CPWF Project Report

Strategic Analysis of India's River Linking Project

Project Number PN 48

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International Water Management Institute

for submission to the

CGIAR Challenge Program on
WATER & FOOD

August 2009

Acknowledgements

The financial support for the project by the "Challenge Program for Water and Food," of the Consultative Group of International Agriculture Research Institutes is greatly acknowledged.

The project greatly appreciates the comments and suggestions made by the members of the project advisory committee chaired by Prof. M.S. Swaminathan. The other eminent members of this committee included Prof. Yojindra K. Alagh, Prof. Vijay S. Vyas, Prof. Kanchan Chopra, Prof. Vandana Shiva, Prof. Frank Rijsberman, Shri Anil D. Mohile, Shri S. Gopalakrishnan and Shri Deep Joshi. Their guidance at various stages of the project was immensely helpful.

The project management team acknowledge the assistance of various government institutions for providing the necessary data and published documents for this project. A special thank goes to the Central Water Commission of India for providing the flow data of various river basins in India. Many of the studies would not have been able to to be completed to our satisfaction without the river flow information.

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Program Preface

The Challenge Program on Water and Food (CPWF) contributes to efforts of the international community to ensure global diversions of water to agriculture are maintained at the level of the year 2000. It is a multi-institutional research initiative that aims to increase water productivity for agriculture—that is, to change the way water is managed and used to meet international food security and poverty eradication goals—in order to leave more water for other users and the environment.

The CPWF conducts action-oriented research in nine river basins in Africa, Asia and Latin America, focusing on crop water productivity, fisheries and aquatic ecosystems, community arrangements for sharing water, integrated river basin management, and institutions and policies for successful implementation of developments in the water-food-environment nexus.

Project Preface

"The Strategic Analysis of India's National River Linking Project" : In 2005, the International Water Management Institute (IWMI) and the Challenge Program on Water and Food (CPWF) started a three-year research study on "Strategic Analysis of India's River Linking Project". The primary focus of the IWMI-CPWF project is to provide the public and the policy planners with a balanced analysis of the social benefits and costs of the National River Linking Project (NRLP).

The project consists of research in three phases. Phase I analyzed India's water future scenarios to 2025/2050 and related issues. Phase II, analyses how effective a response NRLP is, for meeting India's water future and its social costs and benefits. Phase III contributes to an alternative water sector perspective plan for India as a fallback strategy for NRLP.

CPWF Project Report Series

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EXECUTIVE SUMMARY

Coping with annual floods and droughts, both occurring at the same time in different parts, has been a major concern for India over the millennia. These concerns are more acute today as the growing population and the resultant water demand places a heavy burden on the unevenly distributed water resources, and also causes huge economic losses to the vulnerable population. Additionally, there is a huge demand for water to enhance and diversify food production to meet the supply needs of a vast population with changed consumption patterns and higher disposable incomes.

Designed to address these concerns, the National River Linking Project [NRLP] envisages transferring water from the potentially water surplus rivers to water scarce western and peninsular river basins. The NRLP will build 30 river links and some 3,000 storages to connect 37 Himalayan and Peninsular rivers to form a gigantic South Asian water grid. But, the proposed project is a major contentious issue in public discourses in India and outside India. These issues range from dubious project design, negative environmental impacts, huge social and financial cost, and available less costly demand management options. On the other hand, the proponents consider NRLP as the best option for facing India's turbulent water futures. However, many of the arguments, for and against the NRLP project so far, are based on assertions and opinions, and lack analytical rigor. The NRLP of the International Water Management Institute (IWMI) under the aegis of the Challenge Program on Water for Food (CPWF) designed to address this inadequate rigor in the analysis and inform public in their discourses on the NRLP.

Phase I of the project analyzed scenarios and issues of India's water futures. There are clear trends that India will require substantial additional water supply to cater to increasing demand in the coming decades. According to the recent growth patterns, the future demand is projected to increase by 22 and 32% by 2025 and 2050. The population and economic growth, increasing world trade, the changes in lifestyles and food consumption patterns, technological advances in water saving technologies are the most influential primary drivers of India's water future in the short to medium term.

Over the last two decades, groundwater has been the major source for meeting increasing demand in all sectors. It is highly likely that this trend will continue. However, many river basins will have severe water stress conditions under business as usual water- supply and use patterns. With increasing reliance on groundwater, particularly for irrigation, many river basins will have severe groundwater over-exploitation related problems. Indeed, meeting India's short to medium term water demand itself will be a challenging task.

However, many options are available to meet this challenge. Recharging groundwater to increase the groundwater stocks; harvesting rainwater for providing the life-saving supplemental irrigation; 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; increasing research and extension for enhancing agriculture water

productivity; and carefully crafted virtual water trade between basins are important policy options for meeting the increasing demand.

However, with increasing disposable income, people's affordability and willingness to pay for a reliable domestic and industrial water supply will increase. This, along with a reliable water supply for diversifying high value cropping patterns, may require large surface water transfers. The inter-basin water transfers could increase the recharge groundwater in many over-exploited area. While artificial groundwater recharge, rainwater harvesting, and inter-basin water transfers are a solution for meeting the water demand in the near-term, they are also solutions for increasing the potential utilizable water supply in many water scarce river basins. They will indeed have major benefits when full influence of the climate change starts to impact the utilizable supply in many water scarce river basins.

Phase II of project analyze how effective a response NRLP is for meeting India's water futures and its social costs and benefits. Studies of the proposed links in also show inadequate detailed planning in the proposed links. Assessment of available water surplus in river basins should receive significant attention. Future water requirements of different water users within the basin, whether for irrigation, domestic or industrial uses and most importantly for the downstream riverine environment should be assessed before deciding the surplus. It is important to consider water availability at shorter time periods, at least monthly for evaluating the water availability. In the absence of such an analysis, more water is perceived to be available for transfers at different location.

The cropping patterns proposed under the new links also need revisiting. The cropping patterns in the existing irrigated areas are more high-value than those in the proposed irrigated areas. Rice dominates proposed cropping patterns, whereas rice irrigation is decreasing in nearby existing irrigation schemes. Irrigation will be available when rainfall meets most of the irrigation requirement. Many of the proposed links will not be financially viable under the proposed cropping patterns, and yields low net value addition per each additional drop of irrigation water delivery. However, financial benefits from high-value cropping patterns exceed the costs in many instances. When the system is considered as a large project with several smaller schemes, financial benefits are seemed to exceed the project cost, which only include the capital and operation and maintenance cost. Whether, the social cost, when the cost of environmental impacts and rehabilitation and resettlement of displaced people are included, will exceed the net value added benefits is not clear.

When water is proposed to be transferred across the basins, on most occasions the interests of donor and the recipient regions (states/ countries) are at conflict and need to be resolved through innovative win-win solutions. In the absence of mature and experienced river basin organizations and well-established sharing mechanisms, the issues involved are sure to become more complex than the hydraulic structures and, have the potential to become the first stumbling block in the process of water transfer. The associated and equally important issue is the properly designed, disseminated and implemented rehabilitation and relief package for the project affected people. As the land is becoming scarce and valuable and civil society organizations more vocal and effective, the acquisitions must be handled with great sensitivity, tact and empathy.

Phase III analyzed some alternative options that contributes to a water sector perspective plan for India. Improving water productivity, improving rainfed agriculture, water demand management, carefully crafted plan of virtual water trade between states and groundwater recharge and water harvesting have a significant potential managing the demand and augmenting the supply for meeting future water needs.

Water productivity improvement by far h33as biggest potential contribution to an alternative strategy. The strategies of water productivity improvements include, providing full irrigation to meet the full crop evapo-transpirative demand or providing supplemental irrigation in critical periods of crop growth for the rainfed crops for increasing the crop yield; replacing long duration food crops with higher water use efficiency by short duration ones with low efficiency and growing crops in regions where their yields are higher due to climatic advantages or better soil nutrient regimes or lower ET demand; practicing deficit irrigation in areas where yield is large and consumptive water use is very high; improving quality and reliability of irrigation water; managing irrigation for certain crops by controlling allocation or increasing allocation to the said crops; and adoption of high yielding varieties without increasing the crop consumptive use. However, in spite of these large opportunities, there are many constraints for increasing water productivity. Some of the policy recommendations to overcome constraints include: improving the quality of irrigation water supplies from canal systems; improving quality of power supply in agriculture in regions that have intensive groundwater irrigation and improving electricity infrastructure in rural areas of eastern India ; provision of targeted subsidies for micro irrigation systems in regions where their use result in major social benefits; investing in rainwater harvesting for supplementary irrigation in rainfed districts; rainwater harvesting and irrigation infrastructure for supplemental or full irrigation would significantly enhance crop yields in many, and water productivity in some rain-fed areas.

Demand management of irrigation water also has a large potential for contributing to an alternative strategy. An effective demand management strategy can both expand irrigation and also release water for other productive uses even at the current level of water use. Some of the options can have immediate effects and some others have the potential to influence water allocation and use. The demand management options, including water pricing, formal and informal water markets, water rights and entitlement systems, energy-based water regulations; water saving technologies; and user and community based organization etc., however, differ considerably in terms of the scope for adoption and implementation. The two central problems limiting the impacts of demand management are their limited geographic coverage and operational effectiveness. Although the effectiveness of demand management options are constrained by several institutional, technical and financial factors, a lack of well articulated policy, both at the state and at the national level, is the major bottleneck and implementing water demand management both at the national and state levels. Such a policy provides the basis for the much needed financial and political commitments for implementing effective demand management programs.

Groundwater recharge should be an essential part of the water augmentation strategy in the future. Groundwater is the source for more then two-thirds of the area at present, and many of areas suffer due to over-exploitation. In spite of the over-exploitation, due to easy control and larger benefits, dependency on groundwater irrigation is increasing both spatially and temporally. Thus, artificial groundwater recharge and managing groundwater aquifers are essential in future strategies. However, present National Master Plan of Groundwater Recharge requires changing focus and priorities. Master plan should focus more on demand side principle where it should recharge more in areas where groundwater use is heavy and depletion is higher than where water is abundant and demand is low; optimize allocation of financial resources by allocating according to the degree of depletion of resources; have a clearly defined pathway of implementation, indicating the role of different agencies in supervising implementation and monitoring the performance; consider appropriate strategies for the sustainability of the recharge structures; seek active participation of local stakeholders; understand and respect the contextual specificities of ground water depletion; and harmonize priorities with stakeholders' needs. Such a recharge plan can utilize the millions of dugwells blotting various part of rural landscape to benefit both irrigation, drinking water supply and environmental needs.

INTRODUCTION

India is a vast country and its water availability varies significantly across regions and river basins. Water is in plenty in the north-eastern region, but few people live there and food production is low. In the north-western region most of the water resources are diverted for crop production, to such an extent that this region supplies food to the food deficit regions of the country, making it the largest provider of virtual water, that is, the water embedded in food. Water is scarce in the southern and western parts of the country, as the naturally drier areas come under increasing demand. Recurrent floods in the east and droughts in the south and west compound water related challenges that India is facing today. All indications are that India is heading towards a turbulent water future (World Bank 2005).

Coping with annual floods and droughts, both occurring at the same time in different parts, has been a major concern for India over the millennia. These concerns are more acute today as the growing population and the resultant water demand places a heavy burden on the unevenly distributed water resources, and also causes huge economic losses to the vulnerable population. Additionally, there is a huge demand for water to enhance and diversify food production to meet the supply needs of a vast population with changed consumption patterns and higher disposable incomes.

Designed to address these concerns, the National River Linking Project [NRLP] envisages transferring water from the potentially water surplus Himalayan rivers to water scarce western and peninsular river basins (NWDA 2006). The NRLP will build 30 river links and some 3,000 storages to connect 37 Himalayan and Peninsular rivers to form a gigantic South Asian water grid. But, the proposed project is a major contentious issue in public discourses in India and outside India. On the one hand, opponents argue that the concept of NRLP itself is dubious and the water need assessment of the project is not adequate. The environmentalist view is that the assessment of water surpluses in river basins has ignored many eco-system water needs. Activists say NRLP will displace millions of poor, mainly tribal population. And, others argue that the alternative water management options are less costly, easily implementable and environmentally acceptable. On the other hand, the proponents vision NRLP as the best option for facing India's turbulent water futures. They argue that NRLP will increase the potentially utilizable water resources and address the regional imbalances of water availability due to spatial variation of rainfall. However, many of the arguments, for and against the NRLP project so far, are based on assertions and opinions, and lack analytical rigor.

The International Water Management Institute and the Challenge Program for Water under the Consultative Group on International Agricultural Research (CGIAR), have started a three year research project for assessing India's Water Futures to 2025/2050 and analyzing what alternative options, including the River Linking project, are adequate for meeting the future water challenges (CPWF 2005). The research project also attempts to fill the void of analytical rigor in the discourse on the NRLP to date. The specific objectives of the project are to

- Assess the most plausible scenarios and issues of water futures given the present trends of key drivers of water demand,

- Analyze whether the NRLP as a concept can be an adequate, cost effective and a sustainable response in terms of the present socio-economic, environmental and political trends, and if India decides to implement it, how best the negative social impacts can be mitigated, and
- Contribute to a plan of institutional and policy interventions as a fallback strategy for NRLP and identify best strategies to implement them.

Phase I of the project focused on analyzing India's water future scenarios up to 2025/2050 and issues related therewith. This sets the stage for analyzing options for meeting water futures. Phase II, analyses how effective a response NRLP is for meeting India's water futures and its social costs and benefits. Phase III contributes to an alternative water sector perspective plan for India as a fallback strategy for NRLP. The project carried out large number of research activities in different stages. The findings of the project shall add value to the on going debate on the NRLP, which is important to India and also to the neighboring countries of the region. The results[1] of various research activities are contained in a series of volumes of project reports including,

- NRLP Series I: India's Water Futures: Scenarios and Issues (Amarasinghe, Shah and Malik, Eds 2009a),
- NRLP Series II: Proceedings of the Workshop on Analyses of Hydrological, Social and Ecological Issues of the NRLP (Amarasinghe and Sharma, eds, 2008a)
- NRLP Series III: Promoting Irrigation Demand Management India: Potentials, Problems and Prospects (Saleth, ed 2009)
- NRLP Series IV: Towards a Water Sector Perspective Plan: Contributions from Water Productivity Improvements (Kumar and Amarasinghe, Eds. Forthcoming)
- NRLP Series V: Strategic Issues on Indian Irrigation. (Forthcoming)
- NRLP Series VI: State of the Irrigation in Tamil Nadu (Palanasami et al 2009a)

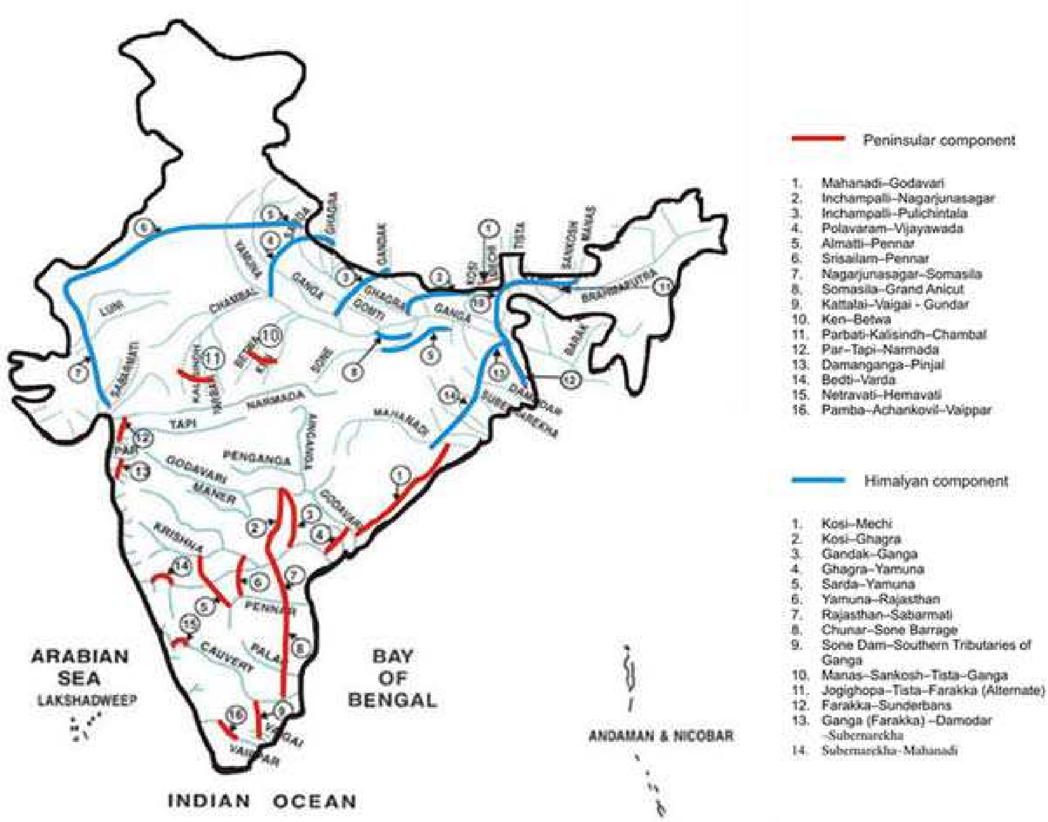
This report, which highlights the findings of the project, has three parts. First we start with a brief synopsis of the NRLP project. Next, Part I deals with scenarios and issues of India's water futures. Part II highlights social cost and benefits issues of the proposed National River Linking Project, and approaches for minimizing the cost should the proposed project, or part of it is implemented. Part III discusses few strategies that can contribute to an alternative perspective plan.

India's National River Linking Project - A Synopsis

The National River Linking Project (NRLP) envisages transferring water from the surplus river basins to ease the water shortages in western and southern India while mitigating the impacts of recurrent floods in eastern India. NRLP constitutes two basic components — the links which will connect the Himalayan rivers and those which will connect the peninsular rivers (figure 1). When completed, the project would consist of 30 river links and 3,000 storage structures to transfer 174 billion cubic meters (Bm^3) of water through a canal network of about 14,900 kilo meters (km).

[1] Some of the results are published in peer-reviewed journals (see annex A for the list of these articles)

Figure 1. The Himalayan and peninsular components of NRLP project.



Components of the NRLP

The Himalayan component proposes to transfer 33 Bm^3 of water through 16 river links. It has two subcomponents linking:

1. Ganga and Brahmaputra basins to Mahanadi basin (links 11-14), and
2. Eastern Ganga tributaries and Chambal, Sabramati river basins (links 1-10).

The Peninsular component proposes to transfer 141 Bm^3 water through 14 river links. It has four subcomponents linking

1. Mahanadi and Godavari basins to Krishna, Cauvery and Vaigai rivers (links 1-9);
2. West-flowing rivers south of Tapi to north of Bombay (links 12 and 13);
3. Ken River to Betwa River and Parbati, Kalisindh rivers to Chambal rivers (links 10 and 11); and
4. some west flowing rivers to the eastern rivers (links 14 -16).

Project Benefits

The NRLP envisages to:

- provide additional irrigation to 35 million ha of crop area and water supply to domestic and industrial sectors;
- add 34 GW of hydro-power potential to the national grid;
- mitigate floods in eastern India; and

- facilitate various other economic activities such as internal navigation, fisheries, groundwater recharge, environmental flow of water-scarce rivers etc.\

The NRLP, when completed, will increase India's utilizable water resources by 25 %, and reduce the inequality of water resource endowments in different regions. The increased capacity will address the long ignored issue of increasing India's per capita storage, which currently stands at a mere 200 m3/person as against 5,960; 4,717 and 2,486 m3/person for the US, Australia and China, respectively.

Project Costs

The NRLP will cost more than US$120 billon (in 2000 prices), of which

- the Himalayan component costs US$23 billion,
- the Peninsular component costs US$40 billion, and
- the hydro-power component costs US$58 billion.

Contentious Issues

The NRLP has many contentious issues to tackle, and these include the following:

- Resource mobilization, despite the fact that India finds it difficult to finance the completion of even the existing uncompleted projects;
- Environmental concerns, as it will increase seismic hazards, transfer river pollution, destroy forest and biodiversity, and
- change the ecological balance of land and oceans, and freshwater and sweater ecosystems;
- Social issues, as it will displace more than 580,000 people under the peninsular component alone, and submerge large areas of agriculture and nonagricultural land; Cost recovery issues, as the interest on the capital during the construction could be twice the estimated cost, and the annual installment and interest on the capital could be more than Rs. 17,000/acre; and
- Political issues, which include issues regarding Interstate water transfers, and transfers between riparian countries-Nepal, Bangladesh and Bhutan.

PROJECT OBJECTIVES

Objective 1: Assess the most plausible scenarios and issues of water futures given the present trends of key drivers of water demand

India's Water Futures: Drivers, Scenarios and Issues

India is indeed a large country in many aspects that water has an intimate relationship. With more than one billion people, it has the world's second largest population now, behind China, and will have the world's largest population by the middle of this century. With more than a quarter of the population active in agriculture economic activities, it also has the world's second largest population whose livelihoods directly depend on agriculture. With agriculture supporting livelihoods of a large a population, India also has the world's largest cropped area. With large crop areas under arid to semi-arid climatic conditions, it also has the world's largest irrigated area. With foodgrains as the staple food, India is the world's largest consumer and producer of cereals and pulses, and most of that, produced under irrigated conditions. With milk as the major animal product in the diet, Indian agriculture raises the world's largest cattle and buffalo population. And above all, it has the world's largest poor population and the majority of them lives in rural areas and depends for their food security and livelihood on subsistence agriculture. And, India is also one of the large economies in the world with an impressive economic growth in recent years. Indeed, water has an important relationship to many of the above. And, water has shown to play an increasingly integral role in the rural livelihoods and economic growth.

Many drivers, either exogenous or endogenous to water system influence India's water futures (IWMI 2005). The exogenous drivers are mainly the primary drivers that set the direction of water futures. Some of the key drivers that are exogenous to water system of India are:

- changing demographic patterns,
- nutritional security and rural livelihood security,
- changing life style and consumption patterns,
- national food self sufficiency,
- economic growth of India and that of other major regional economic powers,
- globalization and increasing world food trade,
- participation of private sector and non-governmental organizations,
- political stability and relations between states and neighbouring countries,
- technological advances, especially in water saving techniques, and
- global climate change.

The endogenous drivers to water system of a country are secondary drivers. They often are responses to the directions set by the primary drivers. Some of the key secondary drivers of the water futures of India are:

- changing agriculture demography,
- increasing water productivity,
- expanding groundwater irrigation and over-exploitation,

- improving rainfed agriculture,
- artificial groundwater recharge,
- rainwater harvesting,
- environmental water needs,
- recycling of urban waste water and marginal or poor quality water use,
- advancements in biotechnology, and
- desalinization etc.

Various assumptions on the direction and magnitude of these key drivers give rise to different scenarios of water futures. For example, nutritional security of all the people, livelihood security of rural population and food self-sufficiency of India were primary drivers of future water demand projections of the National Commission of Integrated Water Resources and Development (NCIWRD) (GOI 1999). Two population growth scenarios have given rise to the NCIWRD's low - and high -water demand projections (Verma and Phansalkar 2009). The NCIWRD scenarios are considered to be the blueprint for future water development of India. And, the NRLP was virtually triggered by the projections of the NCIWRD high-water demand scenario. These scenarios were developed using the information on primary and secondary drivers available at the time of their projections. But the settings that surround these assumptions constantly change. A slight change of the assumptions of key primary drivers could significantly change the direction and magnitude of secondary drivers, and accordingly, the outcome, that is India's water futures (Amarasinghe et al. 2007a, Verma and Phansalkar 2009).

To what extent can the magnitude of these key drivers change in the future? The magnitude of the changes depends on vital turning points of primary drivers and the responses to them thereafter. Many turning points, which are usually difficult to predict, are mainly based on unforeseen human actions, political compulsions or natural catastrophes. Although turning points are difficult to predict, past trends of secondary drivers, which are largely the human responses to turning points, offer the best guide for us to extrapolate the likely course of trends to assess scenarios of water futures and explore policy options for meeting them. The assumptions of the primary and secondary drivers of the NCIWRD were mainly based on the priorities and trends in the 1980's. Before 1990's, livelihoods of a significant part India's rural population largely depended on agriculture. And, agriculture was the main engine of economic growth. With a large rural population and low foreign exchange reserves for large food imports, rural livelihood security and national food self-sufficiency were high priority then. However, the economic liberalization, which started in early 1990, has changed the course of many drivers.

In Part I of the report, we highlight the turning points and recent trends of key drivers and their implications on India's food and water future scenarios.

Water Supply Drivers

Total Renewable Water Resources

The total renewable water resource (TRWR) of a country is the amount of resources that are available for utilization within its borders. The TRWR consists of water resources generated by endogenous precipitation within the borders--the internally renewable water resources (IRWR), and the net inflow from other countries through natural processes or allocated by treaties--the externally renewable water resources (ERWR). With 1,896 billion cubic meters (BCM) of surface runoff—636 and 1260 BCM of ERWR[2] and IRWR—India has the 7th largest, and about 4% of the total renewable water resources (TRWR) of the world (CWC 2004). However, due to un-even rainfall, TRWR vary significantly across river basins (table 1). Basins in the north and east, Ganga, Brahmaputra and Meghna, Mahanadi and Godawari, have most of India's IRWR (table 1).

Climate change, an exogenous driver to the water system, increases the spatial and temporal variation of TRWR. Recent studies show that with climate change, Mahanadi, Brahmani, Ganga and Godavari will experience higher precipitation and larger surface runoff, while many peninsular basins will experience lower rainfall and lower surface runoff (Gosain et al. 2006[3]). Although, the aggregate of TRWR at the national level show no major changes, regional disparities are likely to increase further. Moreover, with increasing incidence of high-intensity short-duration rainfall events due to climate change, the temporal variation of surface runoff will also increase (Mall et al. 2006).

Table 1. Water Resources of India.

River basins	Total water resources (TRWR)	Utilizable surface water resources	Total ground water resources	Potentially utilizable water resources (PUWR)	PUWR - % of TRWR
	Bm^3	Bm^3	Bm^3	Bm^3	%
Indus (Up to border)	73.3	46.0	27	72.5	99
Ganga	525.0	250.0	172	422	80
Brahmaputra and Meghna	585.6	24.0	36	60	10
Subernarekha	12.4	6.8	2	9	70
Brahmani-Baitarani	28.5	18.3	4	21	74
Mahanadi	66.9	50.0	17	66	99
Godavari	110.5	76.3	41	117	106
Krishna	78.1	58.0	26	84	108
Pennar	6.3	6.9	5	12	187
Cauvery	21.4	19.0	12	31	147
Tapi	14.9	14.5	8	23	153
Narmada	45.6	34.5	11	45	99
Mahi	11.0	3.1	4	7	64
Sabarmati	3.8	1.9	3	5	135
WFR1[1]	15.1	15.0	11	26	173
WFR2[2]	200.9	36.2	18	54	27
EFR1[3]	22.5	13.1	19	32	142
EFR2[4]	16.5	16.7	18	35	212
Others[5]	31.0				
All Basins	1896	690	432	1121	59

Notes: 1- WF1 includes west flowing rivers of Kutch, Saurashtra including Luni; 2 – WF2 includes west flowing rivers between Tapi and Kanayakumari; 3. EF1 includes east flowing rivers between Mahanadi and Pennar; 4. – EF2 includes east flowing rivers between Pennar and Kanayakumari; 5 – Minor river basins drainage into Bangladesh and Myanmar.
Source: GOI 1999, CWC 2004.

With monsoonal weather patterns, most of the rain that contributes to TRWR in many river basins falls in less than 100 days in the summer months between June and September and a major part of precipitation falls in locations where surface runoff cannot be captured due to limited

[2] ERWR is the net inflow to India. Inflows to India are from Nepal and Burma and outflows from India are to Pakistan and Bangladesh.
[3] Brahmaputra and Indus were not included in this study.

storage potential. Therefore only a part of the TRWR can be stored or diverted for human use within a basin.

Potentially Utilizable Water Resources (PUWR)

The PUWR is the portion of the TRWR that can be captured for human use within a river basin. This depends on the variation of precipitation and the potential of storage and diversion facilities. For India, this is estimated to be only 58% of the TRWR. Among the river basins, Brahmaputra and Meghna have the largest TRWR, but with limited storage opportunities, only 10% of TRWR can be captured as PUWR (table 1).

The population growth, an exogenous driver to the water system, exacerbates the limitations of PUWR in some locations. The PUWR per person in India in the middle of this century is projected to be 701 m^3, which is only 22% of the PUWR per person in the middle of last century, indicating more than four-fold increase of population over this period (figure 2). Few basins, which are already water stressed now (Amarasinghe et al. 2007a), will have very low per capita PUWR by 2050. Such conditions--below 500 m^3 of per capita PUWR--are, as Falkenmark et al. 1989 described are extremely unhelpful even for human existence.

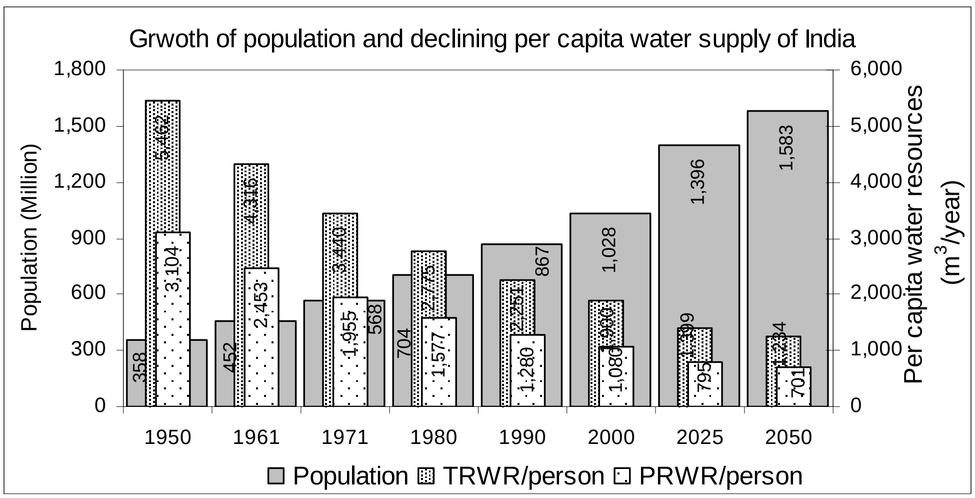


Figure 2. Growth of population and declining per capita water supply in India

Climate change, an exogenous driver to the water system could also reduce PUWR. With increasing incidence of high intensity and short duration rainfall events, the incidence of flash floods increases. Thus, the capacity to capture or divert water will diminish and as a result PUWR will reduce. The PUWR will also be reduced in basins that are predicted to have low rainfall and runoff. Although the magnitude of the reduction in PUWR is still not exactly clear, the PUWR of many Indian river basins could reduce with climate change.

However, various responses are available for augmenting PUWR in water stress regions. Rainwater harvesting (RWH), artificial groundwater recharge (AGWR), and intra - or inter-basin water transfers (IBWT) are three popular methods practised for augmenting PUWR. The RWH and AGWR are mainly local level interventions and they will generate immediate impacts in a neighbourhood of the location where water is captured. On the other hand, the IBWT, which generally requires large infrastructure development, including storage reservoirs, barrages, river links, and distributary canals etc., can increase water availability in far away locations from where water is originally stored or diverted. However, these interventions could incur social cost too. Extensive RW and AGWR in the up-stream of river basins, especially in those which are approaching closure, can impact the uses and users in the down-stream of a basin. The IBWTs can displace many people and submerge large areas of forest or productive land. Yet, all these interventions can have significant spatially distributional benefits. The main question here however is, that with a significant part of the precipitation occurring in short spells, how much can these interventions effectively augment PUWR in Indian river basins?

Rainwater harvesting: The extent that RWH can augment the PUWR depends on the capacity of RWH structures to store part of the un-utilizable water resources. The exact estimates of this are sketchy. The study by Sharma et al. (Sharma et al 2009a) using a district level analysis shows that 99 Bm^3 of surface runoff are available for rainwater harvesting in 25 million ha of rainfed lands. These lands exclude the extreme arid and extreme wet rainfed areas. However, whether all of this quantity of harvested water will augment the net PUWR is not clear. Some harvested water could well have been captured by reservoirs in the downstream, and may already have been included in the present estimate of PUWR. In spite of whether it net augments or not, the RWH is very useful for distributing significant positive benefits to vast areas that a few storage structures cannot provide. Sharma et al. study also showed that it requires only about 20 Bm^3 of the above runoff to be captured to bring relief to about 25 million ha of rainfed lands suffering from mid-seasonal droughts. If this portion can be part of the un-utilizable water resources, then it is only 2.5% of the un-utilizable runoff and augments the present estimates of PUWR only by 1.7%.

There are other viewpoints of RWH too. Kumar et al. (2008) argue that the impacts of many local watershed level RWH interventions will not always aggregate at the basin level. This argument is based on the premise that much of the water that RWH captures is part of the water already captured and used in the downstream. According to Kumar et al. the potential of RWH for net augmenting of PUWR in water scarce areas is low due to varying hydrological regimes, extremely variable rainfall events, and constraints of geology. Furthermore, the demand for water is low in locations where rainwater can sufficiently be captured, thus generating only a small economic benefit vis-à-vis to the cost of construction of many RWH structures.

Artificial Groundwater Recharge (AGWR):

The total renewable groundwater resource of India is estimated to be 432 BCM. For the country as a whole, only about 37% of the renewable groundwater resource is withdrawn at present. But, with intensive withdrawals for irrigation, groundwater resources of some regions are severely over-stressed. The number of over-exploited bocks is increasing, where groundwater abstraction well exceeds the replenishable recharge (CGWB 2008). Yet, the uses and users in the domestic, irrigation and industrial sectors that depend on groundwater are increasing. Sustaining the groundwater supply for various services, especially in the severely water stressed blocks and in areas approaching over-exploitation, and maintaining the base flow in rivers in the dry season is indeed a major challenge.

AGWR have the capacity to alleviate the stress in groundwater over-exploited areas. An ideal example is the mass movement of groundwater recharge in the Saurashtra region of western India (Shah 2000). According to the master plan prepared by the Central Groundwater Board, 36 BCM of un-utilizable surface runoff can be captured through AGWR (CGWB 2008). This augments India's PUWR by 3.4%. However, given the magnitude of the un-utilizable surface runoff, many considered this estimate to be quite low. In fact, Shah 2008 argues that groundwater recharge using the existing dug-wells alone can exceed the potential of AGWR estimated in the master plan. Regardless of the magnitude of the recharge, AGWR is an important tool for net augmenting the PUWR and distributing the hydrological and economic benefits, as in RWH, to vast areas.

Intra - or Inter-basin Water Transfers (IBWT):

The IBWTs perhaps have the potential for large net augmentation of PUWR. They can capture un-utilizable runoff of water surplus basins through large reservoirs or barrages, and then transfer them to water scarce areas within the same or to other basins. For example, the proposed NRLP envisages transferring 178 BCM from water surplus Brahmaputra, Mahanadi and Godavari basins to water scarce basins such as Krishna, Cauvery, Pennar, and Sabarmati, in the southern and western regions (NWDA 2006). If all that diverted water in the NRLP is from un-utilizable surface runoff, then it augments PUWR of India by 18%. Indeed, this is one of the major contentious issues in recent discourses. How, such large quantum of surplus water, mainly floods, in some basins can be transferred to other basins when they also experience floods is indeed an important question.

In spite of the above concern, the IBWTs can have many socio-economic and hydrological benefits. For example, the NRLP expects to mitigate the damage caused by floods which ravages the eastern parts of the country every year, temporarily displacing many people, destroying crops and livestock, and disrupting the livelihood of many, especially the rural poor. The NRLP also provides an insurance against recurrent droughts and expects to recharge groundwater of over-exploited blocks in many parts of the southern and western parts of India. In fact, it can alleviate water scarcities in many river basins, which in some regions are becoming a serious constraint on further economic growth.

However, many other drivers, which are exogenous to the countries water system, also affect implementing IBWTs (Shah et al. 2008). Financing such mega projects, estimated to be more than $125 billion (in 2000 prices) for NRLP, and their impacts on other social-welfare activities are serious concerns under the prevailing economic conditions at present. But, with rapid economic growth, increasing at 7-9% annually in recent years, financing of large IBWTs shall not be a major constraint on a trillion dollar[4] economy in few years time.

The IBWTs often displace lakhs, if not millions of people and submerge large areas of forest and productive agriculture land. And the hardest hit by such displacements are the weakest sections of society, including tribal communities with forest as the main livelihood resource, and landless labourers who depend for their livelihood on the daily wages from working in those agriculture lands that get submerged. The resettlement and rehabilitation issues, if not properly addressed, are major bottlenecks for implementing large IBWTs.

[4] India's GDP has already passed the one trillion, It was 1,027 billion US$ in 2007.

Political stability and relations between states and neighbouring countries are also major drivers of planning and implementing IBWTs. Often, IBWTs cut across several states and at times, several countries. In NRLP, it is even required to build storage reservoirs in other countries. Therefore, the existing level and the future prospects of trans-boundary or inter-state cooperation are major determining factors determining the feasibility of such IBWTs.

Eco-system water needs, another major driver, is often ignored in IBWT planning. But they are highly contentious issues in the discourses thereafter. An important question often raised in these dialogues are whether water resources required for sustaining a healthy eco-system in one basin can be considered for augmenting water resources in other basins. According to Bandyopadhyaya and Praveen 2003, there is no free surplus of water available to be transferred from one river basin to another basin. All water in the un-utilizable water resources, including floods, performs an important eco-system service. Such assumptions, indeed, are an extreme view point in-terms of eco-system water needs. A compromised formula can determine the extent of surplus that can be transferred from the water surplus river basins. How much of water can be transferred depends on whether the environment is considered as a primary driver of water supply or as another sector of water use.

If environment is considered as another sector of water use, it often loses. With increasing demand, different sectors compete for scarce water resources. The agriculture, domestic, industrial, navigation and hydropower sectors have stakeholders who have a voice and also theoretically can afford to pay for the services. However, the environmental sector has no voice by itself or cannot pay for its water demand. Thus, as a 'water use sector', the water needs of the eco-systems are often ignored in IBWT planning. For instance, the NCIWRD water demand scenarios considered the environment as a water use sector, and allocated only 10 BCM, or less than 1% of TRWR.

However, this situation can change if eco-system water needs is considered as a primary driver of water availability. The premise here is that parts of the floods in the rainy season and a minimum river flow in the dry season play a major role in servicing the needs of the riverine ecosystems. Thus, a major part of the un-utilizable water resources cannot be captured and transferred for water use in other basins. In this context, it is important then to know the magnitude of the water needs for sustaining eco-system services in river basins.

Environmental Water Demand

As a primary driver, a good starting point is to assume that at least a minimum environmental flow (EF)[5] requirement to be maintained for providing eco-system services of a river basin. Two factors determine EF. They are the natural hydrological variability of the river flow, an endogenous driver to the water system, and the environmental management class that the river ought to be maintained, often an exogenous driver to the water system. The latter depends on human decisions on the qualitative importance they want to place on riverine eco-systems. Smakhtin et al. (2006, 2007) defined six environmental management classes (EMC), and determined the

[5] This is part of the research conducted under the project for assessing environmental water demand of river basins of India. Details of the procedures and estimation are available in Smakhtin and Anputhas 2006 and Smakhtin et al. 2007.

minimum flow if a river ought to be maintained under different EMCs. The EMC class A corresponds to the pristine conditions of a river. Other—classes - B to F - correspond to slightly, moderately, largely, seriously and critically modified river conditions. The EMC's E to F describe the development states of a river basin where the basic ecosystem functions are destroyed to the extent that the changes to the river ecosystem are irreversible. Table 2 shows the EF under different EMCs for 12 river basins of India, which account for 78% of TRWR of India. The total EF of 12 basins varies from 70% of TRWR in class A to 13% in class F.

Table 2. Minimum river flows of Indian river basins.

River basin	Natural MAR[a] (Bm^3)	Environmental flow (EF)– % of MAR					
		A	B	C	D	E	F
Brahmaputra	629.1	78	60	46	35	27	21
Cauvery	21.4	62	36	20	11	6	3
Ganga	525.0	68	44	29	20	15	12
Godavari	110.5	59	32	16	7	4	2
Krishna	78.1	63	36	18	8	4	2
Mahanadi	66.9	61	35	19	10	6	4
Mahi	11.0	42	17	7	2	1	0
Narmada	45.6	56	29	14	7	4	3
Pennar	6.3	53	28	14	7	4	2
Sabarmati	3.8	50	24	12	7	3	2
Subernarekha	12.4	55	30	15	7	3	2
Tapi	14.9	53	30	17	9	5	3
Total MRF demand (Bm^3)		1,065	731	501	353	260	202
Total - % TRWR		70	48	33	23	17	13

Source: Amarasinghe et al 2007a.

a- Mean annual river runoff

Ideally, one would like to maintain rivers in their pristine condition, or in EMC class A. The EF requirement for maintaining Indian rivers in EMC class A is even more than the estimate of the total un-utilizable water resources at present. And, under such conditions, no water surpluses are available for transferring between basins, and it is feasible only in low populated and low developed river basins. Given the present level of population and economic growth, maintaining large EF as in EMC class A is impossible. In fact, none of the major rivers can be maintained in pristine conditions.

The total water requirement for maintaining rivers in EMC class B is 731 Bm^3. Although this level of demand is within the total un-utilizable water resources of all river basins, a few rivers still require a substantial part of the utilizable water resources for meeting environmental water needs. The EMC class C maintains a river under moderately modified conditions. The minimum flow requirement under this scenario of all river basins, except Cauvery, Pennar and Tapi, is less than the un-utilizable water resources (Amarasinghe et al. 2007a). The un-utilizable water resources of Brahmaputra, Ganga, Mahanadi, and Godavari substantially exceed the corresponding EF under EMC class C. Thus part of the excess flows in these basins can theoretically be transferred to other basins. Nevertheless, if environmental water demand gets high priority, the effective water supply that is available for augmenting PUWR could further diminish in many river basins.

Besides these concerns, some studies also show that the estimates of PUWR that are available at present are significantly over-estimated (Garg and Hassan 2007). This is mainly due to double counting of surface and groundwater resources in the dry season. According to Garg and Hassan 2007, the presently available estimate of PUWR in India is overestimated by at least 66%. Such estimates, indeed, are alarming and require thorough scrutiny before they are acceptable for water supply and demand modeling and such a scrutiny also requires a clear understanding of the interaction of surface and groundwater flows in river basins, for which the available data on water resources in many river basins are inadequate. According to Mohile et al. (2009), a static estimate for PUWR is not any more a useful concept. Instead, they prefer to replace PUWR by 'limits of utilization' of water resources in a basin. The limits of utilization depends not only on the natural flows and the engineering and agronomic constraints, it also depends on environmental constraints and the methods of utilization of water resources. They propose that any surplus water over and above the 'limits of utilization' can be transferred to other basins. A major drawback of this approach is the way it estimates potential utilization in a river basin. It depends on a set of assumption of trends and magnitude of drivers of water demand and the potential water use according to them. As discussed before, these assumptions, especially on primary drivers, as discussed before are difficult to forecast. Therefore, drivers pertaining to water demand estimation themselves require periodic assessment.

Water Demand Drivers

Changing Demographic Patterns

Population growth has a central place among primary drivers of projecting future water demand. The changing regional demographic patterns also play an equally important role in assessing the composition of regional water demand. This is important for a large country like India with a significant spatial variation of water availability, and also when irrigation is the largest consumptive water use sector in many regions. Irrigation has played a vital role in the past in many states where a major part of the rural population depended on agriculture for their livelihoods.

But, the regional demographic patterns are changing with rapid urbanization. Study by Mahmood and Kundu (2009) projects India's total population to reach about 1.6 billion by 2050, and stabilize thereafter (figure 3). It has been estimated that about 53% of the population will live in urban areas by 2050. According to others, this is even a conservative estimate of urban population growth in India (Y.K. Alagh cited by Amarasinghe and Sharma 2008b). In either scenario, demographic trends of many states will change significantly by the second quarter of this century. Many states will have more cities with major urban centers, and more urban than rural population.

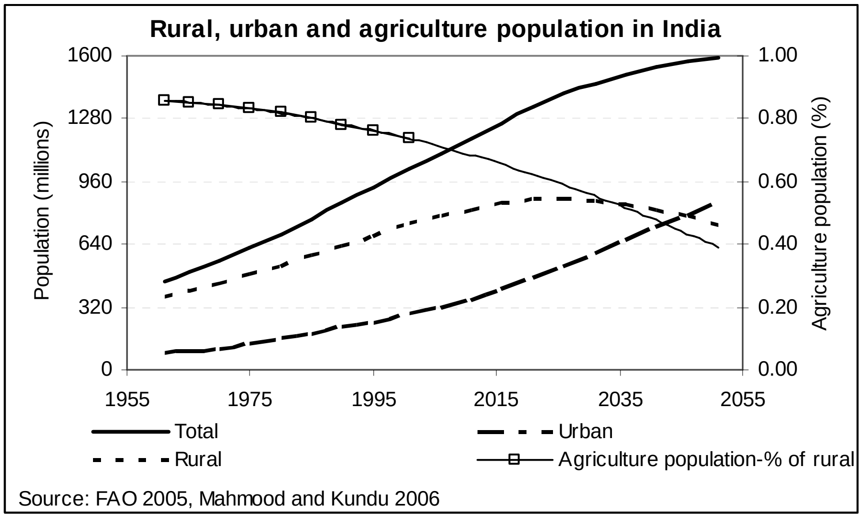


Figure 3. Urban, rural and agriculture depended population in India.

An examination of the demographic trends at the state level suggests that population of Andhra Pradesh, Kerala, Karnataka, Punjab and Tamil Nadu, will have a declining trend by 2050, and a significant part of the population of these states will live in urban areas (figure 4). The states Haryana, Gujarat, Orissa, Maharashtra and the West Bengal will have moderately declining population. In all of the above states, water demand for the domestic and industrial sectors is likely to increase rapidly, and the water use patterns in the agriculture sector will change.

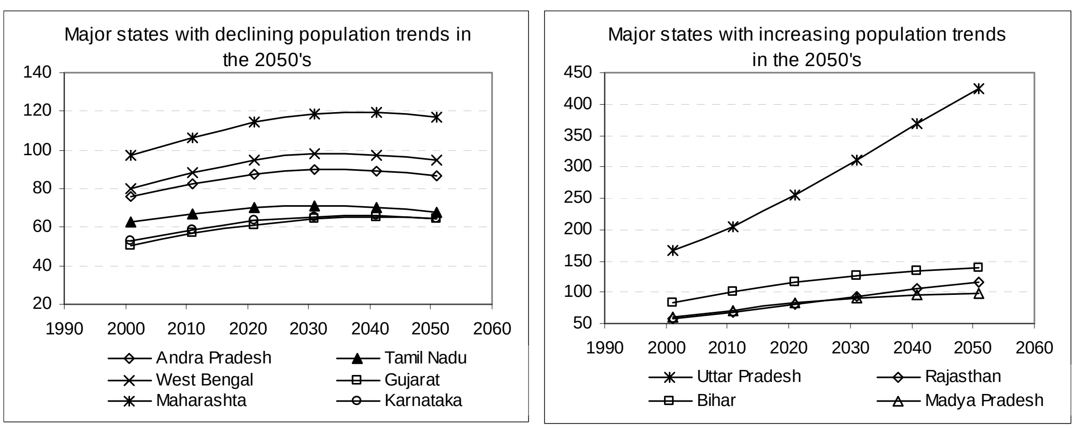


Figure 4. Population growth trends in major states.

However, the so called "BIMARU" states, Bihar (including Jharkhand), Madhya Pradesh (including Chhattisgarh), Rajasthan and Uttar Pradesh (including Uttaranchal) will only continue to have increasing population, and will still have a substantial rural population by 2050. The pressure for agriculture land and water will intensify in these states, where the natural resource base is already over stressed due to extensive agriculture activities.

Many national level projections often do not incorporate regional population growth patterns. This is one major shortcoming of the assumptions of the NCIWRD scenarios. They estimated the future population of states and basins on the basis of their 1991 population figures (page 70 in GOI 1999). Such an assumption can over estimate the rural population and part of the rural population that depend for their livelihood on agriculture in many southern and western states.

Rural Livelihood Security

Rural livelihood security, for which agriculture is the main source for many people, was a vital component of the overall rationale for agriculture water demand projections in the past. However, recent trends suggest that the agriculture demography is fast changing with increasing employment in the non-agricultural sectors. The study by Sharma and Bhaduri (2009) suggests that India may be at the "tipping point" of the transition in its agriculture dependent population to non-farm activities. Agriculture will be a part-time employment activity for many habitants in rural areas. Over the last four decades, the agriculture-dependent population has declined from 86 to 74%. This percentage is likely to decrease further, and could reach even below 40% by 2050 (figure 3). Such trends are compatible with the present level of agriculture population of countries with similar economic conditions that India shall experience by 2050 (figure 5), and perhaps could accelerate in the future as the National Sample Survey show that significant number (40%) of farmers say that would like to exit farming for better opportunities in the non-farm sector.

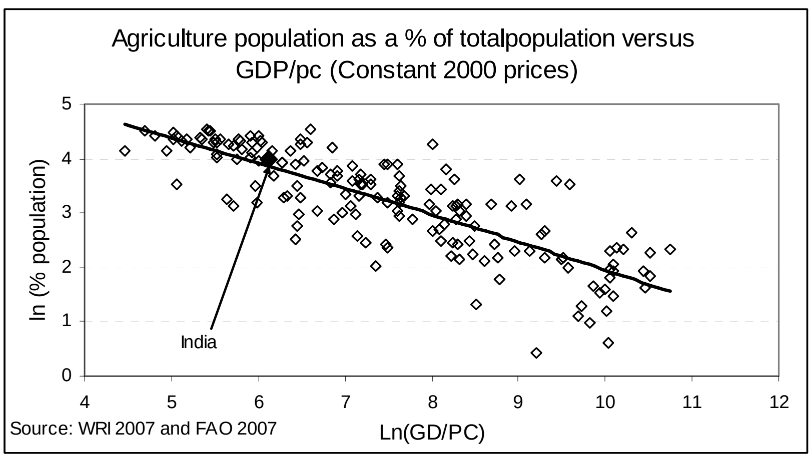


Figure 5. Agriculture population across selected countries in the world.

The implication of the changing agriculture demography is that, although the agriculture dependent population in India will increase in the near-term, the growth rate shall start to decline after the next decade soon. And in 50 years from now, India will have even less population that depends on agriculture than it is now. Sharma and Bhaduri (2009) further shows that withdrawal of rural youth from agriculture is not significantly related to access to irrigation. Rural livelihood security shall decline in importance as a primary driver in determining future irrigation water demand in India. This was another contentious assumption in the NCIWRD projections, where it was assumed that irrigated agriculture would be a major part of the future rural livelihood security.

Changing Consumption Patterns

Generally, the food consumption patterns of a country largely determine what its people produce in the agriculture fields. More than two-thirds of the food consumed in India at present is produced under irrigated conditions. And due to large marginal to small land holders, the producers are also the main consumers of the crops they produce. Thus, the local consumption patterns play a pivotal role in cropping pattern decisions in irrigated agriculture. In the past, grain crops dominated the agriculture production patterns, as food grains provided a major part of the daily nutritional intake. However, a subtle change in food consumption patterns has been surfacing in the recent past in both rural and urban India. While, the demand for food grains, especially for rice and coarse grains in both rural and urban areas are declining in the 1990's, the demand for non-grain food crops such as vegetables, fruits and oil crops, and animal products such as milk, chicken, eggs and fish is increasing (figure 6).

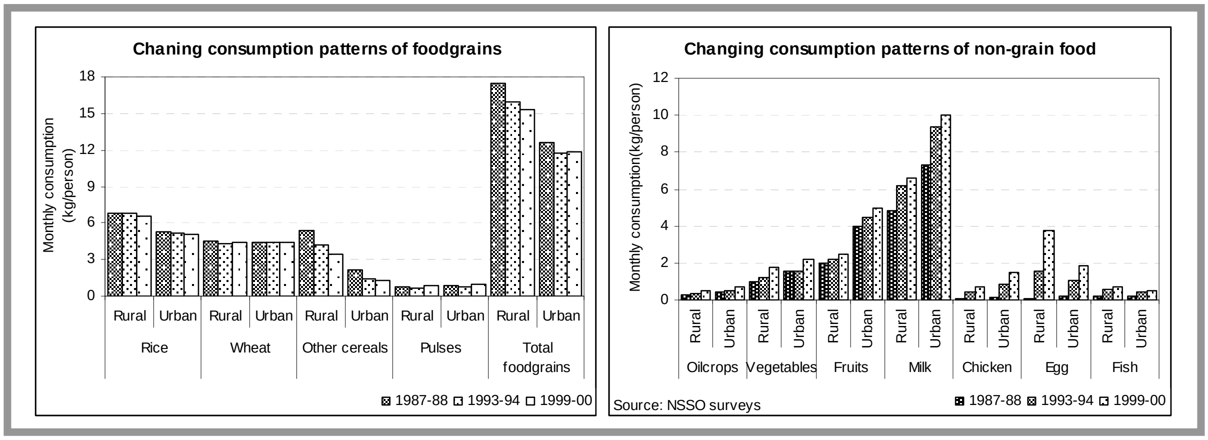


Figure 6. Changing consumption patterns in rural and urban areas.

Increasing income and urbanization will further increase the demand for non-grain food products in the Indian diet. The study by Amarasinghe et al. (2009c) in fact shows that non-grain crops (oil crops and vegetable oils, roots and tubers, fruits, vegetables and sugar), and animal products (mainly milk, chicken, eggs) are expected to provide a major part of the nutritional intake by 2050. Food grains provide more than two-thirds of the nutritional supply today, and this will reduce to less than half by 2050. As a result of decreasing per capita grain consumption in both the urban and rural areas, and the rate of urbanization, the total food grain demand will increase slowly. However, due to increasing consumption of animal products, the feed grain demand will increase several fold. The demand for non-grain crops will also increase substantially. Therefore, non-foodgrain crops will consist of a major part of the additional irrigation geography in the future.

This is quite in contrast to the assumptions of the NCIWRD scenarios, in which they projected a significantly high additional food grain demand. In fact, the NCIWRD projection of demand for foodgrains exceeds 22kg/month/person by 2050, and that level of foodgrain consumption alone can provide a calorie supply of 4,000 kcal/person/day. Such level of calorie supply is highly unlikely as it is even higher than the calorie intake in the most developed countries with animal product dominated diet (Amarasinghe et al. 2007b). Nevertheless, high demand for food grains along with national self-sufficiency assumption required NCIWRD scenarios to project a large irrigated area expansion.

National Self Sufficiency

Another primary driver that dominated the selection of cropping patterns of agriculture in general, and irrigation in particular was full national self sufficiency of food grains. This assumption was mainly based on the three concerns that 1) India has a large population and the food grains are the staple food of its people with mainly a vegetarian diet, because of which large production deficits, such as in the 1960's, are not acceptable; 2) agriculture was the main driver of economic growth and has contributed to substantial part of the gross domestic product; and 3) India's foreign exchange reserves are too low to import large quantities of food from the world market. The first is still true, but as mentioned before, demographic and consumption patterns are fast changing, and demand for non-grain food and feed products are increasing. With changing consumption patterns, there will be more opportunities for Indian farmers to increase income from growing high-value non-grain food products. Moreover, India's agriculture export and import patterns are also changing. Although the share of total agriculture exports is decreasing, which is natural with rapidly growing industrial and service sectors, the total quantum of exports has been increasing in recent years (Malik 2009). Also, India has been importing a significant part of the requirements of vegetable oil, and also some pulses, fruits and nuts etc. However, the value of agriculture exports at present far exceeds that of imports, and the difference is widening gradually. And with expanding global trade, India will have more opportunities for increasing agriculture exports, and pay for its agriculture imports.

In the past, low foreign exchange reserves were indeed a constraint on large food imports. But that was only when the gross domestic product was only a few hundred billion dollars, and food grain production was a substantial part of it. But it is no longer valid under the prevailing economic growth. India has a trillion dollar economy now and has large foreign exchange reserves in comparison with those in the early 1990s. The share of the agriculture sector, let alone the value of food grain production, is only about 23% of the total GDP in 2000 (WRI 2007). And this share will decrease further, and India will have sufficient foreign exchange reserves to pay for even large food imports in a few decades time.

However, the only concern that India should have in large quantity of food imports is its effect on prices. Potential price increases due to large food imports from countries such as India and China can hurt the very consumers that the imports would expect to help, and also can increase the volatility of global grain markets in the years of significant grain production deficits. So, a reasonable degree of food self sufficiency, purely because of the volatility in the grain prices in the markets, can still be a good assumption for projecting future food and water demand.

Realizing the Potential in Rain-fed Agriculture

While India ranks the highest among the countries with rain-fed agriculture area, it ranks one of the lowest in rain-fed yield (figure 7). The total foodgrain production from the existing land can be increased 30% by raising the rain-fed yield by just one ton, which is still much lower than the rain-fed yields of many other large rain-fed foodgrain producers.

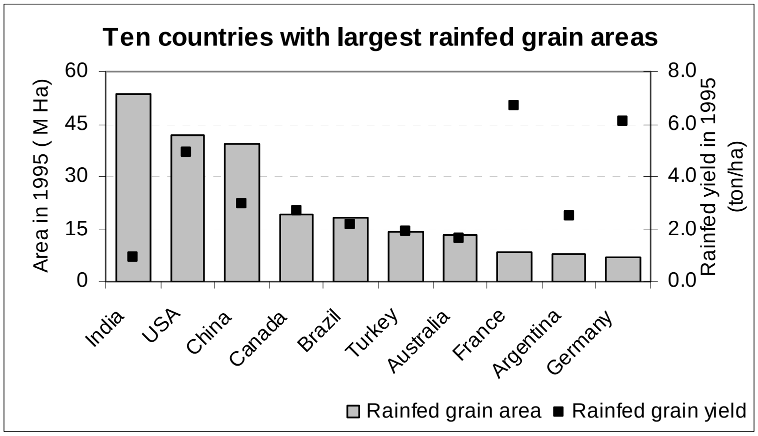


Figure 7. Rainfed yield of major food grain producers in the world
Source: IWMI 2000.

Sharma et al. (2009a) finds that frequent occurrence of mid-season and terminal droughts were the main cause for crop failures or low yield in a major part of the rain-fed cropped area. Small supplemental irrigation during the water stressed periods of mid-season and terminal droughts can significantly increase the rain-fed yields. Providing supplemental irrigation through decentralized, more equitable and targeted rainwater harvesting structures can help millions of resource poor farmers in rain-fed faming. They shall also reduce the requirement for large-scale irrigation projects, which in the present states of water scarcities require large inter or intra-basin water transfers. However, small RWH interventions could bring maximum benefits provided that the marginal cost does not exceed the marginal economic benefits in basins with high degree of development and that there are no significant disparities of water demand in the upper and lower catchments, where there is no significant tradeoff in maximizing benefits of the upstream vis-à-vis optimizing the basin wide benefits (Kumar et al. 2008a).

Increasing Crop Productivity

Assumption of the growth in crop yields is a major driver in determining the requirement of additional agriculture area and irrigation. For example, India can be self sufficient in food grains without any additional irrigation if it doubles the crop yield in 50 years (figure 8)[6]. If India can attain such level of productivity in 50 years from now, it is only similar to the productivity levels of China today, although both countries had more or less similar productivity levels 50 years ago. Indeed, there seemed to be a significant scope for increasing crop productivity over the next few decades.

[6] In 2000, India was self sufficient in food grains with a production of about 205 Mmt. The land and water productivity of food grains in 2000 was 1.67 ton/ha and 0.48 kg/m^3. With two-fold increase in land and water productivity, as shown in Scenario 4, India can increase foodgrain production over 400 Mt without any additional consumptive water use. This level of production is more than sufficient to meet the consumption demand of 377 Mmt projected by Amarasinghe et al. in 2007a).

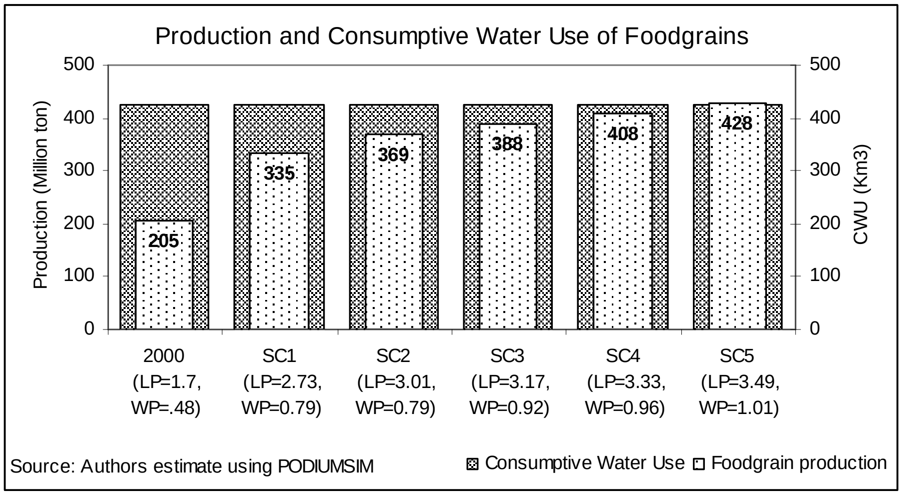


Figure 8. Food grain production under different land and water productivity scenarios

Kumar et al. (2009a) show that significant variations of productivity exist across farms in the same area and irrigation systems in the same regions growing similar crops. They conclude that a significant scope exists for increasing crop productivity in irrigated areas by manipulating key factors which include reliable irrigation supply and input use. As shown by Sharma et al. (2009a), small supplemental irrigation can double the productivity of crops in rainfed areas. Palanisami (2009b) explores ways of increasing the value of productivity through multiple cropping systems. This is a good strategy when there are limited opportunities for increasing productivity through mono-cropping systems.

Growth in Irrigated Area:

Over the last few decades, irrigation expansion was the sole contributor to the growth in gross cropped area, and groundwater was the main driver behind this area expansion. In fact, the groundwater irrigation has contributed to all of the net irrigated area expansion in the 1980's and 1990's (figure 9). Today it accounts for 60% of the gross irrigated area of India. It shows that much of the expansion in recent decades, contrary to popular belief, has occurred outside major canal command area districts (Bhaduri et al., 2009a). In fact, the groundwater irrigation explosion in the last few decades was driven mainly by the population pressure and not necessarily by the water availability through return flows of surface water irrigation. Although the depth to groundwater in some areas is falling, overall expansion for groundwater shall continue in the future in many other regions.

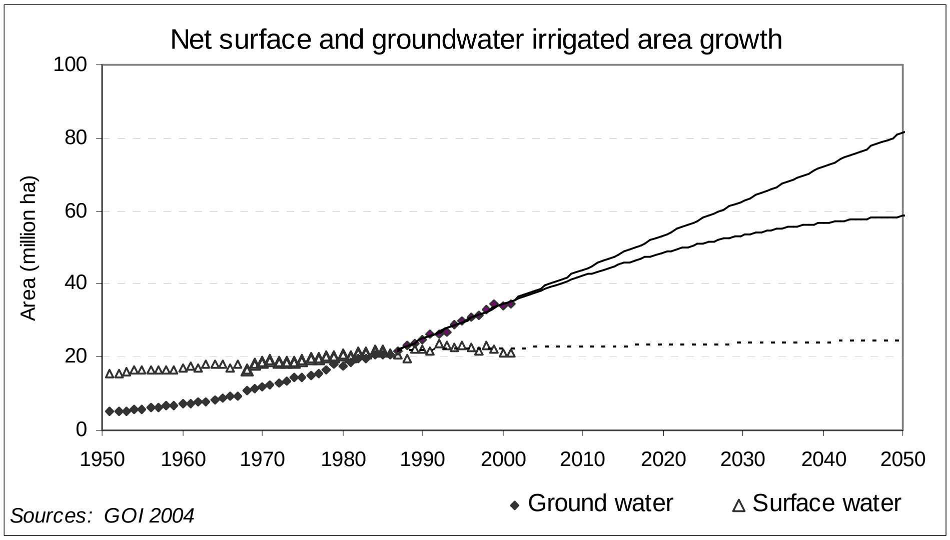


Figure 9. Net surface and groundwater irrigated area growth.
Source: Amarasinghe et al. 2007a

The groundwater irrigated area has expanded at a rate of one million ha annually during the last decade and, in comparison, the surface irrigated area had virtually no growth over the same period. The NCIWRD scenarios assumed that much of the expansion in irrigated areas that will be required for meeting future food demand will come from surface irrigation. However, the trends in the 1990s show a stark deviation from this assumption. Such assumptions indeed have major implications on the financial cost and also on the total water demand. As regards the cost, expanding surface irrigation under the prevailing water scarcity conditions in many river basins will most probably require expensive IBWTs. As regards the water demand, surface irrigation may require significantly higher water withdrawals, as project efficiency of surface irrigation is much lower than groundwater irrigation.

Based on the present level of exploitation, availability, quality and the impact on environment, Sundararajan et al (2009) argue that there are only small pockets for developing further groundwater irrigation. However, as argued by Amarasinghe et al. (2008c), artificial groundwater recharge is an important policy prescription for sustaining the groundwater irrigation in many river basins. And, based on the present trends, Amarasinghe et al. (2007a) shows that groundwater expansion will continue and the net groundwater irrigated area will reach about 50 mha, adding further 16 mha to the level in 2000.

Increasing Efficiency

The project efficiencies of surface and groundwater irrigation systems are another major driver affecting irrigation demand projections. Many claimed that there is a significant scope for increasing project efficiency, especially in surface irrigation systems. However, the little information available suggests that the efficiencies of major systems are hovering around 30-40% and no major increment of efficiency was also seen over the last few decades. Indeed, increasing irrigation efficiency in one location of river basins that are approaching closure may not yield the desired result of gains in overall efficiency, as it affects another user in the downstream of the closing basins. Thus, increasing surface irrigation efficiency to the level suggested by the NCIWRD projections, i.e. 60%, will have limited effect within the water stressed basins.

But it is clear that many water saving technologies, especially micro-irrigation systems, can significantly increase water use-efficiency. Narayanamoorthy (2009) show that sprinkler and drip irrigation can have efficiencies in the range of 75-90%. And, it also shows that more than 70 mha of land can potentially benefit from micro-irrigation. However, this potential can only be reached by overcoming many constraints. Spreading micro-irrigation systems in India is difficult due to the many marginal and small farmers, lack of independent source of water and pressurizing devices for these small farmers, poor extension services, lack of subsidies, unreliable electricity supplies etc. (Kumar et al. 2009b).

Domestic and Industrial Water Needs

The economic growth, increasing income and lifestyle changes drive up the demand for water for the domestic and industrial purpose. Figure 10 shows that water demand in the domestic and industrial sectors increase rapidly with increasing income in the low to middle-income categories and the growth of water demand, especially in the domestic sector tends to stabilizes at the higher income level.

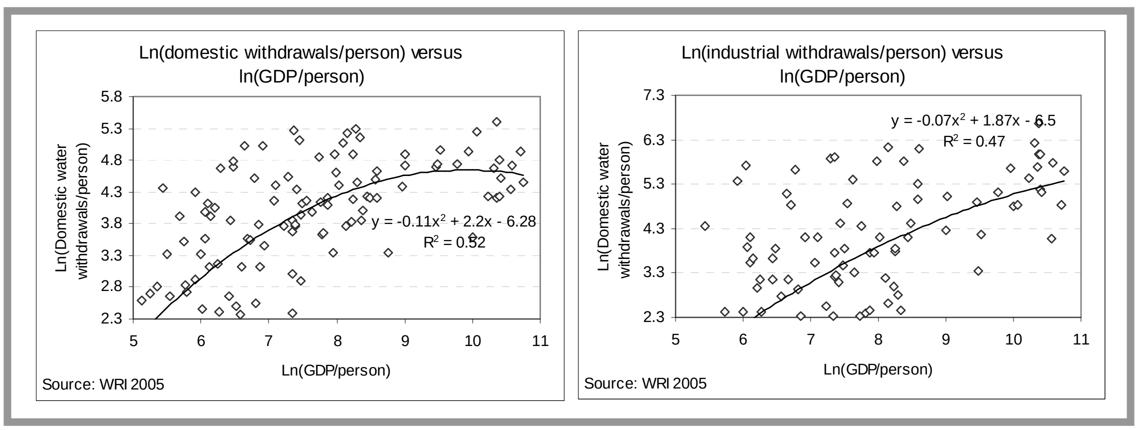


Figure 10. Domestic and industrial water demand in different countries.

In India, the service and industrial sectors expanded rapidly in the 1990's and contributed to a GDP growth of more than 5.1% annually between 1991 and 2002 (figure 11). Over this period, per capita GDP has increased at 3.9% annually, and it is growing 5.3% annually in this decade. Such growth patterns in the economy will exert a significant pressure for water demand in the domestic and industrial sectors in the future. In fact, according to the current trends of economic growth and urbanization, most of the additional water demand between 2000 and 2050 could well come from the domestic and industrial sectors (Amarasinghe et al. in 2007a). Whether that increasing water demand will be met through groundwater or surface water is an important secondary driver for assessing future water needs.

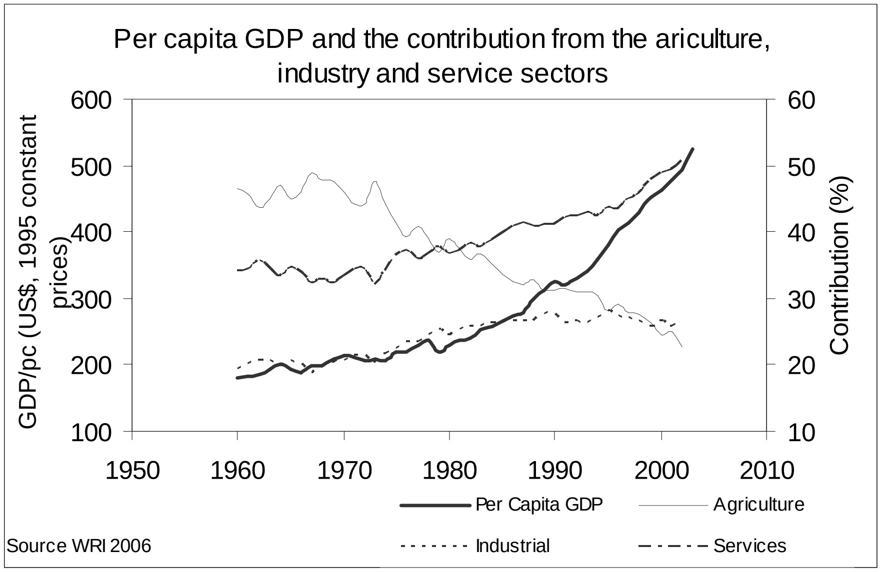


Figure 11. Contribution to GDP growth from different sectors in India.

A national-level analysis (Patel and Sundararajan 2009) reveals a significant spatial variation of the dependence of groundwater for municipal water supply. In the peninsular India, primarily in hard rock regions, cities depend more on (average around 80%) external sources of water. The size of a city is a strong indicator of how much surface water it can import from other areas. The alluvial aquifer cities are more dependent on local groundwater (average 75%). However, as the city population grows its dependence on surface water will increase. And their willingness to pay for a reliable service shall increase too. Thus, growing cities and their population in India will be a major driver of increase in surface water for domestic and industrial sectors in the future. Such increase in demand could be a major justification for large intra-basin water transfers.

Concluding Remarks

There are clear trends that India will require substantial additional water supply to cater to increasing demand in the coming decades. It is estimated that India withdrew about 680 BCB for meeting the demand in the irrigation, domestic and industrial sectors in 2000. According to the recent growth patterns, the future demand is projected to increase by 22 and 32% by 2025 and 2050, respectively (Amarasinghe et al. 2007a). The population and economic growth, increasing world trade, the changes in lifestyles and food consumption patterns, technological advances in water saving technologies are the most influential primary drivers of India's water future in the short to medium term. The climate change will become an influencing factor in the long-term.

Over the last two decades, groundwater has been the major source for meeting increasing demand in all sectors. It is highly likely that this trend will continue. However, many river basins will have severe water stress conditions under business as usual water- supply and use patterns. With increasing reliance on groundwater, particularly for irrigation, many river basins will have severe groundwater over-exploitation related problems. Indeed, meeting India's short to medium term water demand itself will be a challenging task.

However, many options are available to meet this challenge (Amarasinghe et al 2008c). Recharging groundwater to increase the groundwater stocks; harvesting rainwater for providing the life-saving supplemental irrigation; 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; increasing research and extension for enhancing agriculture water productivity; and carefully crafted virtual water trade between basins are important policy options for meeting the increasing demand. With increasing disposable income, people's affordability and willingness to pay for a reliable domestic and industrial water supply will increase. This, along with a reliable water supply for diversifying high value cropping patterns, may require large surface water transfers. The inter-basin water transfers could increase the recharge groundwater in many over-exploited area.

While artificial groundwater recharge, rainwater harvesting, and inter-basin water transfers are a solution for meeting the water demand in the near-term, they are also solutions for increasing the potential utilizable water supply in many water scarce river basins. They will indeed have major benefits when full influence of the climate change starts to impact the utilizable supply in many water scarce river basins.

Objective 2: Analyze whether the NRLP as a concept can be an adequate, cost effective and a sustainable response in terms of the present socio-economic, environmental and political trends, and if India decides to implement it, how best the negative social impacts can be mitigated.

NRLP: Social Cost and Benefits and Implementation Issues

Introduction

The NRLP envisages transferring water from the surplus river basins to ease the water shortages in western and southern India while mitigating the impacts of recurrent floods in the eastern India (figure 1). Although the NRLP envisages generating immense benefits (see NRLP synopsis in section 2) , the project has many opponents too. They question the core assumptions justifying the NRLP. Others believe that the NRLP will have to tackle many contentious issues if and when it is ready to implement. These issues include, hydrological feasibility, financial, economic and social cost and benefits, environmental concerns, cost recovery issues, political aspects including trans-boundary issues etc.

First we re-visit some of the core assumptions justifying the NRLP project. Next we discuss some of the contentious issues of implementation. Although, some of the issues are very contentious, the project could still go ahead due to social and political compulsion due to emerging regional water scarcities. Finally we present some of the lessons that the NRLP project can learn from the existing large water transfer projects, should the project implementation go ahead as planned.

Questioning Core Assumptions

The arguments in the discourse for and against NRLP at present are not evenly balanced. Even the available sketchy arguments based on superficial information and an analytic base raise serious questions about: (a) what precisely are the problems that NRLP would help resolve; (b) what is NRLP? (c) is NRLP the best available alternative for resolving those issues; and (d) are the problems that NRLP is currently designed to resolve likely to remain the same nature and extent when the NRLP project is commissioned, 50 to 70 years hence?

Many of the factors of the National Commission of Integrated Water Resources Development (NCIWRD) projections were based on have already undergone significant changes. These changes could alter future water supply and demand projections. For instance, the justification for, as well as the cost-benefit calculus of the NRLP in its broadest conception, critically hinges upon projections of population growth, urbanization patterns, and occupational diversification. And contrary to NCIWRD prognoses, recent data suggests that all of the said factors are displaying significant rates of change. In contrast to the NCIWRD projected state-wise population growth by pro-rata distribution of national population projections from the 1991 population census, the new regional population growth projections, incorporating age-size structure, HIV/AIDS and adjusted fertility and mortality estimates from the 2001 census, show vastly different emerging patterns (Mahmood and Kundu 2008). According to these new estimates, India’s population is projected to increase from 1,027 million in 2001 to 1,190 million by 2051 and stabilize thereafter. Although the total population is not drastically different to the NCIWRD projections, many states, especially those which are water-scarce, have significantly different growth patterns. Andhra Pradesh, Kerala, Karnataka, Punjab, and Tami Nadu are expected to face appreciably declining population trends before 2050. Haryana, Gujarat, Maharashtra, Orissa and the West Bengal too will experience a moderate decline, while Bihar, Jharkhand, Madhya Pradesh, and Chhattisgarh are expected to show an increase in population. These are the states where pressure on farmlands and demand for irrigation will continue to be high. This new regional demographic calculus needs to be incorporated into future water demand estimations, although even at this stage the differences between these estimates and those used in the overall conception of the NRL project underscore the need to revisit the basic idea of the scope and ultimate effectiveness of NRLP.

NCIWRD’s prognosis of food demand too has received considerable scrutiny from proponents and opponents of the NRLP debate. The food grain demand projection (279 kg/person and 450 million MT/year total by 2050) of the Commission was a major driver for irrigation demand estimation. At this rate of food grain consumption, the total calorie intake per person is estimated to be at least 4,000 kcal/day (assuming that grains constitute 63 % of the total calorie supply). These estimates are way above the average calorie intake of even the most developed economies at present, and are clearly out of line with the changing consumption patterns. A recent study (Amarasinghe et al. 2007a) incorporating a number of significant aspects from the changing consumption patterns over the past decade and their consequences for the future, projects India’s total grain demand to increase from 209 million MT in 2000 to about 380 million MT by 2050. This projection includes 120 million MT of feed grain demand, which is a 10-fold increase from the present levels and a factor that was not considered in the earlier estimates. Even the results of this study, however, fall short of the NCIWRD’s projection of total grain demand by 114 million MT.

It is argued by many that to heighten the need for expanding irrigation, **t**he NCIWRD took an unduly bleak view of the potential to increase food grain yields. They assumed average grain yield to fall from 1.5 tonnes/ha in 1993 to 3.1 tonnes/ha in 2050 (2.3 and 1.0 tons/ha on irrigated and rain-fed yields respectively in 1993 to 4.0 and 1.5 tons/ha on these by 2050). Critics argue that 50 years is a long period and India can easily outdo the Commission’s unrealistically low projections of yield growth with far cheaper and simpler interventions than NRLP. China and India had similar grain yields in the early 1960s, but China’s present yield is two and a half times more that that of India. Over the same period, the USA’s grain yield increased by almost 4 tonnes from 2.5 tonnes/ha in 1961. Can’t India’s average yield be increased to 4.0 tonnes/ha, China’s present level, even over a 50-year period? If yes, India will be self-sufficient in food without *any* additional land for grains.

NCIWRD’s prognosis for how India’s future of irrigation shapes up is also a contentious issue. According to the Commission, surface water supply would be the dominant form of irrigation by 2050. The Commission projects that surface and groundwater irrigated area will change from 1993’s levels of 55% and 45% of the gross irrigated area to 45% and 55%, respectively, by 2050.

However, the developments over the last two decades show a completely opposite trend. There was no appreciable increase in surface irrigated area, although due largely to private small-scale investments, the groundwater irrigated area recorded a rapid growth. Today, groundwater contributes to 33 million ha which constitutes 63 % of the net irrigated area and 64 % of the gross irrigated area. It is therefore, largely due to this increase in groundwater irrigation that the gross irrigated area projection of 79 million ha for the year 2010 has been already achieved by the year 2000. But the consistency of these numbers depends on how far groundwater irrigation can grow without any surface irrigation growth?

Many contend that groundwater irrigation cannot be increased without surface irrigation recharge. But a substantial part of growth in groundwater irrigated areas in the last decade took place in districts outside the command areas (Shah et al. 2003) and showed no significant spatial dependence on surface irrigated area growth (Bhaduri et al. 2009a). Our analysis shows that if the 10 million ha of net surface irrigated area from the projects under construction and another 25 to 35 million ha of net groundwater irrigated area is added to the present level of irrigation, the gross irrigated area will increase to about 130 to 140 million ha. This is the area required for achieving the Commission's projections of, and perhaps the bloated, self-sufficiency targets of grains. With this increase, groundwater (GW) irrigation by 2050 will cover more than 70 % of the gross irrigated area. Such a change will significantly reduce the total irrigation demand due to differences of efficiencies between surface irrigation (60%) and GW irrigation (77%). But, can the commission's optimistic assumptions on irrigation efficiency increase be realized by 2050?

The commission assumed a significant increase in irrigation efficiencies—from 35%-40% to 60% for surface irrigation and from 65%-70% to 75% for groundwater irrigation across all the river basins. The little information we have today on the variation of irrigation efficiency across river basins is not adequate to predict future directions. However, Kumar et al. (2008) shows that groundwater irrigation efficiency is already close to or even higher than the commission's projections, but the surface irrigation efficiency has shown virtually no increase over the last decade. With water-scarce river basins approaching high degrees of closure, there are no flows to the sea on many days of the year. In these, efficiencies of surface irrigation are low, but they have high basin efficiency due to reuse of the return flows of irrigation Thus increasing irrigation efficiency in one location, and then using the saved water for new locations or for other purposes, would certainly affect some other water users elsewhere. We need to know more on the interactions of efficiencies at the system and basin levels before making firm statements on the potential improvement of efficiency in the surface systems. Or, at least we need conservative assumptions on the potential increases based on the information currently available.

To what extent will the younger generation of today take to agriculture as their primary occupation in the future? NCIWRD assumed that many rural people would stay in agriculture and the access to irrigation is necessary for adequate livelihoods for them. However, according to recent research on the agriculture demography of India (Sharma and Bhaduri 2009), today's younger generation perceived it differently. There is a high likelihood that today's young rural farmers will move out of agriculture, or at least keep it as a secondary income activity, regardless of the increased access to irrigation. This is more evident in the group who has different skills and better education. The tendency of moving out of agriculture is higher where the distance to travel to town or urban centers is less. Certainly, future generations of India will be more educated, and will be acquainted with better skills. And many rural centers are being transformed to small towns and towns to sprawling urban centers. Infrastructure facilities such as access to roads, electricity, and telecommunication are also increasing. Thus, the migration from permanent rural agriculture to other primary income generating activities will increase. So we also need a better understanding of the emerging trends of the agriculture demography and the resulting land use patterns to project the future agriculture water demand.

Did the commission's report overlook the potential of rain-fed agriculture? They projected only a modest growth from 1.0 tons/ha in 1993 to 1.5 tons/ha by 2050. At present, rain-fed area accounted for 56 % of the grain crop but contributed to only 39 % of the total production. If the rain-fed yield can be doubled over the next 50 years, the grain production on the existing rain-fed lands can alone be increased by 81 million metric tonnes. This kind of increase in grain production will meet a substantial part of the future food demand. IWMI research shows that supplemental irrigation, especially during the water-stress period of the reproductive stage of crop growth, can benefit a substantial part of the rain-fed area (Sharma et al. 2009a). And this requires collecting only 18-20 Bm^3/year of water through rainwater harvesting using small-scale structures. They argue, that water harvesting of this magnitude would have no effect on the downstream users.

The commission's eco-system water demand estimate is an anathema to environmentalists and a concern to many others too. And, perhaps, they have every reason to be critical. Even the commission has admitted that the eco-system water demand estimate— 20 Bm^3 - 1 %— median of the mean annual runoff of all river basins is not an adequate figure. Preliminary research by IWMI on environmental water demand shows that in many basins, depending on their hydrological variability, a healthy river ecosystem may be maintained even with 10-20 % of the environmental flow allocations from the average annual runoff (Smakhtin et al. 2006). Many argue that environmental water demand should include the needs of wetlands, for cleaning the polluted rivers, for fisheries' needs in the down streams etc. All these, and the resulting ecosystem water needs will have a significant impact on inter-basin water transfers, as the ultimate decision of the surplus or the level of closure of river basins is decided on what part of the utilizable water resources are required for the eco-system water needs.

Issues for Implementation

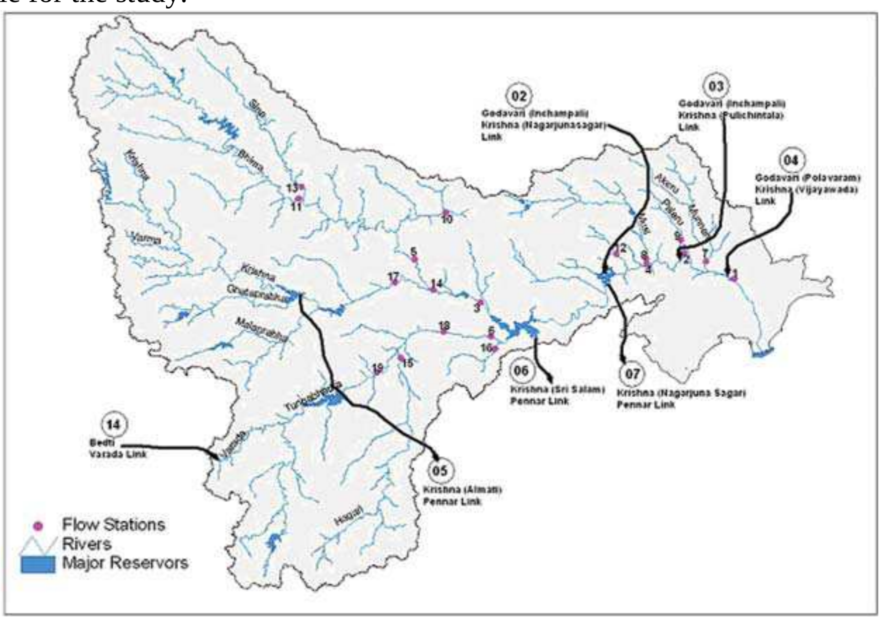
Hydrological Feasibility of NRLP Water Transfers

Hydrological feasibility of large water transfers in NRLP is much discussed and a contentious topic. According to Bandyopadhyaya and Praveen (2003 cited in Shah et al 2008)," … there is no 'free surplus' of water in basin that can be taken away without a price", ".. from a holistic point of view, every drop of water perform some ecological service all the time. The eco-systems evolve by making optimal use of all the water available. If a decision to take away some water from a basin, a proportional damage will be done to the ecosystem, depending on the services provided by that amount water". Indeed, such assumptions are far too extreme to accept in the current context of development and population growth. Mohile and Anand (2009) studied limits of utilizable flows in river basins using various scenarios of future growth and environmental demand. This study covered six major basin in India, including Mahanadi, Godavari, Brahmani-Baitarani, Cauvery, Krishna and Narmada. The results of this study show that considerable dependable surplus flows are available in Brahmani-Baitarani, Godavari and Mahanadi basins. We also know that only 23% of the annual runoff of 634 billion cubic meters in Brahmaputra basin is potentially utilizable.

Although the donor basins--Brahmaputra, Mahanadi and Godavari-- in the NRLP seemed to have water surplus, the estimates of the amount available for transfers at specified sites vary. Smakhtin et al. (2008) analyzed the hydrological feasibility of proposed water transfers of the peninsular links in NRLP that flows into and out of the Krishna River Basin (Figure 12). This study suggest that use of annual flow data, as indicated in the feasibility reports, may show that more water is perceived to be available for transfers at the respective site. If environmental water demand, such as that critically required for the delta areas of the Krishna Basin, is also taken into account, the perceived water surpluses may further be reduced. Study suggest, intra-annual variability of water availability and the environmental water requirements need be to taken into account in assessing hydrological feasibility of large water transfers.

Hydrological modeling in the Godavari (Polavaram)-Krishna (Vijayawada) link canal (Figure 13) under the NRLP also supports the above thesis (Bharati et al 2008). It assessed the implications of alternative cropping patterns on the water demand in the command area and outside the link canal command.

Figure 12. A schematic diagram of the Krishna River basin, showing all proposed inter-basin water transfers in and out of the basin (black lines with numbers) together with flow measuring points (stations) for which some observed flow data were available for the study.



Source: Smakhtin e al 2008

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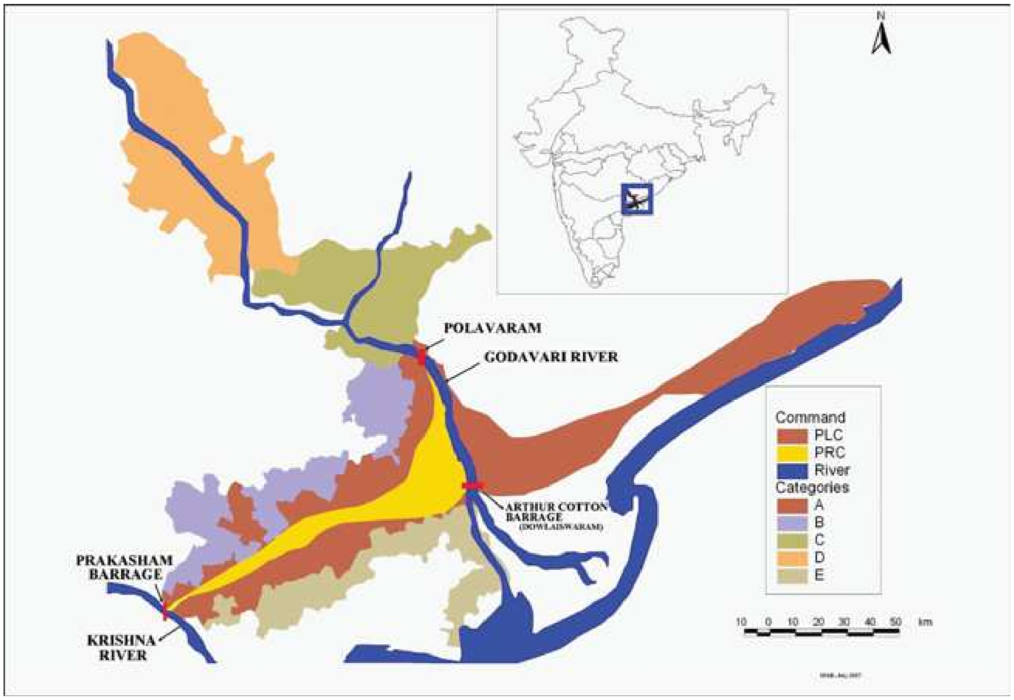


Figure 14. A schematic map of the proposed Polavaram Project. PLC and PRC- the Polavaram left and right bank command areas, respectively.
Source: Bharati et al 2008

Bharati et al (2008) study shows that the proposed water transfers and water use would affect the downstream water users in the Godavari delta, and will not be able to meet environmental water demand in the Krishna Basins. Moreover, water resource development in the region should consider monthly variations of supply and demand into account in planning of water resource development.

In spite of the concerns on available water surpluses, Mohile and Anand (2009) argues that water scarcities are increasing in many regions in peninsular India, and concerns do still exist on inequitable distribution of water in different regions and their implications on national food security. In light of these inequitable distribution concerns, many of the proposed water transfers would generate significant benefit and have medium to low inter-state and international constraints for implementation. A major contentious issue of water transfers in the NRLP is the requirement of large dams for storing surplus flood waters of river basins. The NRLP, when completed, would require more than 3000 new medium to large storage structures.

Shah and Kumar (2008) study focused on the issues and controversies associated with feasibility assessment of small and large dams. According to this analysis, present criteria of classification of large dams, the height of the dam, is not appropriate. The existing criterion often overestimates the social and environmental cost, which often leads to substantial interest and debate. It also leads to a significant underestimation of indirect social and economic benefits that large dams generate. This paper argues that new classification criteria could better assess the benefit and cost of large dams. In fact, an analysis of 145 countries show that improvement in access to water in a country is a major determinant for its development and economic growth. While the per capita storage of countries with major arid to semi-arid climates are large: USA with 5,961 m^3, Australia 4,717 m^3, Brazil 3,388 m^3, and is fast growing in countries like China 2,486 m^3, India's storage capacity per person is only 200 m^3 (Shah et al 2008). Given the impact due to climate change, especially on intra-annual variability of runoff, and due to increasing population, it is essential that India increases its storage for regulating the runoff that otherwise cannot be beneficially utilizable. If implemented fully, NRLP can increase per capita storage by 25% and improve water situation in many water-scarce regions.

Such improvement in per-capita water availability and equitable distribution of water between regions is only possible if water surpluses estimates of the donor basins are accurate. Smakhtin et al (2008) study contest the estimation of water surpluses in the donor basins. In fact, both Smakhtin et al (2008) and Bharati et al (2008) suggest that the intra-annual variability of water availability and demand in both upstream and down-stream and the minimum environmental flows for the down stream of the reservoirs need be to taken into account in assessing hydrological feasibility of large water transfers.

Cost and Benefits of the NRLP Water Transfers

Given the past records, the benefits and cost of surface irrigation schemes that utilizes a major part of the NRLP water storage, is a major issue in the current discourse. In fact, a key plank of the justification of the NRLP is its irrigation and rural livelihood benefits. The proposed water transfers in the NRLP shall irrigate an additional 34 million ha of croplands (24 mha through surface and 10 mha through groundwater). This additional irrigated area will meet a majority of the foodgrain demand projected for India by 2050 (GOI 1999). However, a simple back-of the envelop calculation suggests that the proposed NRLP project could commit to an outlay of about 100,000 crore rupees ($24 billion) per year over the next 50 years (Shah 2008). Thus, a major concern in the NRLP is what net benefits that the irrigation water transfers will generate with such a huge investment.

Past trends of irrigation investments in India and their returns of course show an abysmal picture.

- India has invested more than 100,000 crore rupees ($24 billion in 2006 prices) in surface irrigation since 1990, yet it has hardly resulted in any addition to net irrigated area (Shah 2008b) (Figure 15).

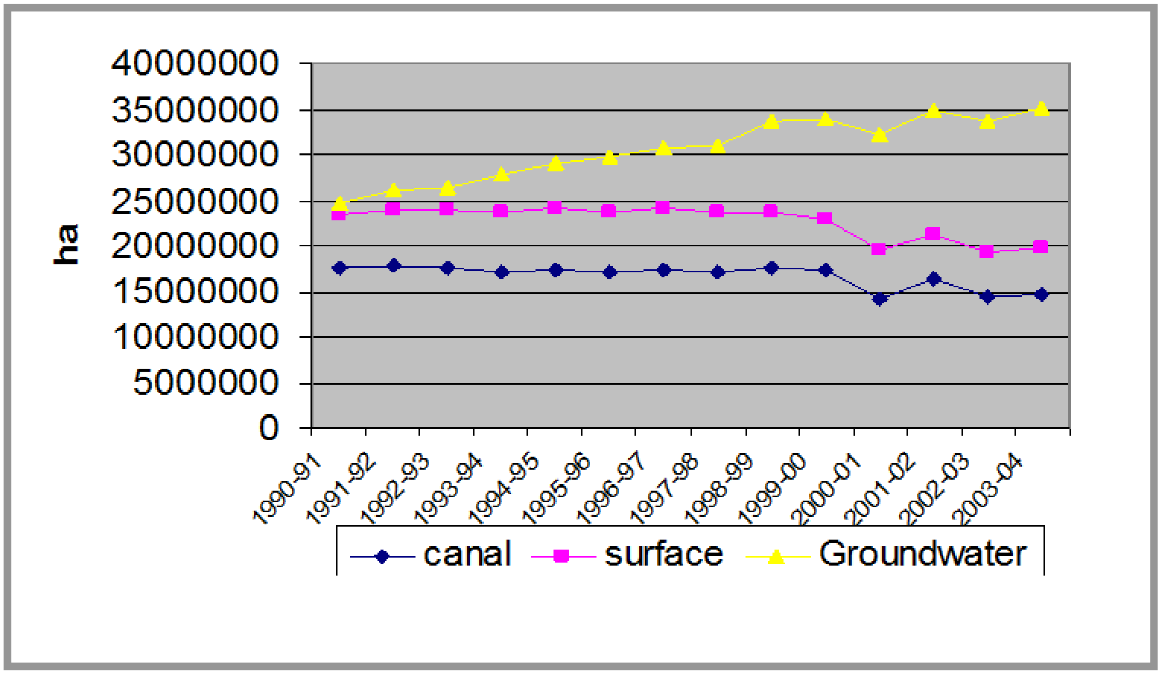


Figure 15. Land use survey data on area irrigated by different sources in India
Source: Shah 2008b

- Among the states and projects: Tamil Nadu and Andhra Pradesh, two of the major water recipient states of River Linking project, spent over 5 billion dollars in canal irrigation since 1970, but lost close to 500,000 ha of net irrigated area under major and medium schemes (Amarasinghe et al 2008e, 2009f, 2009g,). (Figure 16)

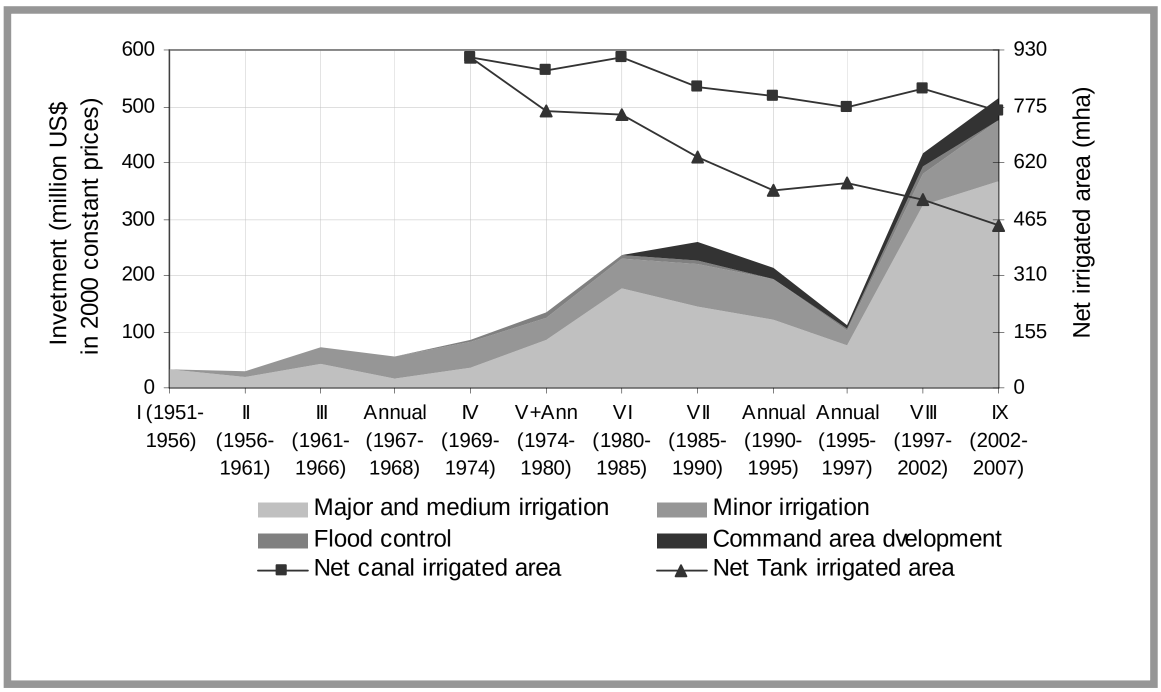
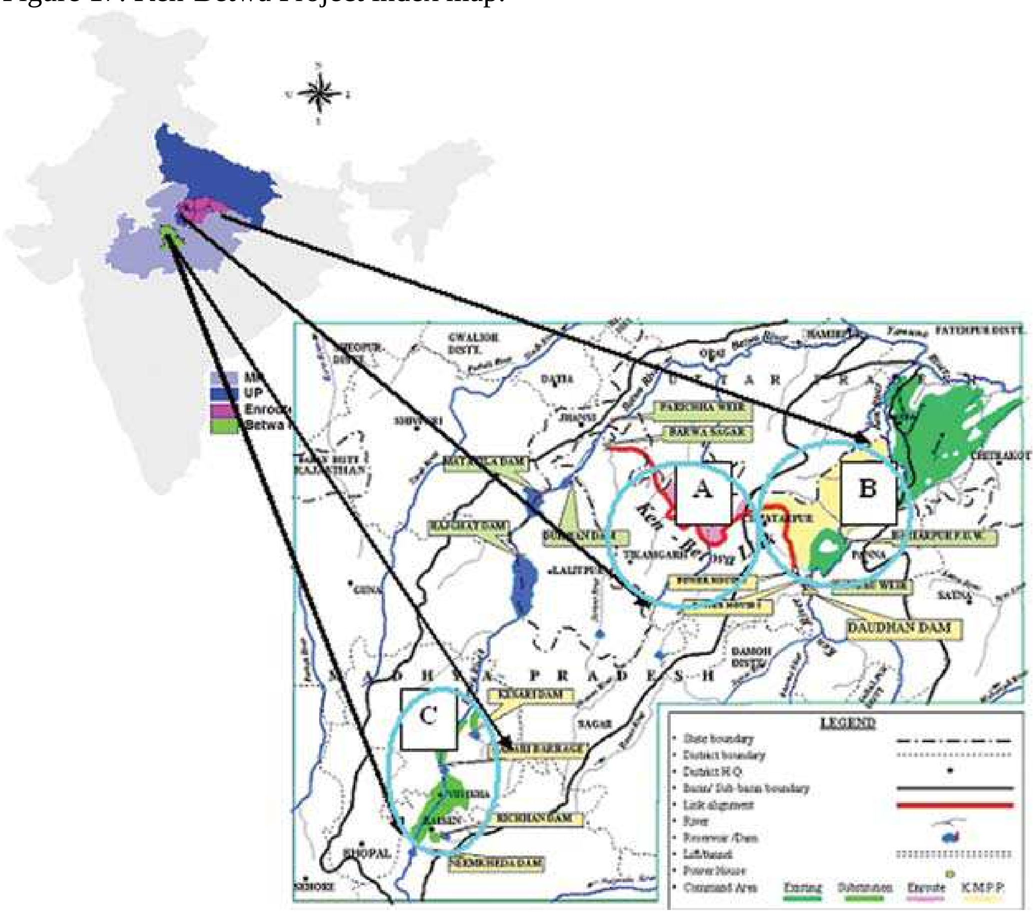


Figure 16. Public investments in major/medium and minor irrigation schemes in Tamil Nadu

- Total investment in minor irrigation in Tamil Nadu alone since 1970 was over $430 million, but net minor irrigated area has declined by 450,00 ha or about 50% (Amarasinghe et al 2009b).
- Gujarat has already spent more than 20,000 crore rupees in the Sarda-Sarovar project, although the envisaged cost of construction in the planning was only 6,840 crore rupee (1986/87 prices). In spite of the huge cost over-run, only 0.1 of 1.8 million ha of the proposed area is irrigated at present (Talati and Shah 2009).
- The ex-post benefit: cost analysis based on 37 major completed irrigation projects in India (Inocencio and McCornick 2009) also shows that economic performance of Indian irrigation indeed has been declining in recent years.

The ex-ante benefit: cost analyses of irrigation water transfers of few links of the NRLP also confirm the above concerns. Bhaduri et al. (2008a) and Amarasinghe et al. (2008d) estimated economic benefits of the proposed water transfers in the Godawari (Polavaram)-Krishna (Vijayawada), (Figure 14) and the Ken-Bethwa links (Figure 17), respectively of the NRLP.

Figure 17. Ken-Betwa Project index map.



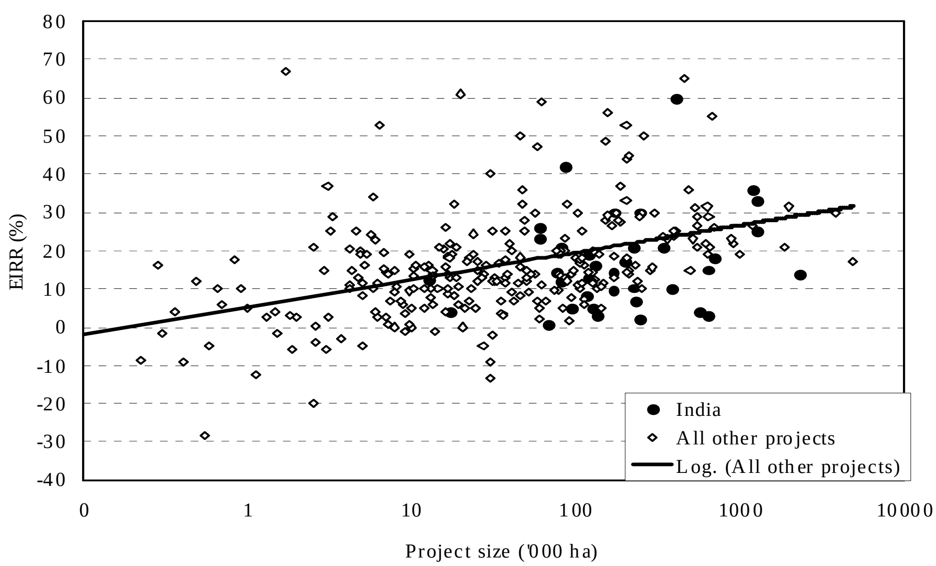
Source: The Ken-Betwa project index map is from the feasibility report (NWDA 2006) reproduced in Amarasinghe et al 2008d

A major part of the proposed command area in both locations is already irrigated. In the Godawari-Krishna link, groundwater irrigates more than 90% of the en-route command at present. Thus, the estimated additional net value added economic benefits per additional cubic meter of proposed water transfers is low.

Studies in Ken-Bethwa link show the importance of local level hydro- meteorological conditions and cropping patterns for planning local level water transfers (Amarasinghe et al. 2008d). The south-west monsoons provide much of the rainfall in the Ken-Betwa link command. Thus, hardly any area of Ken-Bethwa command requires irrigation in kharif season. However, a substantial part of the irrigation transfers is proposed for kharif season. Moreover, rice is a major part of the proposed cropping pattern, whereas rice cultivation in this area even under irrigation conditions has decreased significantly in recent years. This study shows the direct and indirect benefits per every cubic meter of water consumed or delivered is rather low even under most optimistic scenarios of cropping patterns.

The study by Inocencio and McCornick (2008), however shows that large projects with many smaller schemes do perform positively from and economic perspective (Figure 18). This study included EIRR's of 34 Indian irrigation systems. It also found that projects with diversified cropping patterns, or with farmer or water user associations managed systems tend to have better economic performance.

Figure 18. Project size and EIRR of irrigation projects, global sample (n=314)



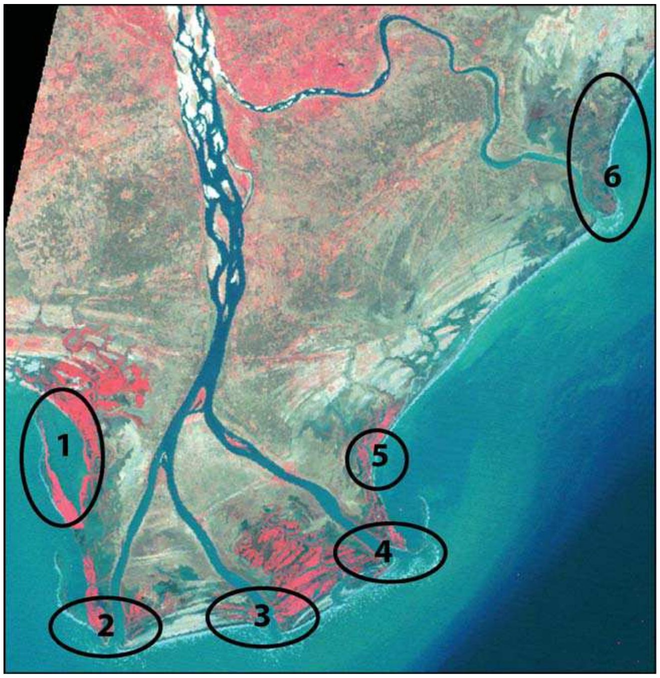
Sources: Inocencio and McCornick 2008

Another study assessing financial benefits of peninsula links (Amarasinghe and Srinivasulu 2009) shows that, although, the individual links of the NRLP could be financially unviable, financial benefits of the interdependent links taken together could exceed the cost. The proposed water deliveries of the peninsular links (see figure 1) start from the northern most link Mahanadi to Godavari. It substitutes water demand for the Godavari down-stream, so that the surplus water of

Godavari can be transferred from the upstream of Godavari basin to Krishna basin. Similar substitutions occur in water deliveries from Godavari to Krishna, Krishna to Pennar, Pennar to Cauvery. Thus, this system of link canals is inter-dependent. Although the net value added financial benefit of water transfers to en-route command areas of some individual links exceeds the cost, peninsular system taken together have higher financial benefits than cost (Amarasinghe and Srinivasulu 2009). In fact, if water transfers are used for irrigating new crop area, even the individual links command areas could be highly financially beneficial. If the irrigation cropping already exists in the proposed command areas, then appropriate high-value cropping pattern could make the system of links financially viable. However, the extent of financial benefits depends on the extent of existing irrigation in the proposed command area. Recent trends of irrigation show that a substantial parts of the proposed command areas are already being irrigated. For example, more than 90% of the en-route command area of the Godavari (Polavaram)-Krishna (Vijayawada) command area by 2005, and much of that was from groundwater.

However, the Amarasinghe and Srinivasulu (2009) study on financial benefits of peninsular basins suffers from some major limitations. First, it does not incorporate the cost of resettlement and rehabilitation of large number of displaced people. It is estimated that more than half a million people will be displaced in the peninsular component alone. Second, it does not take into account the cost of environmental services lost to donor basins due to large water transfers. In fact, Prof. Kanchan Chopra, a well-known environmental economist, contends that environmental cost due to large water transfers in these basins would be rather high and needs to be incorporated into any financial benefit: cost assessment. Smakhtin et al (2008) highlighted some of the environmental cost that can be emerged due to large storage dams in the NRLP (Figure 19)

Figure 19. The image of the Krishna River Delta indicating the areas where a closer inspection of erosion and deposition was made.



Sources: Smakhtin et al 2008

Environmental Impacts of Reservoir Constructions

The NRLP project is associated with large number of storage reservoir constructions. Besides, submergence of area and displacement of large number of people, these reservoirs will substantially change river flow patterns, and hence have impact on aquatic life in the down stream. The changes in reduced flows could reduce sediment loads to downstream delta. Such reduction in sediments could contribute to shrink the river delta, impacting production and mangrove ecosystems. Smakhtin et al (2008) and Gamage and Smakhtin (2008) have shown that large number of reservoirs situated upstream in the Krishna basin already contributes to the shrinking delta. Further construction of reservoirs up-stream will exacerbate the situation.

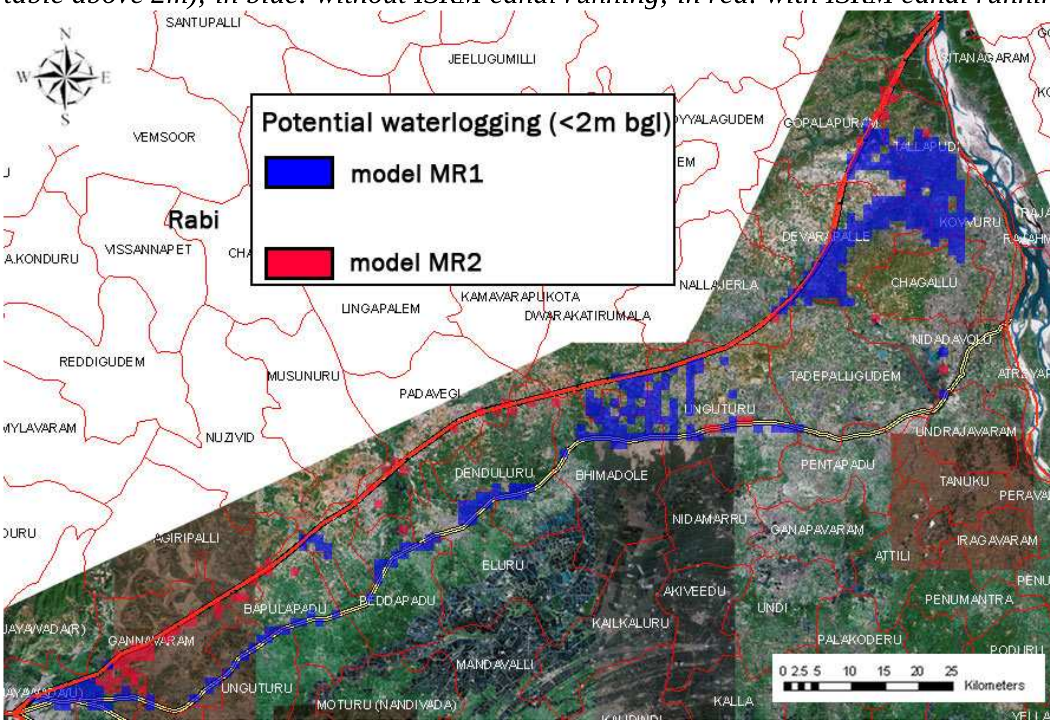
Smakhtin et al (2007) study suggests guidelines for assessing environmental flows, which would at least partially arrest the shrinking delta in major river basins.

Indirect cost and benefits of irrigation

Many financial benefit: cost analysis of new irrigation projects do not consider the indirect impacts due to new irrigation water transfers. These indirect can be both direct and indirect. For example, at present groundwater is the source for irrigation for much of the existing irrigated areas in Godavari (Polavaram) - Krishna (Vijayawada) link. With intensive groundwater irrigation, water table is fast declining in this region. Farmer surveys in the proposed command area shows that declining water tables is presently a major constraint for further diversification, and economic growth in this command area (Bhaduri et al 2008). According to the farmers, the proposed water transfers could recharge the depleting, groundwater tables within the command, and allow more diversification to high-value annual crops, and could bring higher financial benefits.

Massual (2008) and Sharma et al (2008) studies show that proposed irrigation water transfers in the Godavari (Polavaram) - Krishna (Vijayawada) canal could raise the groundwater level on average by 2 meters, and improve the groundwater profile of the over-exploited to semi-critical block in the Krishna basin. However, this paper also highlighted the negative externalities of intensive irrigation in the command area, where about 16% of the proposed command area is also projected to be at risk of water logging (Figure 20).

Figure 20. P*otential waterlogging zones simulated by the groundwater model (water-table above 2m); in blue: without ISRM canal running; in red: with ISRM canal running.*



Sources: Massual 2008

Such negative externalities of water logging could be due to poor understanding of the hydro-geology of the region. Sharma et al (2009b) study in the Indira Gandhi Nahar Project (IGNP) in Rajasthan shows that inadequate attention paid to the drainage issues in the command area where a hard-pan exist few meters below the surface is one reason for water logging. Excessive irrigation supply was another contributor. This study suggests that conjunctive water use with appropriate cropping patterns and irrigation delivery could have arrested water logging in the IGNP. Otherwise, negative externalities of intensive irrigation could offset the indirect benefits that accrue through groundwater recharge.

Managing Rehabilitation and Resettlement in Large Dam Projects

Although there are no definite estimates are available, the NRLP project is expected to displace millions of tribesmen and poor people. Some suggest that it may runs into millions (Vombatkere 2003 cited in Shah et al 2008a). The Peninsular component alone will displace more than 583,000 people (Shah et al 2008a). Two of the proposed reservoirs, Inchampalli at Inchampalli-

Nagarjunasagar and the Polavaram at Godavari-Krishna (Vijayawada) and the canals associated with them displace more than 100 thousand people. A major criticism of the NRLP project is the managing resettlement and rehabilitation (R & R) and social cost of displacement (Bandyopadhyaya and Praveen 2003). In many water resources development projects in the past, it is true that despite government policies and procedures, displaced population still suffer unduly.

Having acknowledged the need for minimizing and wherever possible avoiding displacement, and mitigating short-term impacts, Samad et al (2009) shows that enhanced livelihood opportunities in relocation sites can create longer-term benefits that compensate the short-term losses associated with such resettlement schemes. The study also tests the hypothesis that with proper risk management policies, the short-term negative impacts of the livelihood of displaced people can be fully averted in some cases and largely arrested or to some extent mitigated in others. In these cases, livelihoods of resettled people are restored quickly to those levels at which they were before displacement. The study findings are based on field studies of the resettled population in Ujjani project in Maharashtra and Sardar-Sarovar project in Gujarat and Maharashtra. The hypotheses have been proven true for the 'oustees' in Gujarat, but their success in Maharashtra and Madhya Pradesh lagged in propensity. Although 'oustees' in Gujarat have encountered a period of initial stress and a decline in their standard of living, a majority of them have restored their livelihood to that of the pre-displaced level within 4-6 years. Unlike other states, Gujarat has a unique mechanism for acquiring agricultural land for replacement at market prices, and also has a special agency for implementation. In addition the state has well-developed special units for monitoring the resettlement and rehabilitation process. This study, although discourages forced displacement, adds a new dimension to the discourse on R & R of 'oustees' of major development projects. It reveals that not all is bad for R & R 'oustees', contrary to what is frequently highlighted in many large water transfer projects assessed the long-term benefits generated for the displaced people from new water development projects.

Samad et al (2009) study suggest that in water development projects, there should be a stronger commitment to active engagement to preempt impoverishment risks and take remedial measures., rather than passive contemplation in the flaws of R&R programs and their impoverishing effects.

Trans-boundary Conflicts in Water Transfers

Water transfers in the Himalayan component of the NRLP are saddled with issues and conflicts relating to trans-boundary water diversions. Can existing agreements between countries be modified to augment water supply by transferring more water between basins? A classic case is the agreement between India and Bangladesh on sharing the Ganga's water. Under NRLP, surplus water of the Brahmaputra River is expected to be transferred to the Ganga basin to facilitate further transfers to the peninsular basins. Anik Bhaduri and Barbier (2008b) suggest that existing agreements can be modified to augment water supply, which in turn will benefit both countries. However, this depends on the political altruism of India to transfer water to a downstream country such as Bangladesh. In the absence of political altruism, and if India unilaterally diverts water to her peninsular basins, Bangladesh would incur huge environmental losses. This research is still at an early stage and more work is required for quantifying the water transfers that entail a win-win situation for both countries, under many forms of possible contingencies. However, the study by Bhaduri et al. shows how two countries can transfer water between basins and benefit both if the up-stream country has political altruism to transfer water to the down-stream country or have sound legalistic insurance mechanism in place to safeguard the downstream country in the event of a negation in altruism.

Yet, strong internal political undercurrents may act as a barrier to the transfers of water in the NRLP (Shah et al 2008a). Even within India, creating a strong political consensus around the NRLP project will require considerable effort. Neither political negotiations nor arm-twisting of the kind Mrs. Indira Gandhi used to settle water disputes among states promise such consensus; economics may help wrench open a window to cooperation. Bihar refused to let Ganga waters to be transferred, arguing that if her farmers are unable to use her water today, does not mean they will remain unable to do so forever. Her leader Lalu Prasad Yadav, however, did a volte-face when someone mentioned Bihar might get paid for the Ganga water she allows to be transferred.

Even more serious political issues arise when the dynamics in riparian countries—Nepal, Bangladesh, Bhutan—are considered. The realization of the Himalayan component is critically dependent on the agreement of neighboring countries Nepal and Bhutan to the proposed construction, especially of dams, in their respective territories. Bangladesh, as a downstream country, will be an affected party, and needs to be taken into consideration. Under the India-Bangladesh Treaty of December 1996 on the sharing of Ganga waters, India has undertaken to protect the flows arriving at Farakka, which is the sharing point. West Bengal has only reluctantly agreed to the large allocations of waters to Bangladesh under the Ganga Treaty and has been pressing the needs of Calcutta Port. On the other hand, Bangladesh may feel threatened that a diversion of waters from the Ganga to the southern rivers will not be consistent with the sharing arrangement under the Treaty.

However, existing international agreements provides many lessons for the NRLP. Gichuki and McCornick (2008) highlighted international experiences from agreements on using water in the Aral Sea basin among Central Asian republics, and water transfers between Tagus and Ebro basins in Spain. Much of the initial agreements of water sharing are no longer functional in these basins, and many conflicts have arisen recently. Many of these conflicts are due to the unforeseen circumstances at the time of formulating the initial agreements. Thus, a holistic analysis of the water supply, its use and the future demand for it in different countries in a river basin could reduce these conflicts to a minimum.

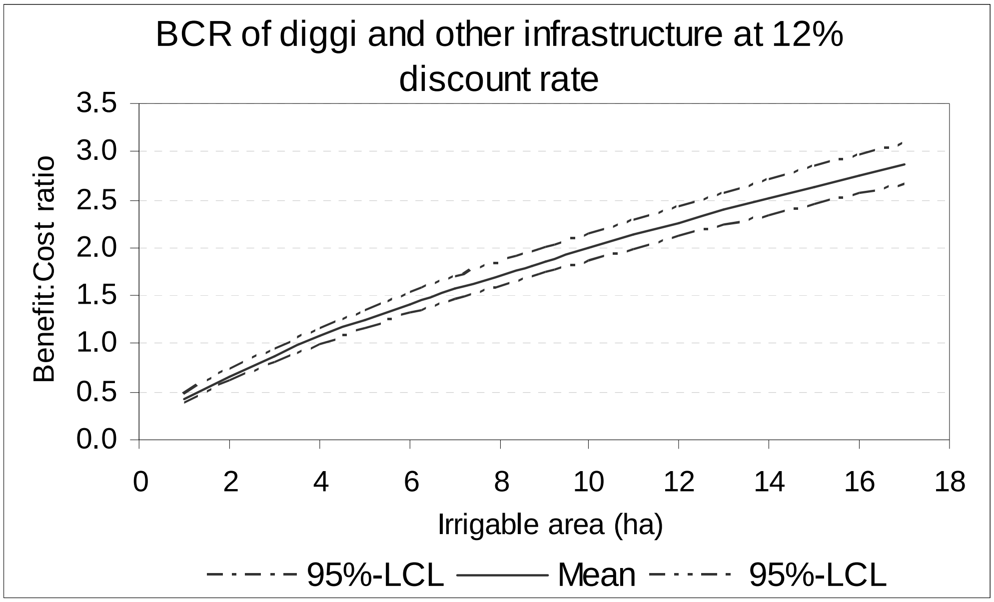
Other Issues

Among the other issues, resources mobilization for the NRLP has also received significant attention. Many are skeptical of the government ability to mobilize large investable funds that NRLP demand (Rath 2003). Budgetary provisions for water development at present are barely adequate for completing ongoing projects. Under the special 'Accelerated Irrigation Benefits Scheme', the government of India allocate funds only for the so-called 'last mile' projects (projects which are nearly complete but have been languishing for years for the lack of relatively modest funds to complete minor residual work). Many incomplete projects scattered in the country,. The NCIWRD estimated that India needs another Rs.70,000 crores during the Tenth Plan and Rs.110,000 crores during the Eleventh Plan just to complete these 'last mile' projects. It is no surprise then that many people doubting the ability for starting thirty mega projects at the same time when India had great difficulty in completing even single projects successfully (Iyer 2003).

Cost and time overrun are indeed major issues in the in large water development projects. The thirty links of the NRLP and command areas for irrigation are to be completed by 2050 to meet the project food demand. However, what we know from the existing projects show no reason to be that optimistic. For example, the envisaged cost of construction of the Sarda-Sarvavo project in Gugarat, Rs 6,840 crores (1986/87 prices), is only a small fraction of the cost of the NRLP (Talati and Shah 2009). But the Gujarat government has already spent Rs. 20,000 crores for the Sarda-Sarvo project. In spite of the time and cost over-runs, only 0.1 mha of 1.8 mha of planned area is irrigated, only 200 MW of the planned 1460 MW hydropower generation realized, only 35 and 1,500 of the 135 and 8,215 towns and cities respectively receive water supply. If the project is to complete as planned, it will take another Rs 20,000 crore investment and 10 years. Talati and Shah (2009) suggests that the Gujarat government should rethink strategies for completing the Sarda-Sarvo project. Instead of investing in field channels, it proposes using piped system of water to distributaries, watercourses and farms. It saves land and water, can irrigate more area, eases pressure on groundwater and then energy for pumping, facilitates public and private partnership, and have large environmental benefits. Massive water distribution programs like NRLP can consider such water distribution to reduce cost and time over and run. They improve water distributions efficiency and reduce social cost of land acquisition for distributary and field channels.

Prevailing low on-farm efficiency of irrigation is a major issue in the NRLP discourses. It is claim that increasing irrigation efficiency in existing irrigation systems can substantially reduce water transfer needs in the NRLP river links. Amarasinghe et al (2009) shows that large gain irrigation efficiency can be possible through intermediate storage structures inside the farm land. The intermediate storage structures called "diggies" in the IGNP command areas not only improves crop water management but also facilitates sprinkler irrigation, which is currently very low in canal command areas. However, 'diggies' are financially viable only for landholdings of more than 4 ha in size (Figure 21). Although, how one implement such interventions in existing irrigation schemes are not clear, they can be useful in new irrigation commands in the proposed NRLP project.

Figure 21 . Financial benefit: cost ratio of diggi and other infrastructure at 12% discount rate



Sources: Amarasinghe et al 2009

Concluding Remarks

If business-as-usual trends continue, India will certainly face a severe water crisis. Inter-basin water transfers could certainly be a solution for water-scarce regions in peninsular India. However, the research conducted under Phase II of this project, although raised many important issues, did not provide precise estimates of the quantity and the locations that can benefit from these water transfers. The need for expanding surface irrigation was always overshadowed by the poor returns to investments in this sector. The colossal investments in the canal irrigation sector in the recent decades had hardly any impact on increasing the surface irrigated area and promoting diversified agriculture. It is indeed intriguing why such stagnation or in some areas declining trends of surface irrigated area continue. Most likely factors are the poor management of the created infrastructure, inefficient water institutions at various levels and economically unviable political policies in the water sector are the factors that lead to such a situation. Inappropriate attention to details in the planning of water resources projects, unreliable supply for on-demand irrigation, inadequate drainage, inappropriate cropping patterns are also contributing to poor performance in the existing canal irrigation command.

Studies of the proposed links in also show inadequate detailed planning. Assessment of available water surplus in river basins should also receive significant attention. Future water requirements of different water users within the basin, whether for irrigation, domestic or industrial uses and most importantly for the downstream riverine environment should be assessed before deciding the surplus. Presently, in the entire discourse on water resources development, environment is a silent stakeholder. Equally important is to consider water availability at shorter time periods, at least monthly for evaluating the water availability. In the absence of such an analysis, more water is perceived to be available for transfers at different location.

The cropping patterns proposed under the new links also need revisiting. The cropping patterns in the existing irrigated areas are more high-value than those in the proposed irrigated areas. Rice dominates proposed cropping patterns, whereas rice irrigation is decreasing in nearby existing irrigation schemes. Irrigation will be available when rainfall meets most of the irrigation requirement. Many of the proposed links will not be financially viable under the proposed cropping patterns, and yields low net value addition per each additional drop of irrigation water delivery. However, financial benefits from high-value cropping patterns exceed the costs in many instances. When the system is considered as a large project with several smaller schemes, financial benefits are seemed to exceed the project cost, which only include the capital and operation and maintenance cost. Whether, the social cost, when the cost of environmental impacts and rehabilitation and resettlement of displaced people are included, will exceed the net value added benefits is not clear.

When water is proposed to be transferred across the basins, on most occasions the interests of donor and the recipient regions (states/ countries) are at conflict and need to be resolved through innovative win-win solutions. In the absence of mature and experienced river basin organizations and well-established sharing mechanisms, the issues involved are sure to become more complex than the hydraulic structures and, have the potential to become the first stumbling block in the process of water transfer. The associated and equally important issue is the properly designed, disseminated and implemented rehabilitation and relief package for the project affected people. As the land is becoming scarce and valuable and civil society organizations more vocal and effective, the acquisitions must be handled with great sensitivity, tact and empathy.

Objective 3: Contribute to a plan of institutional and policy interventions as a fallback strategy for NRLP and identify best strategies to implement them.

Contributing to Alternative Water Sector Perspective Plan

Introduction

Given the concerns for large-scale inter-basin water transfers at present, the NRLP project, most likely in its proposed form, may not take-off in the near future. But, it is clear that India's water needs are increasing fast. In fact, India could be facing a water crisis in the near future (Amarasinghe et al 2008c). If NRLP fails to take-off, what then is the fallback option for meeting India's water needs. This section explores some alternative strategies that contribute to an alternative water-sector perspective plan for the short- to medium-term. These strategies include:

- Improving water productivity
- Realizing rainfed potential
- Promoting demand management
- Increasing groundwater recharge, and
- Increasing virtual water trade, and

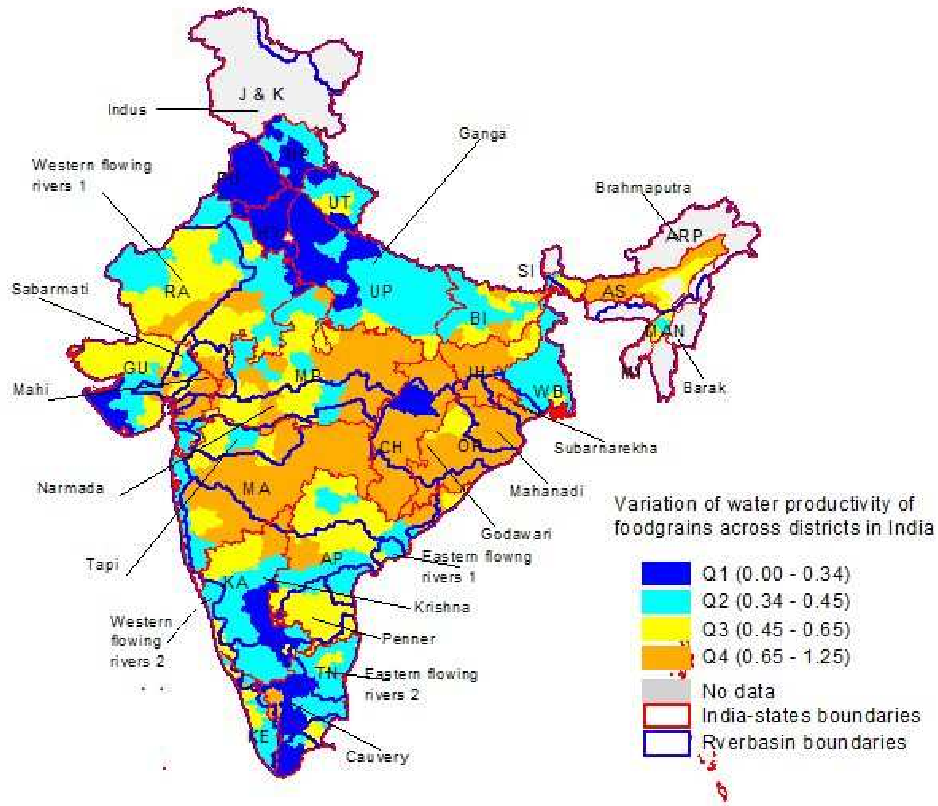
We discuss their potential, prospects and constraints in the next section.

Improving water productivity

Many of India's agriculturally prosperous regions are water-scarce regions, where not only the natural endowment of water is poor (Amarasinghe *et al*., 2007a), but also the demand for water in agriculture alone far exceeds the renewable water resources that are utilizable (Kumar *et al.*, 2008b). Agriculture is in direct conflict with other sectors of water economy, and environment. The common features of these regions are excessive withdrawal of groundwater, and excessive diversion of water from rivers, causing environmental water stress. The scope for augmenting the utilizable water resources in these regions is extremely limited. While there are many regions in India where water resources are abundant, most of these regions offer limited potential for increasing agricultural production due to the limitations imposed by land constraint and ecological constraints. More over, productivity of water use is very low in India for major crops in terms of the amount of biomass produced per unit of water depleted in crop production (Figure 22). So, improving water productivity in agriculture, wherever possible, holds the key to not only sustaining agriculture production and rural livelihoods, but also making more water available for other sectors including the environment.

Improving water productivity in agriculture can bring about many positive outcomes. While in some regions, WP improvement would result in increased crop production with no increase in consumptive use of water, in some others it would result in reduced use of surface or groundwater draft. Both would protect the environment. On the other hand, there are certain regions in India where yields are very poor as the crops are purely rain-fed in spite of having sufficient amount of un-utilized water resources. Augmenting water resources and increasing irrigation in such regions can result in enhanced yield and income returns, as well as WPI. Hence, such strategies have the potential to reduce poverty in these regions.

Figure 22. Water productivity of foodgrains across districts in India



Source: Amarasinghe et al 2009i

Opportunities

There are several opportunities for improving the water productivity of crops. They include:

- providing full irrigation to meet the full crop evapo-transpirative demand or providing supplemental irrigation in critical periods of crop growth for the rainfed crops for increasing the crop yield (Amarasinghe and Sharma 2009i, Sharma et al 2009a);
- replacing long duration food crops with higher water use efficiency by short duration ones with low efficiency; and growing crops in regions where their yields are higher due to climatic advantages (high solar radiation and temperature for instance), better soil nutrient regimes or lower ET demand;
- Practicing deficit irrigation in areas where yield is large and consumptive water use is very high (Amarasinghe and Sharma 2009i);
- improving quality and reliability of irrigation water (Kumar et al 2009c);
- managing irrigation for certain crops by controlling allocation or increasing allocation to the said crops (Palanisami *et al.*, 2008, Kumar and van Dam, 2009);
- adoption of high yielding varieties without increasing the crop consumptive use (Amarasinghe and Sharma 2009i);

- Bridging yield gap in by providing optimal dosage of nutrients such as artificial fertilizing; and improving farming systems with changes in crop and livestock compositions (Singh and Kumar 2009e, Kumar and van Dam, 2009d, Sikka 2009).

There are many irrigated districts in eastern India which are dominated by food crops. The yield of food crops such as wheat and paddy is very low in these districts, and yield gaps high (Kumar *et al*., 2008c), and also the total factor growth is very low (Evenson *et al*., 1999). Amarasinghe and Sharma (2009i) show that there are 202 districts in the country which fall under the category of medium consumptive use of water for irrigated crops (300-425mm), but with high yield gaps. Improved agronomic inputs (high yielding varieties and better use of fertilizers and pesticides) can significantly raise the yields. This will have a positive impact on water productivity, though water productivity is not a concern for farmers in this water-abundant region of India. While there are districts in central India, where better use of fertilizers would help enhance crop yields, these areas also require optimum dosage of irrigation also to achieve this (Kumar *et al*., 2008c).

There are many irrigated areas in Western India with large potential for water productivity improvements through: 1) water delivery control; 2) improving quality and reliability of irrigation water supplies (Palanisami *et al*., 2008; Kumar et al., 2009c); and 3) use of micro irrigation systems (Palanisami *et al*., 2008). Amarasinghe and Sharma (2009c) showed that water productivity in irrigated crops could be enhanced significantly through deficit consumptive water use through deficit irrigation, a key strategy in water delivery control, in 251districts. These districts already show very high yield per unit of land, and receive intensive irrigation.

Most of India's "so called" rain-fed areas are in central India and Peninsular region. Amarasinghe and Sharma (2009i) shows that there are 208 districts where average consumptive use of water for food grain production is low (below 300 mm), due to larger area under rain-fed course grains like pulses such as green gram, black gram and horse gram. These crops give very low grain yields, resulting in low WP. Supplementary to full irrigation can boost both yield and WP significantly in the rainfed areas of these districts.

Constraints

In spite of large opportunities, there are many constraints for increasing water productivity too. They include:

- constraints induced by land availability (Amarasinghe and Sharma 2009); Singh and Kumar (2009),
- food security concerns and regional economic growth (Kumar and van Dam, 2009d). Cereals such as rice and wheat are important for food security of India but have low water efficiency, compared to cash-crops such cotton, castor and ground nut which have high water use efficiency(Kumar and van Dam, Chapter 6, this book),
- existing institutional and policy frameworks in improving water productivity for irrigated crops. For instance, in many situations, improvement in water productivity in kg/ET or Rs/ET does not convert into better returns for the farmers due to inefficient pricing of water and electricity. The policy constraints concern the pricing of water used in canal irrigation and electricity used

in well irrigation, whereas the institutional constraint comes from the lack of well-defined water rights for both surface water (Kumar and Singh, 2001) and groundwater. Both aspects leave minimum incentives for farmers to invest in measures for improving crop water productivity as such measures do not lead to improved income in most situations.

- lack of knowledge and wherewithal to adopt technologies and practices to improve water productivity in agriculture, especially in the communities dependent on rain-fed crops many communities (Kumar 2009a),
- Lack of credits required for investing in water harvesting systems for supplementary irrigation for rain-fed crops, and economic viability issues (Kumar 2009b)

In nutshell, while there seem to be great opportunities for improving water productivity in agriculture. The extent to which this can be achieved depends on the scale at which the above said constraints operate (Palanisami et al 2008). Some of the policy and institutional interventions are:

- improving the quality of irrigation water supplies from canal systems, including a provision for intermediate storage systems like the *diggies* in Rajasthan (Amarasinghe et al 2009h);
- improving quality of power supply in agriculture in regions that have intensive groundwater irrigation (Shah and Verma 2009) and improving electricity infrastructure in rural areas of eastern India (Shah 2009);
- provision of targeted subsidies for micro irrigation systems in regions where their use result in major social benefits (Narayanamoorthy 2009);
- investing in rainwater harvesting for supplementary irrigation in rainfed districts (Sharma et al 2008).
- Rainwater harvesting and irrigation infrastructure for supplemental or full irrigation would significantly enhance crop yields in many, and water productivity in some rain-fed areas. This would be a medium term measure.

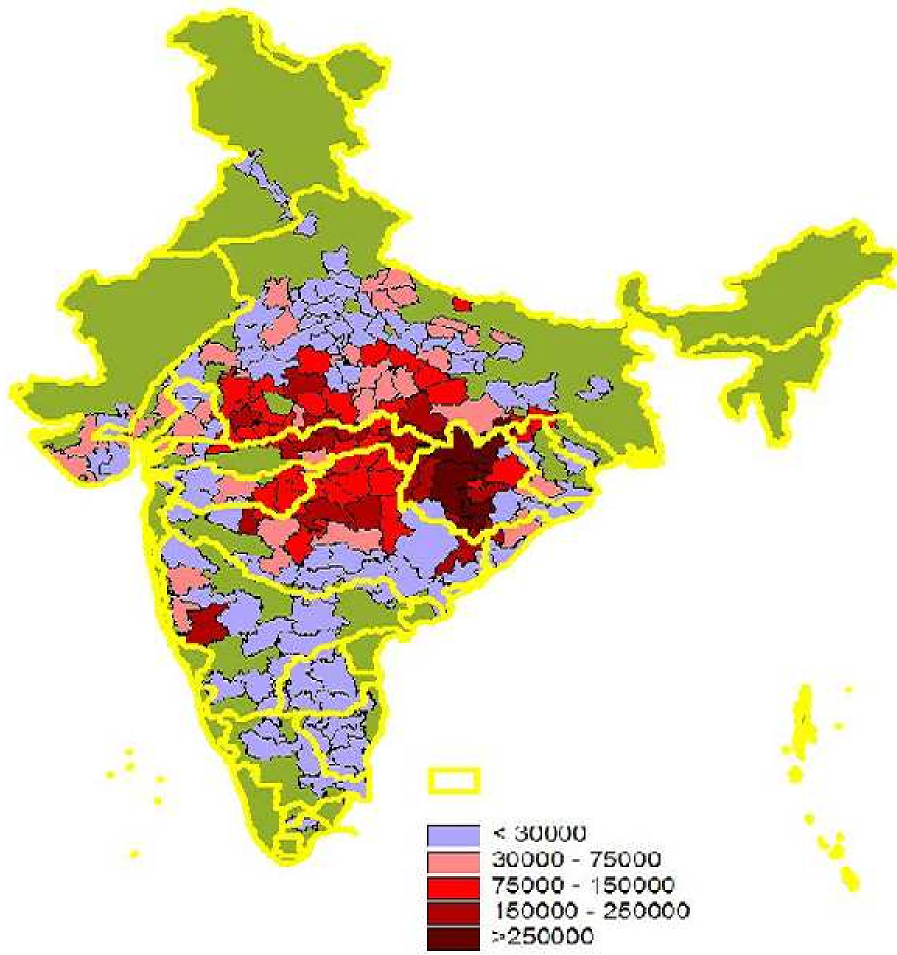
Realizing rainfed potential

Rain-fed agriculture covers 60% of the present crop area in India but contributes to only one-third of the crop production. Improving productivity could significantly increase crop production from the existing rain-fed areas and in turn reduce requirements for large scale intra- and inter basin water transfers for irrigation. The importance of supplemental irrigation in critical periods of water stress for higher crop yields, opportunities and constraints of water harvesting for supplemental irrigation are vital areas of research and development for the Indian rain-fed agriculture.

Sharma et al. (2008) showed that recurrent mid-season and terminal droughts are serious constraints for higher rainfed productivity in India. Supplemental irrigation in these critical periods can significantly increase yields of many rain-fed crops. In large parts of rain-fed areas, water availability is not a constraint for supplemental irrigation. This analysis shows that 28 M ha of rain-fed lands, which can benefit from supplemental irrigation, generate about 114 billion cubic meters of runoff annually (Figure 23). Only a fraction of this runoff can provide critical supplemental irrigation to 25 million ha of crop lands during normal monsoon and 20 million ha during the drought seasons. Supplemental irrigation of this harvested water during the later stages of crop growth has the potential to enhance rain-fed production by more than 50 %. This analysis shows water harvesting for supplemental irrigation in rain-fed lands is indeed economically viable and socially equitable, and could have little negative impact in the downstream. Potential benefits are much higher for oilseeds, pulses and rain-fed rice areas as compared to coarse cereal areas.

This paper suggest that there is a significant opportunities for realizing the potential of rain-fed agriculture in India through the application of a single supplementary irrigation and some follow up on the improved practices. Extensive area coverage rather than intensive irrigation need to be followed in regions with higher than 750 mm/ annum rainfall, since there is a larger possibility of alleviating the in-season drought spells and ensuring a second crop with limited water application. This component may be made an integral component of the ongoing and new development schemes in the identified rural districts. The proposed strategy is environmentally benign, equitable, poverty-targeted and financially attractive to realize the untapped potential of rain-fed agriculture in India.

Figure 23. Spatial distribution of surplus runoff (ha-m) across dominant rain-fed districts and river basins of India.



Source: Sharma et al 2009a

Promoting demand management

Growing gap between the demand and supply in Indian irrigation is serious concern for policy makers. While many regions in India are becoming water scarce where water availability is a constraint for meeting increasing demand, many other regions have significantly higher increasing demand than supply. While, supply side solutions based on new augmentation are essential in some context, they cannot be the exclusive basis for water sector strategies. Many demand management strategies shall help, and they include 1) water pricing, 2) formal and informal water markets, 3) water rights and entitlement systems, 4) energy-based water regulations such as power tariff and supply manipulations, 5) water saving technologies such as drip, sprinklers, crop choices and farm practices, and 6) user and community based organization. Saleth (2009) synthesizes is shows the research studies conducted in assessing potential contribution of demand management strategies in an alternative perspective plan. (Reddy, V.R. 2009; Palanisami 2009b; Narain 2009; Malik 2009b; Narayanamoorthy 2009b; and Reddy, M. V. 2009)

They studies assessed the potential, problems and prospects of the above demand strategies in the Indian context. The major focus of these studies is to asses the present status of these options in the irrigation management strategy in India. It includes extent of their application, their effectiveness in influencing water use decisions at the farm level, presence of policies in promoting them at the national and state level, cases of success and best practices in demand management, and what lessons are there for policy in up-scaling them. What are the bottlenecks and constraints for promoting them on a wider scale, particularly within the irrigation sector? What are the present potentials and future prospects for these options as an effective means for improving water use efficiency and water saving, which are sufficient enough to either to expand irrigation or to reallocate water to nonagricultural uses and sectors?

The focus and coverage show that some demand management options are context-specific, whereas others are applicable in a more generic context (Saleth and Amarasinghe 2009 b). For instance, water pricing is a tool that is largely applicable to canal regions, whereas the option involving energy regulations—involving both supply and price manipulations—is largely applicable to groundwater contexts, though they may also be relevant in canal regions to the extent water lifting is involved there. This is also true in the case of the options involving both the water markets and water saving technologies, as they occur predominantly in the groundwater regions.[7] But, the options involving water rights and user organizations are relevant in the context of both canal and groundwater regions. Similarly, some of the options are more direct and immediate in their impacts on water demand, while others have an indirect and gradual effect and, that too, depends on a host of other factors. For instance, water rights and water saving technologies have a more direct effect on water demand, and the options involving user organizations and energy regulations only have an indirect effect.

The demand management options also differ considerably in terms of the scope for adoption and implementation, especially from a political economy perspective. Among the options, water rights system is the most difficult one followed by water pricing reforms and energy regulations,

[7] The water saving technologies using micro-irrigation—sprinklers and drip—are rare in canal command areas. However, there are evidences that sprinkler irrigation can be adopted in conjunction with intermediate water storage structures in farms (Amarasinghe et al. 2008). There are also evidences that aerobic rice and system of rice intensification can also be used as demand management strategies for saving water in rice cultivation.

but those involving water markets and user organizations are relatively easier to adopt, though their implementation can still remain difficult. Water saving technologies, though politically benign and not controversial, still require favorable cropping systems and effective credit and investment policies. The differences in their application context, political feasibility and the gestation period of impact are very important and should be understood because such factors will determine the relative scale of application and the overall impact of the demand management options.

As for the influence, some of the options can have immediate effects and some others have the potential to influence water allocation and use, these effects are rather too meager to have an impact of the magnitude that is needed for generating a major change in water savings and allocation. The two central problems limiting the impacts of demand management are their limited geographic coverage and operational effectiveness. Concerted policies are also lacking in really exploiting their demand management roles. All these options are pursued as if they are separate and essentially in an institutional vacuum because the necessary supporting institutions are either missing or dysfunctional in most contexts.

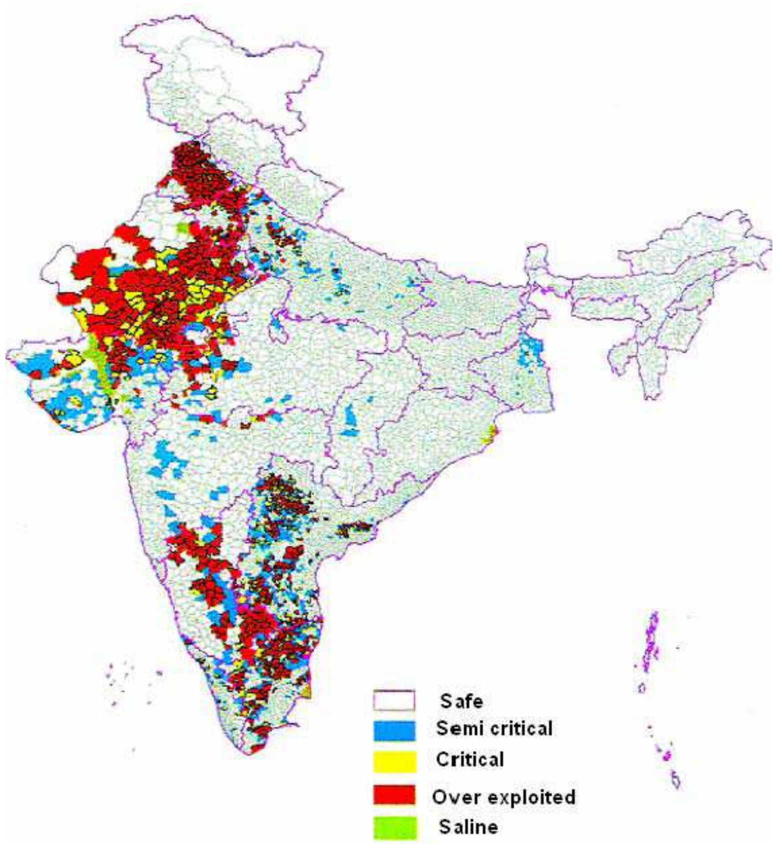
However, the status and performance of the demand management options show a concerted policy for demand management in irrigation is conspicuous for its absence both at the national and state levels. Instead, what is being witnessed is a casual and *ad hoc* constellation of several uncoordinated efforts in promoting the demand management options. In most cases, these options are pursued lesser for their demand management objectives than their other goals such as cost recovery and management decentralization. Even here, the policy focus is confined to only few options such as pricing, user organizations, energy regulations and, to a limited extent, water saving technologies. Although several policy documents and legal provisions clearly imply water rights system, there are no explicit government policies either as to its formal existence or its implementation, except for the recognition of the need for volumetric allocation and consumption based water pricing. This is also true for water markets, though their existence and operation across the country is well documented. Considering the critical importance of water rights and water markets for their direct effects on demand management and their indirect effects in strengthening other demand management options, it is important that they are formally recognized and treated as the central components of a demand management strategy.

Although the effectiveness of demand management options are constrained by several institutional, technical and financial factors, a lack of well articulated policy is the major bottleneck and implementing water demand management both at the national and state levels. Such a policy provides the basis for the much needed financial and political commitments for implementing effective demand management programs. An effective demand management strategy can both expand irrigation and also release water for other productive uses even at the current level of water use. Therefore, it is logical to divert at least part of the investments that are currently going into new supply development.

Increasing groundwater recharge

For many centuries, surface storages and gravity flow has been the main source of irrigation for Indian agriculture. However, over the last four decades, while surface irrigation has been gradually declining, groundwater irrigation through small private tube wells has been flourishing. Tube wells, from a mere 1000's in the middle of last century, blotting the countryside today, swelling to more than several millions by 2000. This number is still growing. By 2005, groundwater contributed to 61% of the gross irrigated area, but this contribution could be even more if all the conjunctive water in canal command areas are also accounted. Indeed, contrary to what most claim, groundwater irrigation has spread everywhere, even outside canal command areas where recharge from surface return-flows could not have reached (Bhaduri et al 2008). As a result of this tube well boom, a significant part of India's agriculture production and rural livelihoods not only depends on groundwater irrigation, but also is at threat due to over exploitation (Figure 24)

Figure 24 . Groundwater over-exploited areas of India



Source: Shah 2009

Sustaining groundwater irrigation is essential for a country like India, for groundwater irrigation, 1) gives large spatially distributed social benefits by spreading to vast rural areas that surface irrigation generally has not reached and cannot reach, especially benefitting the large number of smallholders in Indian agriculture, 2) is more efficient in irrigating crops, thus allowing better application of agriculture inputs and crop intensification and diversification, resulting in higher yields an income per unit land than in canal command areas (Kumar et al 2008), 3) is a better mechanism for drought proofing (Shah 2008a), and enhances the importance of mitigating impacts due to climate change (Shah 2009c). For sustainable groundwater irrigation, India needs to make more artificial recharge in many locations and better managements of aquifer storages.

India already has in place a National Master Plan for Groundwater Recharge, augmenting the resources annually by another 38 Bm^3 (CGWB 2008). The program, costing Rs.24,500 crore (US $ 6 billion at January 2008 exchange rate), proposes many recharge structures including, percolation tanks; check dams, cement plugs and *nala* bunds; Gabian structures akin to check dams; village tanks modified to serve as recharge tanks by desilting and fitting them with cut-off trench and a waste-weir; recharge shaft, that is a trench backfilled with boulder and gravel; sub-surface dykes or groundwater dams; dried up or disused dugwells; injection wells in alluvial aquifers overexploited by tubewell pumpage; and roof-water harvesting structures especially for urban settlements etc. Shah (2009c) assessed the shortcoming of the master plan and how best that can be implemented in the future to reach its potential benefits. Shah contends that the master plan should:

1. be based more on demand side principle- that it should recharge more in areas where groundwater use is heavy and depletion is critical, than the supply side principle- that it locates most recharge structures where uncommitted surplus water is high and aquifers are roomy (See table 3 for areas where groundwater availability is low but use is high).

Table 3 . Demand and supply sides of run-off allocation for groundwater recharge

		Availability of uncommitted surplus water and large groundwater storage	
		Low	High
Groundwater demand for various uses including irrigation	Low	Neither scope nor need groundwater recharge e.g. Jharkhand	Huge scope for groundwater recharge but little need e.g. North Bihar, North Bengal, coastal Orissa
	High	Limited scope for recharge but maximum need for it to sustain groundwater economy e.g. Saurashtra, Krishna, Sabarmati, Godavari, Pennar basins	Scope as well as need for intensive groundwater recharge e.g. Indus basin(Punjab, Haryana, western Rajasthan)

Source: Shah 2009

2. optimizes allocation of financial resources by allocating according to the degree of depletion of resources. These are the areas where groundwater demand is high and supply is not adequate. Else, many regions where groundwater demand is less and water depletion is low could get substantial amount of resources,

3. have a clearly defined pathway of implementation, indicating the role of different agencies in supervising implementation and monitoring the performance,
4. consider the sustainability of the recharge structures, because most of the recharge structures are proposed on government land common property.
5. seeks active participation of local stakeholder participation, i.e. individual users or local communities, for not only on maintenance but also on construction of these structures. Stakeholders' participation is essential for maintenance of these structures.
6. understand and respect the contextual specificities of ground water depletion. It should assess the drivers behind the boom of groundwater extraction. The plan should accept the fact the surface storage will not respond to the socio-ecology of groundwater boom in India, and groundwater recharge should not be the last resort for storing surface runoff.
7. harmonize priorities with stakeholders' needs. While the plan proposes to locate structures where it can recharge the maximum, the stakeholders prefer to have located where the demand is maximum.

Shah's study proposes an alternative plan of recharging dugwells scattered in hard-rock areas, resulting in augmenting more groundwater resources than the master plan does. This alternative plan also responds better to the seven considerations mentioned above.

The study by Sundararajan et al (2009) assessed the prospects and constraints for recharging groundwater through dug wells. Using a survey of 767 dug well own farmers in 7 districts in India, this paper shows that there is indeed an enormous hydrological prospect for recharging groundwater in hard-rock areas through dug-wells. Although there are some reservation by farmers, they generally agree that recharge through dugwells increases water availability, especially during the dry-season. The reservation is mainly on the fact that they can use only small fraction (30%) of the recharge in their farms, but the farmers agree that there are common benefits from this recharge. This paper suggests assessing different models managing dug well recharge, including applying a group of 10 farmers for recharge; the subsidy for constructing structures is transferred to farmers in April or May, as most of the farmers unanimously prefer; promote local businesses around recharge structures, such as to harness the experience of well drillers, who also operate during the same summer months?

Virtual Water Trade

Virtual water trade concept suggest that 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 productivity uses. Verma et al (2008) study[8] quantifies and critically analyzes inter-state virtual water flows in India in the context of a large inter-basin transfer plan of the Government of India.

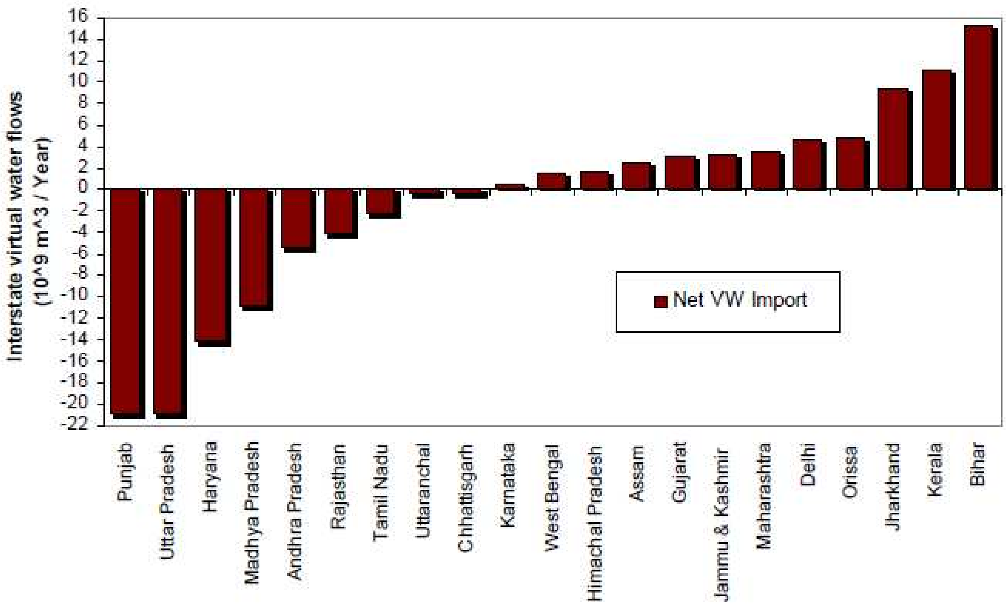
This analysis shows that The amount of virtual water traded between states is more or less equivalent to the water transfers of 178 Bm^3 proposed in the NRLP. Much of the water trade is

[8] This report is part of the MSc thesis of Shilp Verma. The financial support to this study was provided by the "Strategic Analyses of the National River Linking Project.

from water stress to water surplus states at present (Figure 25). In fact, existing virtual water trade between states exacerbates water scarcities in some states. The existing pattern of inter-state virtual water trade is influenced by non-water factors such as "per capita gross cropped area" and "access to secured markets".

This study suggest that in order to have a comprehensive understanding of virtual water trade, non-water factors of production need to be taken into consideration. This includes some changes to food procurement and input subsidy policies.

Figure 25 . Interstate Virtual Water Flows in India



Source: Verma et al 2008

OUTCOMES AND IMPACTS

1 Proforma

Summary Description of the Project's Main Impact Pathways

Actor or actors who have changed at least partly due to project activities	What is their change in practice? I.e., what are they now doing differently?	What are the changes in knowledge, attitude and skills that helped bring this change about?	What were the project strategies that contributed to the change? What research outputs were involved (if any)?	Please quantify the change(s) as far as possible
Policy makers	Have more emphasis on groundwater irrigation, recharge, increasing efficiency	Knowledge on Indian irrigation	Formed a high powered Project advisory committee	Have to wait and see
NGOs	Have more emphasis on environmental flows in river basins.	Independent, unbiased approach analyzing the problem	Communication with stakeholders	
	Appreciation of water scarcities and importance of eco-system services in river basins	Communication with the stakeholders		

Of the changes listed above, which have the greatest potential to be adopted and have impact? What might the potential be on the ultimate beneficiaries? Emphasis on environmental flows, groundwater recharge and irrigation, electricity management in groundwater irrigation

What still needs to be done to achieve this potential? Are measures in place (e.g., a new project, on-going commitments) to achieve this potential? Please describe what will happen when the project ends. More research. Research understanding intricate relationships between surface and groundwater irrigation. Irrigation and its impacts on environmental impacts downstream of basins

Each row of the table above is an impact pathway describing how the project contributed to outcomes in a particular actor or actors.
Which of these impact pathways were unexpected (compared to expectations at the beginning of the project?)

Why were they unexpected? How was the project able to take advantage of them?

What would you do differently next time to better achieve outcomes (i.e. changes in stakeholder knowledge, attitudes, skills and practice)?

Have more effort to involve more partners from the government agencies.

2 International Public Goods

Project published five books on various aspects of water management issues including the National River Linking Project of India

1. India's water future: Scenarios and issues. *Strategic Analysis of National River Linking Project of India. Series 1. Eds. Upali. A.* Amarasinghe, Tushaar Shah and R.P.S. Malik, R.P.S.
2. Proceedings of the Workshop on Analyses of Hydrological, Social and Ecological Issues of the NRLP. *Strategic analyses of the National River Linking Project (NRLP) of India, series 2.* Eds. Upali A. Amarasinghe and Bharat R. Sharma
3. Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. *Strategic Analysis of National River Linking Project of India. Series 3*. Saleth, R.M. (Ed) 2009.
4. Improving Water Productivity in India: Potential, Prospects and Constraints. *Strategic Analyses of the National River Linking Project (NRLP) of India, Series 4.* Eds. M. Dinesh and Upali A. Amarasinghe
5. Proceedings of the Workshop on Strategic Issues in Indian Irrigation. *Strategic analyses of the National River Linking Project (NRLP) of India, series 5.*

3 Publications

Peer-reviewed Publications of CN 48.

1. Amarasinghe, U. A., P. McCornick, and Shah, T. 2009. Projections of Irrigation Water Demand in India: What do Recent Trends Suggest? *Intl. J. River Basin Management* Vol. 7, No. 2 (2009), pp. 157–166
2. Gamage, N. and Smakhtin, V. 2008. Do river deltas in east India retreat? A case of the Krishna Delta. Geomorphology. (GEOMOR-02734; No of Pages 8, Forth coming)
3. Amarasinghe, U, Shah, T. and McCornick, P. 2008. Seeking Calm Water: Exploring Policy Options for India's Water Future. *Natural Resource Forum,* 32(4): 305-315
4. Shah, T., Bhatt, S., Shah, R.K. and Talati, J. 2008. Groundwater Governance through Electricity Supply Management: Assessing an Innovative Intervention in Gujarat, western India. *Agricultural Water Management* 95(11):1233-1242

5. Bhaduri, A. and E. B. Barbier. 2008. International water transfer and sharing: the case of the Ganges River, Environment and Development Economics. 29-51 Vol 13 Issue 1
6. Bhaduri, A. and E. Barbier. 2008. Political Altruism of Water Sharing, B.E. Journals in Economic Analysis & Policy. Vol 8, Issue 1
7. Verma, S., Kampman, D.A., van Der Sarg., P. and Hoekstra, A. Y. 2008. Going Against the Flow. A Critical Analysis of Virtual Water Trade in the Context of India's National River Linking Program. Value of Water Research Report Series 31. Delft, Netherland: UNESCO-IHE Institute for Water Education,
8. Shah, T. 2008. India's groundwater irrigation economy: The Challenge of Balancing Livelihoods and Environment. In Kanchan Chopra and Vikram Dayal (Eds) *Handbook on Environmental Economics in India,* Oxford University Press
9. Shah and Verma 2008. Co-management of Electricity and Groundwater: An Assessment of Gujarat's Jyotirgram Scheme. *Economic and Political Weekly,* Vol.43(7): 59-66
10. Shah, T. 2008. Governing the Groundwater Economy: Comparative Analysis of National Institutions and Policies in South Asia, China and Mexico. In Ballabh, Vishwa (Ed.) *Governanace of water: Institutional alternatives and political economy*, Sage Publications, Delhi, India. pp: 237-266

11. Shah, T. 2008. The New Institutional Economics of India's Water Policy. In Ballabh, Vishwa (Ed.) *Governanace of water: Institutional alternatives and political economy*, Sage Publications, Delhi, India. pp: 307-338
12. Bhaduri, A. and E. Barbier. 2008. Political Altruism of Water Sharing, B.E. Journals in Economic Analysis & Policy (Accepted and forthcoming).
13. Verma, Shilp; Phansalkar, Sanjiv, J. 2007. India's water future 2050: potential deviations from 'business-as-usual' . International Journal of Rural Management, 3(1): 149-179.
14. Amarasinghe, U.A., Shah, T., Turral, H., and Anand, B.K. 2007. India's Water Future to 2025-2050: Business-as-Usual Scenario and Deviations. *IWMI Research Report 123*. Colombo, Sri Lanka: International Water Management Institute.
15. Smakhtin, Vladimir, Gamage, N., and Bharati, L. 2007. Hydrological and Environmental Issues of Inter-basin Water Transfers in India: A case of the Krishna River Basin. *IWMI Research Report 120.* Colombo, Sri Lanka: International Water Management Institute.
16. Amarasinghe, U. A., T. Shah, and O. P. Singh. 2007. Changing consumption patterns: Implications on food and water demand in India. *IWMI Research Report*, 119, Colombo, Sri Lanka: International Water Management Institute
17. Smakhtin, V., M. Arunachalam, S. Behera, A. Chatterjee, S. Das, P. Gautam, G. D. Joshi, K. G. Sivaramakrishnan, and K. S. Unni. 2007. Developing procedures for assessment of ecological status of Indian river basins in the context of environmental water requirements. *IWMI Research Report*, 114, Colombo, Sri Lanka: International Water Management Institute.
18. Shah, T. 2007. Crop Per Drop of Diesel? Energy Squeeze on India's Smallholder Irrigation. *Economic and Political Weekly,* Vol. 42(39): 4002-4009.
19. Shah, T, Giordano, M. and Wang, J. 2007. Irrigation Institutions in a Dynamic Economy: What Is China Doing Differently from India? In Ragone, S., Hernández-Mora, N., de la Hera, A., Bergkamp, G. and J. McKay (eds.) *The global importance of groundwater in the 21st Century: Proceedings of the International Symposium on Groundwater Sustainability*. National Groundwater Association Press, Ohio, USA, 177-187
20. Shah, T. 2007. *Institutional and policy reforms.* In Briscoe, John and Malik, RPS. (Eds) Handbook of water resources in India: Development, Management and Strategies, Oxford University Press, New Delhi, pp: 306-326.
21. Smakhtin, V. and Anputhas, M. 2006. An Assessment of Environmental Flow Requirements of Indian River Basins. *IWMI Research Report*, 106, Colombo, Sri Lanka: International Water Management Institute.
22. Kumar, M. Dinesh, Shantanu Ghosh, O.P. Singh, Ankit Patel and R. Ravindranath 2006 Rainwater harvesting and groundwater recharge in India: Critical Issues for Basin Planning and Research, Land use and water resources research, 6 (1): 1-17
23. Shah, T and Phansalkar, S.J. 2006. The private sector's role in India's water resources development. In Rijsberman, Frank (Ed) *4th World Water Forum – Local Actions for a Global Challenge*, World Water Council pp. 182-194.

Others

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

Amarasinghe, U. A., T. Shah, and O. P. Singh. 2007b. Changing consumption patterns: Implications on food and water demand in India. *IWMI Research Report*, 119, Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A. and Sharma, B. Eds. 2008a. National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. *Strategic Analysis of National River Linking Project of India. Series 2*. Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A. and Sharma, B. 2008b. National River Linking Project: Analyses of Hydrological, Social and Ecological Issues: Overview of the Workshop Proceedings. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2 Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Amarasinghe, U.A., Shah, T. and McCornick, P. 2008c Seeking Calm Waters: Exploring policy options for India's Water Future, Natural Resource Forum, 32 (4): 305-315.

Amarasinghe, U.A., Singh, O.P., Shah, T. and Chauhan, R.S. 2008d. Benefits of irrigation Water Transfers in the National River Linking Project: A Case Study of the Ken-Betwa Link. Overview of the Workshop Proceedings. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Amarasinghe, U.A., Samad, M., Anand, B.K., and Narayanamoorthy, A. 2008e Irrigation in Andhra Pradesh: Trends and Turning Points. Draft paper presented at the Regional Workshop in Hyderabad on 31st August 2008 under the "Strategic Analyses of the India's National River Linking Project.

Amarasinghe, U.A. and Srinivasulu, R. 2009. Cost and Benefits of National River Linking Project: An Analysis of Peninsular Links. In Proceedings of the National Workshop of "Strategic Issues in Indian Irrigation", held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U. A., Shah, T., and Malik, R.P.S. (Eds) 2009a. India's water future: Scenarios and issues. *Strategic Analysis of National River Linking Project of India. Series 2* Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U. A., Shah, T., and Malik, R.P.S. Eds. 2009b. India's Water Futures: Drivers of Change, Scenarios and Issues. In *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A., and Singh, O.P. 2009c. Changing Consumption Patterns of India: Implications on Future Food Demand. In *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A., McCornick, P.G., and Shah, T. 2009d. India's Water Demand Scenarios to 2025 and 2050: A Fresh Look. In *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A., Shah, T. and McCornick, P.G. 2009e. Meeting India's Water Future: Some Policy Options In *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A., Singh, O.P., Sakthivadivel, R. and Palanisami, K. 2009f. State of Irrigation in Tamil Nadu: Trends and Turning Points. In Proceedings of the National Workshop of "Strategic Issues in Indian Irrigation", held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A., Palanisami, K., Singh, O.P. and Sakthivadivel, R. 2009g. State of Irrigation in Irrigation in Tamil Nadu: Investments and Returns. In Proceedings of the National Workshop of "Strategic Issues in Indian Irrigation", held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A., Palanisami, K., and Singh, O.P. 2009h. Managing Unreliability of Canal Irrigation Supply: A Case Study of Diggies in Rajasthan. In Proceedings of the National Workshop of "Strategic Issues in Indian Irrigation", held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Amarasinghe, U.A. and Sharma, B.R. 2009i. Water Productivity of Foodgrains in India: Exploring Potential Improvements. In "*Improving Water Productivity in India: Potential, Prospects and Constraints. Strategic Analyses of the National River Linking Project (NRLP) of India, Series 4. Eds M. Dinesh* Kumar and Upali A. Amarasinghe Colombo, Sri Lanka: International Water Management Institute (forthcoming)

Bhaduri, A., Amarasinghe, U.A., and Shah, T. 2008a. Benefits of Irrigation Water Transfers in the National River Linking Project: A Case Study of Godavari (Polavaram)-Krishna Link in Andhra Pradesh. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Bhaduri, A. and Barbier, E. 2008b. Linking Rivers in the Ganges-Brahmaputra River Basin: Exploring the Transboundary Effects. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Bhaduri, A., Amarasinghe, U.A. and Shah, T. 2009a. Groundwater Expansion in Indian Agriculture: Past Trends and Future Opportunities. In *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute.

Bharati, L., Anand, B.K., and Smakhtin, V. 2008. Analysis of the Inter-basin Water Transfer Scheme in India: A Case Study of Godavari-Krishna Link. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Gamage, N. and Smakhtin, V. 2008. Do river deltas in east India retreat? A case of the Krishna Delta. Geomorphology. (GEOMOR-02734; No of Pages 8, Forth coming)

Gichuki, F. and McCornick, P.M. 2008. International Experiences of Water Transfers: Relevance to India . In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Inocencio, A. and McCornick, P. 2008. Economic Performance of Public Investments in Irrigation in India in the Last Three Decades. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

IWMI 2005. The India's Water Futures Analyses. Scenarios and Issues. Unpublished Proceedings the Inception Workshop on the project "Strategic Analyses of India's Water Futures'

IWMI 2009. Strategic Issues on Indian Irrigation. Proceedings of the 2nd National Workshop of the Strategic Analyses of the National River Linking Project (NRLP) of India. *Series 5.* Sri Lanka: International Water Management Institute

Kumar, M. D., Patel, A. and Singh, O. P. 2008a. Rainwater Harvesting in Water-scarce Regions of India: Potential and Pitfalls. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Kumar, M.D., and Amarasinghe, U.A. (Eds) 2009a. Improving Water Productivity in India: Potential, Prospects and Constraints. *Strategic Analyses of the National River Linking Project (NRLP) of India, Series 4.* Sri Lanka: International Water Management Institute (forthcoming)

Kumar, M.D., Singh, O.P., and Sharma, B.R. 2009b. Water Saving and Yield Enhancing Micro-irrigation Technologies: How Far Can They Contribute to Water Productivity in Indian Agriculture. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Kumar, M.D., Trivedi, K. and Singh, O.P. 2009c. Analyzing the Impact of Quality and Reliability of Irrigation Water on Crop Water Productivity Using an Irrigation Quality Index. In "*Improving Water Productivity in India: Potential, Prospects and Constraints. Strategic Analyses of the National River Linking Project (NRLP) of India, Series 4. Eds M. Dinesh* Kumar and Upali A. Amarasinghe Colombo, Sri Lanka: International Water Management Institute (forthcoming)

Kumar, M.D. and van Dam, J. C. 2009d. Improving Water Productivity in Agriculture in India: Beyond 'More Crop per Drop'. In "*Improving Water Productivity in India: Potential, Prospects and Constraints. Strategic Analyses of the National River Linking Project (NRLP) of India, Series 4. Eds M. Dinesh* Kumar and Upali A. Amarasinghe Colombo, Sri Lanka: International Water Management Institute (forthcoming)

Kumar, M.D. and Singh, O.P. 2009e. Impact of Dairy Farming on Agricultural Water Productivity and Irrigation Water Use. n "*Improving Water Productivity in India: Potential, Prospects and Constraints. Strategic Analyses of the National River Linking Project (NRLP) of India, Series 4.*

Eds M. Dinesh Kumar and Upali A. Amarasinghe Colombo, Sri Lanka: International Water Management Institute (forthcoming)

Mahmood, A. and Kundu, A. Demographic Projections for India 2006-2051: Regional Variations. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Malik, R.P.S. 2009a. Indian Agriculture: Recent Performance and Prospects in the Wake of Globalization. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Malik, 2009b. Energy Regulations as a Demand Management Option: Potentials, Problems and Prospects. In "*Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. Strategic Analysis of National River Linking Project of India. Series 3"* Ed. Rathinasamy Maria Saleth*.* Colombo, Sri Lanka: International Water Management Institute.

Mohile, A.D. and Anand, B.K. 2009. Natural Flows Assessment and Creating Alternative Future Scenarios for Major River Basins of Peninsular India. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Narayanamoorthy, A. 2009a. Drip and Sprinkler Irrigation in India: Benefits, Potential and Future Directions. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Narayanamoorthy, A. 2009b. Water Saving Technologies as a Demand Management Option: Potentials, Problems and Prospects. In "*Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. Strategic Analysis of National River Linking Project of India. Series 3"* Ed. Rathinasamy Maria Saleth*.* Colombo, Sri Lanka: International Water Management Institute

Narain, V. 2009. Water Rights System as a Demand Management Option: Potentials, Problems and Prospects. In "*Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. Strategic Analysis of National River Linking Project of India. Series 3"* Ed. Rathinasamy Maria Saleth*.* Colombo, Sri Lanka: International Water Management Institute

Patel, A. and Sundararajan, K. 2009. Groundwater Situation in Urban India: Overview, Opportunities and Challenges. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Palanisami, K., Senthilvel, S., and Ramesh, T. 2008.Water Productivity at Different Scales under Canal, Tank and Well Irrigation Systems. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Palanisami, K., Amarasinghe, U.A., and Sakthivadivel, R. (Eds) 2009a. State of the Irrigation in Tamil Nadu: Trends, Turning Points and Future Options. *Strategic Analyses of the National River Linking Project (NRLP) of India, Series 6.* Sri Lanka: International Water Management Institute (forthcoming)

Palanisami, K. 2009b. Water Markets as a Demand Management Option: Potentials, Problems and Prospects. In "*Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. Strategic Analysis of National River Linking Project of India. Series 3"* Ed. Rathinasamy Maria Saleth*.* Colombo, Sri Lanka: International Water Management Institute.

Reddy V. R. 2009. Water Pricing as a Demand Management Option: Potentials, Problems and Prospects. In "*Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. Strategic Analysis of National River Linking Project of India. Series 3"* Ed. Rathinasamy Maria Saleth*.* Colombo, Sri Lanka: International Water Management Institute.

Reddy, M. V. 2009. User Organizations as a Demand Management Option: Potentials, Problems and Prospects. In "*Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. Strategic Analysis of National River Linking Project of India. Series 3"* Ed. Rathinasamy Maria Saleth*.* Colombo, Sri Lanka: International Water Management Institute

Saleth, R.M. (Ed) 2009. Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. *Strategic Analysis of National River Linking Project of India. Series 3*. Colombo, Sri Lanka: International Water Management Institute.

Saleth, R.M. and Amarasinghe, U.A. 2009. Promoting Demand Management in Irrigation in India: Policy Options and Institutional Requirements. In "*Water Sector Perspective Plan for India: Potential Contributions from Demand Management in Irrigation. Strategic Analysis of National River Linking Project of India. Series 3"* Ed. Rathinasamy Maria Saleth. Colombo, Sri Lanka: International Water Management Institute.

Samad, M., Shah, Z., Acharyulu, S. and Acharya, S. Managing Rehabilitation and Resettlement of Displaced Population: Lessons from Selected Hydro Projects. In *Proceedings of the National Workshop of "Strategic Issues in Indian Irrigation", held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.*

Shah, T.; Amarasinghe, U. A.; McCornick, P. G. 2008a. India's River Linking Project: The State of the Debate. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Shah, T. 2008b. National River Linking Project (NLRP) and Perspectives on Indian Irrigation. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute

Shah, T 2008. An Assessment of India's Groundwater Recharge Master plan. Draft prepared for the IWMI-CPWF research project "Strategic Analysis of India's National River Linking Project"**.**

Shah, T. 2009a. Crop per Drop of Diesel? Energy Squeeze on India's Smallholder Irrigation. In *National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 1.* Eds. Upali A. Amarasinghe and B.R. Sharma. Colombo, Sri Lanka: International Water Management Institute.

Shah, T. 2009b. Climate Change and Groundwater: India's Opportunities for Mitigation and Adaptation. In Proceedings of the National Workshop of *"Strategic Issues in Indian Irrigation"*, held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Shah, T. 2009c.An Assessment of India's Groundwater Recharge Master plan. In Proceedings of the National Workshop of *"Strategic Issues in Indian Irrigation"*, held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Shah, T. 2009d. Reform or Morph? Unlocking Value in Asian Irrigation. In Proceedings of the National Workshop of *"Strategic Issues in Indian Irrigation"*, held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Shah, T. and Verma 2008. S. Real-time Co-management of Electricity and Groundwater: An Assessment of Gujarat's Pioneering Jyotirgram Scheme. In *National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 1.* Eds. Upali A. Amarasinghe and B.R. Sharma. Colombo, Sri Lanka: International Water Management Institute

Shah, Z. and Kumar, M.D. 2008. In the Midst of the Large Dam Controversy: Objectives, Criteria for Assessing Large Water Storages in the Developing World. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute.

Sharma, A. and Bhaduri, A. 2009. The 'Tipping Point' in Indian Agriculture: Understanding the Withdrawal of Indian Rural Youth. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Sharma, B.R., Rao, K.V.G.K., and Massual, S. 2008. Groundwater Externalities of Surface Irrigation Transfers under River Linking Project: Polavaram-Vijayawada Link. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute.

Sharma, B.R., Rao, K.V., Vittal, K.P.R. 2009a. Converting Rain into Grain: Opportunities for Realizing the Potential of Rainfed Agriculture in India. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute

Sharma, B.R., Rao, K.V.G.K., Sharma, G. 2009b. Groundwater Externalities of Large Surface Irrigation Transfers: Lessons from Indira Gandhi Nahar Pariyojana (IGNP), Rajasthan, India. In

Proceedings of the National Workshop of *"Strategic Issues in Indian Irrigation"*, held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Sikka, A.K. 2009. Water Productivity of Different Agriculture Systems. In "*Improving Water Productivity in India: Potential, Prospects and Constraints. Strategic Analyses of the National River Linking Project (NRLP) of India, Series 4. Eds M. Dinesh* Kumar and Upali A. Amarasinghe Colombo, Sri Lanka: International Water Management Institute (forthcoming)

Smakhtin, V.M; Anputhas, M. 2006. An assessment of environmental flow requirements of Indian river basins. Research Report 107. Colombo, Sri Lanka: International Water Management Institute.

Smakhtin, V., M. Arunachalam, S. Behera, A. Chatterjee, S. Das, P. Gautam, G. D. Joshi, K. G. Sivaramakrishnan, and K. S. Unni. 2007. Developing procedures for assessment of ecological status of Indian river basins in the context of environmental water requirements. *IWMI Research Report*, 114, Colombo, Sri Lanka: International Water Management Institute.

Smakhtin, V.M; Gamage, N. Bharati, L. 2008. Hydrological and Environmental Issues of Inter-basin Water Transfers in India: A Case Study of the Krishna River Basin. In "*National River Linking Project- Analysis of Hydrological, Social and Ecological Issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Bharat R. Sharma and Upali A. Amarasinghe* Colombo, Sri Lanka: International Water Management Institute.

Sundarajan, K., Patel, A., Raychoudhury, T. and Purohit, C. 2009a. Groundwater Exploitation in India, Environmental Impacts and Limits to Further Exploitation for Irrigation. *In India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe and R.P.S. Malik* Colombo, Sri Lanka: International Water Management Institute.

Sunderrajan, K., Indu, R., Shah, T. , Hittalamani, C., Patwari, B., Sharma, D., Chauhan, L., Kher, V., Raj, H., Mahida, U., Shankar, M and Sharma, K. 2009b. Is it Possible to Revive Dugwells in Hardrock India through Recharge: Discussion from Studies in Ten Districts. . In Proceedings of the National Workshop of *"Strategic Issues in Indian Irrigation"*, held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Talati, J. and Shah, T. 2009. Institutional Vacuum in Sardar Sarovar Project: Framing 'Rules-of-the-Game'. Proceedings of the National Workshop of "Strategic Issues in Indian Irrigation", held at New Delhi on April 8-9 2009. Colombo, Sri Lanka: International Water Management Institute.

Verma, V. KAmpman, D.A., Zaag, P. Van D. and Hoekstra, A.Y. 2008. Going Agains the Flow. A Critical Analysis of Virtual Water Trade in the Context of India's National River Linking Program. Value of Water Research Report Series No. 31. Delft, Netherland: UNESCO-IHE, Institute of Water Education.

Verma, S. and Phansalkar, S. 2009. India's Water Future 2050: Potential Deviations from 'Business-As-Usual" Scenario. In. *India's water future: Scenarios and issues. Strategic Analysis of National River Linking Project of India. Series 2. Eds. Upali A. Amarasinghe, Tushaar Shah and R.P.S. Malik.* Colombo, Sri Lanka: International Water Management Institute.

BIBLIOGRAPHY

Bandyopadhyaya, J.; Perveen, S. 2003. The Interlinking of Indian Rivers: Some Questions on the Scientific, Economic and Environmental Dimensions of the Proposal. Paper presented at the Seminar on Interlinking Indian Rivers: Bane or Boon? at IISWBM, Kolkata, June 17, 2003. SOAS Water Issues Study Group, Occasional Paper No. 60.

CGWB 2008. Master Plan For Artificial Recharge to Groundwater in India. http://cgwb.gov.in/documents/MASTER%20PLAN%20Final-2002.pdf.

CPWF 2005. Strategic Analysis of India's River Linking Project. The Project Proposal. www.cpwf.org

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

Evenson, R.E.; Pray, C.E.; Rosegrant, M.W. 1999. *Agricultural research and productivity growth in India.* Research Report 109. International Food Policy Research Institute

Falkenmark, M.; Lundquvist, J.; Widstrand, C. 1989. Macro-scale water scarcity requires micro-scale approaches: Aspect of vulnerability in semi-arid development. *Natural Resources Forum* 13 (4): 258-267.

FAO (Food and Agriculture Organization) 2007. FAOSTAT Database. Accessible via http://www.fao.org

Garg, N. K.; Hassan, Q. 2007. Alarming scarcity of water in India. *Current Science,* Vol. 93, No. 7. 10 October 2007.

GOI 1999. Integrated water resources development. A plan for action. Report of the Commission for Integrated Water Resource Development Volume I. New Delhi, India: Ministry of Water Resources.

GOI 2005. Agricultural Statistics at a Glance 2004. New Delhi, India: Ministry of Agriculture, Government of India.

Gosain, A. K.; Rao, S.; Basuray, D. 2006. Climate change impacts assessment on hydrology of Indian river Bains. *Current Science,* Vol 90, No 3. 10 February 2006.

IWMI 2000. World water supply and demand 1995 to 2025 (draft). www.cgiar.org/iwmi/pubs/WWVison/WWSDOpen.htm

IWMI 2009. Strategic Issues on Indian Irrigation. Proceedings of the 2nd National Workshop of the Strategic Analyses of the National River Linking Project (NRLP) of India. *Series 5.* Sri Lanka: International Water Management Institute (forthcoming)

Iyer, R. 2003. Water: Perspectives, Issues Concerns, at New Delhi, India: Sage Publications.

Kumar, M. D. 2005. Impact of Electricity Prices and Volumetric Water Allocation on Energy and Groundwater Demand Management: Analysis from Western India. *Energy Policy* 33 (1)

Kumar, M. D.; Singh, O. P. 2001. Market Instruments for Demand Management in the Face of Growing Scarcity and Overuse of Water in Gujarat, India. *Water Policy* 5 (3): 86-102.

Kumar, M. D., Patel, A., Ravindranath, R. and Singh, O.P. 2008b. Chasing a Mirage: Water Harvesting and Artificial Recharge in Naturally Water-scarce Regions, Economic and Political Weekly, 43 (35): 61-71.

Kumar, M. D.; Sivamohan, M. V. K.; Narayanamoorthy, A. 2008c. 'Irrigation Water Management for Food Security in India: The Forgotten Realities'. Paper presented at the International Symposium on Food Security in India, Green Peace, New Delhi, October 24, 2008

Mall, R. K.; Gupta, A.; Singh, R.; Singh, R. S.; Rathore, L. S. 2006. Water resources and climate change: An Indian Perspective. *Current Science,* Vol 90, No 12. 25 June 2006.

NWDA 2006. The Inter Basin Water Transfers: The Need. Accessible via http//nwda.gov.in/

Rath, N. 2003 Linking of Rivers: Some Elementary Arithmetic. Economic and Political Weekly 38 (29): 3032-303.

Shah, T. 2000. Mobilizing social energy against environmental challenge: understanding the groundwater recharge movement in western India. *Natural Resources Forum* 24(3): 197-209.
World Bank 2005. India's Water Economy: Bracing for a Turbulent Future. Draft Report. http://go.worldbank.org/QPUTPV5530
WRI (World Resource Institute) 2007. EarthTrends. Environment Infformation. http://earthtrends.wri.org/searchable_db/index.php?theme=5

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Appendix A

[**Appendices – *include copies of Abstracts of all key publications]*