Strategic Issues in Indian Irrigation: Overview of the Proceedings

Upali A. Amarasinghe and Stefanos Xenarios

Introduction

India's National River Linking Project (NRLP), if implemented in its entirety, will form a gigantic water grid that South Asia has never witnessed in the history of its water development. However, from the outset, the proposed NRLP plan was a bone of contention among the civil society, academia, environmental community, policy planners and politicians (Alagh et al. 2006). For opponents its economic benefits will not be sufficiently higher vis-à-vis its social and environmental cost. For its proponents, it is the savior of the pending water crisis in India (NWDA 2009). However, many of the discourses on NRLP lacked sufficient analytical rigor in assessing cost and benefits. And importantly there was very little attention to what determinants are ailing the existing surface irrigation systems leading to their poor performance, and what lessons can be learnt from these for new water development projects. Also, amidst the intense debate on social cost and benefits of the NRLP, many other important issues that require immediate attention for meeting India's water needs have been pushed into the background.

The research project, *The Strategic Analyses of National River Linking of India* of the International Water Management Institute (IWMI), Colombo, under the aegis of the *Challenge Program for Water and Food* (CPWF 2005), tried to address these twin challenges. It tried to fill the void created by the analytical rigor in the NRLP debate and to better informs the public on the pros and cons of the NRLP and the lessons to be learnt from the existing water supply systems. It also raises many strategic issues and challenges in Indian irrigation that require immediate attention.

The second national workshop of the NRLP research project, held at the India Habitat Centre in New Delhi, on April 8-9, 2009, mainly focused on strategic issues of Indian irrigation that require immediate attention. The issues highlighted at the workshop contribute to a cluster of short- to long-term strategies for a perspective plan for the Indian water sector. This paper provides an overview of the proceedings of the second workshop. It includes a description of the deliberations on:

- International and local perspectives on strategic issues facing the water sector, especially the irrigation sector.

- Planning new surface irrigation schemes for increasing benefits under changing dynamics of the Indian agriculture.
- The state of the irrigation of Tamil Nadu, one state that will benefit from the proposed NRLP water transfers. It shows trends and turning points of irrigation in the state, returns to past irrigation investments, and proposes investment options in the short and medium term for meeting increasing water demand.
- Lessons from past water resources development projects that are useful for planning new such projects.
- Prospects and constraints of demand management strategies in Indian irrigation.
- Potential and constraints of water productivity improvements in Indian agriculture.
- Supply augmentation through groundwater recharge and virtual water trade.

The papers in this volume are the fifth of a series of publications under the NRLP research project. The project conducted research in three phases. Research in Phase I, which assessed scenarios and issues of India's water futures, was published in NRLP Series 1, "India's Water Futures: Scenarios and Issues" (Amarasinghe et al. 2009).

Research in Phase II focused on cost and benefit issues related to the NRLP. Some, hydrological, social and ecological issues of the NRLP project were focused in the first national workshop and the proceedings were published in NRLP Series 2 (Amarasinghe and Sharma 2008).

Phase III research assessed potential contributions of various strategies for a water-sector perspective plan for India. Studies on "Promoting Demand Management Options in the Indian Irrigation Sector: Potentials, Problems and Prospects" were published in NRLP Series 3 (Saleth 2009), and the studies on "Water Productivity Improvements in Indian Agriculture: Potentials, Constraints and Prospects" were published in NRLP Series 4 (Kumar and Amarasinghe 2009).

The syntheses of studies on demand management and water productivity improvements were discussed in the 2nd national workshop. Additionally, supply augmentation through groundwater recharge and virtual water trade, and lessons from past water development projects on cost and time overruns, waterlogging and salinity, rehabilitation and resettlement of project-affected persons, are presented in this volume. Brief overviews of the deliberations in sessions 1 to 7 are followed next.

Session 1: Strategic Issues in Indian Irrigation

The major issues that the irrigation sector is facing were addressed by four guest speakers, Dr. Colin Charters, Director General, International Water Management Institute, Prof. M.S. Swaminathan, Chairman, M.S. Swaminathan Research Foundation, Dr. J.S. Samra, Chief Executive Officer, National Rainfed Area Authority and Dr. B.M. Jha, Director General, Central Groundwater Board of India.

Issues across the globe

Dr. Colin Charter's keynote speech focused on pressing global issues influencing water-food dimensions at present. Globally, many poor and hungry people live in regions where access to water is a constraint for increasing food production. In semiarid to arid tropics, about 800 million people are undernourished. Many river basins are already experiencing physical water scarcities while many others are facing economic water scarcities. Large numbers of river basins have low minimum river flows and consequently have high environmental stress. At present, more than one-third of the worlds' population live in river basins with high environmental water stress.

Yet, major demand drivers of water for food are also changing, resulting in rapidly increasing water needs. Consumption patterns are changing, mainly towards diets consisting of more non-cereals and animal products. Changing dietary patterns have significant implications on water demand. While a person needs about 2-5 liters/day, and a household needs 200-500 liters/day, it takes 2,000-5,000 liters/kg of evapotranspiration (ET) for producing grain to 5,000-15,000 liters/kg of ET, mainly from feed products, for producing animal products, such as meat, milk, etc..

The water demand, especially for blue water, of industrial and domestic sectors is increasing, and the demand for biofuel production will increase manifold in the next 20 to 30 years. A major part of biofuel water demand, especially in water-scarce regions, will have to be from irrigation (85% and 65% in India and China, respectivly versus 17% and 8% in the US and Brazil, respectively).

Climate change impacts on water availability are real, and they are already affecting some regions. Rainfall and runoff have decreased significantly in some regions, while the reduction in runoff is comparatively higher than that of rainfall. Implications of such reduction on already water-stressed basins, especially in developing countries, could be catastrophic.

In fact, many countries are facing water crises. But these crises can be averted if the countries do things differently. Some high potential strategies for water-scarce countries include increasing water productivity, turning wastewater to a valuable resource and increasing virtual water trade with few trade barriers. Additionally, various types of storage options, including large to small dams to subsurface storage, clearly need rethinking.

Many countries with low per capita storage require increasing storage to cope with droughts and impacts due to climate change. These countries need large investments, a message that needs to be communicated to politicians and policymakers with added significance. Hydropower industry also needs large dams. But the dams need to be built and managed efficiently for irrigation and for other multiple water uses while reducing environmental damage and ensuring minimum river flows. There are many other options to large dams. Medium-scale reservoirs, village ponds, groundwater recharge and water harvesting can augment water significantly. However, all options need to be evaluated for assessing potential gains and losses under different conditions.

Reforming water governance is essential for demand management to be successful. While protecting the poor, water rights, valuation of water and pricing, water markets, policies and institutional reforms, equitable and gender sensitive management systems need to be in place for effective functioning of supply and demand management systems.

Issues in India

Prof. M. S. Swaminathan highlighted strategic issues of irrigation in India. He noted that water planning for supply augmentation for a national water security system requires integrating of five sources of water: rainwater, river water, groundwater, wastewater and seawater.

- Rainwater is the greatest asset at hand. The most important step for supply augmentation in India today is rainwater harvesting. The national rural employment guarantee program (NREGP) plays a major role in water harvesting and watershed development programs. These programs can be made more effective by empowering the Panchayat Raj institutions, which are responsible for implementing NREGP, to use the unskilled labor of the poor people as productively as possible. Rewarding these institutions/NREGP for conducting better programs could be an incentive for contributing to a water security system.
- River water, a part of the river linking project, is also important. However, there are many conflicts in water sharing between neighboring nations and between states at present. India requires many non-judiciary conflict resolution organizations, such as the Key-Stone centre in the Colorado River in the USA. These centers can resolve many conflicts and have win-win situations for all parties in the conflict without relying on long-delayed judicial processes.
- Groundwater is the most dominant water use at present. It contributes most to both receding and rising water tables in many regions. Managing this resource is the most important short- to long-term water management challenge.
- Wastewater recycling is gradually increasing in metropolitan areas. This is an important source not only for raising fodder and other crops but for breeding fish. Industries can be made to give back the water by proper methods of recycling.
- Seawater is useful for agro-aqua-farming, including agroforestry and aquaculture. Given India's 7,500 km shore line, this aspect of using seawater productively requires more consideration.

Linking of rivers could be one option for easing the water stress in some locations where the links are economically viable and environmentally sustainable. However, as of now, the Himalayan component presents a large number of political problems and may not be feasible in the short term. The peninsular links are feasible to the extent that the political control of designing, planning and implementing is within India. The new government could takes up these as priority issues.

While supply-side solutions are essential, demand management strategies also have significant potential to address water problems in many locations. Policy formulation for effective functioning of demand management strategies requires increased emphasis. Within this, it is important to increase more crops and more income from water, and create more opportunities in rain-fed areas. Some experiments, under the Farmer Participatory Program in rain-fed areas show yield increase in the range of 200-300%. These can reduce the additional demand for large surface storages.

According to Dr. Samra, rain-fed agriculture has a great potential for improving the livelihoods of the poor. Data indicate that 78% of the Indian agriculture is linked to markets. The other 22% is subsistence agriculture, mainly in the rain-fed areas. Many of the poor also live in rain-fed areas, but most of the virtual water trade is occurring from low- to high-rainfall areas. This is a paradoxical situation of virtual water trade, in particular for India. Reversing the trends of virtual water trade within the country could solve many water and poverty problems. Most of the water-intensive crops, such as rice, sugarcane, banana and aquaculture should, as far as possible, be in high rainfall areas and be exported to low-rainfall areas. These forms of high-value agriculture can constitute an attractive proposition for the eastern regions, which are reeling with a high incidence of rural poverty.

Dr. Jha highlighted the criticality of groundwater irrigation in India's food and livelihood security. Groundwater is the source for more than 60% of the irrigation at present. But many regions are fast depleting their resources due to overabstraction. The Government of India has a national master plan for increasing groundwater recharge, which includes recharging from millions of dug wells dotting the rural landscape in India.

Session 2: Benefits of Irrigation Water Transfers

The changing face of irrigation (Paper 2 by Tushaar Shah), and the financial benefit-cost of proposed irrigation water transfers in the NRLP (Paper 3 by Amarasinghe and Srinivasulu) were the foci of this session.

According to Shah, the face of Indian irrigation is rapidly changing. India has spent over Rs 1,000 billion ($22 billion in 2000 prices) on surface irrigation since 1991. But net area under surface irrigation has declined by 24%. Since 1970, Tamil Nadu and Andhra Pradesh, two major water-recipient states of the NRLP, have spent over $5 billion in canal irrigation, but have lost close to 500,000 ha of net irrigated area under major/medium schemes. Since 1990, net area under groundwater irrigation area has increased by 26%. This was mainly due to private investments. Groundwater irrigation is widespread, both in and outside the canal command have areas, although overexploitation is threatening irrigated agriculture in many regions. Many factors contribute to this changing face of irrigation. They include

- pressure of decreasing landholding sizes and large number of smallholders,
- increasing demand for year-round on-demand water supply for increasing income from small landholdings,
- inefficient institutions providing irrigation services and unreliable water supply in canal irrigation,
- differences of existing and proposed conditions supporting surface irrigation, including the nature of both the state and agrarian society,
- changes in agricultural demography, and
- adoption of new irrigation technology.

These factors, thus pose a major question on the viability of large surface irrigation systems such as those proposed in the NRLP.

Amarasinghe and Srinivasulu (Paper 3 in this volume) assessed the financial viability of water transfers in the peninsular links in the proposed NRLP. This study shows that proposed surface irrigation through the river linking program can be financially viable if the planners appreciate the changing face of irrigation and then adapt to these changes. In order to avoid the same fate and issues as that facing surface irrigation at present, many factors need rethinking in the current river linking proposal. Two of the major factors of influence include that

- the proposed cropping patterns will require high-value crops, and those that farmers prefer. This is especially important given the low landholding sizes in these systems.
- new water transfers should be used as far as possible to cultivate new or existing irrigation. A large part of the proposed command areas is already irrigated from groundwater. The return flows from new irrigation should help these command areas as recharge. Farmers would prefer groundwater irrigation to surface water irrigation due to already existing investments on pumps and other infrastructure and to the reliability of groundwater.

Although, many individual links under the NRLP peninsular component seem financially unviable, a set of interdependent links could be financially viable under the above conditions. But financial benefits and cost could vary if financial losses due to reducing river flows, submerging land, waterlogging, etc., and financial benefits due to increased groundwater irrigation are included.

The discussion on the above issues, led by Dr. Ashok Gulati of the International Food Policy Institute and by Dr. Madar Samad of IWMI, indicated the need for unbundling surface irrigation to have separate institutions as in other development sectors. Although, in general, participatory irrigation management (PIM) did not have much success, there are a few successful systems in different states. So, it is important to find what works for different states and different irrigation systems. If PIM does not work at the system level, then explore different institutions at the storage, main canals and the distributary network with the multinationals, and the domestic and private sectors. Creating markets with policies can facilitate effective functioning of these institutions with increasing transparency, accountability, cost efficiency, inclusiveness and sustainability.

Also, there is a significant difference in benefits between canal irrigation systems and surface water systems. Canal irrigation systems provide water for food production whereas surface water systems provide a large quantity of drinking water supply for urban areas, generate hydropower benefits, pump irrigation from rivers due to releases from reservoirs, recharge groundwater and benefit the environment. These benefits, along with food security at the household, regional and national level should be part of a domain for analyzing financial and economic cost benefit of surface water systems. However, it is also important to include the cost to ecosystem services system for demarcating the boundaries of benefits-cost of surface water systems.

Session 3: State of the Irrigation in Tamil Nadu: Trends, Turning Points and Future Options

Tamil Nadu, a major recipient state of the water transfers in the NRLP, had significant changes in irrigation in the recent past. Trends and turning points of irrigation (Paper 4 in this volume) and policy interface for improving declining performance in surface irrigation (Paper 5 in this volume) in Tamil Nadu were the foci of this session.

Irrigation is a major driver of agricultural growth, which is intrinsically related to the economic growth in Tamil Nadu. However, in spite of major investments in the irrigation sector, net surface water irrigated area has declined over the last three decades. The total investment in major/medium irrigation has increased by $730 million (2000 prices) between 1970 and 2000, but the net canal irrigated area has declined by 85,000 ha or 9%. Total investment in tank irrigation in the same period was over $430 million, but net minor irrigated area has declined by 450,000 ha or about 50%. However, with private investment, net groundwater irrigated area has increased by about 500,000 ha. Although the contribution of groundwater has increased substantially, many regions in the state are facing acute groundwater depletion. In fact, 85% of the groundwater resources in the state are already withdrawn at present.

To overcome water woes, Tamil Nadu requires sharper policy focus on short- to medium-term irrigation investments. Some policy recommendations include:

- recharging groundwater in intensive well irrigation regions,
- conserving soil and water in tank irrigation regions,
- combining five to six micro-watersheds to form macro-meso watersheds within a zone of influence of 400 m,
- converting tanks, with less than 40% supply capacity, to percolation tanks and increase groundwater irrigation in the command area by introducing one well per 2 ha in well-only irrigation situation; one well per 4 ha in well-cum-tank irrigation situation, and one well per 10 ha in tank-only irrigated areas,
- increasing wells in surface water irrigation systems and reworking system operation plans,
- increasing investment in watercourse improvements in major reservoir systems,
- increasing investments in main systems in tank irrigation systems, and
- investing in secondary and main system management for increasing demand management.

The discussion of the above issues, led by Eng. A.D. Mohile, former Chairman of the Central Water Commission of India, noted that water transfers of the NRLP can be used within a network of interlinking of rivers within the state, although water received through NRLP may be too low to address all water problems in the state. Moreover, successful implementation of the above recommendations, however, requires a comprehensive water accounting analysis assessing the impact of increase in groundwater in the canal and tank irrigation commands.

Session 4: Lessons from Past Water Transfer Projects

Many existing water development projects, which India has implemented in recent decades, have a plethora of issues that can benefit planning and implementing new water transfer projects. In this session, Thalati and Shah (Paper 6) focused on project implementation issues in the Sarda-Sarovar project; Sharma et al. (Paper 7) addressed waterlogging and salinization issues in the Indira Gandhi Nehar Paryojana (IGNP) project in Rajasthan, and Samad et al. (Paper 8) highlighted resettlement and rehabilitation issues in the Sarda-Sarovar and Ujjini projects.

The Sarda-Sarovar project suffers from many issues due to inadequate details in the planning and implementation (Paper 6). Hydrologically, it suffers from lower inflow to the reservoir than expected. The project planners had not envisaged large-scale groundwater abstractions in the upstream of the reservoir. Hence, the inflow to the reservoir is already 17-30% lower than planned, and will further reduce with increasing upstream development. Significant cost and time overruns were also major issues. The Government of Gujarat has already overspent more than Rs 130 billion (in 1987/88 prices) in the construction of the project. Yet, only 0.1 million ha (Mha) of the 1.8 Mha of planned area are irrigated; only 200 MW of the planned 1,460 MW hydropower generation are realized; and only 35 and 1,500 of the 135 and 8,215 towns and cities, respectively, have received water supply to date. If the project is to be completed as planned it requires at least another Rs 2,000 billion. The failure of the planned institutional model largely contributed time and cost overruns. The expectation that farmers and water user associations would voluntarily provide land and also build watercourses and field channels, has never materialized. Instead, farmers divert a significant part of the water to far-away lands from the main and branch canals by lifting to upland areas and siphoning to lowland areas through underground pipes. Such innovations are not common in surface irrigation projects, but can impact significantly in reducing problems related to land acquisition for distributaries and watercourses, and water distribution to tail-end areas in the project.

A large part of IGNP projects suffers from waterlogging and salinity (Paper 7). A considerable lag period between water availability and water utilization in the command areas was a major cause for waterlogging. For example, in Phase II of the IGNP project, the available water supply is adequate to irrigate 0.925 million ha of croplands, but the distributary network is sufficient to irrigate only 0.144 million ha. Moreover, inadequate attention to the existing hard pan, which is only less than 10 meters from the surface, exacerbated the situation. In fact, in the IGNP, the hard pan with less than 10 m depth covers more than 33% of the flow irrigated area and 76% of the lift irrigated area. Inadequate drainage was a major issue in the IGNP.

Resettlement and rehabilitation are major issues facing implementers of any water development project. The studies on Sarda-Sarovar and Ujjini projects however show that there is an initial distress and fall of standard of living. But many of the displaced persons have restored their livelihoods to the original level in 4-6 years, although the level of restoration and benefits vary spatially. Those displaced in Maharashtra and Madya Pradesh in the Sarda-Sarovar are worse-off than those in Gujarat.

The major conclusions from the discussion of this session, led by Mr. Himanshu Thakkar were:

- Hydrological modeling should incorporate the groundwater irrigation already taking place and expected to come up in the future in the command area and in the upstream of reservoirs, and should assess drainage requirements with regard to the existing hydrogeological conditions and the command area development.
- Be cognizant of the existing modes of water delivery systems at the watercourses, and the farm and field levels in planning new systems .
- The pump and pipe system of water delivery could reduce water and land wastage through watercourses and field channels.
- Piped water delivery system, possibly at or below the distributary canals, can also increase reliability and reduce wastage. But such systems should have a mechanism in place not to deprive water to the tail enders to increase the equity.
- Create institutions for appropriate water delivery management at the branch/distributary canal level.
- Prepare proper command area development plans, optimum water delivery plans and adequate drainage structures.

- Develop distributaries, watercourse and field-level distribution systems quickly to reduce the gap of water availability for irrigation and water utilization, thereby increasing consumptive water use and reducing waterlogging.
- There should be active engagement to reduce not only the initial risk but also the impact of impoverishments after resettlement.

Session 5: Meeting Increasing Water Demand: Potential from Demand Management Strategies

The growing gap between the demand and supply in Indian irrigation is a serious concern for policy planners. While, supply-side solutions based on new augmentation, such as NRLP, are essential in some contexts, they cannot be the exclusive basis for irrigation sector strategies. Many demand management strategies will help reduce the gap. Paper 9 presented the synthesis of six studies of various demand management strategies in the Indian irrigation sector (Saleth 2009). These strategies include water pricing, formal and informal water markets, water rights and entitlement systems, energy-based water regulations such as power tariff and supply manipulations, water saving technologies such as drip and sprinklers, crop choices and farm practices, and user- and community-based organizations.

The major focus of these studies was to asses the present status of these options in the irrigation management strategy in India. It includes the 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 levels, cases of success and best practices in demand management, and what lessons there are for policy in upscaling 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 expand irrigation or to reallocate water to nonagricultural uses and sectors?

The focus and coverage show that some demand management options are context-specific. For instance, water pricing as a tool is largely applicable to canal regions, whereas the options involving energy regulations—involving both supply and price manipulations—is largely applicable in groundwater irrigation. The latter may also be relevant in canal regions to the extent where water lifting is involved. Water markets and water saving technologies also occur predominantly in the groundwater irrigation regions. But, the options involving water rights and user organizations are relevant in both canal and groundwater regions. Similarly, some of the options have more direct and immediate impacts on water demand, while others have an indirect and gradual effect and, that too, depending 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 have only 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, 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. However, these effects are rather too meager to have an impact on the magnitude 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, a concerted policy for demand management in irrigation in India 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 for their other goals such as cost recovery and management decentralization. Even here, the policy focus is confined only to a 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 a water rights system, there are no explicit government policies either as to its formal existence or to 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 are 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, the lack of a well-articulated policy is the major bottleneck for 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 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.

Session 6: Meeting Increasing Water Demand: Potential from Water Productivity Improvements

The agriculture sector in India is in direct conflict with other sectors of water economy, and the environment. The common features of agriculture in some 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, these regions offer limited potential for increasing agricultural production due to the limitations imposed by land and ecological constraints. Moreover, 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. So, improving water productivity (WP) in agriculture, wherever possible, holds the key to not only sustaining agricultural production and rural livelihoods but also making more water available for other sectors including the environment. Paper 10 presents a synthesis of several studies covering various aspects of WP and their potential improvements in India (Kumar and Amarasinghe 2009). These studies include quality and reliability of water supply affecting WP, strategies of WP improvements at different scales, potential WP productivity improvements in food grains, WP in dairying and in different agricultural systems including multiple uses, and taking the concept of WP beyond more crop per drop to more value per drop and its implications for the agriculture sector in India.

Improving water productivity in agriculture can bring about many positive outcomes. In some regions, WP improvement would result in increased crop production with no increase in consumptive use of water, while in some others it would result in reduced use of surface water or groundwater draft. Both outcomes 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 a sufficient amount of unutilized water resources. Augmenting water resources and increasing irrigation in such regions can result in enhanced yield and income returns, as well as improvements in water productivity. Such strategies have the potential to reduce poverty in these regions.

Opportunities

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

- providing full irrigation to meet the full crop evapotranspirative demand or providing supplemental irrigation in critical periods of crop growth for the rain-fed 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 (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,
- improving the quality and reliability of irrigation water,
- managing irrigation for certain crops by controlling or increasing allocation to the said crops,
- adopting high-yielding varieties without increasing the crop consumptive use,
- Bridging the yield gap by providing optimal dosage of nutrients such as artificial irrigation and fertilizing; and improving farming systems with changes in crop and livestock compositions.

Food crops such as paddy and wheat dominate cropping patterns in many irrigated districts in eastern India. The yields of these food crops are significantly lower than the maximum attainable under similar conditions. There are 202 districts in the country which fall under the category of medium consumptive use of water for irrigated crops (300-425 mm), 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 it 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 an optimum dosage of irrigation also to achieve higher crop yields.

There are many irrigated areas in western India with large potential for water productivity improvements through water delivery control, improving quality and reliability of irrigation water supplies, and use of micro-irrigation systems. Water productivity in irrigated crops could be enhanced significantly through deficit consumptive water use through deficit irrigation. This could be a key strategy in water delivery control in 251 districts. These districts already have a 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 the peninsular region. There are 208 districts with low (below 300 mm) average consumptive use of water for food grain production. These districts have large areas under rain-fed course grains like pulses such as green gram and black gram. These crops give very low grain yields, resulting in low WP. Supplementing full irrigation can boost both yield and WP significantly in the rain-fed 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,
- food security concerns and regional economic growth. Cereals such as rice and wheat are important for food security of India but have low water efficiency, compared to cash crops such as cotton, castor and groundnut which have high water use efficiency,
- 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 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,
- lack of credit required to invest in water harvesting systems for supplementary irrigation for rain-fed crops and economic viability issues.

In a nutshell, while there seem to be great opportunities for improving water productivity in agriculture the extent to which these can be achieved depends on the scale at which the above-mentioned constraints operate.

Some of the policy and institutional interventions are as follows:

- improving the quality of irrigation water supplies from canal systems, including the provision for intermediate storage systems like the *diggies* in Rajasthan,
- improving the quality of power supply in agriculture in regions that have intensive groundwater irrigation and improving electricity infrastructure in rural areas of eastern India,
- providing targeted subsidies for micro-irrigation systems in regions where their use results in major social benefits,
- investing in rainwater harvesting for supplementary irrigation in rain-fed districts, and
- 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.

Session 7: Meeting Increasing Water Demand: Augmenting Water Supply through Artificial Groundwater Recharge

Shah (Paper 11) and Sunderrajan et al. (Paper 12) assessed opportunities and constraints of the groundwater recharge master plan and recharge through dug-well programs in India.

For many centuries, surface storages and gravity flow have been the main source of irrigation for Indian agriculture. However, over the last four decades, while surface water irrigation has been gradually declining, groundwater irrigation through small private tube wells has been flourishing. Groundwater is contributing to about two-thirds of the gross irrigated area, but this contribution could be even more if all the conjunctive water use areas are also accounted for. 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. As a result of this boom, a significant part of India's agricultural production and rural livelihoods depend on groundwater irrigation. This boom is also a threat due to overexploitation. Thus sustaining groundwater irrigation is essential for a country like India, because groundwater irrigation, a) gives large spatially distributed social benefits by spreading to vast rural areas that surface irrigation generally has not reached and cannot reach, especially benefiting the large number of smallholders in Indian agriculture, b) is more efficient in irrigating crops, thus allowing better application of agricultural inputs and crop intensification and diversification, resulting in higher yields and an income per unit land than in canal command areas, c) is a better mechanism for drought proofing, and enhances the importance of mitigating impacts due to climate change. For sustainable groundwater irrigation, India needs to make more artificial recharge in many locations and better managements of aquifer storages.

India's National Master Plan for Groundwater Recharge proposes augmenting the water resources annually by another 38 billion m^3. The program, costing Rs 2,450 billion ($6 billion at the 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 cutoff trench and a waste-weir, recharge shaft, that is a trench backfilled with boulder and gravel, subsurface dykes or groundwater dams, dried-up or disused dug wells; injection wells in alluvial aquifers overexploited by tube-well pumpage and roof-water harvesting structures especially for urban settlements, etc. Paper 11 assessed the shortcomings 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 principles—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.
2. Optimize 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 inadequate. Else, many regions where groundwater demand is less and water depletion is low could get a 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 and common property.
5. Seek 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 groundwater depletion. It should assess the drivers behind the boom of groundwater extraction. The plan should accept the fact the surface water 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 they can recharge to the maximum, the stakeholders prefer to have them located where the demand is maximum.

Shah's study proposes an alternative plan by recharging dug wells 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 Sunderrajan et al. assessed the prospects and constraints for recharging groundwater through dug wells. Using a survey of 767 dug-well owning farmers in seven 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 reservations by farmers, they generally agree that recharge through dug wells increases water availability, especially during the dry season. The reservation is mainly on the fact that they can use only a 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 ten farms 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

The virtual water trade concept suggest 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 latter to divert their precious water resources to alternative, higher-productivity uses. The study by Verma et al. (2008) quantifies and critically analyzes interstate virtual water flows in India in the context of a large interbasin 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 from water-stressed to water-surplus states at present. In fact, the existing virtual water trade between states exacerbates water scarcities in some states. The existing pattern of interstate virtual water trade is influenced by non-water factors such as "per capita gross cropped area" and "access to secured markets."

This study suggests that in order to comprehensively understand 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.

Conclusion

Increasing reliance of groundwater and declining area under surface irrigation are the prominent recent trends in Indian irrigation. Given this changing face of irrigation, many issues in groundwater and surface irrigation require immediate attention.

Recharging groundwater is an immediate requirement for sustaining the present groundwater economy and for distributing irrigation benefits to a larger part of the population. Empowering local institutions on watershed development programs, combining several micro-watersheds within a radius of 400 m with meso-watersheds for development, recharging groundwater through millions of dug wells, converting small tanks to percolation ponds, increasing groundwater irrigation tank commands, and changing irrigation scheduling in canal commands to increase conjunctive water use are some measures for sustaining groundwater irrigation.

Water productivity improvements could significantly reduce the requirement for additional water development. Increasing crop yield by providing supplemental irrigation in major rain-fed districts with low consumptive water use (below 325 mm), reducing the yield gap in many irrigated areas without increasing the total consumptive water use (325-475 mm), deficit irrigation to provide deficit consumptive water use in irrigation districts with large consumptive water use (more than 450 mm), and increasing multiple water uses in water-abundant rain-fed areas are some strategies towards increasing water productivity in agriculture.

Demand management strategies can reduce the widening gap between supply and needs. If implemented with stronger policy backing, water pricing, formal and informal water markets, water rights and entitlement systems, energy-based water regulations, water saving technologies, and user and community-based organizations would go a long way towards reducing this gap.

Virtual water trade can ease the stress in water-scarce regions, and provide livelihood opportunities and reduce poverty in the eastern regions. However, proper policy and institutional and infrastructural facilities are necessary to change cropping patterns in different regions to make virtual water a win-win proposition for all regions.

New surface water development projects, including water transfers between rivers as in the NRLP, may become necessary for meeting water demand in some regions. However, planning of such projects should give due consideration to local hydrological, economic and social trends and conditions. Planners should introduce innovative water distribution networks to reduce water and land wastages in watercourses and field channels. They should also set up water allocation institutions that are transparent and accountable to the end users. Proper markets and policies are preconditions for effective functioning of these institutions.

References

Alagh, Y.K.; Pangare, G.; Gujja, B. eds. 2006. *Interlinking of rivers in India. Overview and Ken-Betwa Link.* New Delhi, India: Academic Foundation.

Amarasinghe, U.A.; Sharma, B., eds. 2008. *National River Linking Project- Analyses 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.; Shah, T.; Malik, R.P.S., eds. 2009. *India's water future: Scenarios and issues.* Strategic Analyses of National River Linking Project of India. Series 1. 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 Analyses of National River Linking Project of India. Series 3. Colombo, Sri Lanka: International Water Management Institute.

CPWF (Challenge Program on Water and Food). 2005. Strategic analysis of India's River Linking Project. The Project Proposal. www.cpwf.org

Kumar, M.D.; Amarasinghe, U.A., eds. 2009. *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

NWDA (National Water Development Agency). 2009. The Inter basin water transfers: The need. Accessible via www.nwda.gov.in

Verma, V. K.; Ampman, D.A.; Zaag, P.; Van D.; Hoekstra, A.Y. 2008. *Going against the flow. A critical analysis of virtual water trade in the context of India's National River Linking Project.* Value of Water Research Report Series No. 31. Delft, Netherlands: UNESCO-IHE, Institute of Water Education.