Some of the best water endowed states are also the poorest. If, however, food policies were to be re-aligned to favor water rich regions to encourage them to grow more foodgrains, India's food demand and supply scenarios would drastically change (Verma 2007; Verma et al. 2008a).

(c) Water Intensity of Rural Livelihoods

Agriculture continues to be the biggest absorber of people in India and even if food security concerns were to be met otherwise, people will continue to depend on agriculture for their livelihoods and, therefore, will continue to demand water for irrigation. It therefore becomes important to make studied projections as to what proportion of the country's population will continue to depend on agriculture through to 2050.

As of now, some 64 % of the population in the country derives its livelihoods substantially from agricultural operations: either as cultivators or as agricultural wage laborers. The share of agriculture in GDP has fallen to about 29 % nationally. This fall in share of agriculture in GDP is accompanied by a much smaller fall in the proportion of the people deriving their livelihoods from agriculture. For instance, agriculture contributes only 13 % to the state domestic product in Gujarat while it continues to support 45 % of the main workers. While on the one hand, this indicates the declining share of agriculture, it also perhaps indicates large-scale diversification in rural livelihoods.

The important questions to address are (1) How water-centric will rural livelihoods be in the future[18]?; and (2) Even if a large number of people move out of agriculture, would it mean a reduction in cropped and irrigated area?

The Emerging Agenda for 'Water Future' Research

While the conservative estimates of the commission paint quite a grim picture of India's water future, it must be granted that if no corrective action is taken, no forward planning is done and nothing is done to change the wasteful and inequitable use of water, the situation could well be like the one depicted by the commission. However, the broad statement of the demand and supply as made by the commission is only the canvass; the actual picture will emerge only with people responding to the crisis as they see it cropping up. The report thus offers a good base, a starting point, which needs to be worked and built upon, rather than accepting it as the last word. The authors of the report too were, perhaps, quite aware of some of the inherent drawbacks which might have resulted from the paucity of available data and analyses. That is why even the report itself does not shy away from categorically stating that:

> *"…These estimates should be treated basically as approximations…It would be desirable to review these estimates regularly, say, at the interval of 5-10 years."*

[18] See Phansalkar 2005 for a detailed discussion on this issue.

Table 8 summarizes the foregoing discussion and presents a framework for 'water future' research. While each of these individual studies are important in themselves and may require a diverse set of expertise and competencies, on their own, they might not provide an overview of India's water challenge in 2050. A good prognosis, rather than suggesting definitive answers to how much water India will need in 2050, will generate alternate policy scenarios and sensitivity analyses. Which of the scenarios will be closest to the reality in 2050 will depend on the robustness of the assumptions and on the path India chooses to take over the coming decades.

Table 8. The emerging agenda for 'water future' research.

Theme	Studies	Issues
Rethinking water availability and demand	Managing 'deductions-at-source'	Adding 'accounted' water; forest-water linkages; non-crop ET; sea-water intrusion
	Decentralized water harvesting	Upstream-downstream conflicts; Which water to harvest and where?
	Desalination: How much freshwater can it add (and at what cost)?	Potential of desalination for meeting urban water requirements; costs of desalination
	Wastewater irrigation: boon or bane?	Wastewater economy; Direct and indirect health impacts of wastewater irrigation
	Will requirements expand to fill free supply?	Requirement-demand gaps; pricing and quality of supply; coping mechanisms
Demographic projections	Implications of HIV/AIDS	With and without, high and low HIV/AIDS scenarios
	Urban century	Urbanization trends in India and regional variations
Liberalization of food trade	Impact of world food trade on India's food security	WTO/GATT; food self-sufficiency policy; Chinese food policy; world food prices
Modernization of Indian agriculture	Water saving irrigation technologies	Potential and spread of drip and sprinkler technologies
	GM revolution	Impact of high productivity GM crop varieties
	Horizon technologies	Potential impact of horizon technologies such as SRI
Efficiency and productivity of agriculture water use	Surface irrigation efficiency	PIM/IMT; alternate institutional arrangements; CE-DE-AE
	Future sources of growth in India's water resources	Relative importance of surface and ground water
Macro Variables	India's macro hydrology	Climate change impact on evaporation, ET, Run-off, rainfall, agricultural productivity
	Virtual water trade and Food policy	Food self-sufficiency; food procurement policy; input subsidy concentration
	Rural livelihoods	Water intensity of rural livelihoods; occupational structure

One of the windfalls of the entire debate on NRLP has been a heightened interest among the scientific community in projections about 'India's water future'. Perhaps prompted by the estimates made by NCIWRD, there have been some attempts at the arguably difficult exercise of predicting the future. Irrespective of whether the river linking plan finally gets implemented or not, we believe that it provides an excellent opportunity for India to review its preparedness for meeting the challenge ahead. Admittedly, our analysis raises more questions than we attempted to answer but we hope that this will trigger a studied debate on this very important theme.

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