Strategic Analyses of the National River Linking Project (NRLP) of India: Series 3

Promoting Irrigation Demand Managment in India: Potentials, Problems and Prospects

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Preface

In 2005, the International Water Management Institute (IWMI) and the Challenge Program on Water and Food (CPWF) started a 3-year research project on 'Strategic Analysis of India's River Linking Project'. The primary focus of the IWMI-CPWF project was to provide the public and policy planners with a balanced analysis of the benefits and costs of different components 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 issues. Phase II, analyses how effective a response is NRLP 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.

This volume, the third in a series of publications, presents findings of research in Phase III. It assesses the potential contribution, constraints and prospects of contributions from different demand management strategies in the irrigation sector to an alternative water sector perspective plan for India.

Promoting Irrigation Demand Management in India: Policy Options and Institutional Requirements

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Introduction

The symptoms of an ever growing gap between water supply and demand, which are already visible in a few regions around the country, are soon expected to assume a national proportion and become a permanent feature of the Indian water economy. While water demand is growing fast due to population growth and economic expansion, water supply is not growing at the same level due to constraints in expanding supply and also due to the ultimate physical limit for supply expansion. Although water resources developed at present, i.e., 644 billion cubic meters (bcm), constitute only 57 % of the ultimate utilizable potential (1,122 bcm), augmenting supply beyond this level is going to be increasingly constrained by investment bottlenecks, environmental concerns, and political and legal snags. In this respect, the country's ability to meet the increasing water demand in the next few decades will be a major challenge. According to the Ministry of Water Resources, the total demand is projected to increase to 694-710 bcm by 2010 to 784-850 bcm by 2025 and to 973-1,180 bcm by 2050 (Ministry of Water Resources 2000). A recent analysis of water demand and supply scenarios, which accounts for the major changes in the key drivers of water demand and supply, also confirms this demand trend (Amarasinghe et al. 2007b). Particularly, this study projects that under 'business-as-usual' water use patterns, nine basins amounting to over four-fifths of the total water use in India, shall face physical water scarcity by 2050.

From a larger perspective, water scarcity of this magnitude will constrain the ability of the country in meeting the increasing food, livelihood, and water supply needs of an increasing population. Such an inability for a monsoon-dependent and rural-based economy such as India is likely to have devastating social, economic, and political consequences unless water demand is managed through well-designed and implemented policies for improving water use efficiency and productivity, particularly in the irrigation sector, which accounts for the most water consumption. As the scenario facing the Indian water economy is rather grave, any policy prescription would obviously call for a radical change in the development paradigm governing water resources development, allocation, and management. Supply-side solutions based on physical approaches towards supply augmentation and system improvement, though essential in certain contexts, cannot be the exclusive basis for water sector strategies. A paradigmatic shift is needed for seeking durable solutions rooted in water demand management options, particularly in the irrigation sector that accounts for more than four-fifth of the total water withdrawals in the country. It is even more important as we consider the fact that the consumptive use fraction of the irrigation deliveries at present is only about 40 % (Amarasinghe et al. 2007a).

The demand management options that we consider here for evaluation are well known in literature and practice on water policy. These options include water allocation and management tools such as: (a) water pricing policies that cover both the level and structure of water rates and also the criteria used for fixing them; (b) formal and informal water markets occurring at the micro and macro levels; (c) water rights and entitlement systems for setting access and volumetric limits; (d) energy-based water regulations such as power tariff and supply manipulations; (e) water-saving technologies that cover drip and sprinkler systems as well as crop choice and farm practices; and (f) user and community-based organizations, covering water user associations, *panchayat* organizations, and informal community groups. Although adoptions of these options are critical, what is more critical is the creation of the supportive institutions to ensure their operational effectiveness and water saving performance.

Objectives and Scope

While the importance of demand management options can hardly be disputed, there are still a number of questions that are to be answered from a practical policy perspective in the context of each of the six demand management options. For instance, what is the present status of these options in the irrigation management strategy in India? What is the extent of their application? How effective are they in influencing water use decisions at the farm level? Are there active policies in promoting them at the national and state level? Are there cases of success and best practices in demand management? If so, what are the lessons 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? To explore these and related questions in the context of each of the six demand management options, IWMI has commissioned six separate papers[1] prepared by some of the leading experts on the Indian water sector. These papers were prepared with a common analytical structure to specifically address some of the most relevant practical questions and policy issues (see R. Reddy 2008; Palanisami 2008; Narain 2008; Malik 2008; Narayanamoorthy 2008; and V. Reddy 2008).

[1] These papers were commissioned in phase III of the IWMI project, 'Strategic Analyses of India's River Linking Project', under the aegis of the Challenge Program for Water and Food. Phase III of the project explores the options that contribute to an alternative water sector perspective plan, in case supply augmenting strategies such as the National River Linking Project (NRLP) fail to meet the increasing water demand.

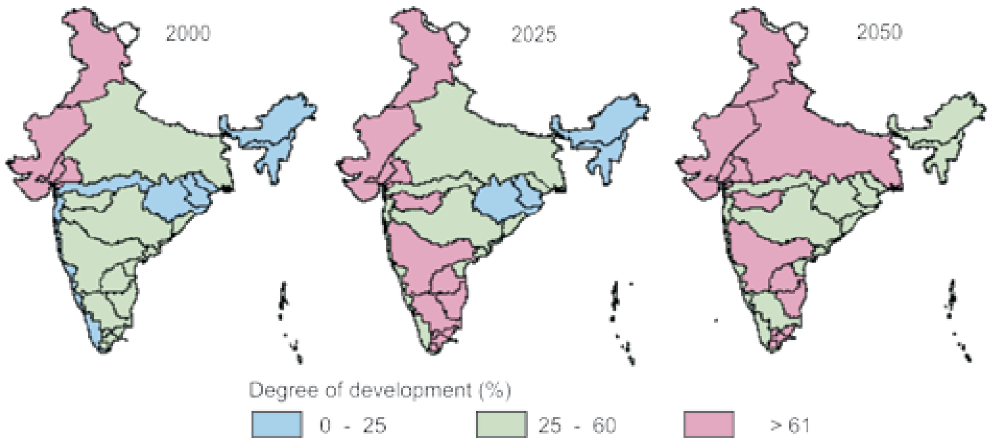
The main purpose of this paper is to: (a) set the basic economic logic of demand management options; (b) provide an overview and synthesize of the option-specific papers prepared by experts; (c) indicate the key differences and common features emerging from the practical experiences of the demand management options; (d) present an analytical framework that will help understand the operations and linkages among the demand management options and their underlying institutional elements; (e) outline a generic strategy that can better exploit the inherent synergies among the demand management options and align them with the underlying institutional structure and environment; (f) discuss how such a strategy can be effectively promoted within the technical, financial, institutional, and political economy constraints; and (g) conclude with practical insights and policy implications of the discussions in this synthesis paper and in all the six option-specific papers. As to the focus, the discussion on demand management options is specifically confined to the irrigation sector. However, the general implications, especially those related to the institutional dimensions, can also pertain to demand regulations in other sectors, though the relevant options may be different.

Demand Management Options: Logic and Focus

Although the adoption of demand management options on a wider scale is slower than needed, given the changing water supply and demand realities both at the national and local levels, an increasing reliance on these options is inevitable, especially in the irrigation sector and in basins where physical water scarcity is already evident. Considering the predominant share of the irrigation sector in total water use and the small consumptive use factor of irrigation withdrawals, the potential of this sector for water savings and efficiency gains from demand management options are obviously immense. Similarly, larger basins with excessive water withdrawals for agricultural uses also offer a better scope for achieving use efficiency and water savings. Besides their implications for the scope and focus of demand management, the current and prospective physical and economic realities of the water sector also provide the basic rationale for promoting demand management options and strategies.

The total water withdrawal for all uses at the national level in the year 2000 was estimated to be 680 bcm (Amarasinghe et al. 2007a). But, if the 'business-as-usual' path of water management and water use pattern continues, water demand is expected to increase by 22 % by 2025 and 32 % by 2050. With such a demand growth, more and more basins are likely to face physical water scarcity, i.e., water withdrawal exceeding 60 % of the potentially utilizable resource. Since withdrawal exceeding this level is expected to be both financially costly and environmentally difficult, more basins are also likely to face economic or financial water scarcity as well. As can be seen in Figure 1, many basins in India are expected to be in this predicament of physical and financial scarcity by the year 2050, if not before. As these basins account for close to three-fifth of the country and cover agriculturally the most important basins, including the Indus, Ganges, Cauvery, and Krishna basins, they will have a pernicious effect on the food and livelihood as well as political fronts.

Figure 1. Degree of development of Indian river basins.



Source: Amarasinghe et al. 2007a

Note: If the degree of development—the ratio of primary water withdrawals to potentially utilizable supply—exceeds 60 %, a basin is physically water scarce. If the additional demand exceeds 25 % of the present level, the basins are economically water-scarce

As can be seen in Table 1, which depicts total water withdrawals by use, source and basins in 2000, the irrigation sector accounts for 89 % of the total withdrawals at the national level. Such a dominant share of irrigation is also evident in most of the basins. Despite such a large share of water withdrawal, the actual consumptive use—the portion that is actually used for the net evapotranspiration of crops—is only 41 % at the national level. The fraction of consumptive use varies from 12 to 59 % across basins, depending obviously on factors such as crop and land use patterns as well as irrigation efficiency at project and farm levels. It is the difference between this consumptive use and the total water withdrawal that provides the physical basis for achieving water use efficiency and water savings through demand management both at the national and basin level. Admittedly, it will not be possible to realize this entire potential for water savings due to various physical, technical, economic, and institutional reasons. But, it is certainly possible to achieve, say, a 20% of this potential water savings with proper targeting of regions for concerted demand management policies and investments.

Table 1. Water withdrawal by use, source and basins, 2000.

River basins	Water withdrawal			NET[3] as % of irrigation withdrawal	Gross irrigated area		
	Total[1]	As % of potentially utilizable resources[2]	Share of irrigation		Total	Groundwater share	Groundwater abstraction ratio[4]
	BCM	%	%	%	Mha	%	%
Indus	98	135	96	37	11.6	58	67
Ganga	285	68	90	41	36.5	69	56
Brahmaputra	6	12	67	14	0.4	14	4
Barak	3	29	76	12	0.3	6	4
Subarnarekha	3	35	81	24	0.4	46	36
Brahmani-Baitarani	6	28	88	24	0.7	28	21
Mahanadi	21	32	92	24	2.2	20	13
Godavari	44	37	85	46	4.3	59	40
Krishna	55	66	89	45	5.2	44	48
Pennar	8	66	90	47	0.7	65	61
Cauvery	22	70	85	39	1.9	48	43
Tapi	9	41	81	55	0.8	80	59
Narmada	13	30	90	46	1.5	61	42
Mahi	6	89	86	43	0.5	55	44
Sabarmati	7	136	86	53	0.9	83	100
WFR1[5]	29	112	88	59	3.2	89	132
WRF2[5]	14	26	52	34	0.9	40	22
EFR1[5]	20	63	92	35	1.9	26	17
EFR2[5]	33	95	86	37	2.2	54	46
All basins	684	61	89	41	75.9	61	48

Source: Amarasinghe et al, 2007a

Notes: [1] Total includes withdrawals for irrigation, domestic and industrial sectors

[2] Figures more than 100% also include recycling

[3] NET is the net evapotranspiration of all irrigated crops

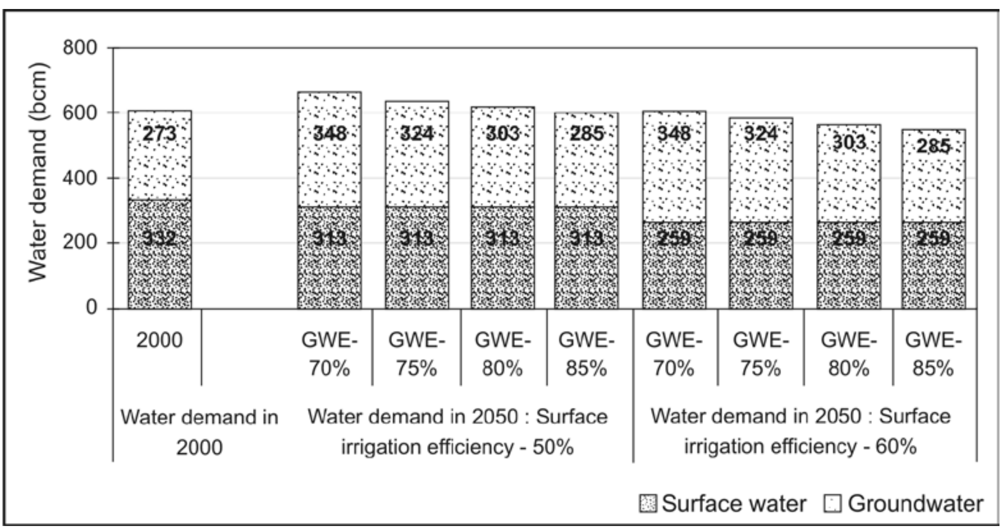
[4] It relates total groundwater withdrawals to the total groundwater availability through natural recharge and return flows

[5] WFR1 is west flowing rivers of Kutch, Saurashtra and Luni; WFR2 is west flowing rivers from Tapi to Kanayakumari; EFR1 is east flowing rivers between Mahanadi and Pennar and EFR2 is east flowing rivers between Pennar and Kanyakumari

In view of the possibility of greater technical control over the volume and use, the scope for realizing water savings is more in groundwater areas than in surface water areas. Notably, in groundwater areas, where irrigation efficiency is already higher than in canal areas, further efficiency improvements are possible, that too, mainly through policy and institutional changes. In contrast, efficiency improvements require mainly technical changes, especially involving a massive redesign of water conveyance and delivery systems, though policy and institutional changes are also essential to enhance and sustain the efficiency gains. As a result of their differential policy and institutional requirements, efficiency gains are relatively more immediate in groundwater areas and would also involve relatively smaller public investments on physical structures. Using this fact taken with the dominant (i.e., 60 %) share of groundwater in total irrigation, it is possible to realize the overall irrigation efficiency targets with a greater attention on the groundwater areas, particularly those with severe depletion problems.

Besides their immediate impacts on agricultural productivity, improvements in irrigation efficiency will also have a direct effect on the irrigation water demand and, hence, on the water savings necessary for meeting urban and environmental needs. As can be seen in Figure 2, if the overall irrigation efficiency in canal regions can be raised from the current level of 40 to 50 % and in the groundwater regions from the present level of 60 to 80 %, the future irrigation demand, even with the larger irrigated area, will not exceed the present level of agricultural water withdrawals. But, if the surface irrigation efficiency is increased by an additional 10 %, i.e., to 60 %, while keeping groundwater irrigation efficiency at 80 %, there will be a reduction in irrigation demand to the tune of 43 bcm (Amarasinghe et al. 2007a). If it is possible to raise groundwater irrigation efficiency by an additional 5 %, i.e., 85 %, then, the total reduction in irrigation demand can be as high as 63 bcm. Notably, this reduced irrigation demand or irrigation water savings is close to the total nonirrigation demand in 2000, i.e., 79 bcm. In a sense, this represents the true magnitude of the potential for water savings that exists in the agricultural sector at present. This potential can be realized gradually though the implementation of demand management strategies involving the judicious application of options such as water pricing, water markets, water rights, energy regulations, water saving technologies and user organizations.

Figure 2. Irrigation efficiency and water demand scenarios.



Source: Amarasinghe et al. 2007b

The immediate goal of demand management is not just the reallocation of water away from irrigation but also to set the conditions for a long-term improvement in the productivity and efficiency of irrigated agriculture. In fact, an excessive focus on water reallocation often creates resistance and constraints for the promotion of the demand management options. In reality, the improving efficiency is the most immediate and central goal, whereas the reallocation is only a secondary goal, which flows as an outcome of the former, that too, within a voluntary and compensation-based incentive framework. This point, though seems to be simple and hence, remains often underestimated, is rather crucial, especially from a political economy perspective of creating the necessary economic and institutional conditions for the application of demand management options.

The macro-logic for demand management is clearly underlined by the increasing water supply-demand gap at the national level. There are also other equally compelling reasons—both the macro and micro ones—for the urgency of promoting these options in Indian agriculture. One of them relates to the food and livelihood implications (see Palanisami and Paramasivam 2007). The total food grain area in India has increased about 1.2 times between 1950 and 2005, i.e., from 97 million ha (mha) to about 121 mha whereas the food grain production has increased by 4.1 times, from 51 million tonnes (mt) to 208 mt (GOI 2007). Irrigation has been a major source of determinant for the productivity increase, where the irrigated area under food grains has increased by 3.0 times, from 18 to 54 mha between 1950 and 2005. Over the same period the total or gross irrigated area has increased by 3.6 times from 22 to 80 mha. This shows that while irrigation has been playing a major role in increasing food grain productivity and production, the demand for irrigation for nongrain crops is also increasing.

It is expected that the water demand of nonfood grain crops will further accelerate with changing consumption patterns (Amarasinghe et al 2007a; 2007b). This, along with the increasing water demand of domestic and industrial sectors will have significant implications for increasing food grain productivity and the food security of India. For instance, given the current level of food consumption and the expected population of around 1.6 billion, India is projected to have a food grain demand of about 400 mt—about twice the present food production—by 2050. Unless an increase in water productivity is realized, meeting this food demand would entail the provision of irrigation to an additional 60 mha more than the current irrigated area. The expanded level of irrigation required to meet the food security targets is clearly impractical to achieve through the usual approach of supply augmentation because of the double whammy effects coming from the binding limits for adding new supplies and the increasing inter-sectoral competition over existing supply itself.

A much more potent argument against the additional allocation for irrigation however, comes from the serious magnitude of water use inefficiency found within the irrigation sector itself. It is a well known fact that the average water use efficiency is rather low in irrigation, ranging from 40 % in the canal regions to about 60 % in the groundwater regions (see Amarasinghe et al. 2007). Such a magnitude of water use inefficiency does suggest the existence of a hidden irrigation potential and such a potential can be realized with improved efficiency in water application, as achieved through the use of demand management options. Simplified estimates, made a few years ago, suggest that it is possible to effect a 10 to 20 % improvement in water use efficiency, on an average, over a 5-year period and such improvement would release an additional 10-20 mha of irrigation potential within the existing level of water use (Saleth 1996). This is very close to what is achieved in an entire 5-year plan period through new supplies obtained with spending so much time and investment. If this time and investment spent on the supply-side solutions are redirected towards the demand side options, it is equally possible to irrigate more areas with the same or, even, a reduced level of water use. This indeed is the central logic for promoting the adoption of demand management options. What is needed, therefore, is not a fringe investment on demand management but rather a major policy and investment shift from supply augmentation to demand management.

As to the focus and coverage, some of the demand management options are context-specific, whereas others are applicable in a more generic context. 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.[2] 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.

More importantly, 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.

Demand Management Options in India: An Overview and Synthesis

Before developing the analytical framework that shed light on the strategic and institutional dimensions as well as the dynamics and impact paths of demand management, it is useful to provide an overview and synthesis of the six demand management options (Reddy 2008; Palanisami 2008; Narain 2008; Malik 2008; Narayanamoorthy 2008; V. Reddy 2008). Since these papers provide a comprehensive evaluation of the present status and effectiveness of the individual demand management options in the particular context of irrigation sector, an overview of them can be helpful both to highlight the main issues and challenges, and also to explore the possible avenues for enhancing the individual and joint coverage and demand

[2] 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.

management performance. With this point in mind, let us provide a quick overview and synthesis of the potential, present status, problems and prospects of individual options as presented in each of the option-specific papers.

Water Pricing

Ratna Reddy (2008), in his most comprehensive review of water pricing as a demand management option, concludes that the ability of water pricing to influence water use in India is severely constrained both by the nature and level of water rates as well as by the lack of effective institutional and technical conditions. Although successive Irrigation Commissions have recommended to base water rates on benefits or gross revenues rather than simple provision costs, the prevailing rates in most states are tuned more to cost recovery than to income or benefits. Even this cost focus is also restricted to operation and maintenance (O&M) costs, and in most states the water rates were able to cover no more than 20 % of these costs. Notably, Ratna Reddy (2008) argues that such lower rates are more to do with technical and political factors than with willingness to pay issues, as farmers willing to pay more, especially with an improved supply and service quality, is well documented across the states.

Besides the lower level, the nature and structure of water rates also make them ineffective both in their cost recovery and allocation roles. Since water rates are charged in terms of area, crop and season (or combinations thereof), they fail to create enough incentive for water use efficiency. While water rates in groundwater areas are relatively higher, they also related to average pump costs rather than water productivity or economic value (see R. Reddy 2008 —Table 3). Under this condition, it is farfetched to expect the present water pricing policy to play the much needed economic role of water allocation. Based on a careful review of both water pricing literature and actual experience in India and abroad, Ratna Reddy (2008) argues that water pricing policy can be an effective tool to manage demand, if it is designed within a marginal cost principle, volumetric allocation and block or tier structure. Besides the design aspects, he has also elaborated on supportive institutional conditions such as the user organizations, locally managed water rights, water markets and system redesigns to improve conveyance and delivery.

Although Indian experience shows that water pricing is largely ineffective in influencing water use, there are interesting examples, which, in fact, show the importance of the necessary technical and institutional conditions. While water pricing has not been that effective, its effectiveness can be enhanced with the proper level and structuring of water rates. For instance, in Israel, marginal cost pricing followed within either the block rate structure or the tier rate system has been successful in reducing water consumption by 7 %. Similarly, pricing policy, when combined with supply regulations either directly or though water rights, can also be very effective. For instance, the Krishna Delta farmers in Andhra Pradesh received 40 % less than the normal supply during the drought of 2001-2004. Interestingly, they have not only managed well with this lower supply but also reported a 20 % improvement in the yield (Reddy 2008). Although this case shows the efficiency and water saving benefits of an accidental supply reduction during drought, it does demonstrate the potential of direct supply regulations in canal regions. The experience in cases such as Australia and California in USA shows that, the effectiveness of water pricing in demand management can be attributed to the supporting institutions such as volumetric allocation, water rights and water markets.

Water Markets

In his critical review and evaluation, Palanisami (2008) highlights both the opportunities and challenges involved in using prevailing water markets as a demand management option in irrigation. He has compiled extensive empirical evidences on the efficiency and equity roles of water markets both in the groundwater and tank regions. But, at the same time, he also notes the negative social and resource effects due to the monopoly tendencies and groundwater depletion. While there is scope for considerable net positive effects of water markets on water use efficiency, he reckons it to be rather small for two major reasons. First, although water markets are observed widely, the area they cover or influence are small and they occur mostly in groundwater regions mainly on a sporadic basis. The estimated area served or *influenced* by water markets varies widely in a range of 15 to 50 % of the total irrigated area in the country. But, given their seasonal character, transitory nature and concentration in few regions, the actual area affected by water markets is likely to be close to the lower bound of this range. Second, since these markets operate without any volumetric limits or other regulatory framework, there is only very little incentive for increasing water use efficiency or water saving. Although water rates vary across markets, the dominant practice of fixing them based mainly on pumping and other operational costs reduce their role in reflecting the scarcity of water.

Due to the size, coverage and nature of functioning, the ability of water markets to perform their economic and efficiency roles is considerably limited in the Indian context. On the other hand, there are evidences for the increasing depletion and economic loss of production due to groundwater mining. In the case of inter-sectoral water markets around peri-urban areas, where water is moved directly from irrigation to urban water supply, there can be serious livelihood issues when urban migration is low and urban-based livelihoods do not increase concurrently in the long-run. Moreover, as Palanisami (2008) argues, this problem is not due to water markets per se but due to the technical and institutional conditions in which these markets operate. Specifically, he mentions the absence of volume-based water rights, spatial issues limiting competition and regulatory framework, including energy supply and pricing regulations and community involvement in local water withdrawal decisions. One can also add here the distorting role of land tenure that tends to link water control with land ownership, especially when there are no volume-based water rights. Similarly, the absence of well-spacing and depth regulations also leads to the crowding of wells in agriculturally productive regions. The successful cases of water markets in countries such as USA, Australia and Chile are provided to underline the importance of supporting institutions such as volumetric allocation, water rights and water regulations to protect equity and environment.

Water Rights

Against a detailed conceptual and legal analysis of water rights within a new institutional economics framework, Narain (2008) evaluates the potential and prospects for its utility and applicability as an option for managing irrigation demand. For water rights to be effective and enduring as an institutional system for managing water, in general, and irrigation, in particular, he suggests the necessity of converting the abstract notion into an operationally applicable practical tool with a clear delineation and quantification of the volume of water. This is not going to be easy in view of the understandable legal, technical, institutional, and political challenges. But, at the same time, there are also considerable potentials for creating a volume-based water rights system as there are growing compulsions from the emerging water demand-supply realities and the attended water-based conflicts at various levels. The arguments also make it clear that the costs and difficulties involved in establishing a water rights system can be more than offset by the potential but definite long-term benefits for the society. Considering the existing legal and institutional potentials and the emerging realities on the resource and technology sides, the development of water rights system will not be as difficult or costly as it is made out to be in current public discourse. In fact, water right systems of various forms are already in operation both at the macro and micro levels in India.

Based on the review of the literature, legal and policy documents and field level perspective of water rights, Narain (2008) concludes that while there is a clear need and basis for establishing water rights systems, it will, however, be unrealistic to contemplate a single form of water rights systems applicable to all contexts. Diverse forms of water rights are needed to suit the location and context-specific realities, though there are common principles of equity, legal pluralism and negotiation. Besides the lease-based water rights issued by government in the Gangetic Delta regions and the macro-level rights implicit in sectoral priorities, there are also semi-legal and informal rights linked to land such as the groundwater rights—based on the legal principle of easement, and canal water rights—based on the location-related principle of fixed-tenure (Saleth 2007). But, the most important ones, which are socially recognized, locally managed, and operating on a larger scale, especially in the north-western and eastern states are the water rights based on time (as in *Warabandi* system) and on volume (as in *Shejpali* system).[3] Narain (2008) provides field evidences for their role in facilitating negotiation, water allocation and use efficiency.

Although the semi-formal and locally-managed water rights systems have an effect on water allocation and use efficiency, their impacts are not that large to perceptibly influence water demand. Obviously, this is mainly due to the absence or ineffectiveness of supportive institutions, particularly the absence of legal and institutional mechanisms for monitoring, sanction and enforcement at the top and technical and organizational arrangements to facilitate a more accurate and responsive water allocations based on time, volume or both. In view of this institutional and technical vacuum, there is neither sufficient incentives for efficient use nor adequate compensation for water saving. Unless this serious gap is addressed quickly, these water rights, though helpful in water allocation, cannot be effective in demand management. For performing this economic role, these local water rights systems should be structures within a 'public trust framework', where the user groups, officials, and stakeholder at different levels of the system could work together within a framework of regional, sectoral and tributary and outlet level water quota system (see Saleth 2007). The transaction costs of creating this framework are obviously high because it entails tremendous information, technical and organizational demand as well as an extraordinary level of bureaucratic and political commitment. Yet, the demand management impacts water rights system cannot be ensured without this framework.

[3] Notably, both the time and volume-based water rights are linked to farm size, as they are determined in proportion to land owned or operated. But, there are instances such as the *Pani Panchayat* system, where even landless persons also have water share, which they can sell. In this case, the shares are based not on land but on family size (see Saleth 1996).

Energy Regulations

Energy regulations, covering both the price and supply of electricity and diesel for irrigation purposes, are relevant for influencing water use mostly in groundwater regions, though they are also relevant even in canal areas involving lift irrigation. Malik (2008) evaluates the potential ability and actual impact of these regulations on demand management using an extensive but in-depth review of available literature and empirical evidences. The evaluation suggests that the efficacy of energy regulation as a tool for demand management depends on their intrinsic nature and enforcement as well as a number of related farm and region-specific factors such as well ownership and depth, farm size, cropping pattern, groundwater marketing possibilities and the groundwater hydrogeology itself. Energy regulations involving relatively higher and metered or use-based tariff will be more effective in controlling water withdrawals as compared to the ones based on fixed and flat rates. Similarly, regardless of the rates, direct supply regulations involving rationed and fixed hours of supply will be more effective, provided farmers do not have multiple wells, resort to illegal use of power with phase converters, or substitute or complement electric and diesel power. Considering the scope for bypassing supply regulations, monitoring and enforcement mechanisms, particularly with local involvement as well as a coordinated regulation of electric and diesel pricing and supply are critical.

There are limits within which energy pricing can be increased, and such limits are set by the economic theory and political feasibility. While the efficient use of energy and water will require the tariff to reflect the opportunity cost or, at least, the cost of alternative energy sources, political considerations lead to tariffs that not even reflect fully the production costs. Therefore, in order to achieve the financial goals in the energy sector and the efficiency goals both in the energy and water sector, there is an urgent need for a major change in the tariff level and structure, especially in the irrigation sector. Citing other studies (e.g., Saleth 1997; Bhatia 2007), Malik (2008) argues that for energy regulations to be effective in affecting water withdrawals, the tariff level and structure need to reflect the value of marginal productivity of energy, discriminate crops, consumption levels and locations, and be accompanied by supply rationing. But, changes in the power tariff level and structure, though critical, are not sufficient given the critical roles played by institutional and technical conditions involved not only in the transmission and distribution of energy for agricultural uses, but also in determining the access to groundwater itself.

Energy regulations do have the potential to influence water withdrawal and irrigation demand and also to improve the efficiency and financial viability of the energy sector itself. But, these roles cannot be expected to be automatic under the current conditions of tariff level and structure, bureaucratic management and unregulated groundwater access conditions. There is a need for major reforms both in power and water sectors. Malik (2008) outlines some key components of these reforms. First, considering the practical limits to which power rates can be raised and also the difficulties for them to effectively influence water withdrawal directly, it is reasonable to use them mainly to achieve the financial goals. Second, the policy of metered rates varying with consumption and crops has to be combined with supply regulations so as to directly influence water withdrawal. Third, the successful experiences in China and US and also in the piloted experiment in Gujarat suggest that the state electricity boards have to bulk distribute power to local organizations such as panchayats (an elected governance body at the village level) and rural electricity cooperatives for them to retail power among users and collect charges. Finally, besides these changes related to the power sector, there are also changes needed in the water sector, especially the strict enforcement of spacing and depth regulations as well as the whole host of institutional and technical aspects related to establishment of legally sanctioned but locally enforced and managed volumetric water rights. When these conditions are created, energy regulations can be a powerful tool within an overall strategy of irrigation demand management.

Water Saving Technologies

The water saving technologies cover not only the methods related to water application (drip, sprinkler and micro-irrigation) but also those related to crop choice and farming practices. Unlike other demand management options, this option has a direct and immediate effect on water consumption and irrigation demand. Having reviewed the available evidences on the extent and impact of water saving technologies, Narayanamoorthy (2008) shows that these technologies can raise water use efficiency to the level of 60 % (sprinkler) to 90 % (drip) in irrigation. Besides the obvious savings in water that may depend on the extent the saved water is available for use elsewhere, these irrigation methods also provide additional savings in terms of energy and labor costs. Empirical studies in India establish that these irrigation technologies save 48 to 67 % of water, 44 to 67 % of energy costs, and 29 to 60 % of labor costs. Overall, private benefit-cost ratio, which depends on the value of water productivity and the underlying role of crop prices, is impressive, ranging from 1.41 for coconut to 13.35 in crops such as grapes. In view of these economic and productivity benefits, these technologies remain highly viable in a range of crops from sugarcane, banana and grapes to even field crops such as wheat and bajra (Narayanamoorthy 1997; Kumar et al. 2004). Since these technologies are scale-neutral, they are also beneficial to farmers even with less than one hectare (Narayanamoorthy 2006). Notably, much more than the private benefits are the social benefits in terms of water savings and input use efficiency (see Dhawan 2000).

Unfortunately, despite the enormous scope and the impressive performance in terms of both private and social benefits, the spread of water application technologies is rather slow and their application is largely confined to a few states and crops. For instance, the total area under drip irrigation is not more than 500,000 to 600,000 ha. Over 85 % of this area is also confined to the groundwater dependent hard-rock states, i.e., Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh. Although the technical and economic viability of this irrigation method is established, as many as 80 crops, more than four fifths of the current application is restricted to vegetable and horticultural crops, including mango and citrus. Notably, coconut, banana and grape together account for approximately half the area under drip irrigation. The issue of low level of application and extent of coverage also applies equally to other water saving technologies related to the selection of water conserving crops and farm practices such as crop spacing, use of plastics and deficit irrigation. The common reason for this low level of adoption is the absence of binding incentives, which emerge not just from the expected benefits of adoption but also from the resource-based compulsions reflecting the real scarcity value of water. Under conditions of unregulated water withdrawals, the latter never enters into the irrigation use decision of farmers.

While it is true that the water saving technologies have the most direct and immediate impacts on irrigation demand, the major problem is that these impacts are limited mainly due to the limited extent of their application and the limited environment within which they are operating at present. Narayanamoorthy (2008) elaborates, then, the policy measures needed both to expand their coverage and also to improve the supportive institutional arrangements. One of the main problems with irrigation technologies such as drips and sprinklers relates to the need for high initial investment. Although state subsidy can be helpful, this is not the only factor in view of the role of other factors such as extension and the need for the involvement of the technology firms as well as other actors such as the sugar factories in the targeting and active promotion of adoption. In this respect, beside the subsidy directed to farmers, it is also necessary to extend tax relief or other incentives for the technology firms and sugar factories. Equally, if not more important, however, is the need for other direct and indirect regulation on the water resource side such as water rights and energy regulations that will reflect the scarcity value of water to the farmers. Field studies reveal that the availability of cheap canal water and unregulated groundwater supply do not provide the farmers with the much needed economic compulsion for adopting the drip irrigation technologies. At the same time, adjustments in farm price and input policies are needed to bolster water conserving crops and farming practices.

User and Community Organizations

User organizations as well as community organizations play a major role in water allocation and demand management in the irrigation sector. They cover both the formal ones such as WUAs and *panchayats* as well as the implicit and informal ones such as those in *Shejpali* and *Pani Panchayats* systems, including those promoted by NGOs and other stakeholders in rural areas. Although the general attention is focused mainly on WUAs and canal irrigation contexts, other organizations and their roles in groundwater irrigation and energy distribution are also equally important. However, a careful evaluation of the WUAs, which are created and promoted under various forms of irrigation management transfer programs in the canal regions of many states, can provide an indication of the overall status and ability of user and community organizations in demand management, either directly or indirectly in terms of facilitating other options. Venkata Reddy (2008) has made such an assessment based on a critical review of the available literature and field evidences on the status, problems and prospects of WUAs, particularly in the canal irrigation sector.

As in the case of other options, the two most important factors that will determine the extent of demand management impacts of user organizations are their area coverage and their design and effectiveness. Despite user participation policy being promoted since the command area development programs of the 1960s and the user organizations being currently promoted actively in almost all states in India, the number of formal WUAs created so far and the extent of area under their influence remain extremely low. According to Palanisami and Paramasivam (2007), the total number of formal WUAs in the country is only about 15,000 and the area they cover is not more than about 500,000 ha. Obviously, these figures do not cover the 800 WUAs created in Rajasthan and also many informal and implicit water-related organizations involved in the *Shejpali*, *Pani Panchayats* and *Warabandi* operating in parts of Maharashtra, Orissa, Punjab and Haryana. While *Warabandi* system covers most canal areas in Punjab and Haryana, there are no clear estimates for the number and area coverage of the other informal systems, especially for Maharashtra. However, according to the estimates for Orissa, there were 13,284 *Pani Panchayats* covering a total area of over 800,000 ha in 2002 (R. Reddy 2008). Even risking a rough estimate, the total areas under the *Shejpali* and *Warabandi* systems cannot be more than 3 to 4 million ha, representing only a fraction of the total canal irrigated area in India.

Much more serious than the low area coverage are the weak design and operational effectiveness of the user organizations. In view of their central institutional role, user and community organizations are where the whole effort to promote demand management strategy is to begin first. Unfortunately, these organizations, especially the WUAs, as they exist today, are designed more to focus on the limited roles of local maintenance, cost recovery and water distribution rather than the broad and long-term roles of being the organizational basis for developing higher levels of economic and institutional functions. As a result, the ability of WUAs to influence real water allocation and demand management is considerably limited. This does not, however, deny their positive roles in cost recovery, system maintenance and service quality in some contexts. In this respect, it is also important to note that the current policy of Maharashtra to introduce bulk water rights at the sectoral and tributary levels and involve local user organizations to retail water is likely to strengthen the kind of institutional role that is needed for demand management.

Similarly, one cannot also deny the effective role of informal organizations, which are well documented by Venkata Reddy (2008), Ratna Reddy (2008) and Narain (2008) in the context of different states. Although their impacts are highly location-specific and also confined only to a few regional pockets, the key for policymakers is to learn the social and resource-related incentives behind these success cases and try to replicate in the case of formal organizations. While having democratic elections and improving farmers' participation are important, much more important and challenging are the policy and institutional aspects of creating effective incentive systems for collective action. In this respect, the creation of volumetric water rights and volume-based water pricing, for instance, can create the necessary incentives for collective action and water use efficiency. This is an interesting case of structural linkages among the demand management options, where the effectiveness of user organizations depends on other institutional options such as water rights and pricing, which, in turn, depends on the effectiveness of the organizational aspects.

Demand Management: Analytics of Institutions and Impacts

The central message of the review of demand management options is rather clear. Although some of the options 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. To see why the demand management options are effective and to know how their effectiveness and performance can be improved, we can develop an analytical framework capturing the linkages and dynamics among these options and their underlying institutional structure.

Although the demand management options appear to have important differences in terms of the nature, mechanics and the gestation period of their impacts, there are fundamentally important operational and institutional linkages among them. Operationally, these options are not independent but linked due to their mutual influences on each other. Similarly, there are also intrinsic linkages among the institutions that support each of these options. A clear understanding of these operational and institutional linkages is so vital not only for designing an integrated strategy for demand management but also to determine its effectiveness and impacts on water management and economic goals. For this purpose, we can use Figure 3 depicting the analytics as well as the institutional ecology of demand management options and their joint impact on sectoral and economic goals.

Before proceeding, it is instructive to note few key aspects of Figure 3. First, the institutions and their linkages noted for each of the options are not exhaustive but only illustrative to highlight some of the most important and immediate ones among them. This also applies to the effects or impact pathways identified both in the sectoral and macro- economic contexts. Second, since the institutions and their linkages form together the 'institutional ecology' of demand management, Figure 3 does capture the 'institutional structure'. But, the 'institutional environment' of demand management, as defined by the joint role of hydrological, demographic, social, economic and political factors, though not a role of hydrological, demographic, social, economic and political factors, though not explicitly specified, actually operate beneath Figure 3 and, hence, will have major effects on the entire system presented therein. From the perspective of the demand management strategy, the elements defining the institutional environment are the exogenous factors, whereas the elements forming the institutional structure are the endogenous factors.

Despite its limited coverage, Figure 3 is able to place irrigation demand management in the strategic context of water and agricultural institutions as well as in the larger context of water management and economic goals. As can be seen, there are five analytically distinct but operationally linked segments. The first segment shows the sequential linkages among demand management options, where the options that form the necessary conditions for other options and those having the most intense linkages with others are shown. The next segment captures the joint effects of these options on the irrigation sector, where the water savings effected through an improved irrigation efficiency lead to either/both expanded irrigation with existing supply or/and increased water savings. The third segment shows the sectoral and economy-wide effects of the initial effects on the irrigation sector, which are captured through increased water transfers and higher agricultural production and productivity and converted finally into the food, livelihood, water supply and environmental benefits. The remaining two segments relate to the institutional dimension of demand management and cover respectively, the immediate institutional structure and the fundamental institutional environment. Notice that the institutional structure covers not only water-related institutions but also those related to agriculture, market and technology. Although the institutional environment is not specified in Figure 3 to avoid clutter, it plays a critical role in terms of providing the economic, resource-related and political compulsions both for the adoption of the demand management options and for the creation of their supportive institutions.

Figure 3. Demand management options: Inter-linkages and institutional environment.

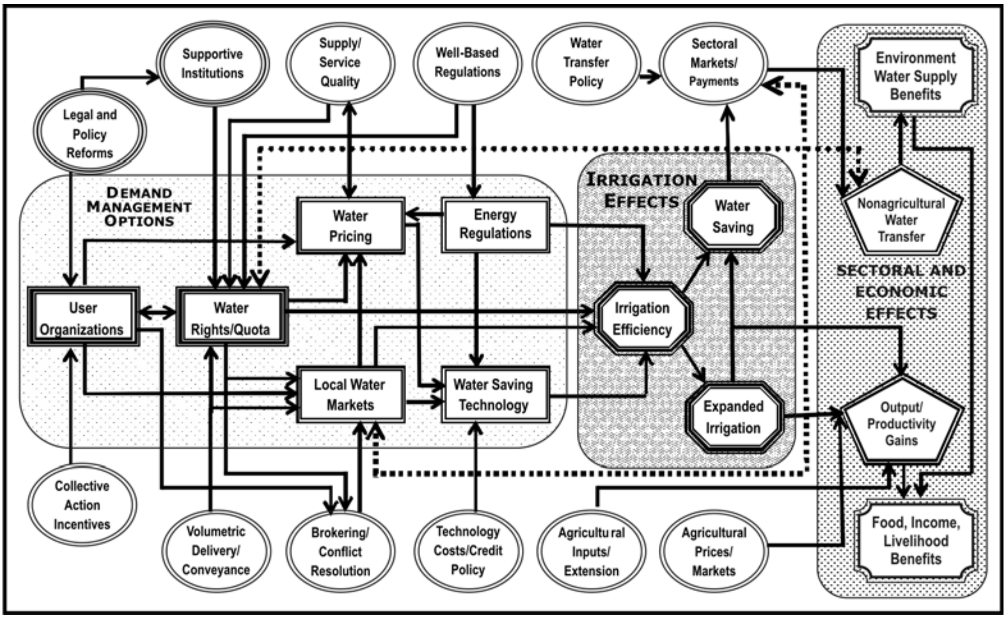


Figure 3 highlights several important points. While all the demand management options are important, the sequential linkages among them suggest that some are obviously more important than others. As noted already, this is either due to their role of being the necessary conditions for others (e.g., user/community organizations) or due to the extent of linkages with others (e.g., water rights/quota system). The options also differ in terms of their nature and magnitude of their impacts on irrigation efficiency and, hence, on water saving and productivity. For instance, the direct effects of user organizations, water pricing and energy regulations will be neither immediate nor substantial partly because of the longer gestation period involved, and partly because its ultimate efficiency effects depend on the effects of related options and the existence and effectiveness of supportive institutions. But, water saving technologies will yield more immediate efficiency benefits, though the extent of such benefits depends on their geographic scale and crop coverage.

Obviously, the options also differ in terms of the institutional, technical and political requirements for their adoption and implementation. For instance, while it is easy to create user organizations, it is more difficult to create the necessary conditions such as the incentives for collective action and the establishment of the volumetric delivery, water quota and loss-free conveyance systems. Thus, the ability of an option to manage depends not just on how efficiently it is designed and implemented but also on how well is it aligned with other options and how effective are the supportive institutional and technical conditions. This fact highlights another strategic feature of the options. Considering the fact that institutions, including water institutions, are defined by the interactive roles of legal, policy and organizational aspects (Bromley 1989; Saleth and Dinar 2004), all options, except water saving technology, are also institutions in themselves. In this sense, the linkages among user organizations, water rights, water markets, water pricing and energy regulations are actually part of the larger institutional setting of demand management. Major institutional issues are involved both in terms of the functional linkages among the options as well as in terms of the structural linkages within the supportive institutional structure.

It is also clear from Figure 3 that the institutional structure for demand management covers not only the institutions that are directly related to individual options but also those that are related to farm input and extension delivery systems, agricultural markets and price and investment policies. Responsive input and extension systems, favorable market and price conditions and well planned investments in volumetric delivery systems and user organizations are vital for the performance of demand management options. Since these sectoral and macro economic policies affect the returns of farm level water saving initiatives, they determine the level of economic incentives and technical scope for the adoption and extension of demand management options. Just as the demand management options cannot operate effectively in the absence of supportive institutions, so cannot the institutions in the absence of these sectoral and macro policy measures. But, unfortunately, the way the demand management options are operating at present suggests that there is a clear disconnection between these options and their institutional and policy environment. Indeed this is the epicenter of all problems related to the poor performance of demand management options at present in India.

From an impact perspective, it is clear that the overall performance of a demand management strategy depends on the way it is designed and implemented. In this context, the strategy has to exploit well the functional and structural linkages among the options and also benefit from the synergies of the sectoral and macro-economic policies. For instance, the efficiency and equity benefits of water markets can be increased manifold when such markets operate with a volumetric water rights system and are supported by effective user organizations. There are also second round institutions that can emerge through the interface among water rights, water markets and local organizations. They relate not only to the conflict resolution roles of user and community based organizations, but also the water brokering and water delivery-related technical activities of other private agencies that are expected to thrive under mature institutional conditions. Likewise, water pricing policy can be more effective, not only in cost recovery but also in influencing water use, if it is combined with volumetric delivery, use based allocation structures and improved system performance and service quality. Similar results can be expected also with other options, when they are aligned with other options and supported well with relevant institutional and technical conditions.

The ultimate impact of demand management can be measured in terms of the nature and scale of water savings obtained within the irrigation sector. Even when water savings are substantial, the social impact can still be low, unless the saved water is properly reallocated either within agriculture or to other sectors. The economic and welfare impacts of such reallocation can be enhanced with additional but higher level institutional and policy aspects such as sectoral water markets and agricultural input and price policies. Thus, the final impact of demand management options within irrigation depends not only on the scale and gestation period of their sectoral impacts but also on the facilitative roles of macro-level institutional and policy aspects. Besides the issues of scale and gestation period, there is also another major issue related to the inevitability of vast uncertainties both in the full implementation and in the expected benefits of demand management options.

Towards a Demand Management Strategy

The overview of the current status and performance of the demand management options, particularly in the light of the analytics of the institutional ecology and impact of demand management presented in Figure 3, makes it clear what are the missing elements in the current policy in this respect. To be real, 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.

As we contrast the present status of demand management policy and the ideal demand management approach evident in Figure 3, we can identify several key points useful for the design and implementation of a well coordinated and more effective and demand management strategy. The functions linkages and the institutional character of the demand management options clearly underline the need for the strategy to treat these options as an interrelated configuration functioning within an institutional environment, characterized by the overall legal, policy and organizational factors. Since the changing economic, technological and resource conditions will tend to alter the political and institutional prospects for demand management, it is important to align the policy for it to benefit from the potential synergies from institutional environment as well. Given such an overall character and thrust of the strategy, the next step is to create technical conditions and strengthen the institutions—both formal and informal ones. The technical conditions include, for instance, the modernization of water delivery system, introduction of volumetric allocation and installation of water and energy meters. Similarly, the institutional conditions will include, among others, the public trust framework for the joint management of users, officials, state, and communities, the creation of a separate but an embedded structure of sectoral, regional, and user level water rights within the overall supply limits at the respective levels, conflict resolution mechanisms and incentives for collective action.

The institutional and policy requirements for demand management identified above are varied and wide ranging. Considering their extent and coverage, what is needed is nothing short of some fundamental changes in the existing institutional arrangements built around the supply-oriented paradigm of water governance. This fact clearly underlines the logical link between the implementation of the demand management strategy and the necessity of broad water sector reforms. Indeed, demand management forms the spearhead around which water sector reforms are to be planned and implemented. While the strategic and institutional logic of designing demand managed strategy in itself as part of a larger program of water sector reforms is clear, its implementation is certainly not easy and quick. But, neither the stupendous nature of the task nor the heavy economic and political costs involved in transacting such a change in the current context can be a source for alarm or complacency.

There are well-tested reform design and implementation principles that can assist policymakers in overcoming the technical, financial and political economy constraints and, thereby, effectively negotiating the demand management strategy and the institutional reforms. The reform design and implementation principles are simple yet powerful when used carefully within a well-planned program and time frame. These principles relate to the prioritization, sequencing and packaging of institutional and technical components based on impact, costs and feasibility considerations. Besides these design-related principles, there are also principles related to implementation, which cover strategic aspects such as timing, coverage and scale. As can be seen, these principles essentially try to exploit the basic features of institutions such as path dependency, functional linkages and institutional ecology, in addition to the inherent synergies and feedbacks that institutions receive from the larger physical, socioeconomic and political environment. The theoretical rationale and the institutional basis for these principles are explained by Saleth and Dinar (2004 and 2005), and how they have been applied in the practical context of reforms in selected countries and regions are discussed by Saleth and Dinar (2006). Here, we can discuss briefly how these design and implementation principles can be used for the planning and implementation of the demand management strategy and its underlying institutional reforms with minimum transaction costs and maximum effectiveness.

As can be seen in Figure 3, there are sequential linkages among the demand management options as well as among the institutions. For instance, we have seen user organizations remain the basis for the operation of water rights, water markets and water pricing (and also for energy regulations). Similarly, water rights are critical for the effective functioning of water markets and could also provide the incentives for the application of water saving technologies and improve the effectiveness of even energy regulations. Clearly, since the user organizations are the foundation for the emergence and operation of other institutions and do not involve much political opposition, they should receive top priority from the long-term perspective. But, in the short-term, the promotion of water saving technologies with the immediate and direct impact should receive priority. Since the establishment of a water rights system involves major legal, technical and political challenges, the focus here should be in creating some of the basic conditions for its emergence, such as the modernization of the water delivery systems and introduction of a volumetric allocation. Along with their roles in facilitating the eventual introduction of water rights system, these conditions will also have direct roles in improving the effectiveness of water pricing. Besides these ways of sequencing and prioritizing demand management options and their institutional components, there are also instances for packaging programs such as the system modernization to be combined with management transfer and improved supply reliability and service quality to be accompanied by higher water rates.

Since the design principles involving sequencing, prioritizing and packaging work on the sequential linkages and path dependent nature of institutions, they help to reduce the transaction costs of creating each of the subsequent institutions. Also, in view of the institutional ecology principle, when a critical set of institutions are put in place, other institutions or new roles for existing institutions can develop on their own. For instance, when volumetric allocation is introduced, it would be possible to negotiate limits for water withdrawals, which can eventually lead to the emergence of water quota systems. Similarly, when water rights are in place, real water markets centered on established water entitlements can emerge. With these emergent institutions, the roles of user organizations will also expand considerably to include new functions such as monitoring and enforcement, forum for negotiation and conflict resolution and brokering and facilitation of water markets. More importantly, all these institutional changes will tend to expand the application of demand management options and reinforce their effectiveness and impacts on water allocation and use. The main point to note here is the importance of identifying the key institutional and technical elements that will form the core components of reforms. This can be done with an understanding of the technical needs, operational linkages, financial costs and feasibility criteria, using a framework similar to the one in Figure 3.

While the design principles do affect implementation, the principles related to the timing, coverage and scale have a more strategic role. This is because they work on the synergies and feedbacks emerging from a larger environment within which the institutional structure is operating. These synergies and feedbacks can relate both to exogenous factors such as macro- economic crisis, energy shortage, droughts and floods, political change and the influence of external funding agencies as well as to endogenous factors such as water scarcity, status of water finance and the physical conditions of water infrastructure. Appropriately seizing these opportunities with proper timing is critical for the success and effectiveness of reform programs. Beside the anticipation and choice of the right time, the issue of time is also significant for another important but least appreciated reason. This relates to the selection of a suitable time frame for the execution of the demand management strategy and its institutional program. Since institutional change is only incremental and slow, a longer time frame involving, say, a 10-year period is to be considered. But, within this frame, time dated reform initiatives with clear prioritization and financial allocations can be planned for sequential implementation. The issue of scale and coverage is mainly determined by financial and technical considerations. Although there are economies of scale in undertaking demand management reforms, this policy cannot be ideal in all contexts. Ideally, it would be useful to prioritize regions and areas where different demand management options and initiatives can be introduced. For instance, while water pricing policy and energy regulations can cover a larger area, it is useful to target scarcity areas so that these options can have a significant impact.

Concluding Remarks

The urgent need and compelling rationale for demand management in the irrigation sector can hardly be overstated, especially given the binding limits for supply expansion and the persisting levels of water use inefficiency. But, unfortunately, the present status and performance of individual demand management options leave much to be desired. While there are cases of limited success in efficiency improvements, especially in the case of demand management options such as user organizations, water saving technologies and water markets, they are too few to have the magnitude of efficiency and water saving benefits that are needed at present. The overview of the performance of demand management options clearly shows how their extent and effectiveness are constrained by several institutional, technical and financial factors. But, a much more serious issue is the absence of a clearly articulated policy for water demand management both at the national and state levels, even though demand management has been very much in policy discourse for a long period. Even though there are policies for promoting user organizations, water saving technologies, water pricing or energy regulations, they are implemented mostly in an ad hoc or partial manner.

The formulation of a demand management policy cannot be considered as a ceremonial need because it is the policy statement that provides the basis for the much needed financial and political commitments for implementing demand management programs. Such a policy can also represent a formal shift from the outdated supply-oriented paradigm that has governed water development, allocation, use and management so far. Since 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, it is logical to divert, at least part of the investments that are currently going into new supply development. Although some of the demand management initiatives have a long gestation period, this may not be as high as that which is associated with new water development projects, especially considering the delay caused by environmental problems and inter-state water conflicts. Besides the direct returns from demand management investments, there are also long-term effects since demand management options and their institutions can enhance the efficiency and sustainability benefits not only in the irrigation sector but also in the water economy as a whole.

An analytical framework similar to the one presented in Figure 3 can help to understand the analytics and dynamics of impacts of a demand management strategy. As we have shown, this framework provides considerable insights on the operational linkages among the options and functional linkages in the underlying institutions. A demand management strategy delineated in the lights of these linkages, formulated within a more realistic time frame and implemented with the design and implementation principles can be more practical and effective in achieving the efficiency and water saving goals within the irrigation sector. Broadly, this strategy involves a sequencing, prioritization and packaging of demand management tools and also their institutions. Similarly, the principles involving the issues of timing, scale and coverage can also be used for planning the implementation of the demand management strategy. While implementing the strategy, areas and regions can also be prioritized in terms of their relative feasibility and also the available financial resources for investment on demand management. The central idea is to achieve immediate efficiency benefits as much as possible while gradually paving the way for institutional and technical foundation for similar benefits in the long term. The approach of gradual, sequential and consistent implementation of demand management strategy within a well-planned time frame is likely to neutralize possible resistance, minimize transaction costs and maximize long-term impacts.

While India has to go a long way in formulating and implementing a demand management strategy as discussed here, one cannot be that pessimistic given the recent trends of institutional changes observed in India (see Saleth 2004). Although the observed changes are slow, partial and inadequate, their direction and thrust are on the desired lines. Several states have raised the water rates and there has also been a gradual and steady improvement in cost recovery. The issues of volumetric allocation and water entitlements have also been receiving increasing public and policy attention in recent years. In Maharashtra, the policy of volumetric allocation on a bulk basis has been introduced. Many policies that were once considered as anathema, such as water markets, privatization and de-bureaucratization are already a reality in India's water sector. There are also constant pressures from factors both endogenous and exogenous to the water sector (e.g., the physical limits for supply augmentation, food security compulsions, water supply challenges and energy issues) for further changes in water policies and institutions. Since the path dependency properties of institutions will ensure that it is costlier to return than to status quo than to continue to proceed with the reform path, the institutional environment is going to favor the formulation and implementation of the demand management strategy sooner than later. Obviously, there is a clear policy demand for more research-based studies for exploring still further the design and implementation properties of irrigation demand management strategy.

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Water Pricing as a Demand Management Option: Potentials, Problems and Prospects

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Introduction

Agriculture is the single largest consumer of water. Agriculture accounts for more than 70 % of the total water demand globally and its share is as high as 90 % in developing countries like India. In this context, even a marginal saving in irrigation water use can release substantial amounts of water for agricultural expansion as well as for meeting the needs of other sectors like domestic water demand. Unfortunately, irrigation water is one of the most ill-managed resources, which creates a severe scarcity of water, both for drinking and irrigation, as well as environmental problems such as waterlogging in endowed regions and desertification in fragile regions. Of late, there has been great emphasis on the judicious management of water at the policy level. Pricing and institutional (user participation) approaches are suggested to overcome the strident problems. So far, even these policy changes have been limited to surface irrigation. An important segment of water resources (groundwater), which covers most of the rain-fed regions, is more or less neglected. In the absence of any effective policy measures, groundwater regions are plagued with water scarcity, inequitable distribution of water and environmental degradation. The situation seems to have aggravated during recent years, especially in the arid and semi-arid regions across the world.

For, hitherto policymaking towards water, in general, and irrigation management, in particular, is based on the philosophy of supply side management to the neglect of demand side aspects. Demand management involves increased water use efficiency, recycling, promotion of water saving technologies etc. Though supply is a major constraint in many cases, the major problem that leads to water shortages is the wastages through distributional and transmission losses, overexploitation and inequity in the case of groundwater, practices of inefficient use etc. As the wastages of water workout to be very expensive, the investments in leak detection and leak proofing may prove to be more productive than the investments in supply expansion. This, coupled with an efficient distribution network and sustainable extraction of groundwater, would not only help increase the supplies but also lead to a more equitable distribution. Even the investment required for improving the supply network is substantial and, hence, resource (both financial and natural) availability is the major constraint in this regard. In this context, demand management becomes critical for sustainable management of the resource.

In spite of the rapidly increasing value for water resources, irrigation water demand functions are totally ignored in the major policy formulations. In most of the cases the projections of irrigation water demand are in terms of crop water requirements. Therefore, the effect of price and other variables on the use of irrigation is not properly evaluated. The most important application of demand functions is in arriving at alternative projections of water use by systematically varying the factors that influence the demand for water. Moreover, the demand function provides a basis for evaluating whether specific investments in flow regulation and inter-basin transfers are justified (Thampson and Young 1973). Lacking in scientific estimation of demand functions, the estimated projections so far are based on cropping pattern and acreage projections along with their normative requirements. However, the literature on water demand estimates for other countries, mostly developed, indicate that the quantity of water demanded has been found to be significantly affected by the price of water and other socioeconomic factors in a number of studies (for a review see Reddy 1996).

Although factors influencing irrigation demand can be categorized under (i) economic, (ii) technological and (iii) environmental, the price of water falling under the economic category has received greater attention as a major irrigation demand management tool. The discussion on price as a demand management variable has been highlighted in a number of studies (see for recent reviews, Molle nd; Dudu and Chumi 2008; Johansson 2005; Tsur 2005). In fact, an unsettled controversy is still going on regarding the specification of price variables and what should comprise the water price. Whether marginal price specification is appropriate or average price specification is appropriate for estimating the water demand function is one of the key issues in this debate. Similarly, the inclusion of implementation costs is another issue. Though the arguments in support of and against these issues are very interesting, we restrain ourselves from entering into this debate and concentrate on the price as a demand management variable.

This paper attempts to explore the intricate issues that prompt the dynamics of water pricing in irrigation demand management. The focus of the paper is on the irrigation sector, both surface and groundwater, and mainly draws from existing literature and studies. It is argued that water is increasingly becoming a political good rather than an economic or a social good. Water pricing has become a political live wire mainly due to the asymmetry in information across the stakeholders. Information asymmetries are often created by the self-seeking interest groups like the water departments / bureaucrats or contractors. This is despite the fact that water bureaucracy is often involved in the reform process. The absence of a comprehensive water policy that clarifies the rights and entitlements of water resources at the central or federal levels appears to be the main bottleneck in the smooth implementation of the reform initiatives. The following section reviews irrigation water pricing policies. Section three discusses the role of pricing in irrigation demand management. Some evidence pertaining to the impact of pricing on irrigation demand is presented in section four while the conditions irrigation water pricing are discussed in section five. And the last section makes some concluding remarks.

Water Pricing Policies: A Review

There is now consensus at various levels that water is scarce and needs to be treated as an economic good. Though pricing is considered to be crucial for efficient allocation of water, allocation of water as a pure economic good is more complicated than other goods and services. This is mainly due to its public good nature and externalities associated with it. The critical linkages between water and poverty, food security brings the equity dimension in to its allocation. This has led to bringing irrigation water largely under public administration across the countries. The various problems viz., inefficiency, poor planning and enforcement, etc., associated with public administration has often ended up treating water as a social good rather than an economic good. Treating water as a social good has led to a financial burden on the state and resulted in unsustainability of the supply systems in the long run.

Financial burden of the supply agencies is reflected in the poor health of irrigation infrastructure resulting in leakages, which are estimated to be in the range of 60 % in most of the areas. A substantial portion of these losses is technical. Any improvement in the system could result in substantial gains in terms of total water supplies. And, even marginal savings (say 5-10 %) in irrigation water could release enough water to meet the needs of other sectors. Financial compulsions force price reforms and, often reforms are initiated to avert extreme crisis situation ('crisis hypothesis'). Pricing decisions are always considered as politically infeasible and, hence, avoided with the excuses of lack of willingness and ability to pay. A number of studies have shown how wrong these perceptions are. In fact, it is argued that it is 'willingness to charge' rather than 'willingness to pay' that is blocking price reforms (Reddy 1996; DFID 1999). People are willing to pay higher tariffs irrespective of resource endowments of the region (scarcity or abundant water resources).

Countries follow different pricing mechanisms for irrigation water though most of them do not adopt any economic principle strictly. For, the first best solutions are often complicated as far as implementation is concerned (Johansson 2005). Pricing of water has five important objectives (Boland and Whittington 2000). They are: 1) revenue sufficiency; 2) economic efficiency; 3) equity and fairness; 4) income redistribution; and, 5) resource conservation. Designing of price policies and tariff structures should take the following considerations into account in order to make the reforms feasible. These include: public acceptability, political acceptability, simplicity and transparency, net revenue stability and ease of implementation (Bolland and Whittington 2000 — p. 222). However, some of these considerations like political and public acceptability may clash with the basic objectives of pricing. For instance, for achieving economically efficient water allocation (that gives highest return to the given water resource), the price of water should be equal to its marginal cost of supply plus its scarcity value. Often, this results in the setting high tariff structures, which are acceptable neither to the public nor to the politicians.

The prevailing pricing mechanisms across nations can be grouped under three categories viz., a) volumetric pricing; b) non-volumetric pricing; and c) market based pricing (Johansson 2000). In volumetric pricing water use is measured and charged. In the case of non-volumetric pricing a number of variants are used in irrigation water (Table 1). These include flat rates, per acre rates, crop-wise rates etc. Market-based pricing follows the price determination based on demand and supply of water in a market environment. Markets can be formal or informal. In the Indian context most water markets are informal (Shah 1993; Saleth 1996). On the other hand, formal water markets require tradable property rights (Saleth 1998) in water that are conspicuous by their absence in most other countries. Water rights also help reduce poverty, improve productivity and resource conservation (Burns and Meinzen-Dick 2005). Water markets may not exist or function in scarcity conditions, as the available water is not enough to meet the needs of well owners. Water markets are also observed to shrink in the context of power regulation for groundwater extraction (Shah and Verma 2008). More importantly, water markets may not be sensitive to resource degradation and equity concerns.

Table 1. Existing irrigation water pricing mechanisms.

Pricing Scheme	Potential Efficiency	Time Horizon of Efficiency	Equity	Implementation Costs	Qualities
Single rate volumetric	First-best	Short-run	Fairness	Complex	Requires monitoring
Tiered	First-best	Short-run	Can be targeted	Complex	Requires monitoring
Two-part	First-best	Long-run	Can be targeted	Complex	Requires monitoring
Output/input	Second-best	Short-run	Can be targeted	Less complex	Requires monitoring
Per area/per crop	Second-best	Short / long run	Can be targeted	Easy	Requires data
Quotas	First-best (if tradable)	Short-run	Can be targeted but difficult.	Easy	Requires information
Water Markets	First-best	Short / long run	Difficult	Complex, especially in scarcity conditions	Requires developed water institutions and infrastructure
Private Management.	Second-best	Short-run	Difficult	Nil for government	Resource externalities

Source: Adopted with modification from Johansson (2005)

Theoretically, marginal cost pricing is the most efficient and considered the first and best option. Whether marginal price specification is appropriate or average price specification is appropriate for estimating the water demand function is being debated empirically. Though the arguments in support of and against these variables are very interesting, we restrain ourselves from entering into this debate here. There are studies using average price alone and others using only marginal price (for a theoretical exposition on long run marginal cost pricing see Munasinghe 1990), while some used both in order to test the specification bias of pricing in the water demand (for a detailed review see Reddy 1996). In fact, increasing block rate tariffs (IBT) are considered to be equivalent to marginal cost pricing though there is no agreement in this regard (for detailed exposition on this see Boland and Whittington 2000). Boland and Whittington (2000) argue that IBTs introduce inefficiency, inequity, complexity, lack of transparency, instability and forecasting difficulties. They suggest uniform pricing with rebate (UPR), which is capable of achieving the benefits of IBT without adopting a block tariff structure. And the popularity of IBT is attributed to the water professional's ignorance or neglect of the adverse effects of IBT on poor households (Boland and Whittington 2000 — p.234).

As far as irrigation water is concerned, there are wide variations in water rate structures across countries and the rate per unit volume of water consumed varies greatly for crops. In some states irrigation charges vary from project to project depending on the mode of irrigation.

The rates vary widely for the same crop in the same state depending on season, type of system etc. There are no uniform set principles in fixing the water rates, a multiplicity of principles are followed such as recovery of cost of water, capacity of irrigators to pay based on gross earning or net benefit of irrigation, water requirement of crops, sources of water supply and its assurance, classification of land linked with land revenue system and combination of various elements. In some states water cess, betterment levy etc., are also levied. There is no consistency or uniformity regarding how these factors are used in arriving at water rates.

A number of irrigation water pricing mechanisms have been adopted across the countries (Table 2). There are also variations within each country like India where different mechanisms are adopted across geographic locations. Water prices are charged according to local conditions and costs of production. In some countries like Jordan and Turkey, groundwater supplies are priced, while in others like India, groundwater is left to private management. The variations in irrigation water rates are quite substantial across the countries. Despite the adoption of volumetric and other theoretically efficient pricing mechanisms water is under priced in most of the countries (Tsur and Dinar 1997). As a result water prices neither reflect its scarcity value nor allocated efficiently.

Table 2. Pricing mechanisms adopted and irrigation water charges in selected countries.

Country	Pricing Mechanism	Water Price
USA (California)	Volumetric	US$ 5 on average per acre foot (Range: US$2–US$200 per acre foot); and US$19.32 per acre foot in some cases
Jordan	Volumetric	US$0.04 per cubic meter for the 1.5 meters of irrigation depth and US$0.08 for any additional amounts
Morocco	Tiered volumetric	US$0.019 per cubic meter of water
Spain	Compensatory tariff	US$0.128 per cubic meter of water
Turkey	Area/crop-based	US$12 and US$33 in the case of wheat for gravity and pump irrigation, respectively US$34 and US$80 in the case of cotton for gravity and pump irrigation
Chile	Tradable quotas	Range: US$993–US$2,978 per share of 1 liter per second delivery
India	Area /crop-based; Flat rates, betterment levy etc.	Varies across states. Ranges from US$0 in Punjab to US$100 in Maharastra per hectare of flow irrigation.

Source: Compiled from Tsur and Dinar (1997) and CWC (2004)

Irrigation water prices vary across states in India and prices are below working expenses in all the cases (Table 3). While Punjab has abolished water rates in 1997, water rates were last revised decades back in some states like Tamil Nadu (1962) and Kerala (1974). Similarly, no water rate is levied for agricultural purposes in most of the north-eastern states except for Manipur. In Orissa, a flat basic compulsory water rate is charged for the staple crop of paddy under the command area of major and medium projects irrespective of water used or not, while crop-wise rates are charged in the case of other crops. In West Bengal, water from minor systems is supplied only on pre-payment basis. In Jammu and Kashmir, Haryana, West Bengal and Kerala variations in water rates appear to be marginal. In most of the southern states of Andhra Pradesh (AP), Tamil Nadu (TN), Karnataka and Pandicherry water rates are clubbed with land revenue and land is assessed as wet and dry. The difference between the dry and wet assessment is taken as water rate. In most of the states public water supplies for irrigation are levied on the basis of area irrigated (in the case of surface irrigation), while water charges are levied on the basis of the number of hours of watering or volume of water (in the case of public tubewell irrigation). The rates for perennial and defussal crops are often higher than those of other crops (www.mowr.gov.in/problems/pricing.htm).

Table 3. Working expenses and range of water rates per hectare of potentially utilized area of irrigation and multipurpose river valley projects in India.

States	WE (Rs/ha) in 1999-2000	Rates for Irrigation Purposes				Status as on
		Flow Irrigation		Lift Irrigation		
		Rate (Rs/ha)	Date since applicable	Rate (Rs/ha)	Date since applicable	
AP	1,556	148.20 – 1,235.00	1996	#	NA	2003
Bihar	375	74.10 – 370 50	2001	#	NA	2003
Gujarat	4,768	70.00 – 2,750.00	2001	23.33 – 1,375.00**	2001	2001
Haryana	683	86.45 – 197.60	2000	43.23 – 98.80	2000	2003
J & K	319	19.76 – 49.40	2000	49.40 - 716.30	2000	2001
Karnataka	2,014	37.05 – 988.45	2000	#	NA	2002
Kerala	442	37.00 – 99.00	1974	17.00 - 148.50	1974	2002
M P	516	123.50 - 741.00	1999	123.50 – 741.00	1999	2001
Maharashtra	3,050	180.00 – 4,763.00**	2001*	30.00 - 495.00**	2001*	2002
Orissa	256	28.00 – 930.00	2002	129.21 – 4,990.63	1997	1998
Punjab	217	Abolished	1997	Abolished	1997	2002
Rajasthan	888	29.64 – 607.62	1999	74.10 – 1,215.24	1999	2001
Tamil Nadu	846	2.77 - 61.78	1962	#	NA	2002
U P	484	30.00 – 474.00	1995	15.00 - 237.00	1995	2002
W B	470	37.05 – 123.50	1977	#	#	2003

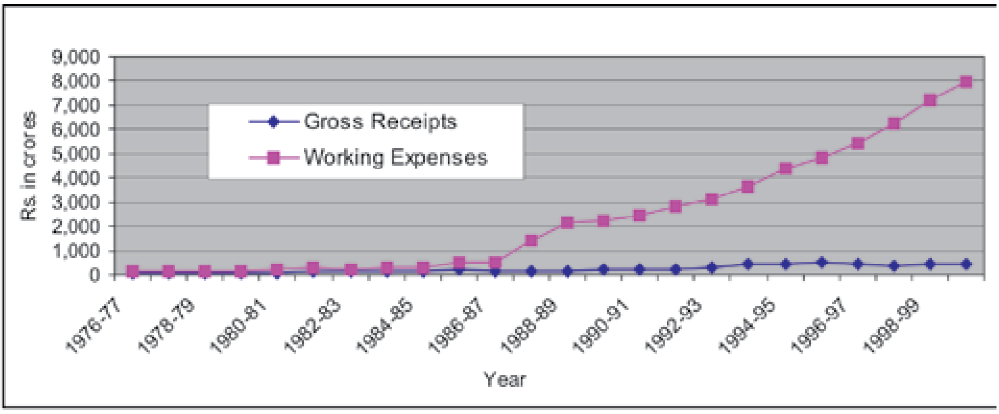
Source: CWC (2004)

Notes: WE= Working Expenses; # - No separate rate for lift was reported; * - Subject to increase at 15-20 % per annum. AP= Andhra Pradesh; J&K= Jammu and Kashmir; MP= Madhya Pradesh; UP= Uttar Pradesh; WB= West Bengal

** - Subject to increase at 15 % per annum

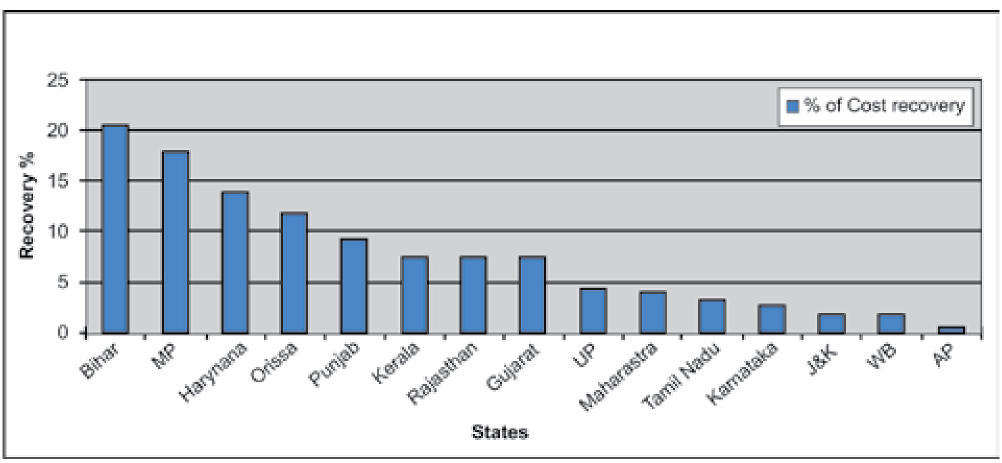
A cursory look at the economic performance of the water sector across the states in India reveals the poor status of the sector. All the states are overburdened with the financial gap (measured as the difference between expenditure on and recovery from the sector) and resorting to heavy borrowings from private sector and multilateral agencies. None of the states are covering the operation and maintenance (O&M) cost, which in itself is an efficiency indicator in most developing countries. Scarcity or incentive gap is the difference between the scarcity value of water and the actual value of water.[1] In the case of irrigation, the price gap is substantial and widening in all the states. (Figures 1 and 2).[2] Operation and maintenance cost recovery in irrigation is less than 5 % in the majority of the states (Figure 2).

Figure 1. Gross receipts and working expenses of irrigation and multipurpose river valley project in India (1976-1977; 1999-2000).



Source: CWC (2004)

Figure 2. Percentage of cost recovery of O&M in irrigation and multipurpose river valley projects in selected states (1999-2000).



Source: CWC (2004)

[1] For an excellent treatment of water sector assessment see Saleth and Dinar 2004.

[2] The sudden increase in the gap between gross receipts and working expenses after 1986-87 is due to the change in the O & M costing methodology (Narayanamoorthy and Deshpande 2005).

Water Pricing and Demand Management

Theoretically demand for any normal good is inversely related with its price, and positively related with individual income, ceteris paribus. All the studies testing these two hypotheses have revealed ample evidence supporting the theoretical propositions, though the magnitude of their estimates varies among the studies (Dudu and Chumi 2008). Pricing of water on cost basis is essential because it not only helps in resource (financial) generation but also results in the efficient usage of water and discourages wastage of water. It is often observed that the decision-makers, in the event of resource constraints, opt for permitting shortages and allocating water by non-price means of supply regulations when the existing capacities are on the verge of full utilization. Though this has become a norm in most of the developing countries, supply regulation is considered to be an unsatisfactory permanent policy. Often pricing policies are thwarted with the excuse that farmers are unwilling to pay for irrigation water. Contrary to this general belief users are willing to pay substantially higher prices for improved water supplies. On the other hand, users tend to pay more than the actual cost of water in the event of supply regulation under a flat rate pricing mechanism (Reddy 1998). Therefore, willingness to pay is not a bottleneck for charging higher prices. In fact, it is the willingness to charge, which is the main obstacle.

While pricing could be an effective tool of demand management, we do not have many instances of getting the prices right to the level that results in efficient allocation of water, as the price does not reflect the scarcity value of water and also does not include the implementation costs in the case of volumetric pricing. Implementation costs could be very substantial in the case of volumetric pricing where metering and monitoring costs are quite high. Though volumetric pricing is implemented in the USA and Australia, the prices do not include these transaction costs (Molle nd). In other countries like Jordan where volumetric pricing mechanism is adopted, irrigation water is under priced by the authorities for the reasons of social welfare and equity (Tsur and Dinar 1997). Often one finds that the impact of volumetric prices on irrigation water demand operates only at the margin, as they do not reflect the real prices. The threshold level prices are quite high when scarcity values and implementation costs are included, making the public administration weary of imposing high prices. Such high prices could adversely affect the social welfare function of water pricing due to its social acceptance and equity concerns.

Efficient allocation takes place as long as prices affect demand. Most of the pricing mechanisms appear to fulfill this condition (Tsur and Dinar 1997). Volumetric pricing based on marginal cost-pricing achieves the first and best efficiency in the absence of implementation costs and scarcity value of water. In the event of under reflection of the actual value of water, volumetric or marginal cost-pricing of irrigation water does not prove to be efficient when compared to other pricing mechanisms like area-based or crop-based or quota systems (Tsur and Dinar 1997). Public administrators opt for quota or regulatory mechanisms, which are easy to adopt, to address scarcity issues. Pricing is never used to regulate irrigation water demand. While setting the right prices is very difficult, implementing the price policy is equally challenging. Pricing cannot operate in a vacuum. Proper implementation of pricing policies requires institutional arrangements for enforcing the price mechanisms.

However, under the existing institutional arrangements, pricing on a cost basis may not lead to sustainability of the water systems in terms of efficient allocation of water or financial viability. In the given institutional set up in the Indian irrigation systems, for instance, recovery rates are very low and declining. Percentage of recovery at the all India level (ratio gross receipts and working expenses) has declined from 92.9 % in 1976-1977 to 5.7 % in 1999-2000. When the interest on capital outlay is included, the recovery rates have declined from 36.4 % in 1976-1977 to 5.7 % 1999-2000 (CWC 2004). The story is no different even at the state level, as the average recovery is less than 5 % in most of the states. In addition, the gap between demand and actual collection of irrigation charges is quite substantial in a number of states. Except in the case of Punjab and Haryana, collections are less than the demand in all the states – ranging from 34 % in West Bengal to 92 % in Uttar Pradesh (Deshpande and Narayanmoorthy 2006). Given the political and institutional conditions it is unlikely that higher water rates would lead to better recovery. This point has been proved in the case of Andhra Pradesh, where increased water rates are accompanied by declining recovery rates despite the advent of institutional changes at all levels (Reddy 2003). Absence of devolution of powers to water user associations (WUAs), in terms of assessment and fee collection etc., are observed to be the main reasons for this trend. Given this background, adoption of first best solutions like volumetric pricing based on marginal cost calculations appears to be a far cry.

Groundwater management is the most challenging part of the water-pricing reforms. Hitherto, groundwater policies are in the lines of encouraging overexploitation. These policies are in the nature of providing incentives for groundwater development such as subsidized credit, and for groundwater exploitation such as subsidized power or diesel / kerosene. While these policies helped in promoting groundwater development in the regions where groundwater development was below potential, they have led to an overexploitation of the resource in fragile resource regions. The first victims in this process are the poor (small and marginal farmers). While small and marginal farmers own mainly open wells, medium and large farmers dominate the ownership of bore wells. As a result of degradation majority of small and marginal farmers have lost or are loosing access to water, as the water tables go down. Even when they own bore wells they can’t compete with medium and large farmers in deepening their wells (Reddy 2005). As a result, these farmers are denied of their genuine share in the common pool resources. It is observed that groundwater markets will take care of the equity problems to a large extent (Shah 1993). But, evolution of water markets is possible only in the regions where groundwater is available in sufficient quantities. Markets do not evolve when there is not enough water to share or sell (Reddy 1999). This is true in many regions where groundwater markets do not operate, as the available water is not enough to irrigate the well owner’s land. Pricing of groundwater has a greater potential for achieving equity and resource conservation objectives. Being the single largest source of irrigation and domestic water supplies, reforms in groundwater governance assumes importance and urgency.

In general, communities perceive that the improved availability of water for irrigation significantly enhances their livelihood security. The poverty goal necessitates a focus on the specific needs of the poor, especially women and landless and land-scarce families. The latter group often includes rain-fed farmers. The issue of how to secure the rights and entitlements of poor people to access water resources needs to be resolved. Unfortunately, there are no policies so far that address the equity and management aspects of water, in general, and groundwater, in particular. Though there are regulations on groundwater exploitation they are inadequate and ineffective. Even the so-called water reforms are in the lines of regulation rather than designing innovative policies that would integrate market and institutional dimensions of resource management. The water sector reforms in some of the states have failed to address the real issues and take the hard decisions. These reforms are often limited to half-baked institutional reforms, where new institutional structures were created without devolving powers. As a result, pricing of water has always taken a back seat in the reform agenda.

Water pricing has become hackneyed and ritual. Everybody supports but nobody implements. While some progress has been made in the case of domestic (urban) water, very little is being done in the case of irrigation (especially canal). Even in the reforming states like Andhra Pradesh (India) very little is done in this direction. Artificially kept low water prices fail to provide any incentive to improve the systems, technically or institutionally, as the economics of transaction costs go against it. Present prices do not even cover the O & M costs in many cases. On the other hand, some argue that pricing based on O & M may amount to penalizing the farmers for the inefficiencies of the department i.e., escalation of working expenses (Deshpande and Narayanamoorthy 2001). The second irrigation commission has suggested that the water rate should relate to the benefits accruing to the farmers rather than the costs incurred by the department (GoI 1972). In any case, the main bottleneck is the lack of political will to take the hard decisions though the constraints for taking hard political decisions may ease when water rates are fixed on the basis of returns.

Often pricing policies are thwarted with the excuse that farmers are unwilling to pay for irrigation water. Contrary to this general belief, farmers are willing to pay substantially higher prices for improved water supplies (Reddy 1998). Hence, willingness to pay is not a bottleneck for charging higher prices. Therefore, rational pricing of water on the basis of benefits accruing to the farmers is essential because it not only helps in resource generation but also enables the efficient usage of water while discouraging wastage. For example, paying for water on a cost basis could be as low as the O & M costs, which are beyond the control of the farmers. And these costs are always increasing irrespective of the returns to farming or efficient delivery of water, due to salary and other components (Deshpande and Narayanamoorthy 2001). It is often observed that the decision-makers, in the event of resource constraints, opt for permitting shortages and allocating water by non-price means of supply regulations when the existing capacities are on the verge of full utilization. Though this has become a norm in most of the developing countries, supply regulation is considered to be an unsatisfactory permanent policy.

While pricing can result in an efficient allocation of irrigation water perfectly at the theoretical level, impact of prices on irrigation in the practical world operates only at the margin. This is mainly due to the distortions in pricing coupled with lack of institutional mechanisms to support the high threshold levels of pricing. While the high prices that reflect the scarcity value of water and implementation costs could prove to be unviable and iniquitous, they may also adversely affect the social welfare objective. Inter- and intra-regional inequities in access to water have made water a political good rather than an economic good. The approach is to meet the demand for water at any cost. This does not make economic sense but makes enormous political sense. In a number of cases, where irrigation development is based on political consideration, the cost of irrigation provision is too high to make agriculture viable. Implementation of such high prices is neither politically feasible nor helpful in ensuring food security. For, at such high prices water has to be reallocated to more productive sectors, e.g., industry. One way out is to improve water productivities in agriculture.

Similarly, groundwater pricing does not reflect its scarcity value. Often groundwater use is regulated through power pricing. While, cost-based power tariff is useful in checking overexploitation, adding a scarcity of water rent to the tariff would be more appropriate. A pre-condition for this is to minimize the risk and uncertainties in groundwater and power availability. Large-scale public investments towards replenishing mechanisms like renovating traditional tanks, rainwater harvesting structures, etc., are necessary. These investments could be cross-subsidized from the revenues generated in the canal command areas. More importantly, institutional arrangements such as making groundwater a real common pool resource and exploiting it on a community basis are critical for equitable distribution and sustenance of the resource.

Technologies are often given little importance in the demand side management of irrigation water. This is mainly because of the reason that the area covered under water saving technologies is negligible. One reason for this is the distorted water tariff structure (Repetto 1986). Of late, more and more area is being brought under these technologies in order to tackle the scarcity conditions. The most important among the irrigation water saving technologies are sprinkler and drip irrigation techniques, also known as micro-irrigation systems. Of late, these technologies are spreading to a diversity of crops instead of being limited to horticultural crops as was the case in the past. In Gujarat, farmers use micro-irrigation systems on various crops such as wheat, bajra, maize, groundnut, cotton, castor and vegetables in addition to horticultural crops (Kumar et al. 2004).And in Maharastra, drip systems are used even on water-intensive crops e.g., sugarcane (Narayanamoorthy 2006).

It is estimated that micro-irrigation systems save 48-67 % in terms of water, 44-67 % in terms of energy and 29-60 % in terms of labor. Farmers have also reported a low incidence of pest attack, reduced weed growth, improvement in soil quality and increased yields. As a result net incomes have increased substantially. Farmers are interested in investing on their own without any subsidy (Kumar et. al. 2004). Cost-benefit analysis of drip irrigation in Maharastra revealed high economic viability for banana, grapes and sugarcane (Narayanamoorthy 1997 and 2006). The economic viability seems to hold good even in the case of smallholdings of just one hectare (Narayanmoorthy 2006). Despite the high economic viability the spread of these technologies is limited due to high initial cost and lack of awareness. The rationale of subsidies for these technologies is valid not only for spreading of these technologies but also due to the reason that social returns are far in excess of private returns accruing to drip investors (Dhawan 2000). Besides, there is a need for strong extension support for better adoption rates (Narayanamoorthy 2006).

Provision and clarity in water rights is expected to result in efficient use of water. Water rights are seen from many perspectives viz., riparian, federalist, formal law, civil society, stakeholder, human rights, environment and economic (Iyer 2003). The best way to deal with water rights would be the integration of all these perspectives. However, converting this theory to practice is going to be rather difficult. For instance, right to use of water is tied to the ownership of land along rivers and groundwater aquifers. As a result common pool resources are used as private property. This is the root cause of all the problems related to equity and sustainability. Furthermore, rights on water use are not clearly defined thus allowing for indiscriminate exploitation. The existing riparian rights while ensuring the natural right of people on water thwart the main objective of equity and sustainability. On the other hand, water rights from an economic perspective would adversely affect the interests of those whose ability to pay is minimal. There is a need to find a middle path that would ensure equity and sustainability of water resources. The recent water policy of South Africa is an interesting case in point.

South Africa (SA) has effectively abolished the riparian system, as it was racially biased (GoSA 1998). In SA the state has become the custodian of all the water bodies in the country. No ownership of water is allowed. Water rights are provided to individuals / firms on a 5-year contract basis (to a maximum of 40 years depending on the use). The rights are allocated by the State. However, water for basic needs and environmental sustainability is given as a right. All other uses will be subject to a system of allocation that promotes optimality for achieving equitable and sustainable economic and social development. This would have an important bearing on the equity, sustainability and efficient use of water, as water allocations keep altering users and uses across locations depending on the scarcity conditions.

On the whole, pricing has the potential to achieve efficient allocation of irrigation water, but its effectiveness in the real world depends on a number of other factors. These include: a) proper valuation of water resources (i.e., use value + scarcity value + existence value); b) institutional mechanisms like water user associations to support implementations of pricing policies,; c) technologies to enhance water productivity as well as viability of agriculture and; d) property rights in water so that water is tradable and reallocated for other productive uses.

Water Management through Pricing: Some Evidence

Volumetric pricing is expected to be effective in conserving water and improving water use efficiency. However, volumetric pricing is followed in very few cases (Table 4). This is mainly due to the high costs associated with fixing water meters and monitoring them. Even in the few cases where volumetric pricing is adopted, water is often under priced with little impact on water demand. In other words, as long as volumetric pricing is not equated with marginal cost pricing, pricing is not going to be an effective tool of demand management. This is mainly due to two reasons: (i) that marginal cost based pricing is often found to be politically unacceptable; and (ii) it may also impose undue burden on the marginal sections of the farming community.

Table 4. Impact of pricing on water demand.

Country	Price Mechanism	Impacts on Water Demand
Israel	Block rate tariff	7 % decline in average water use and 1 % reduction in output
Israel	Tiered system of pricing	Regulates water demand at the margin
India	Price induced water scarcity	Farmers are responsive but water allocation is not efficient
Spain	Arbitrary pricing	Differential impacts due to regional, structural and institutional conditions
Sri Lanka	Arbitrary pricing	Not effective
Turkey	O&M cost recovery pricing	No improvement
Mexico	O&M cost recovery with tradable bulk water rights to WUAs	No improvement at the farmer level. But overall improvement in water use efficiency due internal trading
China	Volumetric pricing at the WUA level	No incentive at the farmer level as the price at the farm level is based on the area
France	Full financial cost recovery	Managers only discourage water use beyond a subscribed amount
Peru	Volumetric pricing	Not used to reduce water demand
USA	Volumetric pricing	Quotas were more effective in times of scarcity

Source: Compiled from Molle (nd.); Dudu and Chumi (2008) and Johansson (2005)

In the absence of volumetric pricing water pricing on the basis of acreage is found to be the easiest way of implementation administratively. As far as the impact on water use and efficiency are concerned, evidence across the globe indicates that quotas are more effective in regulating demand when compared to other pricing mechanisms. Similarly, supply regulation is observed to be more effective in controlling demand. Supply regulation though found to be inefficient in the long run, it happens to be the most preferred option among the administrators. Quotas or supply regulation arises due to resource shortages. Less water is distributed equally among all the farmers in the years of water scarcity. In the case of groundwater it is often the shortage of electricity that prompts supply restrictions and reduced exploitation of water. The mixing of power pricing with supply regulation is found to be effective in groundwater management. During the drought years between 2001 and 2004 the Krishna Delta farmers in Andhra Pradesh were provided with 40 % less supply of water when compared to normal years. Farmers not only managed with low supplies of water but also reported 20 % higher yields. This reveals the extent of water wastage and inefficiencies during normal years. Hence, quotas lead by shortages are more preferred to volumetric or marginal cost based pricing.

Irrigation reforms in Andhra Pradesh, India are among the few success stories. Water sector reforms in Andhra Pradesh were also aimed at financial sustainability of irrigation systems through price reforms. Though water rates were increased initially by three times, they are still short of O&M expenditure. Though user contribution of 15 % is inherent / included in the Participatory Irrigation Management (PIM) Act, there is no evidence of any contribution from farmers. In fact, there are no efforts to collect this contribution. On the contrary, it is indicated that often only 60 % of the irrigated area is reported for the collection of water charges, and the officials take 20 % of the charges on the area as their share. Effectively, the farmer will be paying only for 80 % of the area irrigated by him. This is a mutually beneficial arrangement. These arrangements are widespread in the regions where WUAs are not strong. In fact, it was observed that in some cases the irrigation department has not yet revealed the details of the command area under each WUA. There is a widespread feeling that the department is not keen in strengthening the WUAs, as their continuation will go against the department's interests. In some regions WUAs have turned into mere political entities. Moreover, in the majority of cases contractors have turned into WUA presidents. As a result, WUAs have become money-making ventures (Reddy 2003).

Though some benefits in terms of increased area under irrigation in canal systems and improved quality of irrigation are evident, the sustainability of these benefits is rather uncertain in the absence of efficient institutional structures. While it appears that an opportunity to build stronger and sustainable irrigation institutions has been floundered, the opportunity is not totally lost, as the WUAs are still in place. It is observed that formal institutions are too rigid and rule-bound. Equity in the management and distribution of water is not addressed. No proper incentive (positive and negative) structures were designed and placed to support rule compliance (Reddy and Reddy 2005).

In Rajasthan, though more than 800 WUAs were constituted and elections were conducted almost 5 years back, the progress is very tardy. Water rates were revised only once during 1999. So far no devolution of powers has taken place, though the irrigation department appears to be keen in devolving the powers. These associations should be made autonomous, under the guidance of the irrigation department, and should be entrusted with rights and responsibilities of water distribution, O&M, fixing of water prices, collection, etc. Unless

WUAs are fully evolved in these aspects they remain ornamental. Conducting of regular elections is one way of keeping them alive. But, they should not be made dependent on external funds (Reddy 2006).

The Government of Orissa aims to handover the irrigation projects to 'Pani Panchayats' in a phased manner under the scheme started in 2002. So far 801 thousand hectares of irrigated command areas have been handed over to 13, 284 Pani Panchayats registered under the Registration of Societies Act. The government claims that the PIM program allows farmers to take decisions regarding distribution and management of water resources. In reality, however, the program has created a divide between the large, and small farmers and the landless. The landless are not even members of the Pani Panchayat. The rotation of canal water use resulted in poor farmers being able to harvest their rabi crop only once in 2 years. Consequently, people rebelled against the program and the model has collapsed, but not before causing much misery (Das 2006). Therefore, the experience and evidence on the impact of pricing on irrigation demand even in an institutional context is marginal. This is mainly due to the ineffective or lopsided functioning of the formal institutions.

In the context of groundwater, the water demand is controlled mainly through electricity. Though electricity pricing on cost basis is difficult politically, groundwater demand is often curtailed through regulation of the power supply. It is observed in the case of Gujarat, that increase in the flat rate of power has reduced the subsidy burden of the government though power is still subsidized (Shah and Verma 2008). While the threshold level of the power price that would reduce water demand is quite high, regulation of power supply could be used as an effective demand management tool. It is argued, "…effective rationing of power supply can indeed act as a powerful, indeed all powerful, tool for groundwater demand management" (Shah and Verma 2008 — p.66). Similarly, metering of the power supply has shrunk the water markets, thus reducing the amount of water extraction. The combination of metering with regulation of supply seems to be more effective in managing groundwater demand.

Conditions for Effective Water Pricing

There is no 'silver bullet' for making and implementing appropriate water pricing policies. There is a need for an integrated approach of markets, institutions and policies. The effectiveness of market mechanisms like full cost pricing, marginal cost pricing, etc., depends on the existing institutional and policy environment. Often price policies are adopted due to compulsions rather than due to conviction. For instance, in order to tide over the increasing financial burden, a number of states in India have initiated price and institutional reforms. In most of the cases these initiatives are induced rather than germane. Conditions for water pricing are determined by policy environment, institutional environment and technological options available.

Perpetuation of the supply-side approach has often prompted the exploration of possibilities of meeting the increasing demand for water through enhanced supplies from far off places at huge costs. In the absence of financial self-sufficiency of the supply agencies, they resorted to external funding. These funds, especially from the international agencies, often come with conditionalities in order to ensure repayment. World Bank, Asian Development Bank, DFID, European Commission, etc., are among the important agencies that are pushing reform agendas in some of the states. World Bank is the largest lender in the water sector covering both drinking as well as irrigation water. Although India is the second most important borrower from the World Bank, its investments in the sector account for only 10 % of the total investment (Pitman 2002). Of late, most of the lenders and donors are following the sectoral approach rather than the project approach. Sectoral approach takes an integrated view of the entire sector and initiates corrective measures instead of focusing on specific projects in specific areas. But, state governments are not very enthusiastic about the sectoral approach, as they are happy tinkering with small or little changes rather than embarking on major reforms like adopting a comprehensive water policy, providing legal rights and entitlements to water and establishing enforcement mechanisms, etc. Despite the best efforts of some of the donors, sectoral reforms are getting a lukewarm response and are adopted in a piecemeal manner at best.

The new initiatives in the irrigation sector are mainly institutional in terms of participatory irrigation management (PIM). Under this, some states in India (viz., Andhra Pradesh, Rajasthan, Orissa, etc.), have brought in legislations making water user associations (WUAs) mandatory for managing the public irrigation systems. One of the main objectives of PIM is to enhance the financial sustainability of the irrigation projects by ensuring parity between expenditure and revenue. Water user associations, through their involvement in planning, management and assessment in their locations are expected to smooth out the cost recovery process and move towards volumetric pricing in the long run. Though these reforms are having wider political support, in most of the states the progress regarding implementation of the reform components is not only tardy but also raising doubts regarding the overall sustainability of these initiatives in the long-run. In some cases these new institutional arrangements have fallen prey to the 'elite capture' (Reddy and Reddy 2005), in others the inequity in the distribution of water has led to rebellion and abandoning of the reform (Sainath 2006). On the whole the performance of these initiatives is not satisfactory. As per the World Bank evaluation based on aggregate project performance indicator combining the individual ratings for outcome, institutional and sustainability, (Pitman 2002). And irrigation sector is the worst among all the water sector projects, as only 40 % of the irrigation and drainage projects had satisfactory outcomes.

The fault, however, does not lie in the policies per se. The problem is lack of conviction at the policy-making and implementation levels. The new initiatives somehow are not fitting into the overall framework of self-seeking interests of various stakeholders like political entrepreneurs, bureaucrats, contractors etc. High subsidies and poor quality of delivery seems to serve their self-interests better. The gap between demand and actual collection of water charges is increasing even in reform states due to laxity in enforcement. As per the committee on the pricing of irrigation water during the 1980s, the gap between assessment and collection was in the range of 27 to 70 %. Accumulated arrears were found to be three to four times those of the annual demand in several states (Vaidyanathan 2003). This trend seems to be continuing, as evident in the field studies. The gap is as high as 60 % in the Chambal command of Rajasthan (Reddy 1996). In Andhra Pradesh, the increase in water rates has led to collusion between farmers and officials, with little impact on recovery rates.

Institutions or institutional reforms are critical for the success of irrigation water pricing. It is often argued that the reason for the ills of irrigation management is the alienation of farmers from the process of planning and implementation. Maintenance and management of irrigation systems through user societies and participatory process is expected to bring in efficient and equal distribution of water resources. But such processes often remained at the micro-level as experiments, and were often found to be difficult to replicate. Of late, participatory irrigation management is being scaled up at a wider scale in countries like India. Though flow of funds is the main factor in generating such a response, it is necessary to support the ailing systems in order to generate trust among beneficiaries. For, over the years, farmers have lost faith in the government and are in not inclined to respond to the false promises. Therefore, the initial boost was necessary to regain the lost credibility and build confidence. Once this is in place, implementation of institutional reforms from the top becomes smooth and much easier. But it is necessary to understand the direction in which the reforms are progressing. This direction would ultimately determine the strength and sustainability of the reforms.

Inequity in the distribution of water is the main cause of conflicts. Conflict is pervasive mainly due to historical reasons i.e., some regions are endowed with rivers and others are not. While it is difficult to avoid conflict altogether, it can be minimized through prioritization of the resource distribution. Water pricing also should take the equity concerns in to account. Discriminatory pricing policies would help overcome equity issues to a large extent. The much acclaimed electricity and groundwater management program in Gujarat (Gujarat's Jyotigram Scheme) also encountered equity problems. The scheme that helped reduce power subsidies, water demand and incidence of water markets has, however, adversely affected small and marginal farmers. Metering of power has led to the shrinking of water markets that were instrumental in providing groundwater access to small and marginal farmers (Shah and Verma 2008). This is mainly due to the bundling of water and land rights and the lumpy nature of capital requirements for groundwater exploitation. Discussion on legal aspects of water rights is crucial. De-linking of water rights from land rights would go a long way in addressing the equity issues in the distribution of groundwater. Allocating the rights to the community under the supervision of PR institutions could be a feasible option in this regard. Scarcity regions should be guaranteed with minimum levels of water in the case of regional allocations.

One of the main reasons for the chequered performance of the water sector in India is the absence of scientific information on the status of water resources. In the absence of such information there is widespread misunderstanding about access to water resources and constraints on using them. This is more so in the case of groundwater where farmers tend to mine groundwater in the absence of information on the availability of groundwater in their specific location. Similarly, farmers in the canal commands tend to misuse water and farmers in the dry regions presume that water can be brought from any distance, as they are not aware of the costs of irrigation development. Awareness campaigns should focus on presenting a realistic picture and future consequences if the present trends continue.

Water auditing and budgeting are crucial in minimizing the misconceived notions about water. Though water budgeting needs to be carried out at the village level, to start with, this exercise should be initiated at the watershed or river basin level following a holistic approach. For this purpose, integration of departmental expertise (groundwater, drinking water, irrigation, agriculture, animal husbandry etc.,) at the district level is recommended in providing a blue print on the ecological and livelihood potentials and constraints. The information should include the extent of irrigation that is possible (surface and groundwater), suitable cropping patterns, possibilities for livestock development, non-farm livelihood options, cost of provision, available water saving technologies and the benefits from their use etc. This message should be made transparent, simple and understandable to the people by displaying the information in prominent places like village panchayat office and should be disseminated in a campaign mode.

However, campaigning alone may not be effective unless fostered with the intended policy changes. An aggressive campaign on pricing should be followed by price hikes. Similarly, advocacy on cropping pattern changes should be accompanied by removing the distortion in output prices. For, ultimately it is the price that brings in the behavioral change. A campaign only helps in understanding the situation and prepares the communities for change. In other words, it facilitates a smooth transition in to the structural adjustment. The campaign should be carried out in a professional manner, i.e., preparing different modules for multiple stakeholders and resources. And it should be planned to ensure long term sustainability (at least 10 years).

The bottom line for water management is privatization of water resources or commodification of water; pricing of water use. This is another extreme of the South African (SA) model, which treats water as a public good. While there is no clear agreement in this regard, privatization of water, especially sources, would have a serious impact on the poor. Even in the absence of privatization the poor are paying more for water. However, the rich depriving the poor, often corner the benefits from the social good. Here the state should ensure and protect the entitlements. In the case of irrigation, privatization could help improve the situation by increasing the financial viability. In these cases water can be treated as an economic good. The third option is the middle path i.e., private public partnership in water resource management. This approach is expected to integrate the good aspects of social and economic goods. However, a cautious approach is required given the strident nature of the resource. Understanding the nature, structure and process of such partnership (adopted mainly in the developed countries) and its adaptability to the developing country context is a precondition for adopting such an approach.

While the SA model (discussed above) and the Chinese model (Vaidyanathan 1999) present a centralized public management of water resources, the Dutch model (van Dijk 2006) illustrates the relevance of different types of public-private partnerships in the water sector and who the participants would be. However, water utilities in the western countries are different, both in form and functions, to those in countries like India. The implications obviously are manifold but vitally influence the methods for raising resources. Besides the differences, there have been attempts by government departments in India toward enlisting private participation as well as in raising money for initial and working capital expenses such as Narmada Bonds issued by Sardar Sarovar Narmada Nigam (Corporation) Limited of Gujarat, India. It is interesting to observe that even in the Netherlands one-third of the Water Board’s budget comes by way of loans every year. Even in the other two-thirds component, pollution tax appears to be the principal factor. In a country where pollution laws are in a nascent stage but not integrated to water management institutions there is no immediate logical case on which an argument could be made for an integration. Similarly, ‘who benefits pays and also have a say’ model have equity dimensions in smallholder-dominated agriculture. The equity aspects need to be resolved in an amicable manner.

Conclusions

Irrigation water pricing is one of the most discussed and little acted upon issues in the policy discourse. While pricing, as a demand management instrument is the prima dona of a policy economist, it has become a political nightmare for the policy implementers. Pricing of irrigation is critical from many angles: a) more than 70 % of the total water resources are used for irrigation and, hence, takes a lion's share in the public investment; b) irrigation generates surpluses to the farmers and, hence, an economic good; c) irrigation also attracts substantial private investments, especially groundwater; d) improvements in irrigation efficiencies could result in substantial resources, physical as well as financial; and e) irrigation investments are becoming increasingly capital intensive and can no longer be considered as social welfare measure, e.g., food security.

Though price is an important demand management variable in a strict economic sense, the criticality of water for irrigation makes it inelastic to price. As a result, the threshold levels of pricing that are required for making irrigation demand sensitive are very high. Even in the case where water is priced volumetrically, the prices fixed are often below the threshold levels. This is true even in the case of water markets. As a result, no evidence could be found on the effectiveness of price as a demand management variable. Institutional reforms have failed to address the pricing issue effectively i.e., moving towards cost-based / marginal-cost pricing. Moreover, the feasibility of pricing on a cost basis has been diminishing over the years in the context of agrarian crisis and globalization. Increasing input costs has been identified as the main reason for agrarian crisis in countries like India. Globalization has brought in the contrasts in the agriculture subsidies across countries, further strengthening the demand for subsidies in the developing world. The recent growth spurt in economies like India has pushed the cost-based pricing issues to the margin i.e., subsidies are no longer a big burden on the exchequer. In fact, allocations for expensive and unviable irrigation projects have gone up in the recent years (Reddy 2006). This appears to be a politically correct strategy, at least in the short run.

Provision of irrigation has become a major political concern rather than an economic issue. Irrigation needs to be provided at any cost to sustain agriculture, and agriculture continues to support 50 % of the population in countries like India. Since water is not a finite good, demand management becomes critical for judicious management and equitable distribution of water resources across regions and communities. Pricing of water is not an effective instrument of demand management as long as prices do not reflect the actual costs of provision. At the same time pure supply management may not be efficient in the long run. As evident from the literature available it is the combination of demand management and supply regulation that is more effective. In the given socioeconomic and political context, (cost-based) pricing though necessary is not a feasible option for demand management. And the present level-pricing is not sufficient to effect demand management on its own. On the other hand, supply regulation has been the main strategy of the irrigation administrators for demand management, especially to address scarcity. But, often supply-side management is used to the neglect of demand-side management pushing the departments into debt.

Pricing in the present context need to be considered to the extent of generating resources in order to meet the O & M costs and reduce the financial burden on the exchequer. Pricing is also needed to emphasize that water is not a free social good. Supply regulation should be fostered and perhaps linked with pricing i.e. prices may vary as per supply. But in any case supplies need to be measured at the level closest to the actual users. In the Indian context supplies should be metered at the water user association (WUA) level. The WUA should take the responsibility of distributing the water equitably among its members and collect the water charges. For this, metering of supplies and strengthening of WUAs is mandatory. As evident in the case of Gujarat, metering of power along with supply regulations alone could not address the equity issues in groundwater distribution. Institutions should make equity issues integral to overall resource management. This is being tried in a project in Andhra Pradesh where groundwater is managed at the community level in 638 villages (APFAMGS 2008).

Pricing becomes affordable if the land and water productivities are enhanced. This coupled with effective institutional arrangements could pave the way for full-cost or marginal-cost based pricing in the long run. Water saving technologies like sprinkler and drip systems need to be promoted through institutional arrangements rather than through subsidies. WUAs need to be encouraged and capacitated to promote these technologies. Of late, labor saving technologies like mechanical threshers and harvest combines are promoted through WUAs in Andhra Pradesh, India (Deshpande et. al. 2008). Either way, institutional strengthening holds the key for effective demand management of irrigation.

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Water Markets as a Demand Management Option: Potentials, Problems and Prospects

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Introduction

Water resources development and management have been the common policy agenda in many developing economies, particularly in arid and semi-arid tropical countries. Both the physical and economic scarcity of water across regions made the water resources economists and policymakers critically analyze different options to manage this precious resource. A study by the International Water Management Institute (IWMI) shows that around 50 % of the increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation. Most of this gain in irrigation effectiveness would be in countries with a high percentage of irrigated rice. India and China together would account for as much as one-half of the world's total estimated water savings from increased irrigation effectiveness. Therefore, the capacity of large countries like India and China to efficiently develop and manage water resources is likely to be a key determinant of global food security in the twenty-first century (Seckler et al. 1998). In countries like India, almost the entirety of the easily possible and economically viable irrigation water potential has already been developed, but the demand for water for different sectors has been growing continuously (Saleth 1996; Vaidyanathan 1999). Moreover, the water use efficiency in the agricultural sector, which still consumes over 80 % of water, is only in the range of 30-40 % in India, indicating that there is considerable scope for improving the existing water use efficiency.

Moreover, in recent decades the issue of inter-sectoral water demand and allocation poses challenges to water economists and policymakers alike. Burgeoning population, expansion in the urban sector of the economy and increase in the industrial sector led to an increase in demand for water in domestic, industrial and, of course, in the irrigation sector. The problem is further compounded by environmental pollution. Under these circumstances, it is more important than ever before to use water efficiently. The existing literature on water resources management shows that the solution to the problem of growing groundwater scarcity is centered on two strategies. First, the supply side management practices like watershed development, water resources development through major, medium and minor irrigation projects. The second is through demand management by efficient use of the available water both in the short-run and long-run perspectives. Though there are a number of demand management options available, one of the demand management strategies adopted either formally or informally across regions by water markets is by reallocation of water, particularly in regions where groundwater scarcity is acute.

Water Market as a Demand Management Strategy

The water policies of many developing countries including India show that the existing policies on irrigation are mainly supply-side oriented rather than demand-side. Policies such as tariff rate, power pricing in the irrigation sector and institutional components for supplying irrigation water are far too inadequate to effectively manage the scarce water resources. Moreover, the command and control mechanism does not adequately reflect the farmers' preferences because the farmers' preferences are determined by various physical, socioeconomic and contextual factors. Under these circumstances, informal water markets emerged in order to bridge the gap between the demand and supply of water, and these markets continue to exist in many parts of the country and elsewhere as well. (Venkatachalam 2008).

Water markets have been considered as a coping strategy for managing water scarcity and reallocation of water from surplus to scarcity regions/localities/farms. Evidences show that the groundwater markets play a significant role in India's groundwater economy (Bhatia et al. 1995). It is found that in Gujarat, for instance, the value of groundwater extracted and used per year is worked out to be in the range of Rs.5,000 to Rs.6,000 million. Of the total water transacted, about 40-60 % of water is sold to the resource-poor farmers who experience the capital requirement as a major constraint in establishing their own water extraction mechanisms (Shah and Raju 1988). Evidences also show that well-developed groundwater markets have existed in Gujarat for as long as 70–80 years. Groundwater markets assume importance for three critical reasons. (i) They enable marginal and small farmers to enjoy the benefits of groundwater lifts and, thereby help enhance their incomes. (ii) Groundwater markets help their owners to improve the economic viability of their lifts and, thereby enhance their incomes. (iii) These markets help the society by minimizing investments in groundwater lifts. Under these situations, groundwater markets are considered as one of the best demand management strategies (Narain 1997).

In this context, it is argued that the markets can increase economic efficiency by allocating resources to their most valuable uses, i.e., markets create adequate incentives and lead to efficient water use (Mohanty and Gupta 2002). With only limited scope for further expansion in irrigation potential, the formal or informal water markets can play a crucial role in water allocation across villages and regions. Therefore, the study of water market and its nature, function and role in water resource management assume importance. Recognizing the importance of water markets as a strategy for managing scarce water resources, this paper analyses how water markets can be an option for managing the ever increasing demand for water.

Water Markets: Functioning, Size, Significance and Economics

Functioning of Water Markets

The literature on water markets in India dates back to as early as the 1960s. The term 'water market' has been widely used in regions where water selling and buying takes place. Literature suggests that the term has been used to describe a localized, village level institutional arrangement through which owners of the Lift Irrigation Schemes (LIS) supply irrigation service to other members of the community at a price (Shah 1986). The markets for water function in a slightly different manner to markets for other commodities and inputs. As indicated earlier the emergence of markets for water is determined by several socioeconomic and cultural factors. The water markets are typically spontaneous (initiated by private individuals to achieve mutual gains), informal (transaction of water takes place without any legal bindings and to get mutual benefits between the buyers and sellers), unregulated (no strict regulation is followed), localized (mostly functioning at the village level), fragmented (geographical separation of sellers) and seasonal (demand varies across seasons)—(Shah 1986).

Studies on groundwater markets are not a new development as many have attempted across regions and countries to address the wide range of issues such as functioning of water markets, equity and efficiency in water sales, size and structure, allocative efficiency, monopoly power and determinants of monopoly power, impacts of water markets and policy-oriented issues such as power pricing and so on. Studies have also attempted find out the conditions under which water markets emerge. For instance, studies have revealed that markets for groundwater have emerged where well-owners have a surplus of water and there is high demand for irrigation water (Kolavalli and Chicone 1989).

Water markets are actually not uncommon. Wherever people have more water than they need they sell it to others. In the USA, rural water markets have become institutionalized, with farmers' associations selling water to each other and to urban centers in need of water. Farmers' markets exist in India where prices are fixed through negotiation, and payments are made by different modes such as cash or kind. Water sales by well-owning farmers have occurred as long as wells have been in existence, but the first reports of widespread sales appeared in studies of well irrigation in the1960s (Moosti 1970; Patel and Patel 1969 cited in Kolavalli and Chicone 1989). The main focus has been on the monopoly power of the water sellers / well-owners and the impact of high-priced water sales on the non-well owners or the poor (Asopa and Tripati 1975; Shah 1985). However, much deeper examination of the operation and functioning of water markets were formally done by Shah (1985) and Bliss and Stern (1982). The water markets in India are highly imperfect and the prices are determined by the marginal cost of pumping and elasticity of water demand (Shah 1985).

Experiences show that the key determinants of monopoly power in groundwater markets are rainfall, cost of water extraction mechanisms, density of water extraction mechanisms, spacing norms, cropping pattern, access to canal water and electricity and lined water conveyance system (Shah and Raju 1988). Empirical evidences confirm that the water markets in rural areas fairly reflect natural oligopolies (Shah 1986). Of course, there are several reasons to support these types of markets. The density of LIS tends never to be so high as to make the individual water sellers completely powerless. Topographical barriers and seepage losses through unlined channels prevent the sellers from enjoying full monopoly power, and the huge capital investment acts as a natural barrier in preventing the entry of new firms to the market. Moreover, enforcement of spacing norms and electricity boards either directly or indirectly limit the operation of water markets and, thereby make water markets operate as oligopoly markets.

In places where there are fragmented holdings and parcels of land (far from each other), often coupled with the surplus of water in the wells, well-owners are motivated to sell their surplus to the neighbors (Kolavalli and Chicone 1989). Similarly, groundwater markets emerge in regions where well-owners have a surplus of water and an increasing demand for water due to the growing of water-intensive crops and adoption of improved agricultural technologies such as high-yielding modern varieties, fertilizers and plant protection chemicals etc. (Abbie et al. 1982). Since, the buyers seem to be price takers and primarily depend on sellers' decisions; the sellers enjoy the monopoly power as there is no immediate alternative available for the buyers. In addition, the price discrimination is also observed in the form of different prices for crops of different value, seasons, and locations. A study conducted in the Gujarat State of India, found that the capital appears to be the major constraint for the emergence of water markets in groundwater abundant areas. The lack of capital is seen as the primary barrier preventing smallholders entering the water market. It is also found that the water sellers are unable to enjoy a monopolistic position because of the simultaneous existence of many markets in the rural areas (Kolavalli and Chicone 1989).

Size and Significance of Water Markets

Experiences from different parts of the country and elsewhere show that water markets function in varying size from much localized areas to regions. Though the water markets are prevalent in many parts of India such as Gujarat, Punjab, Uttar Pradesh, Tamil Nadu, Andhra Pradesh and West Bengal, they are most developed in Gujarat. The extent of area irrigated through water markets, which is often considered to be a surrogate for the magnitude of water traded, varies across regions as well as over time, influenced by many factors like rainfall, groundwater supply, cropping patterns, and the cost and availability of electricity (Saleth 1994). As such it is difficult to assess the size and nature of the groundwater market as a whole. The major part of the problem is the limited attention paid to this issue in the past. Whatever is known, however, indicates that up to half or more of the land area served by private modern water extraction mechanisms (WEM) in many parts of India is likely to be owned and operated by the buyers of water themselves (Shah 1993).

Earlier estimates have shown that over 12 million private WEMs, which depend on small surface water bodies and on groundwater, serve a gross irrigated area of some 30 mha at an average of around 2.5 ha per WEM. Field studies indicate that the actual gross area irrigated by both WEM owners and water buyers from WEMs is often two to three times greater, especially in water abundant (WA) areas indicating the intensive use of land and water with certainty of water supplies. In the Allahabad District of Uttar Pradesh, Shankar (1987) studied over 150 private WEM owners and found that the average gross area irrigated by them was 24 ha. In Punjab, Jairath (1985) found the average gross area irrigated by a sample of diesel and electric WEM owners in Ludhiana and Amristar districts to be 5.7 ha in case of diesel WEMs and 9.6 ha for electric WEMs. Evidence from West Godavari District of Andhra Pradesh shows that small 5 - 7.5 hp pumps on private bore wells are providing intensive irrigation for crops like paddy, banana and sugarcane on an average of 3.5 ha per WEM. However, the same study showed that electric WEMs in the Kheda District of Gujarat as providing irrigation to an average of over 20 ha of gross irrigated area. Some private WEMs sampled by them in Gujarat irrigated as much as 50-60 ha of gross area (Shah and Raju 1986).

These studies show that the sellers provided sustained intensive irrigation to those who have no access to irrigation water. Often, a seller may provide small amounts of irrigation to a large number of buyers who use this irrigation to grow an additional crop in critical periods of moisture stress. Water selling by private WEM owners can have a dramatic beneficial impact on the community in such a context. Water sales is a pervasive feature where large as well as poor WEM owners are selling supplementary irrigation to their neighbors at prices ranging from Rs.8 to Rs 25 per hour from 5 hp diesel or electric WEMs in the tribal regions of West Bengal (Pant 2004). The seller made a tidy profit of some Rs.3,000 per year but the tribal who could grow an additional potato crop on their land gained much more (Shah 1987). The average number of buyers with whom a WEM owner deals is another indicator of the significance of water markets. As discussed elsewhere in the 'Groundwater Markets and Irrigation Development-Political Economy and Practical Policy' book (Shah 1993), the figures range from 2-3 to 70-80 across regions. In the coastal Andhra (West Godavari), and Uttar Pradesh, the number of buyers per WEM is typically smaller, whereas in Gujarat, the number of buyers per WEM tends to be large. Likewise, a typical WEM in a water-scarce area can serve a smaller number of buyers than in water-abundant areas.

The studies on water markets mostly concentrated on water-scarce regions than water-abundant regions. The reason may be mainly to cope with the increasing water scarcity. Though it is hard to define the size of the water market and though water is unlike other commodities, researchers defined the extent of the spread of the water market as one to be measured in terms of breadth and depth, which Shah and Ballabh (1997) define, respectively, as the proportion of farm and farm lands that come into the beneficial ambit of the water market. At the regional level, water markets have acquired tremendous breadth as shown by multi-village studies conducted by Mukherji and Shah (2002), e.g., in villages where groundwater irrigation is prevalent, groundwater market is all-pervasive. At the micro-level, there is evidence to show that breadth of water markets has increased over time. Evidences show that the breadth of water markets in terms of percentage of irrigated area served by the water sales varied from 20.8 % in Eastern Uttar Pradesh to 100 % in West Bengal.

There are several factors that contribute to the breadth of water markets and, generally, it is seen to be inversely related to the existence of other modes of cheap irrigation, e.g., public tubewells and canals. Another dimension in the size of water markets is the depth of the water market defined in terms of the intensity of water transactions. The depth of a water market is defined as the ratio of average hours of operation of the Water Extraction Mechanism (WEM) per year to the average hours of water sold per year, higher the value the greater the depth of the water market. The depth of a water market ranged from as small as (0.17) in Bihar to as large as (0.68) in Bangladesh (see Mukherji 2004). .

Water Pricing and Water Markets

The water is charged in different modes and it varies across the region. The water charges are paid in terms of cash, kind (agricultural output, labor etc.), and crop sharing agreements between the buyers and sellers. Evidence shows that cash transaction (Clay 1974 cited in Mukherji 2004; Shah 1991; Shah and Ballah 1997; Fujita and Hossain 1995) is very common in water markets. Shah (1991) viewed these kinds of cash transactions as an indicator of market maturity for groundwater. There were also situations where water sale through cash transaction accounted for only 3 % of the total area irrigated in Bangladesh, while the major portion was accounted for by tenancy contracts between landowners and WEM owners (Fujita and Hossain 1995). Sometimes, water sales are dominated by seasonal cash contracts (Lewis 1989). Pant (2003), Ballabh et al. (2002) found that in many of their study villages, water sales are carried out by hourly payments of both in cash and kind. WEM owners are also seen to adopt leasing in and leasing out practices for transactions in the water markets. A review of these studies conducted therefore indicates that there can be two types of transactions in the water market : first, is the outright sale of water (against cash, kind or a mix of both, either at hourly or seasonal rates); and the second, is some kind of tenancy arrangement under which the WEM owner can either lease in land from other landowners or lease out land in lieu of a certain return, either fixed (in terms of money or in kind) or share of the produce (Mukherhji 2004).

Experiences from the earlier studies show that the prices charged by the sellers vary significantly across regions, crops etc. The hourly price ranges between Rs. 3 in the West Godavari District of Andhra Pradesh to Rs. 45 in the Mehasana District of Gujarat (Shah 1993). Non-cash contracts, which typically take the form of sharecropping (i.e., seller collects a water rent in the form of a share of the buyer's output), are not uncommon. They have been found to be incentive compatible (Aggarwal 1999). However, this practice is found in Tamil Nadu, particularly in tank and canal command areas, where the well-owners sell water to the non-well owners for supplemental irrigation requirements. The payment is made in the form of kind, i.e., paddy outputs. These contracts work as a 'double-sided' incentive, providing the seller an incentive to ensure that the water supply is timely and reliable, and providing the buyer an incentive not to shirk the application of labor. In Tamil Nadu, there are cases where water buyers have to offer labor services such as operating the pump and irrigating the well owners' fields for a paltry sum or no remuneration at all (Janakarajan 1993).

Can Water Markets be a Demand Management Tool?

In the midst of growing water scarcity, increased emphasis has been given to market-based instruments to solve the scarcity problem. The advantages and disadvantages of water trading, the nature of functioning and impacts of water markets at different levels have been well documented, argued and debated with evidence from field experiences. When we look at the impact of groundwater markets, the literature ranging from highly positive ones that confirm the groundwater markets are the 'vehicle of poverty alleviation' to those which accuse groundwater markets of 'creating water lords' and appropriating the surplus from the poor. There are two major ways in which the impact of groundwater markets are manifested; first, in changes in cropping pattern and cropping intensity among the buyers and sellers; and second, in terms of employment generation among the landless (Mukherji 2004).

Arguments for Water Markets

The emergence and existence of groundwater markets could be viewed as a response to the nature of groundwater use, extraction and management in the country. The water markets ensure efficiency and equity and, thereby generate adequate social benefits to the society. Efficient functioning of a water market implies the narrowing of margins of the price charged by the seller and price paid by the buyers. In other words, in efficient water markets, sellers sell water at a price close to the average economic cost of pumping. This ensures larger irrigation surpluses and more livelihoods for the resource poor and the landless (Shah 1986). In such a situation, the water markets have beneficial effects: (i) higher and more risk-free income flows from farming for non-well owners who have no access to water; (ii) appreciation of non-well owners land; and, (iii) increased wages, and adequate employment opportunities for the land owners.

Increase in Producers' Surplus and Income

Water markets promote higher efficiency because water users can sell any surpluses they create or use them to increase their production, such as by experimenting with a new crop grown under a different irrigation system. Groundwater markets contribute significantly to agricultural production and growth in a region. In Bengal, private shallow tubewells (STW) diffused very rapidly during the 1980s, which contributed to the high agricultural growth rate and in the reduction of poverty in rural areas. The major reason why tubewells diffused rapidly, in spite of the lack of progress of land consolidation projects was the emergence of a groundwater market.

Reallocation of Resources

In the event of an absence of property rights mechanisms, the water markets may play a crucial role in reallocation of water from surplus regions to scarcity areas and have significant positive impacts and help achieve administered efficiency pricing (i.e., pricing marginal unit of water at marginal cost)—(Mohanty and Gupta 2002). Furthermore, studies show that farmers are sensitive to changes in water price – increasing the price of agricultural water by 10 % decreases demand by 20 %. In other words, the demand is price-elastic. Thus, a marginal reduction in subsidies for agricultural water would reduce its use by this sector. It is not necessary that agricultural output would decline as a consequence. Increasing the price of agricultural water would simply give agricultural communities an incentive to use water more efficiently, e.g., by using new technologies and planting high-value crops such as nuts, fruits and vegetables that are less water intensive (Fowler 1999).Moreover, even if water markets reduced agricultural production, such a reduction would probably be seen in marginally productive lands and crops. In this context, it has been estimated that agricultural water use could decline by as much as 15-20 % through conservation without significant decreases in production (Wahl 1989). Numerous trends indicate that a significant reallocation of water from agricultural to urban regions occurred in western states, and a reallocation of as much as 15 % of agricultural usage is plausible (Haddad 2000). It is also increasingly clear that markets will play an important role in this reallocation.

Water Quality Enhancement

Water quality improvement is also achieved through water markets. In water surplus areas with high drainage problems, the water markets transfer the surplus water to scarcity areas and, thereby reduce many quality-related problems, e.g., salinity (Weinberg et al. 1993). Water markets could also be considered as the best solution to achieve the conjunctive use of surface and groundwater. A study conducted by Kolavalli and Chicone (1989) has been successful in creating an understanding of how farmers in different parts of the canal command supplement canal irrigation with their own or purchased groundwater to obtain better results.

Increased Water Productivity

Water markets lead to high water productivity. In areas where irrigation is done through water markets, the buyers can get the water that they need, when they need, and the water productivity will be high as markets fulfill the requirements in the most crucial stage of crop growth. Evidence shows that the water markets led to additional crop cover of 50-80 acres of 35-40 buyers land. The water seller earned an income of Rs.3,000 per year and the water buyers gained much more with the increase in crop production (Shah 1988). Since water is purchased in a market, the buyers use water more efficiently and judiciously. Thus, the water markets play a vital role in improving efficiency in agricultural production, ensuring equity in resource allocation, managing demand and promoting the conjunctive use of both surface and groundwater, particularly in command areas and improving water quality.

Arguments Against Water Markets

In spite of the positive impacts, water markets significantly generate negative externalities or other ecological and equity problems also.

Creation of Monopolies

Easy access to buy water and the huge initial investment linked with water extraction mechanism have dissuaded farmers from owning such a mechanism. It is also found that the use of unlined channels to transport water to buyers' fields results in seepage losses as high as 30 to 40 %. This implies that buyers who are at some distance from the owner' tubewell incurred an effectively higher price, which has resulted in the emergence of localized monopolies (Shah 1993).

Generators of Negative Externalities

Water markets sometimes lead to adverse effects in the agricultural sector. For instance, the water market in the Tirupur and Coimbatore districts of India has emerged as a major threat to the irrigated agriculture. Due to labor scarcity, high wage rates and inadequate water storage, farmers prefer to sell their water rather than engage themselves in actual farming work. Moreover, the extensive water use in dying and bleaching industries has resulted in making water transfer from agriculture to industry become more significant. Consequently the value of production loss in agriculture also has become significant as indicated below (Table 1).

Table 1. Loss of agriculture production: Tirupur and Coimbatore districts of India.

Particulars	Loss in area and income
Reduction in irrigated area	431 ha
Revenue foregone	Rs. 54 lakhs / season

Water Mining and Social Inequity

The water markets will lead to social inequity in a situation where water sellers have a monopoly of the market. In this case, the water sellers will have the major share of the buyer's profit too through water sales. As more people resort to water selling, water markets can cause excess pumping of water, making groundwater aquifers more prone to depletion This will pose challenges to achieve sustainable water management, and to ensuring intergenerational equity to resource access, particularly in water-scarce regions. It is evidenced that water markets generate negative externalities such as inequity in agricultural productivity, reduction in efficiency and reduction in agricultural production both at the farm level and regional level. In spite of various negative externalities generated by water markets, it could be viewed best as a demand management tool as it helps in a big way in reallocation of water from surplus to scarcity areas/regions.

Experiences of Water Market

International Experiences

Water markets and associated trading of water has been practiced in many parts of the world since a long time ago. Not only in developing countries but also in many developed countries like Australia and the USA, the water markets function either formally or informally. The functioning of water markets in few countries are discussed below.

United States

Evidence shows that the Western United States (California, in particular) is one of the earliest instances where water markets have played a role in managing water scarcity. Many argued that water markets are the key to redressing the imbalance and achieving a more efficient allocation of water. Irrigators in California have been trading water among themselves for years, both formally and informally, and trading even occurs in some districts that are supplied with federal water. Members of the Westland's Water District (WWD), for example, negotiated roughly 4,500 transfers during 1990-91. In March 1996, WWD introduced an electronic bulletin board system that enables farmers to buy and sell annual entitlements to federal water using a personal computer and a modem (Anderson and Snyder 1997). Perhaps the most established market for federal water operates in the Northern Colorado Water Conservancy District near Fort Collins, Colorado. Annual water entitlements within the district are freely transferable. About 30 % of the water delivered to the district each year passes through the rental market, with rents ranging from US$ 5-7 per acre-foot (Wahl 1989). There are also numerous examples of water trading between agricultural and urban users in western United States in the states of Utah, Arizona, Colorado and Nevada. For instance, groundwater in Arizona was made freely transferable by law in 1980. Following this the cities of Phoenix, Tucson, Mesa and Scottsdale acquired more than 50,000 acres of farmland in order to leave the fields fallow and to utilize the water. A study by researchers at the University of Arizona found that during the late 1970s and during the 1980s there were about 6,000 transactions in Utah, 1,455 in New Mexico, and 1,500 in Colorado (Steinhart 1990 cited in Mohanty and Gupta 2002).

Australia

Water sector in Australia has moved to the forefront of national policy debates aimed at meeting expanding social, economic and environmental objectives. The proportion of water used for agriculture is ever increasing both in absolute and relative terms. Seventy percent of water use in Australia is for agricultural purposes compared with 12 % in France, 40 % in the USA and 53 % in Italy (Stringer and Wittwer 2001). Various policies were introduced by the Australian Government over a period of years such as Environmental Protection (Water Quality) Policy 2003, Natural Resources Management Act 2004, The River Murray Act 2003 etc. The new National Water Initiative for 2004-2014 incorporates regulatory, market-based, informational and educational policy instruments, with demands placed at new and relatively weak administrative scales. The key elements of the National Water Initiative are: a) water access entitlements and planning framework; b) water markets and trading; c) best practice water pricing; d) integrated management of water for environmental and other public benefit outcomes; e) water resource accounting; f) urban water reform; g) knowledge and capacity building; and h) community partnerships and adjustment (Hussey and Dovers 2006).

Australia is also one of the pioneering countries where water trading has been practiced since a long time ago. Australian states have started allowing transfers of water entitlements through markets. Transferable rights were a response to increasing scarcity of water. As in the case of India, informal markets had already evolved before the state enacted legislation during the 1980s that codified water trading. Prior to this, farmers transferred water entitlements through 'dual ownership' whereby they purchased two landholdings and transferred water from one to the other. The fact that they chose to do this despite the high transaction costs associated with such transfers indicates the value of the gains that can be obtained from water trading. It has been estimated that water transfers along the Murray-Darling River Basin stretching over 2,500 kilometers led to a significant increase in farm incomes. In 1988-89 this increase in income was US$5.6 million through 280 transfers of 85,000 mega-liters of water. In 1990-91 the increase was US$10 million comprising 437 transfers of about 120,000 mega-liters (Sturgess and Wright 1993 cited in Mohanty and Gupta 2002). Market-based tradable permits, i.e., transferring of water rights, have assumed importance in Australia and are being widely adopted in different states.

Chile

Recognizing the importance of water trading, Chile established secure and transferable water rights. With these rights, individuals can buy or lease water quite easily. The aim is to strengthen private property, increase private autonomy in water use and favor free markets in water. Water rights in Chile are now completely separate from land ownership and can be freely bought, sold, mortgaged, and transferred like any other piece of real estate. The Chilean experience with water markets is one of mixed success and is "something for other countries to learn from rather than to copy" (Bauer 1997 cited in Mohanty and Gupta 2002). The lesson that emerges from the Chilean experience for India is that water users strongly favor the increased legal security that private property rights provide. Not only have stronger property rights increased the autonomy of local canal associations, they have also encouraged investment in agricultural water use, particularly by those growing high-value export crops like fruits.

Meinzen-dick (1997) analyzed the functioning of groundwater markets in Pakistan and their impact on agricultural productivity and incomes. The effects of the physical, social and agro economic environments on the density of private tubewells and the activity of water markets were studied, including the participation in groundwater markets. Furthermore, the determinants of tubewell ownership and groundwater purchase at the micro-level were identified using data from a household survey. The impact of groundwater markets on productivity and incomes were analyzed comparing the extent of irrigation acquired by farmers through surpluses attributable to water from canals, purchased groundwater and their own tubewells (Meinzen-Dick 1996). As per the study by Weinberg et al. (1993), in addition to improving the allocative efficiency of water use, water markets reduce irrigation-related water quality problems. This potential benefit is examined with a nonlinear programming model that was developed to simulate agricultural decision-making in an area with experienced drainage problems in California's San Joaquin Valley. Results indicate that a 30 % drainage goal is achievable through improvements in irrigation practices and changes in cropping patterns induced by a water market. Although water markets will not, in general, achieve a least-cost solution, they may be practical alternatives to economically efficient, but information-wise intensive, environmental policies such as the Pigouvian taxes.

Water Markets in India

Water markets in India are quite informal, localized and spontaneous as indicated by Shah (1993) and others. However, the water markets in India are functioning in varying size and degrees across the regions. As far as water markets are concerned, numerous studies were conducted in India by different authors over a period of time. A recent study by Abijit et al. (2006) made an attempt to analyze the institutions and markets that govern groundwater allocation in the sugarcane belt of Uttar Pradesh, India. One of the findings was that plots are water-rationed owing to the inadequate supply of power. Rationing and the village-level mechanism of water sales lead to a great misallocation of water across the plots, and result in large crop losses for plots that irrigate with purchased water. The existence of a social contract will mitigate these potential losses in the study area to a remarkable extent. However, in the absence of such a contract average yields are estimated to be lower by 18 %.

Box.1. Case Study from Tiruppur, Tamil Nadu, India

The domestic requirements of the Bhavani River basin as well as the adjacent Noyyal Basin are met partly by surface water in the Bhavani River. The river provides water to several municipalities, town panchayats and village panchayats for domestic consumption. The municipalities pump water for domestic requirements directly from the river. The annual draw from the river for the existing schemes and the schemes that are proposed in the future by the TWAD Board is in the order of 174 MCM. There are two water supply circles for household water requirements in the Lower Bhavani Basin

As such, nine schemes are running to provide drinking water supply to the 'Coimbatore Circle'. The total draw from the Bhavani River for this circle is 378.50 mld (0.38 MCM) and yearly 138.5 MCM. Among the nine schemes, five schemes are running to give 335.86 mld (0.34 MCM) and yearly 122.58 MCM of water to the Noyyal Basin. There are 32 schemes running to give drinking water to the 'Erode Circle'. The total draw from the Bhavani River in this circle is 97.126 mld (0.09 MCM) and yearly 35.45 MCM. Hence, the total drinking water drawn from the Bhavani River is both for Coimbatore and Erode circles, which is 475.626 mld (0.48 MCM) and yearly it is 173.60 MCM.

About 400 tankers are operating daily in transferring water from the agriculture sector to urban sectors. The price charged at the farm level is about Rs.100/tanker (13,000 lit). and it is sold to the industries at Rs. 400-600/tanker.

Source: Palanisami (2005)

Pant (2004) traces the evolution of water markets in eastern and western Uttar Pradesh. He observed a surge in investment in privately-owned tubewells and in the demand for electricity. The surge is attributable to the demands placed by the high-yielding variety of seeds and the consequent need for timely and reliable water supply, coupled with farmers' drive to maximize the yield. Pant concludes that growth increased the demand for power, which while available in plenty in the 1970s, has now become a constraining factor. Transactions in groundwater are noted for their importance in elevating the position of the small farmer by providing access to water.

Informal Water Markets in Tamil Nadu

Continued progress in water resources development in Tamil Nadu, India, will require that the state's existing irrigation potential be used more efficiently. Only 15 % of surface water potential in Tamil Nadu remains unexploited, and the rapidly escalating construction cost constitute a growing drain on state finances while increasing the already high financial subsidy given to irrigated farms. Further complicating matters the private exploitation of groundwater by individual farmers has tended to result in an indiscriminate and unregulated proliferation of wells, which has lowered the water table in several regions of the state. Additionally, increasing demand for nonagricultural purposes has compelled the government to divert adequate water supplies from the agricultural sector to nonagricultural users on a priority basis. Increasing water scarcity in Tamil Nadu has caused the development of informal water markets, both within the agricultural sector and between the agricultural and nonagricultural sectors.

Informal water trading in agriculture is often initiated by the selling of a small plot of land adjacent to a river to people who can dig a well and pump the water either from a shallow well or directly from the river through underground pipelines to fields 5 to 15 km away from the well. This practice is illegal, however, because wells within 200 m of the river are considered to be recharged directly from the river. Thus, by pumping from these wells, pump owners divert water to which they have no rights. In most cases, farmers who pump water from riverside wells use diesel pump sets to do so. However, some farmers use electricity by transferring their existing electric connections to these new wells. This practice further compounds the illegality of river pumping, selling water from pumps using electrical power is prohibited, because electricity is provided free for direct agricultural purposes only.

Informal inter-sectoral water markets are also operating in and around the major river basins in Tamil Nadu. Well-owners sell water to truckers, who in turn transport the water to urban centers. Two locations, i.e., Coimbatore City and Tiruppur Town in Tamil Nadu have particularly active water markets. In informal markets, well-owners pump water using diesel or electric motors (the latter, again, being illegal) and sell it to middlemen for US$0.08 to US$0.10/m^3 (The middlemen – bullock-cart owners and lorry tanker operators – are the main distributors of water to households and other customers. This cost of water to the end consumer averages approximately US0.75m^3$ more than 10 times the subsidized rate paid by households connected to the public distribution system. (Relatively well-to-do households served by the public water system pay only US$0.06/$m^3$).

Despite significant restrictions on the tradability of water in Tamil Nadu, the state's informal water markets have developed in response to increasing water scarcity and to the differential value of water across the sectors. Particularly active trading takes place between the agricultural and urban sectors. The markets serve a useful function of supplying water to users who otherwise would not be served by the highly subsidized municipal water system. However, the markets would be far more effective if the legal restrictions and excessive electricity and municipal water subsides were removed. Especially, the subsidized municipal system, which leaves out many of the poor, has negative welfare implications. The reform of water laws and water allocation systems in Tamil Nadu to permit more flexible water trading could greatly benefit the state.

Dimensions of Water Markets

No doubt that irrigation water plays a crucial role in agricultural production, and many claim that the irrigation water in most of the water-scarce regions are allocated through water markets (Shah 1997; Palmer Jones 1994 cited in Mukherji and Shah 2002). The size, nature and functioning of water markets significantly vary across hydrogeological and socioeconomic and cultural conditions. A study conducted across regions in South Asia confirms the proposition that the dimensions of water markets vary across regions.

The differences are observed in proportion to well-owners selling pumped water, average number of buyers and sellers, hours of sale per year, proportion of well-owners who bought water, number of hours bought and the area irrigated with purchased water. Considerable variations are found across regions. For instance, average number of hours bought per year varied from 31 hours in Nepal Terai to as high as 140 hours per annum in Bangladesh. Similarly, average annual hours of sale per seller varied from 72 hours in Coastal South India to 680 hours in Western India (Table 2). It is thus clear that the size and functioning of water markets significantly vary across regions and are influenced by different factors.

Table 2. Dimensions of water markets in South Asia.

Particulars	Pak. Punjab	Punjab Haryana West UP	East India	Tribal India	West India	Interior South India	Coastal South India	Bangladesh	Nepal Terai
Percentage of well owners selling pump irrigation	33	24	46	2.5	10	6	9	88	62
Average number of buyers /seller	3	4	5	4	3	3	1	11	4.5
Average annual hours of sale/seller	317	127	150	90	680	340	72	634	98
Average size of buyer area served per seller (ha)	10	5	3.7	0.5	4	1.3	0.53	3	3
Percentage of well owners who bought pump irrigation	5	11	6.6	Negligible	2	1	0	36	2
Average number of hours bought/yr	133	53	85	NA	98	35	NA	140	31
Average area irrigated with purchased water (ha)	6	2	1.1	NA	1	2	NA	0.6	0.67

Source : Mukherji, A and T Shah : 'Socio-Ecology of Groundwater Irrigation in South Asia: An Overview of Issues and Evidence' in Selected Papers of the Symposium on Intensive Use of Groundwater, held at Valencia (Spain), December 10-14, 2002, IAH Hydrogeology Selected Papers, Balkema Publishers

Potential for Water Markets in India

Several micro-studies illustrate the degree of variation in the use of water trading in India. In terms of area irrigated through groundwater markets, estimates vary from 80 % for Northern Gujarat (Shah 1993) to 60 % in the Allahabad District in Uttar Pradesh (Shankar, in his 16-village sample study in 1992) to 30 % in the Vaigai Basin, Tamil Nadu (Janakarajan 1993). There is no systematic estimate at the national level of the magnitude of water trading. The area irrigated through water markets has been projected to be about 50 % of the total gross irrigated area with private lift irrigation systems (Shah 1993). Other estimates, using a methodology based on pump set rental data, put the figure at 6 million hectares or 15 % of the total area under groundwater irrigation (Saleth 1999). Assuming a net addition to output of US$230/ha/year (based on the difference between the average irrigated and rain-fed yields as reported by the Government of India), the total value of the output due to water sales is estimated to be US$1.38 billion per year (Mohanty and Gupta 2002).

Though water markets are not new and the fact that they have evolved over time and for several reasons across the regions, being an important institutional mechanism for managing water scarcity, it would be important to identify the potential areas where the markets for water could be extended or promoted. The size, nature and extent of development of water markets depend on factors such as cropping pattern, water availability, type of water extraction mechanisms installed, irrigation potentials, socioeconomic conditions and the sources of irrigation. Experiences from many parts of India reveal that, water markets are mostly well developed where the groundwater scarcity is predominant. Few studies also attempted to study the functioning of water markets in the command areas where the non-well owners buy water from the well-owners for supplemental irrigation. However, the water markets or trading of surface water in India is rather limited or not well studied. There is significant potential for studying water trading in the surface irrigation system where water is tradable through permits.

Shah (1986) studied the nature and pattern of the development of water markets across regions of India considering the lift irrigation potential as a major criterion. The pattern of development of water markets varies across regions based on the lift irrigation potentials and the extent of utilization. Shah considered mainly five criterion to classify the development of water markets, and they are: (i) mode of transactions (cash or kind); (ii) proportion of water sold by the well owners; (iii) differences in cropping pattern, input use and technology adoption between the well and non-well owners; (iv) percentage of non-lift irrigation systems' owners and percentage of their land that uses purchased water; and (v) objective function of the sellers. In low lift irrigation potential and low utilization areas like many hard-rock areas where well yields are very low, there is only limited scope for development of water markets. For instance, in Karimnagar District of Andhra Pradesh (Shah 1986) where there is limited potential for lift irrigation system, the development of water market is still at the primitive stage.

Regions with low lift irrigation potential and high utilization coupled with wider adoption of modern crop production technologies have greater scope for the development of water markets. Regions such as Mehsana, Sabarkantha, Banaskantha and other regions of Saurashtra, Gujarat and southern Tamil Nadu apparently have developed water markets in spite of having low water potential. Contrary to the above, in regions where there is high potential for lift irrigation system but with low utilization, such as the regions of Orissa, Bihar and West Bengal, in spite of having huge groundwater reserves, the groundwater markets remain highly underdeveloped. The reasons attributed to this negative trend in the development of water markets in these regions are: a) poor infrastructure development; b) slow rate of rural electrification; and c) irrigation being dominated by the traditional water lifting systems.

The existing literature on water markets and groundwater economy suggests that challenges to manage the groundwater differ across the regions. In spite of the abundance of groundwater resources in water surplus regions such as eastern Indian states like Bihar, the state is yet to solve its problem of poverty and achieve economic growth and development at a much faster rate. Contrary to the above, in water-scarce regions like Peninsular Southern India and Western Indian states, the groundwater resource degradation is alarming and it is imperative that the water markets should be promoted in regions where supplies are rechargeable with the available surface water.

Scholars like Shah and Saleth projected the size of the water market in terms of the area covered under the market. Based on the estimated projections, an attempt has been made to assess the size of the water market across regions of India. The size of the water market would be quite larger in Western Indian states like Maharashtra, Gujarat, Rajasthan and also in Madhya Pradesh and Southern Peninsular states like Andhra Pradesh, Karnataka and Tamil Nadu (Table 3). In the face of growing water scarcity, encouraging water markets in these states would be a viable option to manage water scarcity and in the efficient allocation of water resources.

The earlier researchers projected the size of water markets based on the area under groundwater irrigation only. It is mainly based on the perception that the water markets in India operate where the lift irrigation system is a common one coupled with water scarcity. However, there is also another area one has to focus on, i.e., the surface irrigated areas. In areas where the surface irrigation is predominant, water sharing issues often arise between the water users. At most times the head reach farmers enjoy maximum benefits of increased crop yield due to irrigation supplies and tail end farmers face acute water scarcity. This is also a common phenomenon in a chain of tanks which share water from a common source (Palanisami and Suresh Kumar 2004). In this case, the tradable water rights can be introduced so that the water savers would get an incentive for saving water. The surplus water could be sold to the scarce regions at a price accepted by the farmers in the surplus region. Thus, the size of water markets should allow for the total area under irrigation rather than the area under groundwater irrigation only. The studies on tradable permits are rather limited in India and there is scope for introducing such institutional mechanisms to manage the growing water scarcity.

Table.3. Estimated size of water market in India across regions ('000 hectares)

Regions	States	Groundwater Irrigation			Total Irrigated Area		
		Area under well irrigation	Size of water markets[1]	Size of water markets[2]	Gross area from all sources	Size of water markets[1]	Size of water markets[2]
Southern	Andhra Pradesh	2,573	1,286	385	4,781	2,390	717
	Karnataka	1,323	661	198	2,702	1,351	405
	Tamil Nadu	1,529	764	229	2,479	1,239	372
Western	Maharashtra	2,384	1,192	357	3,668	1,834	550
	Gujarat	3,188	1,594	478	3,637	1,818	546
	Rajasthan	4,368	2,184	655	6,393	3,196	959
	Madhya Pradesh	3,829	1,914	574	5,776	2,888	866
Northern	Uttar Pradesh	13,356	6678	2,003	17,690	8,845	2653
	Punjab	5,739	2,869	861	7,667	3,833	1150
	Jammu /Kashmir	3	1.5	0.45	446	223	66.9
Eastern	Bihar	3,131	1,565	469	4,567	2,283	685
North-eastern	Mizoram	0	0	0	18	9.0	2.7
	Nagaland	0	0	0	104	52.0	15.6
	Meghalaya	0	0	0	82	41.0	12.3
	Manipur	0	0	0	42	21.0	6.3

Notes: [1] Data pertaining to 2003-04, http://www.indiastat.com
Based on the assumption that 50 % of total gross irrigated area is with private lift irrigation (Shah 1993)
[2] Based on the assumption that 15 % of the total area under groundwater irrigation (Saleth 1999)

Supporting Conditions

Market-based instruments are proving to be an effective mechanism for increasing the productivity of water and reallocating the water saved. Experiences from many parts of the country and elsewhere clearly show that there are no formal water markets functioning in India and also that there is no legal binding for such formal water markets. Another important issue that emerges is that no defined property rights system is followed. In spite of these lacunas, the emergence and existence of informal water markets were noticed across the regions. In these circumstances, it is essential to identify the supportive conditions which are needed to transform the water markets into an effective demand management tool in the event of growing water scarcity. Hence, the water market reforms may include the property rights, water charges and the tradable water rights.

Property Rights for Water

Unlike in other countries, there is no proper property rights system that exists in India. Traditionally, the water resources have been managed either by the State or State Agencies or through property systems that focus on land ownership. Issues relating to ownership of water are not only complex but also different from other resources. In India, the use, control, management and ownership of water is linked to the other resources like land in the case of groundwater and irrigation structures in the case of surface irrigation. Thus, appropriating and defining property rights in water is complex in the present day context and, as such, need to be dealt with separately for groundwater and surface water. Though no property rights system for water exists, establishment of some sort of water rights and responsibility system, specifying the withdrawal or entitlement of water, is crucial for the development and promotion of water markets in a much more formalized manner.

Institutional Arrangements

The study revealed that there are no institutional arrangements in place to: a) govern water rights; b) property systems; c) control the functioning of informal water markets; d) pricing in informal water markets; and e) resolving conflicts. Furthermore, institutional arrangements are needed for resolving conflicts over water rights. There is an increasing emphasis today on the formation of water markets, and many experiments are underway. However, effective water markets do not emerge naturally from local systems of exchange or from individual market behavior. Legally protected water rights for all water market actors depend on state institutions above the local level. Informal and traditional systems of rights in local systems of collective management often rest on traditional power structures, which do not provide solid foundations for effective water markets. Thus the legal formalization of property rights in water is the necessary basis for effective water markets.

Tradable Water Rights

The introduction of a system of trading in water rights will provide opportunities for individuals who own water rights to trade that property right to other potential users anywhere within the basin. At present, there are opportunities for owners of property rights to trade within the catchment in which they operate and in some cases between catchments. There is limited opportunity for individuals to trade between states. From a national perspective, it is argued that the best economic returns from water resource will be generated if it is allowed to move to its highest value use. For this to occur, the necessary infrastructure, and water itself, must be available. This is not always the case. Existence of a water trading market would mean water could be purchased from elsewhere and thus make the venture feasible. The introduction of a market for water could provide substantial assistance for some irrigators: in situations where the demand for water is not high in a region because of shallow water tables, or the need to maintain minimum flows, irrigators could both reduce environmental impacts and generate income by selling their water rights to a user in another area.

Water Pricing

Pricing is an effective strategy for demand management as long as the water-rate structures contain strong incentives to conserve water. The development and implementation of pricing strategies aimed at achieving economic efficiency and demand management could become the most important option for balancing water supply and demand in the future. Water providers can encourage consumers to conserve water by reforming water rates or introducing surcharges to deter high usage of water, or by establishing fines as a deterrent to wasteful practices of water use. A major shortcoming of the literature on groundwater prices in India is that it generally does not record prices per unit volume of water; obviously a volumetric measure is necessary for a variety of reasons, including the assessment of the efficiency of water allocation within and across river basins. The percentage of area covered under water market as per the studies conducted in the Bihar and Uttar Pradesh states of India varies from 23 to 90 % in Bihar and 55 to 80 % in Uttar Pradesh.

In India, the water rates presently being charged from the users are highly subsidized and have resulted in low revenue realization. The revenue realization from water charges has proved inadequate and has been meager, and much less than even the recurring O & M charges, thereby adversely impacting the satisfactory nature and adequacy of maintenance. There is an urgent need for a review and to restructure the water rates to ensure full recovery of recurring O & M cost initially, and a part of the capital cost subsequently. Although states are giving due considerations to the cost aspects and crop water requirement etc., in the fixation of water rates, in reality the rates fixed by the states seem to be restricted ultimately to the paying capacity of the farmers. No doubt the paying capacity of the farmers cannot be ignored altogether, but if the water rates are to ensure full recovery of recurring O & M cost initially and a part of the capital cost subsequently as stressed in the National Water Policy Statement 2002 and also recommended by various Finance Commissions and Official Committees, the alternative may lie in adopting differential water rates as per the holding size of the cultivators.

In most cases in India, water is charged on crop basis and it also incorporates the cess and surcharges using the crop water rate as the basis. For instance., in the case of Lower Bhavani System, the water charge is Rs. 37.5/ha and the cess is the same and the cess surcharge is five times this rate thus making the total charge as Rs. 187.5 /ha (see Table 4). In the case of the tank irrigation systems of South India, the water market works in the later part of the crop season (see Table 5). The rate varies from Rs. 20 to 50 /hr depending on the crop period and the demand. Normally, about 2-3 buyers are covered under single well-owner (Palanisami 2004).

Water Demand

Palanisami et al. (2000) made an attempt to project demand for water among competing uses using the SHACOWAR model in the Bhavani Basin of Tamil Nadu, India. It was found that the nonagricultural demand will increase from 6.56 TMC to 13 TMC in 2010 and 16.86 TMC in 2015 and the revenue from water will be about Rs.1,062 million and Rs.1,382 million (Table.6). In the case of the Bhavani River, which has the riparian rights, the supply of water will be constant over the years. However, in the case of Lower Bhavani Sector the total water demand in odd season is estimated to be much higher than in the even season. Since, it is impossible to operate the second season without the required water supply of 8 TMC, the second season may be abandoned from 2010 onwards. The rice area will be reduced only marginally whereas the other irrigated crops will decline dramatically. In these circumstances, the groundwater use should be encouraged in the turn of seasons because with future energy pricing, the water use will not be much affected, as the energy is found to be inelastic or much lower.

Table 4. Water rates for major crops in Tamil Nadu, (Rs. /ha).

Crops	Water Rate
Rice	37.5
Sugarcane	50.0
Groundnut	25.0
Pulses	19.0

Table 5. Water charging on cost basis, tank irrigation systems in Tamil Nadu.

	Tank		Well		
Months	Storage (Meter)	Yield (Meter)	Pumped (Hrs)	Quantity (Rs./hr)	Price (Rs/1,000 lit)
October	5.3	4.6	12	6	0.40
November	1.5	1.7	6	8	0.53
December	0.5	0.3	4	8	0.53
January	0	0.3	4	10	0.66

Note: Quantity pumped will be about 15,000 lit/hour.

Table 6. Agricultural and nonagricultural water demand in the Bhavani Basin.

Particulars	1995	2000	2005	2010	2015
Water use (TMC)					
Nonagricultural	6.56	8.28	10.48	13.28	16.86
Agricultural					
a) Bhavani River	19.79	19.79	19.79	19.79	19.79
b) Lower Bhavani					
1) Odd season	16.88	16.88	16.88	16.88	16.17
2) Even season	8.96	8.84	8.11	4.39	0.62
Revenue (Rs. Million)					
Nonagricultural	489.50	632.67	819.20	1,062.99	1,382.21
Agriculture Area (000ha) :					
Rice	71.48	71.21	70.48	70.48	70.48
Other Crops	52.01	47.00	45.20	28.40	9.30

Note: TMC = Thousand million cubic feet

The inter-sectoral water allocation can thus be defined under the framework of a water market, as the nonagricultural sectors are paying the agreed charges to the canal authorities, including the industries which are also paying the rate fixed by the government departments. Under these circumstances it should be carefully examined how in the future the inter-sectoral water allocation could be covered under the framework of a water market. Thus, even in the command areas, there is potential for promoting groundwater markets as groundwater plays a crucial role in supplementing the surface water. This is further supported by another research on estimation of the 'Stabilization Value of the Groundwater' (Palanisami et al. 2008).

The stabilization value of groundwater is about 19 % higher than what it is now in the tank systems. Furthermore, the higher stabilization value may be acting as an indirect incentive to the non-well owners to buy the groundwater even though the well-owners are increasing the selling price during the peak demand periods. However, this also will encourage more large farmers to invest in wells. The stabilization value of groundwater will be always higher (19 %) even if a charge is levied on electricity, indicating the importance of the conjunctive use of tank and well water in the tank command as without the groundwater supplementation, the crop yield will be much less or in several cases crop failures will be seen. Since rice yield response to supplemental irrigation is attractive to farmers, efforts should be made to augment groundwater supplies to enhance the rice yield by providing technical and financial assistance to small and marginal farmers. This will also reduce the demand for as well as the price of groundwater in the long-run.

Increasing the water supplies in the tank through sluice management strategies (where about 20 % saving is possible) is looking very attractive. Furthermore, this could be achieved with lesser investment. The stabilization value of groundwater will also be very high (77.5 %) when tank water is used at higher levels thus minimizing the groundwater use. This also will have more implications for the sustainability of tanks, in that since a greater number of wells in the tanks always results in poor tank performance, improving the tank management will enhance tank supplies, which in turn will reduce the demand for a greater number of wells in the tank command. Hence, efforts should be made to improve the system efficiencies through tank modernization strategies. Since the tank management by the farmers will be a more attractive proposition, efforts should be made to strengthen the water user's organization at the tank level. Since most of the water user's organizations at the tank level are informal, it is important to make them formal, so that they could handle financial transactions when undertaking tank improvement activities. In a conservative estimate if we take the entire tank systems in southern India, the potential for localized water market will be about 2 mha. This estimate assumes the potential for water markers in non-system tank areas, which accounts for 80 % of the total tank area of 2.5 mha. Besides encouraging the urban (domestic) water allocation with different pricing regimes, stabilization value of groundwater is also justified in big cities like Chennai in India, where increased water pumping is realized from tank commands in a radius of about 50 km for domestic uses. The stabilization value there is high since, without the groundwater, people get lesser surface supplies without meeting their demand. This is also an interesting area to be examined under the framework of water markets.

In summation, market forces, which treat water as a commodity, offer an effective way of reallocating limited water supplies among competing uses. Both the rights to the use of water and the actual volumes of water can be exchanged in market transactions within regions. This will facilitate better allocation of scarce water resources across different sectors so that the overall developmental objectives could be achieved at a much faster rate.

Conclusion

The debate on water markets as an option for demand management has diverging views. Water markets have been in operation in many parts of the world including India. Although informal water markets have been in existence for decades, formal markets with clearly assigned, private and transferable water rights are of relatively recent origin. In Chile, Western USA and Australia, where there are developed formal water markets, there have been significant gains from water trading, particularly from trades between agricultural and urban users as water gets reallocated to more productive uses. International experiences also show that formal and developed water markets strengthen the incentives for conservation and more efficient use of water. For example, farmers have responded by switching to water-saving technologies and high-value, less water intensive crops. The Indian experience with water markets has been positive, although there have been only limited gains, because markets have remained informal, localized and primitive. Thus, while these markets have led to some efficiency gains and have expanded the scope for many resource-poor farmers to access irrigation, inter-sectoral water transfers have not taken place so far.

The current challenge in India and similar countries, where no such formal water markets have been established, is therefore to establish formal water markets, which will facilitate the trading of water and help achieve inter-sectoral water allocation. Furthermore, since formal water markets have a legal basis, effective regulation can be designed to address the issue of environmental sustainability. Formal water markets not only can provide low-cost solutions for quick augmentation of water supply, but be a viable demand management tool as farmers could use the water efficiently thus resulting not only a saving in water use but an increase in water productivity as well. So far a wealth of studies has been carried out on water markets and their implications in water-scarce regions. However, the water markets in water surplus regions are limited or rather water markets are not pervasive in these regions except in West Bengal, India. Hence, the development and promotion of water markets in the water surplus regions should be encouraged. In the water surplus regions, groundwater markets can transform a stagnant agricultural economy into a vibrant one, with positive productivity and equity impacts.

Like in Australia, market-based instruments such as tradable permits could be introduced, particularly in the surface irrigation areas. This could be introduced either at the basin level or at the sub-basin level. As the tradable water rights provide incentives for the water conservators, this would be the best bet option for managing the increasing demand for water in surface irrigated areas. Assigning separate rights to groundwater would be the first step needed for the development of water markets. Under the riparian system being used in India, ownership of groundwater accrues to the owner of the land above. This constrains the potential for inter-sectoral allocation. To establish an active water market, rights to water use must be authorized separate from the land.

Growing water demand in nonagricultural sectors may demand more water diversions from irrigation. There is evidence that payments to the irrigation water are justified for increased water diversions, besides National and State Water Polices too give priority for domestic water use. The related issues once defined will strengthen the case for encouraging water markets. Formal institutional mechanisms at different levels must be established so as to govern the functioning of water markets. Furthermore, institutional arrangements are needed for resolving conflicts over water rights. The Water Users Associations (WUAs) can be involved in this process. The role of such groups would depend on how clearly water rights are specified and how well they are established and distributed to users. If water rights are unclear and hence, allocation is contentious, conflicts would become complicated and difficult to resolve. In such cases, courts rather than committees of users will become the conflict resolving forum.

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Energy Regulations as a Demand Management Option: Potentials, Problems and Prospects

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Introduction

Irrigation is the predominant user (more than 80 %) of water resources in India. Of the total net irrigated area (NIA) of 58.54 million hectares (mha) in the country during 2004-05, almost 64 % was irrigated by groundwater. The NIA by tubewells and wells is almost double the net area irrigated by canals. During 2003-04 more than 50 % of NIA in Bihar, Gujarat, Punjab, Madhya Pradesh, Maharashtra and Rajasthan, around 50 % in Haryana and Tamil Nadu and close to 40 % in Orissa and West Bengal was irrigated by wells and tubewells. Increased reliance on groundwater for irrigation has led to an increase in the demand for energy, i.e., electricity and diesel for pumping groundwater. At the all-India level, of the total electricity consumption of 411,887 Gwh during 2005-06, consumption for agricultural purposes accounted for about 22 %. In a number of states electricity used for pumping groundwater constitutes more than 30 % of the total electricity consumption. The electricity consumption for irrigation pumping over the years has been increasing both as a result of an increase in the number of tubewells and an increase in electricity consumption per tubewell. The latter has partly been on account of the larger amount of electricity required to pump groundwater from greater water depths as a result of a decline in the water table.

Groundwater irrigation has been a preferred source of irrigation for the farmers. Irrigation with groundwater not only enables individual farmers irrigation 'on demand', which few surface systems can offer, it is also generally more productive compared to surface irrigation. In general, one cubic meter of groundwater applied to crops is more productive than one cubic meter of surface water. Some of the available evidence in India suggests that crop yield/cubic meter on groundwater irrigated farms tends to be 1.2-3 times higher than on surface water irrigated farms (Dhawan 1989). A study conducted by IWMI indicates that farmers with wells obtain 50 to100 % higher value of output per acre compared to canal irrigators (quoted in Shah et al. 2003). As a result, the rapid expansion and increasingly greater reliance on the use of groundwater for irrigation has contributed significantly to agricultural and overall economic development of India, thereby providing stability to agricultural production and contributing towards reducing the incidence of poverty. It is estimated that about two-fifths of India's agricultural output comes from areas irrigated with groundwater (World Bank 1998).

The increased dependence on groundwater has largely been necessitated by the poor performance of the existing surface irrigation water infrastructure. Furthermore, its limited coverage and lack of extension to newer areas over the years; huge financial requirements and long gestation period required for its construction; inadequate availability of water in the available canal network; and its inability to meet the time-specific irrigation water requirement of the water-intensive and water-sensitive crops have all been attributed as negative factors associated with surface irrigation, which have compelled farmers to opt for groundwater irrigation. Most of the groundwater development has taken place through the private initiative of millions of individual farmers, though the government has facilitated this development through provision of several incentives and concessions such as subsidized credit, subsidized diesel, and extensive coverage of rural electrification, and also by making electricity available at highly subsidized rates with liberal tariff charging policies.

The creation of an enabling environment for development of groundwater has succeeded in: a) the proliferation of tubewells; b) in extending irrigation to newer areas; c) in accelerating the pace of food grain production and contributing to its stability; and d) in providing significant economic benefits. However, in the absence of any strategy to monitor, regulate or restrict the growth of tubewells and the amount of water that can be extracted from these structures, the amount of water that is being currently extracted from these structures in several parts of the country far exceeds the amount of water that should be extracted for promoting sustainable use of groundwater. Table 1 gives an overview of the extent of over development of groundwater in some of the important groundwater using states of India, while Figure 1 gives a pictorial view of the regions of over development of groundwater. As a result of over development of groundwater, the groundwater tables are falling rapidly in several regions raising serious concerns and posing major challenges, which require to be addressed both to sustain the benefits of groundwater irrigation and to ensure the sustainability of gains in agricultural production. A quarter of India's harvest may well be at risk from groundwater depletion (Seckler quoted in Shah et al. 2001).

Based on a review of some of the available literature, the present paper attempts to synthesize the experiences gained from some of the attempts made at limiting groundwater overdraft through intervention of energy supply and/or pricing policies. Based on the experiences gained from these exercises the paper attempts to suggest some alternative interventions, which in isolation and/or in combination with energy policies can help achieve a more sustainable use of groundwater.

Approaches to Groundwater Management

Developing effective management systems for groundwater, unlike surface irrigation systems, is beset with problems. The lack of information and understanding regarding groundwater availability and its dynamics presents a major challenge. Without both the data and a shared understanding of the problems, those engaged in developing solutions and evolving social consensus needed to implement such decisions are finding it difficult to promote a more sustainable use of groundwater. Nevertheless, given the concerns over falling water tables, promoting more sustainable use of groundwater has attracted the attention of researchers and policymakers not only in India but in several other countries around the world, which are also confronted with problems of groundwater overdevelopment.

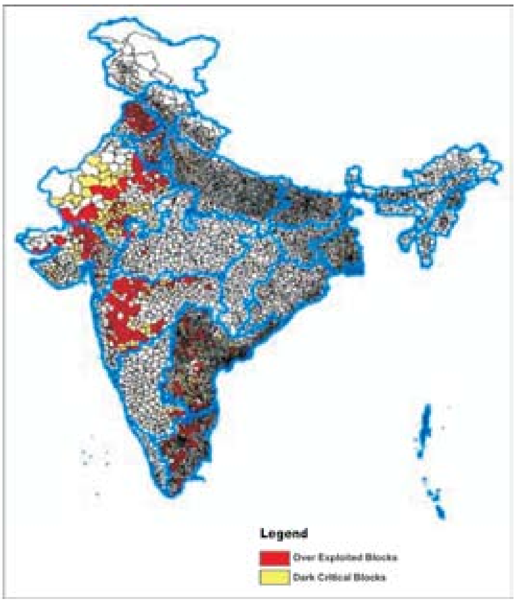
Table 1. Stage of groundwater development in some of the important states of India.

State	Rainfall (mm)	Districts	Mandals /Blocks/ Talukas	Net Annual GW Available (BCM)	Annual GW Draft (BCM)	Stage of GW Develop -ment	Over-exploited	Critical	Semi-critical
Andhra	561-1,113	23	1,104	32.95	14.90	45	219	77	175
Bihar	1,232	37	589	27.42	10.77	39	0	0	0
Gujarat	1,243	25	184	15.02	11.49	76	31	12	69
Haryana	615	20	108	8.63	9.45	109	55	11	5
Karnatka	1,779	27	175	15.30	10.71	70	65	3	14
Kerala	3,073	14	154	6.23	2.92	47	5	15	30
M.P.	917	48	459	35.33	17.12	48	24	5	19
Mahrashtra	1,433	35	231	31.21	15.09	48	7	1	23
Orissa	1,502	30	314	21.01	3.85	18	0	0	0
Punjab	780	17	138	21.44	31.66	145	103	5	4
Rajasthan	504	32	236	10.38	12.99	125	140	50	14
Tamil Nadu	995	30	384	20.76	17.65	85	142	33	57
Uttrakhand	1,523	13	78	2.10	1.39	66	2	0	3
U.P.	1,279	70	-	70.18	48.78	70	37	13	86
W.B	2,074	18	341	27.46	11.65	42	0	1	37

A number of direct and indirect demand-side management and supply-side augmentation approaches have been suggested in the literature and tried in various parts of the world at different points in time in order to address issues relating to groundwater overdraft and its more sustainable use. Some of the approaches that have been employed include regulatory, participatory community-based management, augmentation of groundwater supply through artificial recharge, and energy supply and energy pricing policies. While the impact of these approaches, in isolation and/or in combination, and in the short-term and the long-term, on groundwater management has varied in different locations, in the prevailing underlying conditions in general, none of these approaches have been uniformly effective in controlling excessive groundwater abstractions at different locations. We briefly review the salient features of three of the approaches that have often been attempted.

The regulatory approach to bring groundwater extraction down to sustainable levels envisage putting direct restrictions on the amount of groundwater that can be extracted - through metering of all wells, establishment of formal water rights, issuing of permits, administrative controls including regulatory and economic mechanisms etc. The direct approach to groundwater management thus requires putting in place a legal and regulatory framework to allocate, administer and enforce the requirements of the approach. Sometimes very innovative regulatory approaches have been used to curb groundwater extraction. For example, to conserve groundwater, the Government of Punjab would not start paddy procurement operations at a time when early sown paddy, which requires more water than paddy sown at normal time, arrive in the market after harvest. However, this did not work. The Punjab Government has recently introduced the Punjab Preservation of Sub-Soil Water Ordinance 2008, which prohibits the planting of paddy by the farmers in the state before June 10 to conserve groundwater. The ordinance provides for the government agencies to plough the area with the standing crop of such farmers who transplant paddy before the notified date. The effectiveness of this order in dissuading farmers to sow early paddy and thereby conserve groundwater is, however, yet to be seen.

Figure 1. Overexploited and dark critical blocks.



Source: Government of India, Ministry of Water Resources, Central Ground Water Board

To enable the states to enact groundwater legislation, a model bill to regulate and control development of groundwater has been circulated by the Ministry of Water Resources to all the States/Union Territories (UTs). So far 11 States/ UTs Andhra Pradesh, Goa, Tamil Nadu, Kerala, West Bengal, Bihar, Himachal Pradesh and Union Territories of Chandigarh, Lakshadweep, Pondicherry, Dadra and Nagar Haveli have enacted and implemented groundwater legislation. However, the effectiveness of their implementation and enforcement is not known.

While some success in reducing groundwater draft through some such and similar regulatory measures have reportedly been made in a few water-scarce countries such as Jordan and Israel, the situation is more complex in countries such as India where millions of individual private tubewell owners, dispersed through the length and breadth of the country with varying groundwater availability and demand conditions, are engaged in groundwater extraction. Putting into effect such an approach and overseeing its implementation in a country of the size of India is nearly impossible. The Chinese, with stronger state commitment to groundwater regulation, with a more elaborate reach and local authority structures have still found it impossible to regulate groundwater overdraft in North China Plains (Shah, Giordano and Wang 2004). Nor have the Americans been able to implement real groundwater demand management with their elaborate structure or water rights and groundwater districts, nor have Spaniards and Mexicans with their efforts to promote groundwater user associations.

As an alternative to state regulation of groundwater, some experts have suggested community management of groundwater, similar to community involvement in management of surface water irrigation projects. Though this approach in its various formats has been tried at a number of locations in several countries of the world, the global experience on the outcome of this approach is limited and is conditioned upon conditions prevailing at a very local level. In India such an approach is being tried in the seven drought-prone districts of Andhra Pradesh under the Andhra Pradesh Farmer Managed Groundwater System Project (APFMGS). However, the effectiveness of this approach in promoting sustainable use of groundwater is still not known. Attempts at managing groundwater have, therefore, relied more on indirect management approaches.

Several indirect approaches have been employed in the past with varying degree of effectiveness in different regions at different points of time. Some of these approaches include: restricting institutional credit for installation of tubewells and denying new electricity connections for tubewells. For example, the National Bank for Agriculture and Rural Development (NABARD) has been using 'control of institutional financing for development of wells' in overexploited areas. But this approach has by and large been ineffective in checking overdraft due to large-scale private financing in the development of wells. Similarly, the State Electricity Board's denial of new agricultural power connections in overexploited areas, and in critically developed areas when regulations in relation to spacing of wells are violated, has been ineffective due to the use of old power connections for newly drilled wells (Gass et al. 1996).

Since groundwater development depends directly on energy, management of energy supply and pricing have often been suggested as more effective indirect options for controlling groundwater extraction. In what follows, we elaborate further on these two approaches and examine the likely efficacy of energy management in reducing groundwater withdrawal and slowing down the rate of decline in the water table.

Energy Regulations as a Demand Management Option

The two primary sources of energy for groundwater pumping are electricity and diesel. The regulations governing the use of energy basically relate to pricing of energy and its supply. We briefly describe these below:

Energy Pricing Policy

To encourage development and use of groundwater for irrigation, the government has been providing to the farmers both electricity and diesel for irrigation pumping at prices which are far lower than their supply costs. However, the level of subsidy in the two cases differ, and as a result the energy cost for a given amount of groundwater extraction using electric tubewells is much lower than that of a diesel pumping set. Coupled with problems in availability of diesel; ease in operation, lower running, repair and maintenance cost of electric tubewells; the technological superiority of electric tubewells in drawing water from deeper aquifers; the general preference of the farmers in areas which have access to electricity is to use electricity operated tubewells. However, in areas with poor or no rural electrification or where electricity supply is severely restricted or uncertain, the farmers have no choice but to use diesel pumping equipment either as a stand alone device or as a standby arrangement with electric tubewells. Diesel pumping sets also offer a choice in areas with a shallow groundwater table. In fact, most of the eastern Indo-Gangetic Basin and parts of the western Indo-Gangetic Basin rely on diesel pump-sets for groundwater pumping.

The subsidy on electricity works not only through the lowering of the price of electricity per se but also through the way the electricity is charged from the farmers. The government has been charging farmers for electricity on very liberal tariff terms. Electricity for irrigation is charged either on the basis of a flat rate (FR) tariff structure or on a pro-rata basis on the actual metered consumption, though some states also provide free electricity. The system of charging for electricity on FR basis, wherein an electric tubewell owner is charged for electricity at a flat monthly/annual rate per horsepower of the electric motor installed regardless of the number of hours for which the electric motor is actually used or could be used (due either to availability of electricity or crop water requirement), is the most widely practiced power tariff system.

While some states charge uniform per HP tariffs irrespective of the size of the motor, some may charge on the basis of a 'stepped-up-flat-rate-system' where higher horse power motor owners pay a higher per horse power charge. In this method, since the marginal cost of pumping additional water is almost zero, the farmer has incentive to pump more for his own use or for sale to other farmers. At the same time farmers do not have any incentive to use either the available electricity or groundwater more efficiently. Abbie et al. (1982) argue that the fixed cost of electricity (FR) "… provides no incentive for efficient use of energy, and hence water." The Rajadhyaksha Committee (1985) report on efficient generation and use of power has indicated that FR policy of electricity invariably encourages wasteful use of electricity since its marginal cost becomes zero for the owners of water lifting tubewells. . According to the working group of minor irrigation for the 'Eighth Five Year Plan' the introduction of a FR tariff of electricity would make farmers waste water and take to crops that require more water.

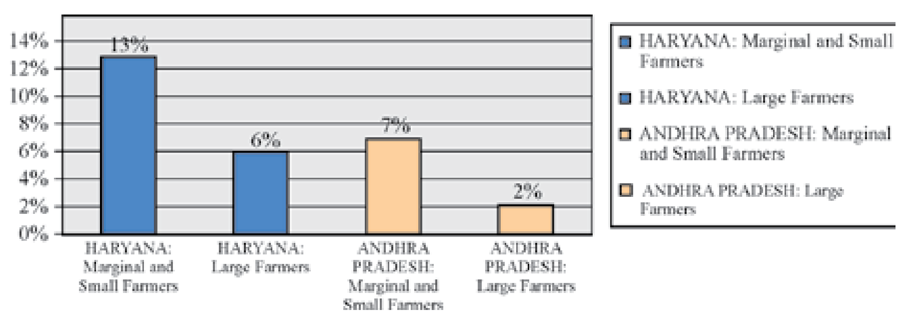
While charging for electricity on a flat rate basis has often been criticized for promoting inefficient use of groundwater and electricity, and for the mounting losses of the SEBs, these tariffs have also been credited with resulting in a significant growth in the market for pumped water. Empirical studies record some form of exchange of groundwater in Gujarat, Punjab, Uttar Pradesh, Andhra Pradesh, Tamil Nadu and West Bengal. (Dubash et al. 2000). According to Shah (1993) although flat rate system of pricing electricity would produce a low level of efficiency in the use of energy, it would produce higher levels of social welfare as compared to a pro rata system of pricing due to the incentive it offers farmers to resort to pump more water and the incentive to sell water at any positive price given the zero marginal cost of pumping water. This has enabled even those farmers who could not buy a pump to benefit from subsidized power supply and has made it possible for the power subsidy to reach even small and marginal farmers who do not own pump-sets.

It has also been suggested that the flat tariff regime is wrongly maligned; in fact, the flat tariff that South Asia has used in its energy–irrigation nexus so far is a completely degenerate version of what might otherwise be a highly rational, sophisticated and scientific pricing regime. A zero tariff is certainly not a rational flat tariff; nor is a flat tariff without proactive rationing and supply management. To most people, the worst thing about a flat tariff is that it violates the marginal cost principle that advocates parity between the price charged and marginal cost of supply. Yet, businesses commonly price their products or services in ways that violate the marginal cost principle, but make overall business sense. Flat rates are often charged to stimulate use to justify the incremental cost of providing a service.

However, in regions with limited groundwater availability, the flat tariff system has widely been argued to be regressive and inequitable towards small landowners and irrigators. According to Bhatia (2007), although small and marginal farmers, generally, operate pumps with lower hp in absolute terms, there appears to be an inverse relationship between the farm size and the horsepower per hectare of gross cropped area, i.e., small farmers tend to invest in higher hp per unit of cultivated area relative to large farmers. For farmers who use electric pumps only, under the flat rate system of electricity pricing in Haryana, electricity tariffs for small and marginal farmers,[1] accounted for more than 13 % of the gross farm income compared with only 6 % of the gross farm income for large farmers (see Figure 2). According to the World Bank (2001) study, "to gain more insight into the regressive nature of the flat rate tariff, it is useful to compare the share of electricity tariffs for electric pump-set owners with the share of diesel costs for non-electric diesel pump owners." For non-electric diesel pump owners, the share of diesel costs account for an average of 7 % of the gross farm income compared with electricity charges that constitute 13 % of the gross farm income for small and marginal farmers using electric pump-sets only. The highly regressive nature of the electricity tariff cost share, as opposed to diesel cost share, arises due to the flat rate tariff structure of electricity pricing, wherein farmers pay on the basis of installed hp rather than on the basis of per unit consumption (as in the case of diesel pumps).

Under a metered or pro-rata tariff system, an electric pump-set owner is charged for actual (kWh) power consumed on the basis of metered consumption of electricity. Some of the states, which charge for electricity on a flat rate basis, too offer farmers a choice for paying for electricity on an actual metered consumption basis rather than on a flat rate basis. While a majority of the farmers prefer the flat rate basis for payment, some farmers (between 10 to 15 %) in some states use the metered tariff. For example, in Haryana, electricity supply to almost 90 % of agricultural consumers is unmetered. In Maharashtra, metered connections used 865 million kWh or 11 % of the total agricultural consumption of 7,757 mn kWh in 2002-03. In no state in India is electricity consumption to the agricultural sector charged wholly on the basis of metered consumption. The tariffs even in the case of metered consumption are also highly subsidized and are nowhere near the true cost of generation and distribution of electricity.

Figure 2. Electricity costs as a % of gross farm income in Haryana and Andhra Pradesh: 2000.



[1] In Haryana, marginal and small farmers operating less than 2 ha of land accounted for 52 % of total farmers while large farmers operating more than 5 ha accounted for 17 % of total farmers.

Many researchers argue that pro rata electricity tariff, with built in positive marginal cost of pumping could bring about an efficient use of the resource (Shah 1993; Moench 1995; Saleth 1997; Kumar and Singh 2001). Nevertheless, some argue that the levels of tariff at which demand becomes elastic to pricing are too high to be viable from political and socioeconomic points of view (de Fraiture and Perry 2002). Shah (1993) opines that while the pro rata system of pricing might induce higher efficiency in the use of energy and water, it will produce lower level of social welfare including farmers' economic surplus as compared to a flat rate system of pricing due to the reduction in demand for groundwater, and the increasing marginal cost of supplying energy. Electricity for the agricultural sector, like any other electricity consuming sector, was charged from farmers, up to around mid-1970s, on the basis of actual metered consumption. During the mid 1970s and 1980s, most of the State Electricity Boards (SEBs) shifted away from metering of electricity sales to agriculture consumers and introduced flat-rate tariffs based on the capacity of the pump-set (Shah 1993; World Bank 2001). This was mainly on account of the difficulty in monitoring the large number of pump-sets and the very low collection rates. This shift was apparently a matter of administrative convenience, meant to minimize transaction costs involved in metering, billing and the collection of bills from agriculture consumers scattered in remote areas. This practice was put in place due in part to the numerous complaints about the harassment of farmers by the SEB field staff.

Of late, however, in spite of most Indian states offering major inducements to tubewell owners to opt for metered connections, only a few have taken to them. . In Andhra Pradesh, Gujarat and Kerala all moves towards metered power consumption have met with farmer opposition on an unprecedented scale. In other states of India, however, farmers' opposition to metered tariff has been partly due to the subsidy contained in the flat tariff and also because they find the flat tariff more transparent and simple to understand. It also spares them the tyranny of the meter readers. Moreover, there are fears that under a metered tariff system, SEBs will start imposing all manner of new charges under different names. In addition, groundwater irrigators raise the issue of equity with canal irrigators, arguing that if the latter can be provided irrigation at subsidized flat rates by public irrigation systems, they too deserve the same terms for groundwater irrigation.

Energy Supply Regulations

Due to the existence of an overall demand-supply gap in the electricity sector, electricity supply to the agriculture sector is generally restricted and falls far short of the sector's requirement. Already the SEBs in almost all the states are supplying electricity to agriculture only for a limited number of hours – generally on an average between 2 to 8 hours per day. Even this limited supply is often provided during night hours. The quality of supply, e.g., certainty, reliability and voltage stability leaves much to be desired. The reason for the supply of electricity to the agriculture sector generally during night hours is because of the low demand of electricity from other sectors of the economy at that time and, as such, the opportunity cost of power is lower at that time than its supply cost. It is, however, very unlikely, that some SEBs are deliberately restricting the supply of electricity to agriculture to conserve groundwater.

To partially circumvent the constraints created by the shortages/uncertainties in the availability of electricity, a number of farmers have installed electric motors of higher horse power than is required in order to draw the requisite quantity of water during the restricted hours of supply of electricity. In addition they have installed an automatic switching mechanism to turn on the tubewell as and when electricity is made available. A number of farmers have also invested in diesel operated pumping equipment as a backup arrangement or use even their tractors in place of a diesel engine to draw groundwater. Those who cannot invest in any backup arrangement try to apply more than the required water during the period when the power supply is available, reduce the area under water-intensive crops, apply the available water thinly over larger areas and accept lower crop yields, attempt to buy water from neighbors, or simply take the risk of letting the crop ruin for want of water. Such an electricity-water supply scenario has led to: a) overcapitalization of agriculture; b) constrained the growth of agriculture; c) resulted in inefficient use of water, energy and equipment; d) led to a reduction in farm profitability; and e) has increased pollution through increases in CO2 emissions into the environment from the burning of diesel. Such a supply scenario has also disproportionately affected the marginal and small farmers and other farmers who do not have a tubewell of their own and therefore, depend on buying water from their tubewell-owning neighborhood farmers.

While the prevailing electricity supply scenario might have succeeded either marginally or not at all in restricting the groundwater withdrawal in water-scarce areas, it has hurt badly the area where groundwater availability scenario is not stressed. Some of the available estimates suggest that the shortages in and poor quality of the supply of electricity for irrigation pumping causes huge private and social losses every year in terms of foregone agricultural production and frequent burn-out of transformers and electric motors. While no economy wide estimates of the impact of shortages/ unreliability of electricity on the agricultural sector are available, some of the available estimates of power restrictions suggest a cost to the agriculture sector in the range of Rs. 9 to Rs. 14 /kWh (at 1995-96 prices) against the true resource cost of generating and distributing electricity in rural areas, which is estimated at between Rs. 3.50 to Rs. 4.00 /kWh and actual cost to the farmer of about Rs. 0.20 /kWh (Dhawan 1999). Other available evidence suggests that voltage fluctuations cause tubewell electric motors to burn-out at least twice in a year resulting in an annual repair cost of more than Rs. 2,000 per tubewell. Depending upon the type of strategy adopted, the capital cost of back-up systems to cope with the prevailing power situation could vary over a wide range – from a minimum of Rs. 10,000 to more than Rs. 100,000 per farm.

Can Power Price per se Reduce Groundwater Extraction?

While energy pricing policies have contributed positively in promoting the development of groundwater and in extending irrigation to hitherto unirrigated areas, it is now increasingly being suggested that these same energy pricing policies, especially that of electricity, have also been responsible for the overdevelopment and unsustainable use of groundwater, leading to a decline in the water tables in many parts of the country. It has, therefore, been advocated that increasing the price of electricity for irrigation pumping, with or without a change in the system of charging for electricity, can curtail the demand for electricity and thereby lower groundwater withdrawals and promote more efficient use of electricity and groundwater. The question that needs to be addressed is: can raising the price of electricity, with or without a change in tariff charging regime, curtail groundwater withdrawal? If so, at what level of price increase this can happen? Does increased electricity price also imply improved equity and improved efficiency in the use of electricity and groundwater?

In India, pricing of power to farmers has always remained an important issue - for power sector reforms, for agricultural policy and also as a politically tempting ploy. The issue of using power pricing policy as an instrument for electricity and groundwater conservation in the farm sector in India has been extensively debated, and continues to be the focal point of the many discussions that take place in the country. However, there is an absolute paucity of sufficient empirical data to compare and analyze the differential impacts of different levels of pricing of electricity on water and energy demand and productivity. Due to lack of data and the complexity of the issues involved, divergent views have emerged on the efficacy of raising electricity prices in influencing the withdrawal and use of groundwater and/or in promoting its equitable, efficient and sustainable use (Shah 1993; Palmer-Jones 1995; Saleth 1997; Kumar and Singh 2001; IRMA/ UNICEF 2001; de Fraiture and Perry 2002).

In most of the discussions on the impact of increasing electricity price on groundwater extraction, it is assumed that the demand curve for power is continuous and presumably its shape convex throughout its entire range, and that all increases in price of electricity lead to a reduction in the electricity demand and, therefore, a fall in groundwater extraction. This assumption has often been made without reference to the groundwater availability scenario, electricity availability scenario, the depth to water table, the prevailing price of electricity or the level of price increase envisaged, the relationship between electricity prices and diesel prices and the relationship between price of surface water and groundwater. Most of these one to one relationships between increase in electricity prices and a reduction in groundwater withdrawal implicitly assume that all other factors remain unchanged and do not influence the water use decision of the farmer. This line of discussion also does not take in to consideration the purpose (crop) for which the groundwater is being used and the prevailing agricultural production scenario aside from availability of and price of groundwater. Any discussion on the likely impact of increased electricity price cannot be constructive if this discussion is divorced of the purpose (crop) for which the water is being extracted from the use of that electricity, or the marginal value of production that is being derived from the use of this electricity/ groundwater.

Electricity for irrigation is one of the many inputs that go into the agricultural production process. From the government's perspective, electricity price is one of the many policy interventions that it makes, in isolation or in combination with other inputs, in promoting the growth of the agricultural sector, in general, or any region or crop, in particular. Similarly, from the farmers' perspective, electricity price is one of the many factors that goes in to the decision-making process in regard to deciding on optimal factor and product combinations, in particular, which crops to grow, how much area to allocate to different crops, and what production inputs to use and in what quantity. Additionally, for many groundwater irrigated crops, cost of electricity for irrigation pumping may constitute a small component of the total cost of production (Naraynamoorthy 1997). If one were to take these broad decision-making factors into consideration, probably one may find that increases in electricity price per se over a substantial range may not necessarily make any impact on a farmer's decision relating to groundwater draft. In all probability so long as the marginal value product of groundwater is positive, any increase in the price of electricity will not lead to a reduction in use of electricity or of groundwater.

Perhaps, in one of the most comprehensive and systematic analysis of the issues involved, Saleth (1997) opines that the nature and magnitude of efficiency, equity, and sustainability impacts of power tariff policy depends on the nature and shape of the power demand curve, both at the individual and aggregate level that links power tariff and power consumption on the one hand and power consumption and groundwater use on the other. Saleth (1997) suggests that the power demand curve is not continuous throughout its range, but actually has a 'kink' or discontinuity, the position of which is determined by a combination of economic, agronomic and hydrological and even technological factors. The presence of kink in the power demand function implies that within a certain range of power tariff, power consumption (and hence groundwater withdrawal) becomes insensitive to variations in power tariffs. First, the larger the size of the kink, the lesser will be the scope for making groundwater withdrawal sensitive to changes in the power tariff. Second, if at all the farmers are responsive to tariff changes there is a point in which they will switch to diesel pump-sets provided the groundwater table and diesel availability make such energy switching technically and economically feasible. Thus, to the extent power tariff changes trigger energy switching, electricity tariff changes become still less effective in controlling groundwater withdrawal.

Saleth (1997) concludes that there is no way we can avoid either the kink in the power demand both at the individual and aggregate contexts or its multifarious implications for water withdrawal and use. The persistence of the kink under the current power tariff structure and power supply conditions clearly suggests how ineffective a power tariff could be as an instrument of groundwater regulation. It is, however, important to empirically estimate the level at which the kink appears under standardized conditions, and according to Saleth (1997), policy-wise this is the most relevant issue for further empirical research.

To What Extent Can Electricity Tariffs be Raised?

There are essentially three criterion which can rationally be employed to fix upper limits of electricity tariffs - (1) on the basis of the cost of generation and distribution of power; (2) on the basis of parity with diesel prices - in terms of what it would cost to draw an equivalent amount of water using a diesel pumping set; and (3) in terms of opportunity cost of electricity used for pumping groundwater. However, if the government wants to cross-subsidize other power consuming sectors at the cost of the agricultural sector, which may perhaps never be politically or otherwise feasible, or forcefully discourage withdrawal of groundwater by farmers, it can raise electricity price to a level even beyond the three stipulated criterion.

Fixing electricity prices on the basis of its opportunity cost has problems. The opportunity cost of electricity can vary substantially depending upon several factors such as the extent of shortages in availability of electricity, the alternative uses to which the power diverted from irrigation pumping can be put, place, time of the year and time of day etc. No estimates of opportunity cost of electricity are generally available, and this criterion has never been used for fixing power tariffs in agriculture. The maximum tariffs thus can be fixed in terms of the remaining two criteria. According to Saleth (1997), so long as the marginal productivity of power in the reckoning of farmers remains higher than the full cost price of power, full cost tariff would not be effective in controlling power consumption, and hence groundwater withdrawal. Under the second option, he argues that, farmers could as well shift to diesel pumps, which could have positive efficiency effects but tariff fixation based on the price of diesel would certainly have some adverse impacts on small and marginal farmers, vis-à-vis income from irrigated crops, and access and equity in groundwater.

To illustrate, with any increase in the price of electricity, even up to the level equivalent to its cost of generation and distribution or to the level of price comparable to the corresponding cost of diesel, as long as the marginal value product of water is positive the farmer will continue to extract groundwater. And so long as cultivation of a given water-intensive crop (say Paddy in Punjab) is more profitable than the cultivation of the next most profitable crop, irrespective of the water requirement, say Maize, a rational farmer will continue growing water-intensive paddy. Increases in price of electricity will, of course, narrow down the profitability gap between the two crops as also the absolute profitability of the farmer from cultivation of paddy. As a result there may occur some saving in groundwater extraction and electricity consumption owing to an improved efficiency in the use of electricity and groundwater. But this minor efficiency-induced water conservation is unlikely to make any significant change in groundwater withdrawals, not least the kind envisaged through an increase in electricity tariffs.

It is also frequently argued that as a result of an increase in electricity prices and the increased cost of water, farmers may switch their cropping pattern in favor of high-value crops by which they could keep the 'marginal value productivity' of power and water, high (Saleth 1997). However, in practice such switching of crops may not happen. Even if the cultivation of high-value crops such as horticultural, sericulture, or floriculture is more profitable than cultivation of say, paddy, at higher prices of electricity, such a switching may not take place if the supporting infrastructure for disposal of such specialized high-value crops (such as marketing, processing, cold storages etc) is not available. If these crops are more profitable than say, paddy at a higher price of electricity, then they are more profitable at lower prices of electricity also. So if a farmer were to switch his cropping pattern in favor of high-value crops in response to an increase in electricity prices he could have done so even at the subsidized price of electricity. If that were so, diversification in cropping patterns and savings in water would have occurred even at lower prices of electricity.

Under such circumstances, to make a dent on the withdrawal of groundwater, electricity tariffs may need to be raised to a level so as to completely appropriate the difference between the marginal productivity and marginal cost of power. While such a rate would be in the responsive region of the power demand curve that can alter power demand and groundwater use, there are high chances of poor social viability and political acceptability. Poor social viability is owing to reduced net returns. Whereas political risk is owing to the fact, that the tariff regimes which run into the responsive region of power demand curve would be different for the various geohydrological environments. Apart from political difficulty in raising the power tariff for agricultural users, it is also unfair to do so as long as canal water continues to be given at a low rate (Saleth 1997).

Realizing both the political problems of raising the power tariff for agricultural users and also the unfairness of doing so when canal water continues to be given at a low rate, the Planning Commission in a recent study, without elaboration, suggested that in order to make farmers account for the marginal cost of pumping water, the farmers may be given an entitlement upfront of say, Rs.6,000 corresponding to 3,000 kwhr at Rs.2/kwhr. The charges for their consumption will be deducted from this amount and the surplus, if any, will be handed over to the farmers at the end of the year. This approach may be tested on a pilot basis to examine if the transactions costs of implementation can be kept manageable (Planning Commission 2007).

Can Power Supply Affect Groundwater Extraction?

Given the likely limited effectiveness and political sensitivity of raising the electricity tariffs, it is often suggested that tariffs remaining the same, restricting the quantum of electricity supplied to farmers would constrain the farmers from operating the tubewells and, thereby help in lowering the withdrawal of groundwater. This would also help the SEBs in containing their losses on account of supply of electricity to the agricultural sector. In fact, the current electricity supply scenario to the agricultural sector in most of the states in India is already one of restricted supply. The restrictions on supply of electricity are, however, partly due to the overall demand-supply gap in the availability of electricity and partly due to the desire of the SEBs to contain the level of subsidy. In practice, however, the restrictions on availability of electricity operate not only in terms of fixed hours of supply during the day or night following an announced supply schedule (the hours and period of supply), but is often random and decided at the last minute by the SEBs. Furthermore, it is not only the hours of electricity supply that matter, but also the quality of the electricity supply (voltage of supply and fluctuations in voltage) during those hours that is equally important in determining the quantum of the groundwater withdrawal that can be made during this period. It is not known if these restrictions on electricity supply in any state have been made with the deliberate aim of reducing groundwater draft.

Power rationing is an important instrument that could definitely help reduce water withdrawal. To partially circumvent the constraints imposed by the restrictions/uncertainties in the availability of electricity, a number of farmers have, however, installed: a) more than the required number of tubewells; b) installed electric motors of higher than required horse power to draw the requisite quantity of water during the restricted hours of supply of electricity; c) installed automatic switching mechanism to turn on the tubewell as and when electricity is made available; and d) have invested in diesel operated pumping equipment as a backup arrangement or use their tractors in place of a diesel engine to draw groundwater (see among others, Saleth and Thangaraj 1993). Those who cannot invest in a supplementary/backup arrangement try to: apply more than the required water during the period when the power supply is available; reduce the area under water-intensive crops; apply the available water thinly over larger areas and accept lower crop yields; attempt to buy water from neighbors; or simply take the risk of letting the crop get ruined for want of water.

The decision on the appropriate response action by the farmer is, of course, governed by the relative economics of investing in / adopting alternative strategies and the likely marginal returns from adopting such a strategy. Such an electricity-water supply scenario has, nevertheless, led to an overcapitalization of agriculture; constrained the growth of agriculture; resulted in inefficient use of water, energy and equipment; and, has led to a reduction in farm profitability. Such a supply scenario has also disproportionately affected the marginal and small farmers and such other farmers who do not have a tubewell of their own and depend on buying water from their neighbors who own tubewells. It is, however, not known if these restrictions on the supply of electricity have been able to make any reduction in groundwater draft. In a recent study, Planning Commission opined that restricted power supply can help in some situations but not across-the-board, However, with time, farmers, like others, will demand supply for longer hours and eventually on a 24X7 basis (Planning Commission 2007). The benefits of restricting groundwater use through restricting electricity supply, if any, will then disappear.

Need for Combining Power Price and Supply

Given the likely limited or possibly no impact per se of either altering the price of electricity for irrigation pumping or of restricting the supply of electricity on groundwater pumping, some researchers have suggested intelligently combining electricity supply restrictions with suitable adjustments in electricity pricing as a possible solution to restricting groundwater withdrawal and in lowering the rate of fall in the water table. In a comprehensive analysis of the issues involved, Shah[2] et al. (2003) have suggested that the flat-tariff option, combined with intelligent power supply rationing, is a logical, viable alternative that could cut wasteful groundwater extraction and reduce power use in groundwater extraction. The approach involves: (1) gradually raising flat tariffs to cut power utility losses; (2) supplying farms with fewer hours of power per year, but ensuring a quality power supply during periods of moisture stress; and (3) metering at the feeder level to measure and monitor farm power use, to allow better management of agriculture power supply and use. Pitching for a flat rate tariff setting the authors argue that "the metered and flat-tariff regimes are not simply alternative pricing policies—they are completely different business philosophies." Using a metered tariff, a power utility can, of course, recoup its costs and supply the customers with as much power as they want, when they want it. The flat tariff, by contrast, allows power utilities to use sophisticated management to provide a high-quality, but carefully rationed, power supply and yet remain viable. According to the authors, "the key to making a flat tariff work is supply rationing."

For example, Gujarat does not need to supply 3,000 hours of farm power per year. It can make its farmers happy (and cut its losses) by supplying only 1,200 hours, provided those 1,200 hours are made available when most needed. It is thus suggested that the rational tariff with intelligent power supply rationing to the farm sector holds out the promise of minimizing the wasteful use of both resources (water and power) and of encouraging a technical change towards water and power saving. It has been suggested that "with intelligent management of power supply, it is possible to satisfy irrigation power demand, e.g., by ensuring 18-20 hours of power a day for 40-50 key moisture-stress days in the kharif and rabi seasons (around 2 and 5 weeks, respectively)." Providing an order of magnitude figures on the likely savings in groundwater extraction and power consumption following such an approach, the authors assert: "our surmise is that such a strategy can reduce annual groundwater extraction in western and peninsular India by 12-18 km3 per year, and also reduce power use in groundwater extraction by around 2-3 billion kWh of power, valued at Rs. 40-60 billion per year" (Shah et al. 2003). It is, however, not known how practical and effective this approach is to groundwater management and, whether this approach has been tried anywhere. In a subsequent paper, Shah asserts that the 'Jyotigram Yojana', wherein the Government of Gujarat has separated the feeder line for agriculture consumers from the domestic line in some parts of Gujarat, is premised on the suggested approach to co-manage groundwater and electricity.

Other researchers (e.g., Kumar 2008, personal communication), however, do not share the perceptions of Shah on both the practicality of the suggested approach to groundwater management in Gujarat as well as the suggestion that this groundwater management approach formed the basis of 'Jyotigram Yojana'. The viability and feasibility of separating the agriculture supply network from other rural supply networks has been questioned. On the approach to groundwater, it has been argued that practically, with supply of full power for 30-40 days of

[2] See Shah (2003). Also see, Shah (2000; 1993) and Shah and Raju (1987).

the year, no crop except some very short duration ones can survive in the semi-arid and arid regions, where groundwater use is intensive. Even in winter for crops like wheat, irrigation is required for more than 90 days as the crop water demand is more or less evenly distributed over the season. This is because there is a significant time lag (nearly 30-45 days) between the farmer who does sowing first and the one who does sowing last. Also, at a given point of time, macro-level power rationing cannot simulate the micro-level demand, which varies from farmer to farmer depending on the area irrigated, crop type, date of sowing, climate etc. Kumar also argues that the main idea behind 'Jyotigram Yojana' was to boost and vitalize rural small industries with 24-hour supply of good quality 3-phase power for the domestic sector. Fearing that it would encourage farmers to run their agro-pumps round the clock, the GEB separated the feeder line for agriculture from the domestic one. It continues to ration the power supply to agriculture to about 8 hours per day throughout the year as it has been doing for more than 2 decades now. And, there has been no change in the power supply hours.

This Yojana seems to help only the farmers in some places (in alluvial areas with plenty of groundwater), who used to indulge in power theft using converters, use power beyond the official supply hours, and stopped power theft with feeder line separation. But, they are now using higher capacity pumps to abstract more water, and are often under-reporting the 'connected load'.[3] In any case, in the hard-rock areas, the power rationing is unlikely to have any impact either way. In these areas, the open wells and bore wells yield 3-4 hours, and farmers do not need power for several hours. Hence, it does not matter even if GEB 'reduces' the supply to 8 hours per day. In fact, contrary to the findings of Shah, after Jyotigram, the groundwater draft in Gujarat has gone up substantially, if GEB data on electricity use in the farm sector is any indication. Again, the reason is more groundwater is available for pumping owing to good monsoons. Kumar also opines that the suggested approach, though not helping to solve the problem of over-draft, would, at the same time, make access to groundwater more inequitable. The reason is that the rich farmers would find ways to overcome the constraints of reduced power supply hours and would eventually increase their monopoly power, but it is the resource-poor farmers who would bear the brunt.

Need for Metered and Progressive Power Pricing

While it is important to combine power pricing with supply regulations, it is necessary for power pricing to be based on progressive rates rather than fixed and flat rates. This is in view of the serious limitations of flat rates in managing groundwater draft. In a critical examination of the groundwater management approach based on flat rates suggested by Shah et al. (2003), Bhatia (2007) argues that flat rate tariff combined with rationing of power may not be the ideal way to make optimum use of scarce resources. Bhatia's articulates his reservations on the following counts.

[3] In a subsequent communication Dinesh Kumar (personal communication dated June19, 2008) suggests that on the basis of field work undertaken in North Gujarat, heavy theft of electricity in the region through under reporting of the connected load and the use of Thetta continues. In fact, UGVCL has been running into heavy losses during the past 2-3 years. The estimated loss in the first quarter of this year is Rs. 62 crores.

Opportunity Costs of Peak Power

It is important to recognize that the 'allocation' of power to the agricultural sector has to be seen in a 'power systems' perspective and also take in to recognition the opportunity cost of allocating power to agriculture during the peak periods (during the day or season). Allocating 18-20 hours of power a day for 40-50 days in a year will deprive other users of this critical power for their priority uses during these periods. While it is difficult to estimate the 'opportunity cost' of this type of management of power, the 'benefits foregone' in alternative uses may be so high that from a societal perspective the allocation of power to agriculture may not be an optimum use of the scarce peak power. Alternatively, the costs of coping strategies for users other than agriculture may be so high that this will raise the total system costs to a high level.

Revenue Loss

In the ongoing power sector reform process, it would not be possible to ensure that farmers will get the power that they need, at the time when they need it because that will be against the philosophy of revenue maximization that is being suggested for power supply companies. Accepting the system of flat rates for electricity use will provide incentives to managers in the power sector to 'minimize' supply of power to the agricultural sector as the revenue from an additional unit of electricity will not only be negative but will reduce the total revenue for the power company. Under a flat rate tariff system, the power supply to agriculture during the peak period is likely to be reduced by about 50 % of the power availability from the current level.[4] This will result in the type of 'de-electrification' that occurred in the East UP during the 1980s and 1990s (Shah 1993; 2000), since power distribution companies will avoid supplying power to the farm sector.

Centrality of Metered Tariffs in Power Reform

In a large number of states, state electricity regulatory commissions (SERCs) have been set up as a part of the reforms process to rationalize tariffs and improve the power supply. Some of these SERCs have mandated/suggested the installation of meters for all consumers. Flat rate tariffs will go against the mandated requirements imposed by the SERCs. Reducing subsides through raising flat rates will be politically unacceptable, since this will involve raising fixed rates to very high levels. For example, to comply with the demands from the Gujarat Electricity Regulatory Commission., Gujarat's board intends a 350 % price-hike on the supply of power to the farmers, raising the annual charge from Rs. 500/hp (unchanged since 1989) to Rs. 1,700/hp and, eventually to Rs. 2,100/hp (Shah et al. 2003).

Equity Implications

Although small and marginal farmers generally operate pumps with lower hp in absolute terms, there appears to be an inverse relationship between farm size and the horsepower per hectare of gross cropped area, which small farmers tend to invest in higher hp per unit of cultivated area relative to large farmers. As a result the flat rate tariff structure of electricity pricing, where farmers pay on the basis of installed hp rather than on the basis of per unit

[4] It is difficult to get data on how much of the power used in agriculture takes place during the peak period. This figure of 50 % is from the IWMI-Tata studies.

consumed, becomes regressive in nature. As against this regressive tariff structure under the flat rate system, electricity regulatory commissions may devise 'life-line rates' under metered tariffs for some categories of users (up to a given level of electricity consumption).

Administrative Problems

Like metered tariff systems, flat rate tariff systems too are not free from administrative problems. For example, in a recent study (World Bank 2001) of the flat rate system in Haryana, a number of problems have been noted including the detection of illegal connections and the presence of discrepancy between the hp record of the utility and the actual pump size hp. The readings of 78 electronic meters installed on agricultural pump-sets showed that, on average, the actual connected load is about 74 % higher than the official utility record. The implementation of unmetered tariffs is seen to result in a significant loss of revenue for the utilities due to under-reporting of the actual capacity of pumps by farmers. This tends to allow the utility staff discretion in how they monitor and verify the capacity of pump-sets in the field at regular intervals, which may in turn result in increased collusion between consumers and utility staff and ultimately lead to corruption.[5]

Conservation Incentives

In the flat rate system of electricity pricing, once the user pays the charges as per pump capacity, the marginal cost of electricity for operating the pump-set is zero, and the farmer can pump more water subject to availability of power and water. In areas of relative water abundance (e.g., east U.P., Bihar, Orissa and West Bengal), this may be a good thing since additional water supplies can be used for irrigating crops on the farm or water may be sold to farmers who do not own electric motors. However, in areas of relative water scarcity (western India and peninsular India), this will create problems since there is no incentive for energy (and groundwater) conservation.

Based on the points noted above, Bhatia (2007) argues that for energy regulations to be an effective indirect means for groundwater management, power supply regulations should be combined with metered rather than the flat rate electricity tariff. When electricity is metered, farmers would learn the real cost of power and water and be forced to economize on their use. Plus, the power utilities would gain valuable information on actual power usages (essential for efficient management and cutting commercial losses). Furthermore, in addition to charging for electricity based on metered consumption, innovations in metering (including 'Smart Cards') and charging for power consumption should be scaled-up so that charging separate tariffs for peak and off-peak power is possible. Efforts should be made to have a politically acceptable solution where off-peak power is charged at very low rates (to cover marginal cost of supply) and peak power is charged at its opportunity cost, which may be higher than its cost of supply. This will provide the right price signals to consumers to use power when it is most valuable for them. Also, it will maximize the revenues of producers since they will allocate power where it brings best value.

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[5] In the Haryana study (World Bank 2001), under the farmers' attitude survey, it was found that about 69 % of farmers surveyed favored metered supply. According to HVPN these statements by farmers are not confirmed by their actual practices in reality, because the metered connections have decreased from 107,000 in 1996 to 74,000 in 2000, compared to unmetered connections that have increased over the same period from 267,000 to 285,000.

Coupled with these efforts, Bhatia (2007) suggests that innovations in institutional mechanisms for power distribution in agriculture (e.g., making village Panchayats responsible for power distribution) should be tried. Bulk power could be supplied to persons (as in China) or community organizations and they, in turn, can be responsible for its distribution and collection of revenues. As a part of the Orissa power sector reforms, village committees were setup in a number of villages to facilitate interaction between utility and consumers, redressing grievances, bill distribution, and metering and cash collection. Such village committees are expected to perform like a cooperative where they will be billed based on the transformer readings, and the entire responsibility for collection will be transferred to them. In Gujarat, a MOU has been signed among GEB, GERC and IRMA for the pilot project, which has been given to IRMA for a feasibility study and for identification of co-operatives in each of the five zones of GEB, so as to facilitate the handing over of the distribution system to local bodies/ consumer co-operatives. According to Shah et al. (2003) there are also institutional solutions to this that are not receiving sufficient attention. In the early decades of this century, USA resolved this problem by promoting Rural Electricity Co-operatives (RECs); India also tried these in the 1960s but only half-heartedly. RECs are interesting because they target precisely the problem that makes power supply to South Asian agriculture costly and unprofitable. If the village buys power in bulk and retails it to its members, the transaction costs of power supply can be reduced dramatically.

Way Forward

Sustainable management of groundwater is a key challenge in a large number of countries facing overexploitation of groundwater. Given the strong linkages between groundwater and energy, energy management obviously holds an important, though definitely not the sole, key to face this challenge. Although the debate on the efficacy of energy management in controlling groundwater overdraft continues, recommended policy alternatives, as discussed above, have tended to be ineffective. Several additional complementary policy measures suggested for regulating groundwater overdraft, such as enacting and enforcing groundwater laws, establishing clear tradable property rights of water, pricing of groundwater, installing licensing and permit systems, have also not proved to be effective in checking groundwater overdraft. Saleth (1997) opines that even an imperfect system of water rights will have much more sustainable benefit than the most perfectly designed but ineffective instruments. While nobody disagrees with the need for some measures, nothing has yet worked on the ground, and as a result the groundwater situation continues to degenerate from bad to worse.

It is important to underline that mere availability of groundwater coupled with sufficient or insufficient availability of energy on the one hand, and availability or non availability of subsidies on energy for groundwater pumping on the other hand, does not constitute a sufficient condition for either extraction or overextraction of groundwater. It is the return from the use of the groundwater that primarily drives its extraction, though prevailing energy prices themselves may, in part, determine the profitability from the use of groundwater. If the cost of groundwater extraction at unsubsidized energy prices is uneconomical, provision of subsidies may help in bridging this gap and encourage groundwater extraction. If, however, the extraction of the groundwater at unsubsidized, prices is economical, the subsidy on energy prices may increase the returns from the use of groundwater not necessarily only by the amount of the subsidy on electricity, but by a much larger amount, if the subsidy encourages shifts in cropping patterns.

The current situation of overextraction of groundwater in many regions obviously has occurred, because the yield derived from the use of groundwater is more than the cost of its extraction. The yield derived from the use of groundwater cannot, however, be attributed as the yield of groundwater as groundwater is one among many other factors acting either independently or jointly in conjunction with several other factors, which culminate in determining this return yield. There is, however, no denying the fact that water productivity in groundwater irrigation is higher than that in surface irrigated and rain-fed areas. Given the multiplicity of factors determining the yield of groundwater irrigated areas and returns from the use of groundwater, it is not surprising that energy management policies per se either via manipulation in energy prices or supply controls, as discussed above, may have made limited or possibly no impact in farmers' decision regarding limiting the extraction and use of groundwater to sustainable levels. As such, they are unlikely to contribute towards a meaningful solution to overextraction and excessive groundwater irrigation. When groundwater use is influenced by a multiplicity of factors, it is clear that no single factor can alter the nature of groundwater use. Saleth (1997) also concludes that power tariff policy alone cannot be an effective tool for achieving efficiency, equity and sustainability in groundwater use.

Efforts aimed at controlling groundwater extraction, to bring it closer to sustainable levels of development, have to be made simultaneously on a number of fronts, including through development and more intelligent execution of policies – supply, pricing, regulatory, participatory - affecting groundwater-energy nexus. Perhaps a change in demand behavior of agricultural users, brought about through encouragement of shifts in cropping patterns in favor of less water using crops, can play a more important role in bringing down the level of groundwater extraction. This would, however, require action on a number of fronts. The first, and most important, is demystifying the science of groundwater hydrology and empowering groundwater users at the micro-level to understand the dynamics of groundwater availability, the process and sources of groundwater recharge, and the sustainable level of groundwater yield available for use in a year. This would create a much better appreciation of the problem at the ground level and create awareness and a need for conserving groundwater, and prepare the basis for introduction/adoption of new crop varieties, which are less water intensive and/or for better ways of water application, without any shifts in the crops cultivated or sacrificing the crop yields. It could, additionally, lay the basis for bringing in shifts in cropping pattern towards less water intensive crops. Encouraging such shifts in the cropping pattern, however, would require engineering shifts in relative crop profitability in favor of crops intended to be introduced. Apart from other factors, this would require interventions on two important issues: 1) realignment in output pricing policies; and 2) ensuring market support for the new crop.

To substantiate the relevance of the two factors listed above, it is important to cite an example. Concerned by declining groundwater tables, several half-hearted interventions have been made in different states in India to bring about shifts in cropping pattern towards less water using crops. For example, a few years ago, in Haryana, cultivation of sunflower as a substitute for paddy was encouraged to conserve groundwater. Due to the relatively higher profitability of sunflower, a small number of farmers responded to this initiative and shifted partly from cultivation of paddy to sunflower. The next year, through the demonstration effect, some more farmers followed suit. In the following year too, some more farmers made these shifts in their cropping pattern. As a result of increased production, and lack of market support, the output prices crashed and relative crop profitability again tilted in favor of paddy. The farmers again switched back to cultivation of paddy and, thus the efforts aimed at conservation of groundwater through shifts in cropping pattern ended.

Hence, given the importance of a large number of factors in influencing extraction and use of groundwater, efforts aimed at promoting more sustainable use of groundwater must take a system's view of the situation and not try to limit solutions to only those arrived at through improved management of groundwater-energy interactions, though improved management of groundwater-energy nexus will continue to be central to any other complementary strategy adopted. Given the differentials in ownership and access to different factors of production by different categories of households, any interventions aimed at promoting more sustainable use of groundwater must evaluate the differential implications such an intervention makes on different sections of the society, and the trade-offs involved in conserving groundwater vs. food security, environmental sustainability and other social impacts.

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Water Saving Technologies as a Demand Management Option: Potentials, Problems and Prospects

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Introduction

Studies from different countries including India have corroborated that irrigation plays a paramount role in increasing the use of yield increasing inputs and enhancing cropping intensity as well as productivity of crops (Dhawan 1988; Vaidyanathan et al. 1994). Irrigation development also helps to increase employment opportunities and the wage rate of the agricultural landless laborers, both of which are essential to reduce poverty among the landless labor households (Narayanamoorthy 2001a; Bhattarai and Narayanamoorthy 2003; Narayanamoorthy and Deshpande 2003; Saleth 1997; Saleth et al. 2003). Nevertheless, water is becoming increasingly scarce worldwide due to various reasons (Rosegrant et al. 2002). With the fast decline of irrigation water potential and continued expansion of population and economic activity in most of the countries located in arid and semi-arid regions, the problems of water scarcity are expected to aggravate further (see, Biswas 1993 and 2001; Rosegrant 1997; Rosegrant et al. 2002). Macro-estimates carried out by the International Water Management Institute (IWMI) indicate that one-third of the world population would face absolute water scarcity by the year 2025 (Seckler et al. 1998 and 1999). The worst affected areas would be the semi-arid regions of Asia, the Middle-East and sub-Saharan Africa, all of which are already having heavy concentrations of population living below the poverty line.

Though India has the largest irrigated area in the world, many regions are already reeling under severe water scarcity problems, partly because of the inefficient use of water. Owing to various reasons, the demand for water for different purposes has been continuously increasing in India, but the potential water available for future use has been declining at a faster rate (Saleth 1996; CWC 2004). The agricultural sector (irrigation), which currently consumes over 80 % of the available water in India, continues to be the major water-consuming sector due to the intensification of agriculture (see, Saleth 1996; MOWR 1999; Iyer 2003). In spite of having the largest irrigated area in the world, the coverage of irrigation is only about 38 % of the gross cropped area as of today in India. One of the main reasons for the low coverage of irrigation is poor water use efficiency under the flood (conventional) method of irrigation, which is predominantly practiced in Indian agriculture. Available estimates indicate that water use efficiency under the flood method of irrigation is only about 35 to 40 % (Rosegrant 1997).

Considering the availability of water for future use and the increasing demand for it from different sectors, a number of demand and supply management strategies have been introduced in India to augment the supply as well as to control the demand for water. One of the demand management strategies that was introduced recently to control water consumption in Indian agriculture is the drip method of irrigation (DMI). Unlike the flood method of irrigation, drip method supplies water directly to the root zone of the crop through a network of pipes with the help of emitters. Since it supplies water directly to the crop and not to the land as followed in the flood method of irrigation, the water losses occurring through evaporation and distribution are completely absent (INCID 1994; Narayanamoorthy 1996; 1997; 2001; Dhawan 2002). The on-farm irrigation efficiency of a drip irrigation system that is properly designed and managed is estimated to be about 90 %, while the same is only about 35 to 40 % for the surface method of irrigation (INCID 1994).

Objectives, Scope and Data

Among the various reasons for the slow progress made in the adoption of this new technology, its capital-intensive nature seems to be one of the main deterrent factors. Drip irrigation technology requires fixed investment that varies from Rs. 20,000 to Rs. 55,000 per hectare depending upon the nature of crops (wide or narrow spaced) and the material to be used for the system. Since the Indian farmers have been getting water at a low cost from the public irrigation system and also from well-irrigation (because of the introduction of flat-rate electricity tariff), there is less incentive for them to adopt this capital-intensive technology unless it is absolutely necessary. Moreover, since it involves fixed investment, farmers often ask questions like what will the water saving and productivity gains be? Is investment on drip irrigation economically viable? What will be the pay back period of the drip investment? These issues are raised because of the lack of sufficient credible field- based studies on DMI covering different regions of the country. Some of the studies have shown that the results derived from research station data are substantially different from that of survey data (see, Narayanamoorthy 2001).

In the absence of reliable field studies, it is difficult to judge the actual economic viability of drip method of irrigation (DMI). Keeping in view the various issues of drip method of irrigation, an attempt is made in this paper to review the adoption and impacts of water saving technology namely, drip method of irrigation in India using secondary data and available case studies. Specifically, the study discusses (a) the scope and rationale for the adoption of water saving technologies; (b) the government policies and programs being pursued to promote this technology; (c) the nature and extent of their actual adoption in different regions and cropping systems; (d) its impacts in terms of water saving and crop productivity; (e) economic viability of drip investment; and (f) the major issues and questions that require attention for future research and policy.

Data for this study has been used mainly from secondary sources published by government and other agencies, particularly, reports of the Indian National Committee on Irrigation and Drainage (INCID), the Central Board of Irrigation and Power (CBIP), the National Committee on Use of Plastics in Agriculture (NCPA) and the report of the Task Force on Micro-Irrigation (TFMI). In order to explain the farm-level issues and the position of drip method of irrigation, the author's own studies on three different crops namely, sugarcane, banana and grapes, which were carried out in Maharashtra (an advanced state in terms of using drip irrigation) and Tamil Nadu, have been utilized (Narayanamoorthy 1996; 1997; 2001; 2005).

Water Saving Technologies: Rationale and Scope

The primary objective of introducing DMI is to reduce water consumption and increase water use efficiency in agriculture. However, it also delivers many other economic and social benefits to the society. Reduction in water consumption due to the drip method of irrigation over the surface method of irrigation varies from 30 to 70 % for different crops (INCID 1994; Narayanamoorthy 1997; Postal et al. 2001). According to data available from research stations, productivity gain due to drip method of irrigation is estimated to be in the range of 20 to 90 % for different crops (see INCID 1994). While increasing the productivity of crops significantly, the system also reduces the cost of cultivation substantially, especially in labor-intensive operations. The reduction in water consumption in drip method of irrigation also reduces the energy use (electricity) that is required to lift the water from irrigation-wells (see Narayanamoorthy 1996; 2001).

A few studies have been carried out focusing on the impact of the drip method of irrigation on various parameters in different crops over the last 10 years or so. Studies, by and large, have focused mainly on the impact of the drip method of irrigation on water saving, including water use efficiency, productivity of crops and cost of cultivation. While some have studied the impact of DMI on electricity saving, others have studied its economic viability in different crops, using both experimental and field survey data. Results of experimental data reported in INCID (1994) show that water saving in DMI over the method of FMI varies from 12 to 84 % in different vegetable crops. In the case of fruit crops, the lowest water saving was found to be 45 % (pomegranate), whereas the highest water saving is estimated to be 81 % (lemon). Water saving was also found to be 65 % in sugarcane and about 60 % in coconut. As in the case of INCID results, various studies reported in CBIP (1998 and 2001) also indicate a similar level of water saving in different crops. Similar to experimental data, studies carried out using field level data in Maharashtra also show that the water saving due to DMI is about 29 % in banana, 37 % in grapes and about 44 % in sugarcane (Narayanamoorthy 1996; 1997 and 2001).

Though DMI increases the crop productivity and saves a substantial amount of water, it requires relatively larger fixed investment to install the system in the field. Therefore, some studies have attempted to find out whether the investment in drip irrigation is economically viable or not in regard to different crops. While some have estimated benefit-cost ratio including water saving as well as excluding water saving (INCID 1994), others have estimated benefit-cost ratio and net present worth both with and without a subsidy condition (Narayanamoorthy 1997; 2001; 2004). The benefit-cost ratios provided for different crops in INCID (1994) indicate that investment in drip irrigation is economically viable, even after excluding water saving from the calculation. The estimated benefit-cost (B-C) ratio comes to 13.35 in crops like grapes and 1.41 in the case of coconut. However, it is not clear whether the B-C ratios presented in INCID (1994) are estimated using discounted cash flow technique or not. Unlike INCID estimates, using discounted cash flow technique and that too, utilizing field survey data covering three crops namely, grapes, banana and sugarcane, Narayanamoorthy (1997; 2001;

2004) estimated B-C ratio and net present worth. The results of these studies suggest that the investment in drip method of irrigation is economically viable even without a subsidy.

In spite of having many economic advantages over the method of flood irrigation, the coverage of area under drip method of irrigation is not appreciable in India except for a few states as of today. The area under DMI has increased from a mere 1,500 ha in 1985 to 70,859 ha in 1991-92 and further to 500,000 ha as of March 2003 (INCID, 1994; GOI, 2004). India has enormous potential for DMI. INCID (1994) report, which presents an overview about the development of drip irrigation in India, indicates that about 80 crops, both narrow and widely spaced crops, can be grown under DMI. Although DMI is considered to be highly suitable for wide-spaced and high-value commercial crops, it is also being used for cultivating oilseeds, pulses, cotton and even for wheat crops (INCID 1994). Importantly, research suggests that DMI is not only suitable for those areas that are presently under cultivation but it can also be operated efficiently in undulating terrain, rolling topography, hilly areas, barren land and even in areas which have shallow soils (Sivanappan 1994).

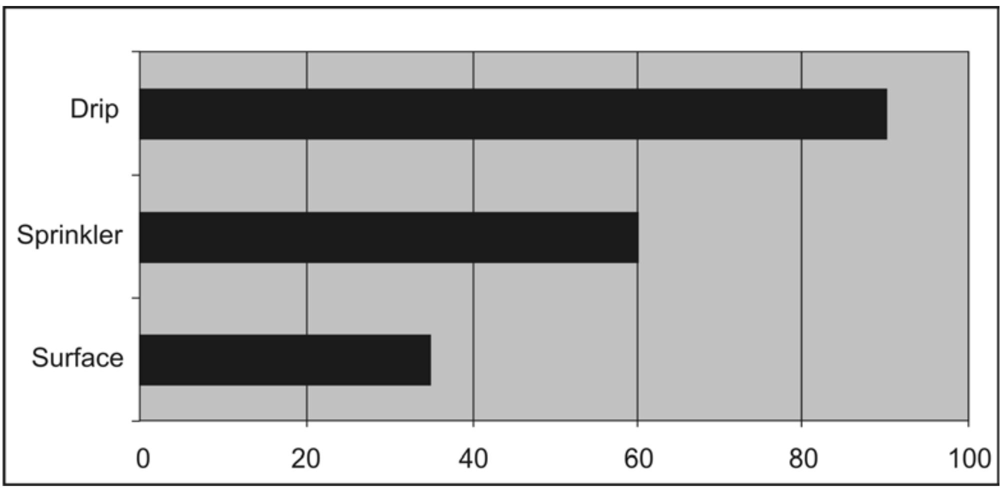
Role of Water Saving Technologies in Demand Management

Given the fast decline of irrigation water potential and increasing demand for water from different sectors, there is a need to conserve and increase the efficiency of water use so as to avoid a water crisis in the future. Drip irrigation technology is proved to be an important water-saving technology and, therefore, there are many justifiable reasons for adopting drip method of irrigation in countries like India. Some of these reasons are related to water availability and capital cost of irrigation, while others are related to production and productivity of crops, etc. The first and foremost reason for adopting DMI is the fast decline of irrigation water potential and growing demand for irrigation water. Up to 2001-02, about Rs. 1,360.65 billion (in current prices) have been spent exclusively for the development of irrigation by the government sector alone. As a result of this, area under irrigation has increased from 26.61 mha in 1950-51 to 86.67 mha in 1996-97, an increase of 2.60 % per annum. Despite the substantial increase of area under irrigation, the share of irrigated area to gross cropped area is only about 40 % as of today.

One of the main reasons for the limited expansion of area under irrigation is the predominant use of flood method of irrigation (FMI) for cultivating crops, where water use efficiency is very low due to various reasons. Water use efficiency under flood method of irrigation is estimated to be only around 40 % mainly due to huge losses through evaporation, conveyance and distribution (Sivanappan 1994; Rosegrant 1997; Rosegrant and Meinzen-Dick 1996). Unlike FMI, water use efficiency can be achieved over 90 % in DMI (see, Figure 1). Since water is supplied directly to the root zone of the crops using pipe network under DMI, the evaporation and distribution losses are completely absent under this method. Though FMI has been followed predominantly all over the world for cultivating crops, it is no longer desirable for countries like India, mainly due to the limited availability of water resources and growing demand for water for irrigation and other purposes. Therefore, for achieving sustainable agricultural development, it is essential to increase the existing water use efficiency for which drip method of irrigation can be one of the viable options.

India has the largest irrigated area in the world, but its water potential available for the future use of irrigation has been declining at a rapid pace since independence owing to various reasons (Saleth 1996; CWC 2004). As per the estimate of the Central Water Commission (CWC 1996; 2004), India's total irrigation potential is 139.9 mha. Of this total, about 58 mha (41.46 %) can be utilized from major and medium irrigation (MMI) sources and about 81.40 mha (58.54 %) can be utilized from minor irrigation (MI) sources. Up to 1999-2000, we have created about 94.73 mha of irrigated area, which accounts for about 67 % of the total potential (see, Table 1). Researchers have been cautioning that any additional creation of irrigation facility by constructing new major irrigation projects would not only require a huge cost but would also create adverse environmental problems (Singh 1997). However, considering the growth of population and the requirements of foodgrains in the future,[1] there is a need to increase the area under irrigation. One of the options available before us is increasing the existing water use efficiency in all sources of irrigation. Though many programs have been introduced to improve the existing water use efficiency under FMI, they have not been successful in bringing about the desired results up to now.[2]

Figure 1. Irrigation efficiency (in percentage) by irrigation methods.



[1] The Report of National Commission for Integrated Water Resources Development (1999) points out that India will require 320 million tonnes of foodgrains to feed a population of 1,333 million people in the year 2025 and 494 million tonnes of foodgrains to feed a population of1, 581 million people in the year 2050.

[2] Command Area Development (CAD) Program was introduced during the fifth 5-year plan with the aim of reducing the gap between the irrigation potential created and utilized. However, this program could not make any significant breakthrough in achieving its objectives and the gap between irrigation potential created and utilized has been increasing. The amount of money spent on CAD program was about Rs. 11,530.30 crore up to the 10th plan.

Table 1. Irrigation potential and utilization in India: Up to 1999-2000.

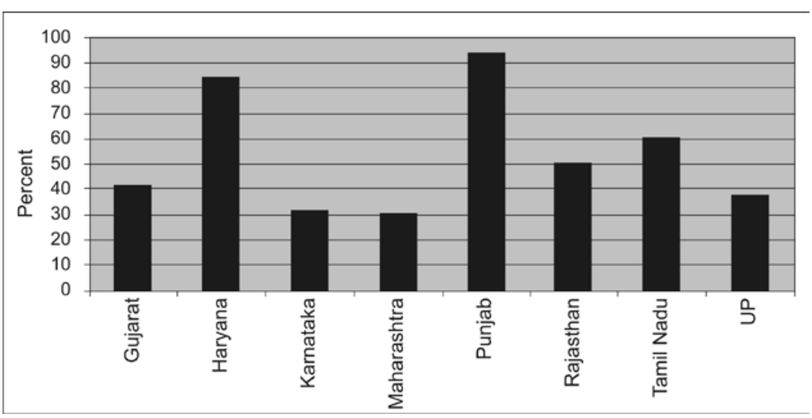
Particulars (1)	Potential (2)	Created (3)	Utilized (4)	(3)/(2) x 100 (5)	(4)/(3) x 100 (6)
MMI	58.50 (41.82)	35.35	30.47	60.43	86.20
MI:					
(a) Surface	17.40 (12.44)	12.26	10.86	70.46	88.59
(b) Groundwater	64.00 (45.75)	45.59	41.93	71.23	91.97
(c) Total	81.40 (58.18)	59.38	54.23	72.95	91.33
Total (MMI+MI)	139.90 (100.0)	94.73	84.70	67.71	89.42

Sources: CWC (1998 and 2002)
Notes: Bracketed figures are percentage to total; MMI – Major and Medium Irrigation; MI – Minor Irrigation

The irrigation potential available for future use has also been declining in many states. In fact, the condition is precarious in agriculturally advanced states like Punjab, Haryana and Tamil Nadu. The irrigation potential created to the total potential of MMI up to the ninth plan ranges from 69 to 103 % in states like Haryana, Punjab and Tamil Nadu. Similarly, the irrigation potential created to the total potential of MI also varies from about 53 to 123 % in states like Haryana, Punjab, Rajasthan, Gujarat, Maharashtra, Tamil Nadu and Uttar Pradesh (see, Narayanamoorthy 2002). Further exploitation of water through MMI and MI sources from these states certainly would create adverse environmental problems. Therefore, cultivating crops with the flood (conventional) method of irrigation is no longer desirable.

The state of groundwater is also precarious. The available groundwater for the use of irrigation has also been steadily declining in most of the agriculturally advanced states. The New Agricultural Technology (NAT) introduced during the mid-1960s has significantly increased the demand for irrigation water, which ultimately resulted in overexploitation of groundwater in many parts of India. Again the principal reason for the overexploitation of groundwater is the predominant cultivation of water-intensive crops under the flood method of irrigation. A recent state-wise estimate on groundwater potential and utilization has shown that the use of groundwater is going beyond the socially acceptable limit in many agriculturally advanced states (see, Figure 2). As a result of this, there is tremendous pressure on water resources now more than ever before, but the quantum of available water is fast declining.

Figure 2. Groundwater development in India: Selected states.



Another important reason for adopting WST in India is to reduce the ever increasing capital cost of surface irrigation development. A massive investment has been made exclusively for the irrigation development in India by the public sector over the years. As a result of this massive investment on irrigation, the total area under irrigation has increased from 22.61 mha in the pre-plan period (1950-51) to 86.26 mha in 2001-02. Though the massive investment on irrigation was justified by many experts in view of the nature of the Indian economy, capital cost required to create one hectare of irrigation has increased substantially, especially after the fifth 5-year plan. For instance, the requirement of investment (in current prices) for creating one hectare of irrigation in the MMI sector was only Rs. 1,513 in first 5-year plan, but the same increased to over Rs. 2,37,729 in 2001-02 (Gulati et al. 1994; Narayanamoorthy and Kalamkar 2004). One of the main reasons attributed for this huge increase in the requirement of investment per hectare is that the new irrigation projects are more capital intensive, as most of the easily available potential has already been exploited (Vaidyanathan 1999; Gulati et al. 1994).[3] Besides involving higher financial investment, the major irrigation projects are also capable of creating many social and environmental problems (Singh 1997; Rosegrant 1997).[4] Though drip method of irrigation is a capital-intensive technology, its capital requirement per hectare is relatively less when compared to the same required for MMI projects. In addition to this, the operation and maintenance costs of MMI projects have also been increasing due to various reasons (Gulati et al. 1994). Though drip irrigation cannot be a substitute for MMI projects, the cost-related problems associated with the large irrigation projects could be reduced to some extent by adopting drip method of irrigation at a large scale.

Third important reason for adopting WST is to increase production and productivity of agricultural commodities. Although the new agricultural technology has helped to increase production of food grains impressively from about 72 million tonnes in 1965-66 to over 211 million tonnes in 2001-02, the achievement in production of non-food grain commodities such as oilseeds, vegetables, fruits, etc, is not very impressive (Kumar and Mathur 1996).[5] Despite various efforts made by the policymakers, production (supply) of non-food grains is much less when compared to the domestic demand (Kumar and Mathur 1996). This has forced the government to import these commodities from other countries to meet the domestic requirements. Since most of the non-food grain crops mentioned above are cultivated predominantly under rain-fed conditions, where moisture stress is common, production of these commodities could not be increased to a desired level. Unlike FMI, the crops cultivated under DMI do not face any moisture stress as water is supplied on a continuous basis at the required level. The yield increasing inputs (e.g., fertilizers) applied for crops cultivated under the flood method of irrigation also do not fully reach the crops, due to leaching and other reasons. As fertilizers (liquid) can be supplied through water (which is called fertigation), the loss of fertilizers by way of leaching and evaporation is very less, hence high-level input

[3] The cost of irrigation per hectare in real term has also substantially increased over the years. The reasons for increasing real capital cost of new irrigation projects in different countries are discussed in Rosegrant (1997).

[4] It is reported by studies that though the benefits from Sardar Sarovar Dam (SSD) are large, the environmental and human costs of construction of dam are also estimated to be large. Some estimates indicate that SSD would flood about 37,000 hectares of forest and farmland (Rosegrant 1997).

[5] Even in cereal production the position is not very comfortable. Recent estimates relating to future demand and supply of cereals show that India will have cereal deficits of 36 to 64 million tonnes per year by 2020. A detailed account on India's cereal supply and demand is available in Bhalla et al. (1999).

use efficiency is possible under DMI. Since both moisture level and input use efficiency are maintained at a higher level under the drip method of irrigation, productivity of crops cultivated under the drip method of irrigation is significantly higher than those crops cultivated under FMI.

The production of foodgrains and other agricultural commodities have to be increased keeping in view the pace at which the population increases. The growth in foodgrains productivity was already very low during the 1990s (1.52 % per annum) when compared to the growth in the 1980s (2.74 % per annum)—(GOI 2002). Experience indicates that production of foodgrains also goes down sharply whenever fluctuations occur in rainfall. New areas with irrigation facility need to be brought under cultivation so as to avoid this problem. With the limited irrigation potential, creating irrigation facilities through MMI projects would cost more for the exchequer and also take a longer gestation period. Using the already exploited irrigation potential, the area under irrigation can be expanded further if drip method of irrigation is followed, as it requires less water when compared to flood method of irrigation.[6] Apart from water saving and productivity-related reasons, large-scale adoption of WST would also solve the ever increasing problems of electricity (energy) scarcity, waterlogging and other environmental problems, all of which one way or the other are associated with the present conventional method of irrigation.

Promoting Water Saving Technologies in India

Since drip method of irrigation is a new technology in India, introduced relatively recently, government-supported promotional programs have been in operation since the sixth plan. In fact, the promotional programs have made significant impact on the adoption of drip irrigation in India over the years, especially in states like Maharashtra and Andhra Pradesh, both of which are operating specific state supported schemes for promoting drip method of irrigation. Drip method of irrigation was introduced in India during the early 1970s at the Agricultural Universities and other Research Institutions. The scientists at the Tamil Nadu Agricultural University (TNAU), Coimbatore, who are considered to be the pioneers in drip irrigation research in India, have conducted large-scale demonstrations in farmers' fields for various crops, which received encouraging responses from the farmers (INCID 1994). However, the adoption of drip method of irrigation was very slow till the mid-1980s, mainly because of the lack of promotional activities from the State and Central Governments.

The formation of the National Committee on the Use of Plastics in Agriculture (NCPA) by the Ministry of Petroleum, Chemicals and Fertilizers, Government of India, during 1981 under the Chairmanship of Dr. G. V. K. Rao is termed as the first milestone for the development of micro-irrigation in India (GOI 2004). With the establishment of 17 different Plasticulture Development Centers (PDCs) across different agro-climatic regions in the country, the NCPA has played a crucial role in the technological development of micro-irrigation in India.[7] Besides recommending policy measures to the government, the NCPA also played an important role in

[6] According to an estimate of the World Bank, with a 10 % increase in the existing water use efficiency, India could add 7-8 mha of irrigated area without utilizing additional water resources (World Bank 1998).

[7] NCPA was later renamed as the National Committee on Plasticulture Applications in Horticulture (NCPAH) due to the prominent role plasticulture plays in the productivity of horticultural crops.

promoting drip method of irrigation through conducting seminars focusing on micro-irrigation and its beneficial impact (GOI 2004).

Apart from the government efforts, some research institutes and private drip set manufactures have also been playing an important role in promoting drip method of irrigation in India. For instance, The Report of Task Force on Micro Irrigation mentions "Jain Irrigation Systems Ltd., Jalgaon has been playing a pioneering role since its inception in 1989 for promoting micro irrigation" (GOI 2004 — p. 124). The establishment of the Jain Irrigation Systems Limited in 1988-89 marked a watershed in the spread of this technology. Their approach was unique, committed, scientific and persistent. A 'systems approach' from concept to commissioning was adopted by them. Learning from the mistakes and the short- comings of the past, this new company undertook extensive surveys in the market, interacted with scores of customers who had installed drip irrigation systems in their fields, critically evaluated its ills and took systematic and determined steps to remove these ills. The concept, in fact, was pioneered in the country by the Jain Irrigation, Jalgaon. A decade ago, the company established a 600-acre agro-related research and development farm at Jalgaon, where experiments on various aspects related to agronomy, irrigation, water management, watershed and wasteland development are now conducted on a regular basis.

Since drip irrigation is a new technology and a capital-intensive venture, the government operates schemes for drip irrigation with a subsidy. In states like Maharashtra, both the Central and State Governments are operating schemes for promoting the drip method of irrigation. Central scheme was started during 1982-83 (during the Sixth Plan) by the Ministry of Water Resources (Minor Irrigation Division), Government of India. Through this scheme, the Government of India provided a subsidy of 50 % to the farmers with a matching contribution from the State Governments for installation of micro-irrigation devices. Of the total amount of subsidy, 75 % was allocated for small and marginal farmers and the balance of 25 % for other groups of farmers. The Government of Maharashtra has made pioneering efforts for the successful adoption of drip irrigation system. For example, to make drip irrigation cost-effective, it provided subsidies to small and marginal farmers to the extent of Rs. 2,282.35 lakhs during the period 1986-1993 (INCID 1994). As per the latest information available from the *Economic Survey of Maharashtra: 2002-03*, an amount of Rs. 432 crore (Rs. 332 for drip irrigation and Rs. 100 crore for sprinkler irrigation) have been distributed to the cultivators in the form of subsidy by the government to promote micro-irrigation up to March 2002 (GOI 2003). Central scheme for drip irrigation was also introduced in the Seventh Plan with the following modifications:

a) The non-conventional energy devices like solar pumps and windmills were excluded from this subsidy scheme, as the same were included in the other schemes operated by the Department of Non-Conventional Sources of Energy;

b) The subsidy was limited to the small and marginal farmers only, excluding other farmers from the scope of the scheme;

c) The percentage of subsidy eligible under the scheme was on par with the on-going Integrated Rural Development Program;

d) Farmers growing horticultural crops like grapes, papaya, areca nut and coconut were also eligible for the subsidy; and

e) SC and ST farmers belonging to small and marginal categories of the size of land- holding and co-operative community schemes of small and marginal farmers were provided with 50 % subsidy under the scheme.

However, the central scheme of drip irrigation did not get a good response during the Seventh Plan since the subsidy was limited to only small and marginal farmers. Furthermore, due to capital paucity this group could not afford the drip systems even at the subsided rate. After knowing the ground realities, many new measures were incorporated under the new schemes introduced during the eighth plan. Under the new schemes, the subsidy amount is limited to either 50 % of the cost or Rs. 15,000/ha, whichever is lower. The Government of India has contributed the entire 50 % of the subsidy up to the financial year 1994-95. Thereafter the state governments have contributed 10 % towards the subsidy for the years 1995-96 and 1996-97, which, in fact, added up to 50 % with the center's contribution of 40 %. However, a beneficiary can avail a subsidy for a maximum area of one hectare only.

The subsidy scheme has undergone lot of changes over the years. During the period 1999-2000, the Government of India provided assistance for installation of drip for horticultural crops at 90 % of the cost of the system or Rs. 25,000/ha, whichever is less for small and marginal, SC/ST and women farmers, and 70 % of the total cost or Rs. 25,000/ha, whichever is less for other category of farmers. Assistance was also provided for drip demonstration at Rs. 22,500 or 75 % of the system cost per hectare, whichever is less (GOI 2004). It is to be noted that the rate of the subsidy tends to vary with the schemes implemented by the state. While most of the horticulture crops are included under the subsidy scheme, water-intensive crops such as sugarcane are excluded from the subsidy scheme supported by the Central Government. However, states like Maharashtra have been providing a subsidy for the sugarcane crop, because of the increase in the consumption of water by sugarcane when cultivated under the surface method of irrigation.

Water Saving Technologies: Extent of Adoption[8]

Drip method of irrigation was initially introduced in the early 1970s by the agricultural universities and other research institutions in India, with the aim of increasing the water use efficiency in crop cultivation. The development of drip irrigation was very slow in the initial years and significant development has been achieved, especially since the 1990s. Due to various promotional schemes introduced by the Government of India and states like Maharashtra, area under the drip method of irrigation has increased from 1,500 ha in 1985 to 70,589 ha in 1991-92 and to 246,000 ha in 1997-98 (INCID 1994; AFC 1998). According to the latest information, the area under DMI is estimated to have been increased to about 450,000 hectares, which includes about 350,000 hectares covered under the Government of India Schemes (GOI 2004— p. 130). This estimate is based on the information available from GOI departments,

[8] Data availability on micro-irrigation (MI) is one of the serious constraints in India. In spite of the fact that most of the area currently cultivated under micro-irrigation is established through various government-sponsored schemes, coverage of area under MI by states, crops and farmers' category are seldom published by any single agency. This does not allow the researchers to study the trends and determinants of micro-irrigation across states in detail. It is pertinent to collect and publish the data on micro-irrigation periodically so as to strengthen the research on micro-irrigation.

which have been operating subsidy schemes for promoting the drip method of irrigation. However, as mentioned in the *Report of the Task Force on Micro-irrigation*, a large number of institutions, commercial organizations, universities, large public/private sector companies, NGOs, etc., in the country have taken up drip irrigation for their farms/crops, which does not get reflected in the data available with GOI departments. Therefore, approximately, another 100,000 hectares are covered under the drip system by these organizations, whereby the total area under the drip irrigation system in the country would be about 500,000 hectares as of March 2003 (GOI 2004— pp. 130-131).

Table 2. State-wise area under drip method of irrigation (DMI).

State	Area ('000 ha)			Percentage to Total Area		
	1991-92	1997-98	2000-01	1991-92	1997-98	2000-01
Maharashtra	32.92	122.995[a]	160.28	44.64	50.00	53.16
Karnataka	11.41	40.800[b]	66.30	16.17	16.58	18.03
Tamil Nadu	5.36	34.100	55.90	7.59	13.86	15.20
Andhra Pradesh	11.59	26.300	36.30	16.41	10.70	9.88
Gujarat	3.56	7.000	7.60	5.05	2.85	2.07
Kerala	3.04	4.865	5.50	4.30	1.98	1.50
Orissa	0.04	2.696	1.90	0.06	1.10	0.52
Haryana	0.012	1.900	2.02	0.17	0.77	0.55
Rajasthan	0.30	1.600	6.00	0.43	0.65	1.63
Uttar Pradesh	10.11	1.500	2.50	0.16	0.61	0.68
Punjab	0.02	1.100	1.80	0.03	0.45	0.49
Other States	2.127	1.150	5.40	3.00	0.47	1.47
Total	70.59	246.006	367.70	100.00	100.00	100.00

Sources:AFC (1998) and GOI (2004)

Notes: a- includes state subsidy scheme area of 58,498 ha.
b- includes area under central and state schemes for development of oil palm and sugarcane

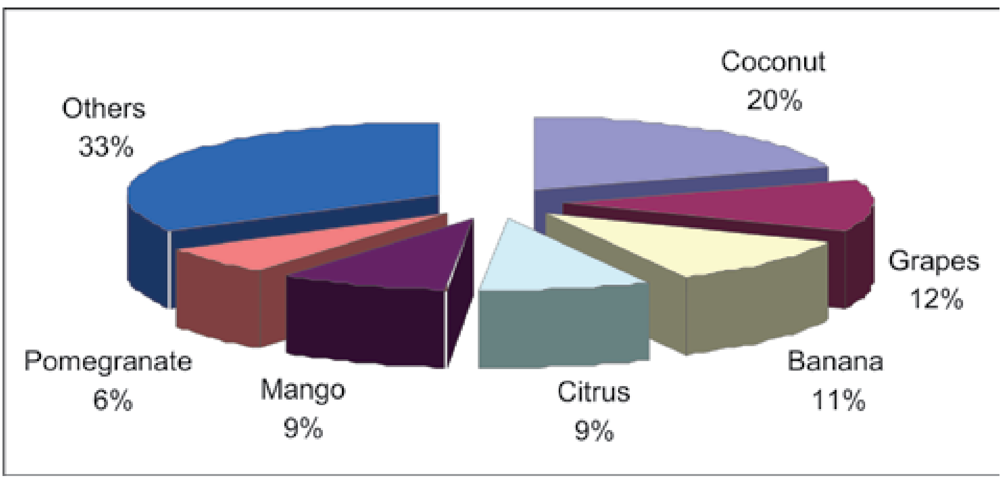
In spite of having many advantages over FMI, the development of drip irrigation does not match the expectations in most of the states. Table 2 presents state-wise area under drip method of irrigation for three time-periods namely, 1991-92, 1997-98 and 2000-01. It is evident from the table that the drip irrigated area has increased substantially between 1991-92 and 2000-01 in all the states of India. In all three time-periods, Maharashtra State alone accounted for nearly 50 % of India's total drip irrigated area followed by Karnataka, Tamil Nadu and Andhra Pradesh.[9] Over the last 10 years, significant growth has been achieved in

[9] There are many reasons for the rapid development of drip method of irrigation in Maharashtra. First, the state government is very keen in promoting drip irrigation on a large scale by providing a subsidy along with technical and extension services to the farmers. The Maharashtra Government has been providing a subsidy from 1986-87 onwards through state schemes. Second, the area under irrigation from both surface and groundwater is quite low and hence, many farmers have adopted the drip method of irrigation to avoid water scarcity, largely in divisions like Nashik, Pune, etc. Third, owing to continuous depletion of groundwater, farmers were not able to cultivate wide-spaced and more lucrative crops like grapes, banana, pomegranate, orange, mango etc., by using surface method of irrigation in many regions. As a result, farmers had to adopt drip irrigation as these crops are most suitable for it. Importantly, the farmers who adopted drip irrigation initially for certain crops have realized the importance of drip irrigation in increasing the water saving and productivity of crops. This has further encouraged many farmers to adopt the drip method of irrigation in some of the regions in Maharashtra.

the area under the drip method of irrigation in absolute terms in many states. However, drip irrigated area constitutes a very meager percentage in relation to the gross irrigated area and also in relation to its total potential area, which is estimated to be 27 mha by the Task Force on Micro-Irrigation (GOI 2004). For instance, during 2000-01, the share of drip-irrigated area to gross irrigated area was just 0.48 %, and about 1.09 % in relation to total groundwater irrigated area of the country.

Although over 80 crops are suitable for the drip method of irrigation, only a few crops have been dominant in the total area under drip irrigation so far. As of 1997-98, crops like coconut, grapes, banana, citrus, mango and pomegranate together have accounted for nearly 67 % of the total drip irrigated area (see Figure 3 and also Table 3). States like Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka account for a major share of the area in all these crops. More importantly, out of the total area of 26,460 ha of the banana crop, the Maharashtra State alone accounted for as much as 93 % at the end of 1997-98. It shows that the adoption of drip method of irrigation is very much concentrated only in a few states despite many different regions in the country experiencing severe water scarcities. It is essential to bring more water-intensive crops under the drip method of irrigation so as to avoid aggravating the supply-demand gap in irrigation water in the future.

Figure 3. Crop-wise share of drip irrigated area in India: 1997-98.



Who is using DMI in India? Do farmers use DMI without a subsidy being given by state agencies? Unfortunately clear answers are not available for these questions from the existing reports and studies, despite the fact that the drip method of irrigation has been promoted by the government over the last 15 years or so. However, a nationwide study carried out by the Agricultural Finance Corporation (AFC1998) reveals that the drip method of irrigation is still essentially considered to be the scheme of the government. As of 1997-98, the area under DMI other than government schemes (without subsidy) accounted for only about 18 % of India's total drip irrigated area, indicating that farmers are reluctant to adopt drip irrigation without subsidy. Studies need to be carried out as to why the individual farmers without subsidy are not willing to adopt DMI, despite the substantial benefits that can be derived from it.

Water Saving Technology: Economic and Resource Impacts

It has been proved by some studies that the drip method of irrigation helps to save water and improves water use efficiency, reduces the cost of cultivation and increases productivity of crops and farm income (INCID 1994). While reducing water consumption, it also reduces by a substantial amount, the electricity required for irrigation purposes, by reducing the number of working hours of irrigation pump-sets (Narayanamoorthy 1996a). Normally, the impact realized using experimental data may not match the field data because of varying agro-economic conditions between the two-settings. Therefore, we have discussed the impact of DMI on different parameters using both the experimental and field data.

Table 3. Drip method of irrigation: Water saving and productivity gains.

Crop's Name	Water Consumption (mm/ha)		Yield (tonne/ha)		Water Saving over FMI (%)	Yield Gain over FMI (%)	Water Use Efficiency$	
	FMI	DMI	FMI	DMI			FMI	DMI
VEGETABLES								
Ash gourd	840	740	10.84	12.03	12	12	77.49	61.51
Bottle gourd	840	740	38.01	55.79	12	47	22.09	13.26
Brinjal	900	420	28.00	32.00	53	14	32.14	13.13
Beetroot	857	177	4.57	4.89	79	7	187.53	36.20
Sweet potato	631	252	4.24	5.89	61	40	148.82	42.78
Potato	200	200	23.57	34.42	Nil	46	8.49	5.81
Lady's fingers	535	86	10.00	11.31	84	13	53.50	7.60
Onion	602	451	9.30	12.20	25	31	64.73	36.97
Radish	464	108	1.05	1.19	77	13	441.90	90.76
Tomato	498	107	6.18	8.87	79	43	80.58	12.06
Chillies	1,097	417	4.23	6.09	62	44	259.34	68.47
Ridge-gourd	420	172	17.13	20.00	59	17	24.52	8.60
Cabbage	660	267	19.58	20.00	60	2	33.71	13.35
Cauliflower	389	255	8.33	11.59	34	39	46.67	22.00
FRUIT CROPS:								
Papaya	2,285	734	13.00	23.00	68	77	175.77	31.91
Banana	1,760	970	57.50	87.50	45	52	30.61	11.09
Grapes	532	278	26.40	32.50	48	23	20.15	8.55
Lemon	42	8	1.88	2.52	81	35	22.34	3.17
Watermelon	800	800	29.47	88.23	Nil	179	27.15	9.07
Mosambi	1,660	640	100.00	150.00	61	50	16.60	4.27
Pomegranate	1,440	785	55.00	109.00	45	98	26.18	7.20
OTHER CROPS:								
Sugarcane	2,150	940	128.00	170.00	65	33	16.79	5.53
Cotton	856	302	2.60	3.26	60	25	329.23	92.64
Coconut	--	--	--	--	60	12	--	--
Groundnut	500	300	1.71	2.84	40	66	292.40	105.63

Sources: INCID (1994) and NCPA (1990)
Notes: $ - water consumption (mm) per quintal of yield

One of the prime advantages of drip irrigation is that it saves a substantial amount of water as compared to conventional methods of irrigation. Though studies using field level data are rarely available, focusing on water use efficiency and water saving of DMI, many research stations situated in different parts of the country have evaluated the water saving capacity of DMI for different crops. We have presented the water requirements, saving of water and water use efficiency under DMI and FMI for different crops in Table 3 based on the data from experimental stations. The water saving capacity of DMI is expected to be different for different crops as the consumption and the requirement of water varies from crop to crop. As expected, the water saving for vegetable crops varies from 12 to 84 % per hectare over the conventional method of irrigation. In fruit crops, water saving varies from 45 to 81 % per hectare over the conventional method of irrigation. In crops like cotton, coconut and groundnut, water saving varies from 40 to 60 % per hectare. Importantly, water saving in sugarcane, which is one of the water-intensive crops, is over 65 % per hectare when compared to the conventional method of irrigation.

Similar to the results available from INCID (1994) report, various experimental studies carried out by the Precision Farming Development Centre (PDCs) also clearly demonstrate that water saving due to DMI is substantial over the method of surface irrigation in different crops (see, GOI 2004). Water saving under the drip method of irrigation occurs mainly because of three reasons. First, since water is supplied through a network of pipes, the evaporation and distribution losses of water are minimal or completely absent under DMI. Second, unlike FMI, water is supplied under DMI at a required time and required level and thus, over-irrigation is totally avoided. Third, under the conventional method of irrigation, water is supplied for the whole of cropland, whereas DMI irrigates only the plants. Though the results of the experimental data discussed above clearly suggest that water saving due to DMI is substantial, one cannot completely rely on these results because the environmental conditions that are prevailing under experimental stations are totally different the conditions prevailing at the farmers' field. Therefore, we discuss below the water saving including its efficiency under DMI using farm level data in the context of three crops namely sugarcane, banana and grapes.

Water consumption per hectare for any crop is determined by factors like horse power of the pump-set, water level of the well, capacity of the pump, size of delivery pipes, condition of the water extraction machineries (WEMs), distance between place of water source and field to be irrigated, quality of soil, terrain condition etc. These factors vary considerably across farms. Pump-sets with higher horse power (HP) lift more water per unit of land compared to the pump-sets with lower horse power. Most of the studies based on research station data have measured water consumption in terms of centimeter (CM) in drip irrigation. But, in practice, measuring water in terms of CM is not an easy task at the field level as HP of the pump-sets and water level of the well changes considerably across the farms. In order to avoid these difficulties, water consumption is measured in terms of horse power (HP) hours of irrigation.[10]

[10] HP hours of water is computed by multiplying HP of the pump-set with hours of water used.

Table 4 presents per hectare consumption of water in terms of HP hours for drip and non-drip adopters for all three crops—sugarcane, grapes and banana. It is clear from the table that the consumption of water by crops under the drip method of irrigation is significantly less than that of the flood method irrigation (FMI). While water saving in sugarcane comes to about 44 %, the same is estimated to be about 37 % in the case of grapes and about 29 % in the case of banana. Among these three crops, water saving in terms of HP hours is much higher for the banana crop as compared to the other two crops. Drip method saves about 3,245 HP hours of water per hectare for banana, while it is about 1,412 HP hours for sugarcane and about 1,968 HP hours for grapes. The requirement of water varies for each crop depending upon the soil quality and other factors and, therefore, the saving of water due to DMI is varied among the three crops discussed. As mentioned earlier, unlike flood method of irrigation, since water is supplied only at the root zone of the crops and that too at a required quantity, water losses occurring in the form of evaporation and distribution are completely absent under DMI. This helps DMI adopters to save water considerably as compared to the non-adopters of DMI. Though there are differences in water saving between the three crops, the study shows that drip technology helps saving relatively more water in water-intensive crops like banana.

Table 4. Water use efficiency in drip and non-drip irrigated crops.

Particulars	Method	Sugarcane	Grapes	Banana
Water Consumption (HP hours/ha)	DMI	1,767.00	3,310.38	7,884.70
	FMI	3,179.98	5,278.38	11,130.34
Yield (quintal/ha)	DMI	1,383.60	243.25	679.54
	FMI	1,124.40	204.29	526.35
Water Use Efficiency (HP hours/quintal)	DMI	1.28	13.61	11.60
	FMI	2.83	25.84	21.41

Source: Calculated from Narayanamoorthy (1996, 1997 and 2001)

While the consumption of water per unit of area is a good indicator to measure the efficiency of water use in drip and non-drip crops, water consumed to produce one unit of crop output is the most appropriate method to judge the efficiency of water consumption in DMI and FMI. In order to study the water use efficiency under the two methods of irrigation, we have calculated water consumption required producing one unit of output under drip and non-drip irrigated conditions. As reported by experimental data based studies, the results of field data also show that water use efficiency (WUE) is substantially higher for drip-irrigated crops as compared to the same cultivated under flood method of irrigation (see, Table 5). The analysis shows that sugarcane cultivated under drip method of irrigation consumes only 1.28 HP hours of water to produce one quintal of output when compared to 2.83 HP hours of water for producing the same quantity of output under non-drip irrigated condition, i.e., to produce one quintal of sugarcane under non-drip irrigated condition about 1.55 HP hours of additional water is consumed.

Table 5. Electricity consumption by drip and non-drip irrigated crops.

District	Electricity Consumption (Kwh/ha)		Electricity Saving over FMI		
	DMI	FMI	In percentage	In quantity (Kwh)	In money value (Rs)*
Sugarcane	1,325.25	2,384.99	44.43	1,059.74	3,454.75
Grapes	2,482.77	3,958.78	59.45	1,476.01	4,811.80
Banana	5,913.53	8,347.75	41.16	2,434.00	7,934.80

Source: Estimated using Narayanamoorthy (1996, 1997 and 2001)

Notes: * - Rs.3.26/Kwh, which is the current (2003-04) average cost of electricity supply in Maharashtra State, is assumed to estimate electricity saving in terms of money value

Similar to sugarcane crop, water required to produce one quintal of output in banana and grapes is also found to be substantially lower under DMI as compared to their counterpart. Under DMI, banana consumes only 11.60 HP hours of water to produce one quintal of banana output as against the use of 21.14 HP hours of water for the same quantity of yield under non-drip irrigated method. In the case of grapes, each quintal of output involves the use of just 13.60 HP hours of water under DMI as compared to the use of 25.84 HP hours under non-drip irrigated method. The fact that comes out clearly from the analysis is that DMI not only reduces the per hectare consumption of water but also reduces the water required to produce one unit of crop output substantially when compared to the flood method of irrigation.

Along with water, electricity (energy) used for lifting water from wells is also saved considerably due to the drip method of irrigation. Water saving and electricity saving are highly interrelated under DMI and, therefore, an analysis on electricity use under drip method is presented in this section. It is observed in the foregoing section that HP hours of water used per hectare of crop under DMI are significantly less than those of FMI. Therefore, it follows simply that the consumption of electricity also reduces significantly under DMI. We have estimated electricity consumption based on the hours of pump-set operations for both the drip adopter and the non-drip adopter groups. For estimating the quantum of electricity saved, it is assumed that for every hour of operation of a pump-set, 0.750 kwh of power is used per HP.[11]

Since all the farmers in both the groups have used only electrical pump-sets, we have simply multiplied HP hours of water with assumed power consumption of 0.75/kwh/HP to arrive at the per hectare electricity consumption. The estimated consumption of electricity (in kwh) presented in Table 5, clearly depicts that farmers using DMI utilized a lesser amount of electricity as compared to FMI farmers in all three crops. Farmers who cultivated sugarcane under DMI could save about 1,059 kwh of electricity per hectare as compared to those farmers who cultivated sugarcane under FMI. Similarly, while the farmers cultivating grapes could save about 1,476 kwh/ha of electricity due to DMI, the saving of electricity is estimated to be about 2,434 kwh/ha in banana in comparison to the farmers who cultivated the same crop under FMI with a similar environment. The substantial amount of electricity saving due to DMI is not a surprising result, because any reduction in consumption of water would ultimately lead to reduction in the consumption of electricity.

[11] Details of consumption of electricity by pump-sets and the relevant estimates can be seen from Shah (1993).

Farmers with drip irrigation operate pump-sets for a fewer number of hours and therefore, consumption of electricity is quite low. Since the saving of electricity through the drip method of irrigation is very high, it would help to reduce the total electricity bill to be paid by the farmers. We have estimated the money saved in the total electricity bill per hectare through energy saving. Since Maharashtra State Electricity Board supplies electricity on a flat-rate (FR) basis for agriculture, it was not possible to get per kwh price of electricity. Therefore, we have assumed Rs. 3.26/kwh, which is the current average cost of electricity supply in Maharashtra, as a nominal rate to estimate the saving of electricity in monetary terms. In accordance with this, on an average, about Rs.3,454/ha can be saved on the electricity bill alone by cultivating sugarcane under the drip method of irrigation. Similarly, farmers cultivating grapes and banana under DMI can save about Rs. 4,811and Rs. 7,934 per hectare, respectively. It suggests that the drip irrigation technology helps to reduce the cost of cultivation enormously by reducing the cost of electricity besides helping to save precious inputs like electricity and water.

As in water consumption, the energy used to produce one quintal of crop output is computed by dividing the per hectare energy (electricity) consumption by yield of each crop per hectare. Electricity consumed to produce one quintal of sugarcane is quite low for drip adopters in Maharashtra. For instance, on an average, sugarcane cultivators under DMI used about 0.968 kwh to produce one quintal of sugarcane, whereas the same is estimated to be about 2.121 kwh for those who cultivated sugarcane under FMI. This means that for every quintal of sugarcane production about 1.163 kwh of electricity can be saved through drip method of irrigation. Electrical energy consumed to produce one quintal of crop output is also found to be low for drip adopters in banana and grapes as well. While grapes cultivators under DMI used about 10.21 kwh to produce one quintal of grapes, the non-drip adopters have used about 19.37 kwh. A similar trend is observed in the case of banana crop as well. Obviously, higher productivity and relatively low amount of water consumption have reduced the per quintal requirement of electricity significantly in drip irrigated crops.

Drip method of irrigation also helps to reduce the cost of cultivation and improve productivity of crops as compared to the same crops cultivated under the flood method of irrigation. In this section, using both the experimental and field level data, we discuss the impact of DMI on the cost of cultivation and productivity of crops. First, we discuss the productivity enhancement in different crops due to DMI using experimental data and then we study the impact of DMI on the cost of cultivation and productivity of crops using field level data pertaining to three crops namely sugarcane, grapes and banana. It can be seen from the results of the experimental station data presented in Table 3 that the productivity of different crops is significantly higher under DMI when compared to FMI. Productivity increase due to drip method of irrigation is noticed over 40 % in vegetable crops such as bottle gourd, potato, onion, tomato and chilies, while over 70 % increase in many fruit crops. In the case of sugarcane, productivity difference is found to be over 33 %. Specific experiments carried out at *Punjabrao Krishi Vidyapeeth*, Akola, (Maharashtra State) on vegetable crops such as cauliflower, tomato and brinjal also suggest that productivity enhancement due to DMI is substantial (see, INCID 1994). Similar kinds of results have also been noted at different experimental stations located in different states.[12]

[12] More details on productivity on different crops cultivated using drip and flood method of irrigation can be seen from (INCID 1994; CBIP 1993; Verma and Rao 1998).

Though various studies using experimental data reported that DMI increases the productivity of crops, none of these studies seem to have compared the productivity of crops with the cost of cultivation. This is one of the major limitations of the existing studies, which are based on experimental data. There is a possibility that productivity of crops under DMI may be higher due to higher use of yield increasing inputs. Therefore, in order to find out the real impact of DMI on productivity of crops, one needs to compare the cost of cultivation of crops with the productivity of crops. Keeping this in view, an attempt is made below to relate the cost of cultivation with productivity of crops under DMI and FMI in the context of sugarcane, grapes and banana.

Studies carried out using experimental data in different crops underline that the DMI can reduce the cost of cultivation, especially in labor-intensive operations like weeding, irrigation, ploughing etc (see, INCID 1994; Dhawan 2002). When the labor cost reduces, the total cost of cultivation also reduces, because labor cost constitutes a considerable portion in the total cost of cultivation. Let us first study the cost of cultivation in the sugarcane crop. It is clear from Table 6 that drip irrigation reduces the total cost of cultivation by about Rs.6,550/ha (nearly 13 %) for the adopters as compared with the non-adopters with regards to the sugarcane crop. Though the total cost saving in terms of percentage is not very high in aggregate, it varies across different operations. Among the different operations, cost saving is very high in irrigation, furrows and bunding followed by seed and seed sowing. Saving under cost of cultivation is also found in fertilizers (about 8 %). This is because of the reason that some of the adopters have used liquid fertilizers and thus, the cost incurred on fertilizers is relatively less.

Table 6. Cultivation costs of adopters and non-adopters of drip method of irrigation (Rs/ha).

Operations	Sugarcane			Grapes			Banana		
	DMI	FMI	% change over FMI	DMI	FMI	% change over FMI	DMI	FMI	% change over FMI
Ploughing and Preparation	3,385	4,087	-17.18	5,918	6,131	-3.48	2,633	3,223	-18.30
Furrows and Bunding	1,433	1,837	-21.98	IUPP	IUPP	----	IUPP	IUPP	----
Seed and Seed Sowing	7,155	8,516	-15.98	DNC	DNC	----	5,331	5,416	-1.56
Fertilizers (in-organic)	9,396	10,253	-8.35	21,828	25,329	-13.83	16,378	17,494	-6.38
Farm Yard Manure	6,940	7,434	-6.65	13,273	16,410	-19.12	9,975	8,316	19.95
Pesticides	991	973	1.88	47,695	50,107	-4.81	10	---	---
Weeding and Interculture	4,583	5,208	-12.00	7,782	8,855	-12.11	1,826	2,123	-14.00
Irrigation[a]	5,676	7,195	-21.11	8,586	8,429		5,757	6,379	-9.75
Harvesting	b	b	----	14,256	11,908	19.72	4,613	5,547	-16.84
Transport and Marketing	b	b	----	3,966	5,322	-25.47	2,706	2,346	15.32
Others	2,434	3,037	-19.86	11,202	14,424	-22.34	2,207	1,895	-16.47
Total Cost	41,993	48,540	-13.49	134,506	147,915	-9.07	51,437	52,739	-2.47

Source: Calculated from Narayanamoorthy (1996, 1997 and 2001)

Notes: a - Includes operation and maintenance costs of pump set and drip set; b - Costs of harvesting, transport and marketing are not included since sugar factories have incurred these costs; IUPP – Included under ploughing and preparation; DNC – Relevant data could not be collected as grape gardens are very old

A few earlier studies have reported that the drip method of irrigation also reduces the cost of fertilizers enormously as it can be supplied along with water – liquid fertilizers. Some of the farmers have argued that even without using the liquid form of fertilizers, the same can be reduced by avoiding wastage under the drip method of irrigation. Since water is supplied through a pipe network under the drip method of irrigation, it does not require more labor.[13] But, in the case of the surface method of irrigation, labor input is necessary to control water supply (changing course of water from one field to other) and to govern leakage and seepage. In addition to saving in the cost of labor, cost incurred on account of electricity (for operating pump-set) is also less as drip irrigation requires less amount of water when compared to flood method of irrigation. Under DMI, a saving of about 17 % in the cost of cultivation is noticed in ploughing and preparatory operations. This is because of the fact that the drip method of irrigation does not warrant much ploughing as it supplies water at the root zone of the crops. As indicated by earlier studies, the cost saving is also very high in weeding operation under DMI, which comes to about 12 % over the cost incurred by the farmers who cultivated sugarcane under FMI. Cost saving in weeding operation is high because it does not allow weed to come up in the non-crop space by not supplying water beyond the root zone of the crop. It should, however, be noted that the cost of cultivation varies with situational factors like soil quality, condition of the terrain, farmers' approach etc.

Farmers who cultivated grapes and banana under DMI have also incurred relatively lower cost of cultivation. In the case of banana, drip irrigation reduces the total cost of cultivation by about Rs. 1,300/ha as compared to the farmers who cultivated the same crop under the flood method of irrigation. Among the different operations, cost saving is very high in irrigation. Second highest saving under the cost of cultivation is noticed in the ploughing operation. This is because of the fact that drip method does not warrant much ploughing as it supplies water at the root zone of the crops. The cost saving is also high in weeding operation as indicated by earlier studies. Gain in cost of cultivation is relatively higher in grapes as compared to banana. In banana, cost saving due to DMI was only about 2.50 %, whereas the same is nearly 10 % in grapes. As in the case of banana crop, cost saving varies with operations in grapes as well. Cost saving is found to be higher in operations like weeding, irrigation, fertilizers and ploughing. On the whole, the major difference in cost of cultivation between the adopters and the non-adopters of DMI is observed in irrigation, weeding and inter-culture, ploughing and preparation, and seed and sowing.

Now let us turn our discussion to productivity gains using field data. One of the important advantages of the drip method of irrigation is productivity gain. Most of the time yield is affected because of moisture stress faced by crops. It is difficult to maintain water supply constantly for crops by the surface method of irrigation due to various reasons. Studies related to the drip method of irrigation have confirmed that the problem of moisture stress is completely reduced by providing irrigation through drip, as it supplies water at the root zone of the crops at a required frequency and quantity. As a result, the yield of crops cultivated under the drip method of irrigation is much higher than the crops which are cultivated under the surface method of irrigation.

Productivity of crops presented in Table 7 shows that it is significantly higher for the farmers who have adopted the drip method of irrigation as compared to the non-drip adopters

[13] INCID (1994) report mentions that one laborer can easily attend to up to 10 hectares under DMI, which is not possible under conventional method of irrigation.

in all the three crops selected for analysis. The yield difference in absolute terms between the adopters and the non-adopters of drip method of irrigation comes to nearly 259 quintals per hectare for sugarcane, a gain of 23 % over non-drip irrigated crop. In the case of grapes, the productivity difference between DMI and FMI adopters comes to about 19 % and the same comes to 29 % for the banana crop. The important point to be underlined here is that despite incurring more cost on yield increasing inputs, productivity of crops cultivated under FMI is significantly lower than that of DMI.

Table 7. Productivity of crops under drip and flood irrigated condition.

Crop	Productivity (quintal/ha)		Productivity increase over FMI	
	DMI	FMI	%	Quantity
Sugarcane	1,383.60	1,124.40	23.05	259.20
Grapes	243.25	204.29	19.07	38.96
Banana	679.54	526.35	29.10	153.19

Source: Computed from Narayanamoorthy (1996, 1997 and 2001)

There are three main reasons for higher yield in drip irrigated crops. First, the growth of crops cultivated under DMI is better because of lower moisture stress, which ultimately helps to increase the productivity. Second, unlike the surface method of irrigation, drip does not encourage any growth of weed, especially in the non-crop zone. But under the surface method of irrigation weeds consume a considerable amount of yield increasing inputs and thereby reduce the yield of crops. Third, unlike in the surface method of irrigation, fertilizer losses occurring through evaporation and leaching through water are less in the drip method of irrigation as it supplies water only for crop and not for the land. Though the expenditures incurred by the non-adopters on different yield-increasing inputs are more than those incurred by the adopters in all three crops, this ratio of expenditures does not coincide with the increased yield of crops. Therefore, one can conclude that this productivity enhancement in all three crops is the result of using the drip method of irrigation.

Besides increasing productivity of crops, DMI also increases cost efficiency, i.e., it reduces the cost required to produce a unit of crop output. This can be seen in Table 8. The estimated per quintal cost (calculated by dividing the total cost of cultivation with per hectare yield of three crops) shows that the non-adopters spend nearly Rs.13 more than the adopters to produce every quintal of sugarcane in Maharashtra. Likewise, in grapes, the non-adopters have incurred over Rs. 171 per quintal over the adopters, and in banana, the non-adopters have incurred nearly Rs. 30 to produce one quintal of output over their counterparts. It suggests that apart from increasing the productivity of crops, the drip method of irrigation also increases cost efficiency more substantially than the flood method of irrigation. On the whole, the analysis carried out using both the experimental and field level data clearly suggests that the drip method of irrigation increases productivity of crops, and that too with reduced cost of cultivation.

Table 8. Expenditure to produce unit of output under drip and non-drip condition.

Particulars	Sugarcane		Grapes		Banana	
	DMI	FMI	DMI	FMI	DMI	FMI
Yield (quintal/ha)	1,383.6	1,124.4	243.2	204.3	679.5	526.3
Cost of Cultivation (Rs/ha)	41,993.2	48,539.8	134,506.2	147,914.9	51,436.7	52,738.5
Cost of Production (Rs/quintal)	30.35	43.17	552.95	724.04	70.69	100.19

Source: Computed from Narayanamoorthy (1996, 1997 and 2001)

Economics of Water Saving Technology

It is clear from the above that drip method of irrigation reduces costs of cultivation, saves substantial amount of water and electricity and also enhances productivity of crops. Despite this, one of the important questions often asked about the drip method of irrigation is whether or not drip investment is economically viable to farmers cultivating crops using this new water saving technology. This question arises mainly because the drip method of irrigation requires a relatively large amount of fixed investment to install it in the field and, therefore, everyone (from policymakers to farmers) wants to know its economic viability in different crops. Though quite a few studies have analyzed the impact of drip method of irrigation on different parameters, not many studies have attempted to look into the economic viability of drip investment even by using experimental data. Some estimates on benefit-cost ratios are available from three secondary sources namely, INCID (1994); Sivanappan (1995) and AFC (1998). Although it is not clear whether the estimates available in these three studies were obtained using the discounted cash flow technique, let us discuss the results of these studies before going into analyzing the estimates made using field data.

The capital cost required for installing DMI for different crops has been increasing over the years due to the increase in the cost of materials used for manufacturing the drip system (GOI 2004). The capital cost of drip system largely depends upon the type of crop (whether narrow or wide-spaced crops), spacing followed for cultivating crops, proximity to the water source (distance between the field and source of water) and the materials used for the system. Wide-spaced crops, generally, require less capital when compared to the crops having narrow space, as the latter would require more laterals and drippers per hectare. INCID (1994) results, which are reported in Table 9, clearly indicate that the requirement of capital cost is much higher for banana (Rs. 33,765/ha) as compared to the same required for mango (Rs. 11,053/ha), which is a wide-spaced crop.

Table 9. Benefit-cost ratio of different drip irrigated crops.

Name of the Crop	Spacing (m x m)	Capital Cost (Rs/ha)	Benefit-Cost Ratio	
			Excluding Water Saving	Including Water Saving
Coconut	7.62 x 7.62	11,053	1.41	5.14
Grapes	3.04 x 3.04	19,019	13.35	32.32
Grapes	2.44 x 2.44	23,070	11.50	27.08
Banana	1.52 x 1.52	33,765	1.52	3.02
Orange	4.57 x 4.57	19,859	1.76	6.01
Pomegranate	3.04 x 3.04	19,109	1.31	4.40
Mango	7.62 x 7.62	11,053	1.35	8.02
Papaya	2.13 x 2.13	23,465	1.54	4.01
Sugarcane	Between biwall 1.86	31,492	1.31	2.78
Vegetables	Between biwall 1.86	31,492	1.35	3.09

Source: Compiled from INCID, (1994)

As regards B-C ratio, the results available from INCID (1994) show that investment in drip method of irrigation is economically viable, even if it is estimated without taking into account the subsidy given to farmers. The B-C ratio estimated, excluding water saving, varies from 1.31 in sugarcane to as high as 13.35 in grapes. Obviously, the B-C ratio increases significantly further, when it is estimated after including the water saving. Various case studies reported in INCID (1994) also indicate that investment in drip irrigation is economically viable for different crops. Similar to INCID (1994), Sivanappan (1995) also estimated B-C ratio for different crops cultivated under DMI using data pertaining to the year 1993. It also suggests that the investment in drip irrigation is economically viable for different crops since the B-C ratio estimated was more than one. While the B-C ratio for pomegranate was estimated to be 5.16, the same is estimated to be 1.83 for cotton, which is a less-water intensive as well as a narrow-spaced crop.

Unlike the results reported in INCID (1994) and Sivanappan (1995), AFC (1998) estimated B-C ratio using field survey data collected from 3,850 sample farmers, consisting of beneficiary and non-beneficiary farmers. The survey covered 26 sample districts in 6 states. While the B-C ratio provided in AFC (1998) does not show the picture clearly, using the same data Dhawan (2002) has estimated B-C ratio for different crops at 12 % discount rate. Though the estimated B-C ratio appears to be very high, it is found to be relatively higher in all those districts belonging to the Maharashtra State as compared to the districts considered from other states. The inter-district variation in B-C ratio is possibly caused by inter-districts variation in the crop composition. The overall B-C ratio for the 21 sample districts or a drip investment of Rs. 27,000 is about 10, which is by any measurement extremely very high and attractive (Dhawan 2004).

Though B-C ratio available from different sources suggests that the investment in drip irrigation is economically viable for farmers, one cannot completely rely on these results because of the following reasons. First, the studies discussed above have not clearly mentioned as to how the income stream is estimated during the entire life period of a drip irrigation set. Second, studies, especially by Sivanappan (1995) and INCID (1994) have not mentioned the methodology that is followed for estimating the B-C ratio for different crops. These estimates also appear to be output-input ratio, but not Benefit-Cost ratio estimated using discounted cash flow technique. Third, the past studies on this aspect have been carried out either by a B-C analysis without proper methodology or relied on the experience of one or few farmers adopting DMI. Fourth, none of the above studies mentioned the assumptions that are followed for estimating B-C ratio. In view of the limitations of the available studies, there is a need to empirically evaluate the economic viability of DMI within a relatively more systematic methodological framework.

In order to evaluate the economic viability of drip investment in the context of three crops, we have computed both the net present worth (NPW) and the benefit-cost ratio (BCR) by utilizing the discounted cash flow technique. Since the NPW is the difference between the sum of the present value of benefits and that of costs for a given life period of the drip set, it collates the total benefits with the total costs covering items like capital and depreciation costs of the drip set. In terms of the NPW criterion, the investment on drip set can be treated as economically viable if the present value of benefits is greater than the present value of costs. The BCR is also related to NPW as it is obtained just by dividing the present worth of the benefit stream with that of the cost stream. Generally, if the BCR is more than one, then, the investment on that project can be considered as economically viable. A BCR greater than one obviously implies that the NPW of the benefit stream is higher than that of the cost stream (Gittinger 1984). The NPW and BCR can be defined as follows:

$$\text{NPW} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

$$\text{BCR} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

Where, B_t = benefit in year t; C_t = cost in year t; t = 1, 2, 3 ….n; n = project life in years; i = rate of interest (or the assumed opportunity cost of the investment).

Since drip irrigation involves fixed capital, it is necessary to take into account the income stream for the whole life span of drip investment. However, since it is difficult to generate the cash flows for the entire life span of drip investment in the absence of observed temporal information on benefits and costs, we need to make few realistic assumptions so as to estimate both the cash inflows and cash outflows for drip investment. These assumptions are:

1. The life period of the drip set is considered as 5 years for sugarcane and banana, but 10 years for grapes as followed by the INCID study (1994) as well as the experience gathered from the field.

2. The cost of cultivation and income generated using the drip method of irrigation is assumed to be constant during the entire life period of drip set in all three crops.

3. Differential rates of discount (interest rates) are considered to undertake the sensitivity of investment to the change in capital cost. These are assumed at 10 %, 12 % and 15 % as alternatives representing various opportunity costs of capital.

4. The crop cultivation technology is assumed to be constant for all three crops during the entire life period of drip set.

As a backdrop to our benefit-cost analysis of DMI, we first briefly discuss about the gross cost of production, profit without discount, capital cost (without and with subsidy) and the amount of subsidy received by the farmers. Table 10 presents the details of production, gross income and other details for the three crops namely, sugarcane, grapes and banana. To complete the analysis of the relative economics of DMI and FMI, we have calculated the relative profit levels of the three crops for the adopters and non-adopters of DMI. Profit of a crop is not only determined by its total quantity of output but also its quality. Prevailing market conditions also play a crucial role in determining the price of agricultural commodities. It has come out from the earlier studies that the drip method of irrigation not only helps in increasing the yield of the crops but also improves the quality of the product and fetches a higher price in the market (INCID 1994; Sivanappan 1994; Narayanamoorthy 1997).

Let us study how profit (undiscounted) varies between drip and non-drip irrigated crops in our study. While calculating profit, the total cost was calculated by considering only the variable costs but not the fixed cost components like interest rate and depreciation.[14] To calculate per hectare profit, we subtract the total cost of cultivation from the total income for the group of adopters and the non-adopters. The gross income (in rupees) is calculated by multiplying total yield with price received by the farmers for their crop output. It can be seen from Table 10 that per hectare profit[15] of the adopters in sugarcane is Rs. 27,424 higher than that of the non-adopters. In terms of percentage, profit of the drip adopters is higher by about 74 % over the profit of the non-drip farmers. This is not surprising, because on the one hand drip irrigation reduces the cost of cultivation of sugarcane and on the other hand it increases the yield of sugarcane.

[14] The cost of cultivation used in our analysis refers to cost A2, which includes all actual expenses in cash and kind incurred in production by owner plus rent paid for the leased-in land. See, CACP (1998) for more details about different cost concepts.
[15] This profit is calculated by deducting gross income from cost A2.

Table 10. Costs, income, and subsidy among drip and non-drip irrigated crops.

Particulars	Sugarcane		Grapes		Banana	
	DMI	FMI	DMI	FMI	DMI	FMI
Cost of cultivation (Rs/ha)[a]	41,993	485,39	134,506	147,914	51,436	52,738
Gross income (Rs/ha)	106,366	85,488	247,817	211,037	134,043	102,934
Profit (Rs/ha)[b] (Farm business income)	64,372	36,948	113,310	63,122	82,607	501,96
Capital cost of drip set (Rs/ha) (without subsidy)[c]	52,811	----	32,721	----	33,595	----
Capital cost of drip set (Rs/ha) (with subsidy)[c]	33,547	----	20,101	----	22,236	----
Subsidy (Rs/ha)	19,263	----	11,359	----	12,620	----

Source: Calculated from Narayanamoorthy (1996, 1997 and 2001)

Notes: a - production cost (A2) includes the operation and maintenance cost of drip set and pump-set; b - This is the difference between gross value of production and production cost (A2) and c - it does not include pump-set cost

In crops like grapes and bananas, the average profit among the drip adopters is significantly higher than that of the non-drip adopters. The profit level among drip adopters in grapes is Rs. 50,187/ha higher than that among non-adopters, whereas the same is about Rs. 32,400/ha for banana. While the profit differential is substantial for drip irrigated crops, it cannot be taken as a conclusive indicator of the comparative advantages of the new irrigation technique, as our profit calculation is based only on the variable cost but ignores fixed cost components like depreciation and interest accrued on the fixed capital while calculating the net profit. The life period of drip-set is one of the important variables which determines the per hectare profit. Moreover, since it is a capital-intensive technique, the huge initial investment needed for installing drip systems remains the main deterrent for the widespread adoption of DMI. To what extent this discouragement effect is real and to what extent such effect can be counterbalanced by a government subsidy are some of the important policy issues requiring empirical answers.

Fixed capital is needed for installing the drip method of irrigation. The magnitude of capital requirement varies with each crop depending upon certain factors as indicated earlier. Generally, wide-spaced crops require a relatively low-fixed investment and narrow-spaced crops need a higher-fixed investment. Besides the crop type, the proportion of the fixed capital requirement is also sensitive to the quality of the materials used for the systems as well as the distance between the water source (well) and the field (NABARD 1989). Let us now evaluate the empirical pattern of capital cost of the drip system, production cost (cost of cultivation) of crops and the amount of subsidy received by the sample farmers. Table 11 presents the details of capital cost and subsidy for all three crops. Since DMI is a capital-intensive technology, government provides nearly 50 % of the capital cost as subsidy to encourage the adoption of drip irrigation in crop cultivation. The average capital subsidy comes to Rs. 19,263/ha for sugarcane, Rs. 11,359/ ha for grapes and Rs. 12,620/ha for banana. As a proportion of the total capital cost of drip set, subsidy amount accounts for about 35 to 37 % among the three crops, which is within a limit of provision made by the government. With this background, let us analyze the benefit-cost pattern of drip investment using the discounted cash flow technique.

Table 11. Economic worth and benefits of drip irrigated crops with and without subsidy.

Particulars	Sugarcane		Grapes		Banana	
	without subsidy	with subsidy	without subsidy	with subsidy	without subsidy	with subsidy
Present Worth of Gross Income						
(Rs/ha)	356,645	356,645	1,243,794	1,243,794	449,449	449,449
At 15 % discount rate	412,902	412,902	1,400,166	1,400,166	483,228	483,228
At 12 % discount rate	434,206	434,206	1,522,588	1,522,588	508,026	508,026
At 10 % discount rate						
Present Worth of Gross Cost						
(Rs/ha)	186,749	169,990	692,574	703,553	201,696	191,814
At 15 % discount rate	198,546	181,343	777,909	789,179	215,431	205,287
At 12 % discount rate	207,254	189,725	844,677	856,148	225,484	215,159
At 10 % discount rate						
Net Present Worth (Rs/ha)						
At 15 % discount rate	169,896	186,656	551,220	540,241	247,753	257,635
At 12 % discount rate	214,357	231,558	622,257	610,987	267,797	277,941
At 10 % discount rate	226,952	244,481	677,911	666,440	282,542	292,867
Benefit Cost Ratio:						
At 15 % discount rate	1.909	2.098	1.795	1.767	2.288	2.343
At 12 % discount rate	2.079	2.277	1.799	1.774	2.243	2.353
At 10 % discount rate	2.095	2.289	1.802	1.778	2.253	2.361

Source: Computed from Narayanamoorthy (1996; 1997; 2001)

In order to assess the potential role that subsidy plays in the adoption of DMI, we have computed both the NPW and the BCR separately by including and excluding subsidy in the total fixed capital cost of drip set. Financial viability analysis under different rates of discount will indicate the stability of investment at various levels of the opportunity cost of investment. Although the BCR is sensitive to discount rate and the degree of such sensitivity depends on the pattern of cash flows, it is interesting to observe the sensitivity of the BCR when there is a simultaneous change in both subsidy and discount factors. Table 11 presents the results of a sensitivity analysis for sugarcane, grapes and banana crops computed under the assumption that there will not be any change in the cost of production and gross income during the entire life period of drip set.

As regards the sugarcane crop, the NPW of the investment with subsidy is marginally higher than that of a 'no subsidy' option. At 15 % discount rate, the NPW of drip investment is about Rs. 169,896/ha without subsidy and Rs.186,655/ha with subsidy. This means that the subsidy enables the farmers to get an additional benefit of Rs. 16,759/ha. It can also be observed that the difference between the NPW under 'with subsidy' and 'no subsidy' scenarios is decreasing along with each increase in the discount rate. For instance, the NPW under without subsidy increased from Rs. 169,896/ha at a 15 % discount rate to Rs. 226,951/ha at a 10 % discount rate. Similarly, under subsidy, the NPW increased from Rs. 186,655/ha at a 15 % discount rate to Rs. 244,481/ha at a 10 % discount rate. Similar to this, under without subsidy condition, the BCR also increased marginally from 1.909 at a 15% discount rate to 2.095 at a 10 % discount rate. The higher BCR under subsidy suggests the positive effect of subsidy on the economic viability of the drip method of irrigation in sugarcane.

The NPW and BCR, which are estimated separately for banana and grape crops, reveal that the NPW of the investment with subsidy is marginally higher than that under `no subsidy' option for both these crops. For instance, at a 15 % discount rate, the NPW of drip investment for banana is about Rs. 247,753/ha without subsidy but Rs. 257,635/ha with subsidy. This means that the subsidy enables farmers to get an additional benefit of Rs. 9,882/ha. It can also be noted that the difference between the NPW under the two scenarios is decreasing along with each increase in the discount rate. The difference in NPW for the two scenarios which is Rs. 10,325 for banana and Rs. 11,471 for grapes at a 10 % discount rate declines to Rs. 9,882 and Rs. 10,979 for Banana and Grapes, respectively at a 15 % discount rate. This differential behavior of NPW across discount rates for the two crops is attributable to the observed differences in cash flows and cultivation practices and the assumed difference in drip set life span for the two crops. As can be seen from Table 11, the BCR without subsidy for banana is about 2.253 at a 10 % discount rate, and the BCR slides down to 2.228 at a 15 % discount rate. For grapes, in contrast, the BCR declines only marginally as the rate of discount increases. Although the same pattern of decline in BCR is observed across the discount rates even under the alternative scenario of cash flows with subsidy, the BCR is higher with subsidy than otherwise. This suggests the positive role that subsidy plays in improving the economic viability of DMI for our sample crops irrespective of the time preference of the farmers.

An important policy issue in the context of DMI adoption is the number of years needed to recover fully the capital costs involved in drip installation. The year-wise computation of NPW for sugarcane, banana and grapes clearly shows that farmers can recover the entire capital cost of the drip set from their net profit in the very first year itself. This finding contradicts with the general belief that the capital cost recovery for drip investment takes more time. More importantly, when farmers can recover the capital costs within a year, the role of the discount rate as a device to capture the time preference of farmers seems to be of considerably lesser importance than one might think. However, in order to have more definite answers to the economic and social viability of DMI, we need a social rather than the private cost-benefit evaluation that is being attempted here. A comprehensive evaluation can be done by incorporating both social benefits such as water saving, additional irrigation, lower soil degradation and retention of soil fertility, as well as the social costs in terms of the negative food and fodder in the crop pattern shift and labor displacement. On the whole, the BCR under different discount rates indicates that drip investment in three crops considered for detailed analysis remains economically viable even without subsidy.

Conclusions and Implications

The study clearly demonstrates that micro-irrigation has many advantages over the method of flood irrigation that is followed predominantly in India. The drip method of irrigation reduces cost of cultivation, weed problems, soil erosion and increases water use efficiency as well as electricity use efficiency, in addition to being a useful devise in reducing the over-exploitation of groundwater. However, despite providing substantial amount of subsidy, the spread and coverage of drip irrigation in India is not very encouraging today due to various reasons. There is a feeling among some quarters of policymakers and researchers that the adoption of the drip method of irrigation cannot be increased without providing a subsidy because of its capital-intensive nature. It is true that drip irrigation is a capital-intensive technology, but it does not mean that its adoption cannot be increased without a subsidy.

Subsidy can be a necessary condition for encouraging the adoption of drip method of irrigation but cannot be a sufficient condition for sustaining the growth of it, as many other factors determine the growth of drip irrigation adoption. Studies carried out using field level data covering three important crops clearly show that the investment in drip irrigation is economically viable even without the government subsidy. The estimated benefit-cost (BC) ratio varies from 1.73 to 2.23 among the three crops under 'no-subsidy' scenario. Even though subsidy is not needed to enhance the economic viability of the drip system, it is still needed to enhance the incentive for the widespread adoption of DMI, particularly among the resource-poor farmers (marginal and small categories). Subsidy can be phased out eventually once the new irrigation technology covered an adequate enough area to expand subsequently through the demonstration effect. The most important task standing before the policymakers is to find out ways and means to convince farmers about the economic and social feasibility of drip method of irrigation. Since it involves a relatively higher amount of investment, farmers often ask questions such as: What will be the payback period? Whether investment will be viable? How much will be the water saving? What will be the productivity gains? It appears that these questions arise mainly because of poor awareness about the social and economic advantages of drip technology. Therefore, efforts are needed to convince the farmers through the quality extension network. Many policy initiatives are needed to expand DMI in India, specifically, the following are critical.

First, by recognizing drip industry as an infrastructure industry as well as announcing a tax holiday for specific time periods to all those drip set industries, which produce genuine drip materials. Finally, the competition can be increased to bring down the cost of the system. The economic and environment viability of the low cost drip irrigation system being introduced by some companies should also be evaluated using farm-level data.

Second, the present subsidy scheme, which provides a uniform rate of subsidy for all crops, needs to be restructured taking into account the water consumption of the crops and level of groundwater exploitation of the region. A higher subsidy should be given for water-intensive crops, including sugarcane. Also areas with overexploitation of groundwater (dark areas) and water scarcity should be given a higher subsidy than water-abundant areas.

Third, for a speedy growth of drip irrigation, an interlinked special package scheme can be introduced. In such a scheme, priority must be given to providing bank loans for digging wells and electricity connection (pump-set) for those farmers who are ready to adopt the drip method of irrigation for cultivating any crop.

Fourth, sugar industries should play a proactive role in increasing the adoption of drip irrigation in sugarcane, using their close contract system with the cultivators. In spite of the fact that sugarcane consumes the bulk of the irrigation water in different states,[16] serious efforts are not taken to bring the sugarcane under the drip method of irrigation. Some target must be fixed for each sugar industry to bring the cultivation of sugarcane under the drip method of irrigation within a specific period.

[16] It is reported that in states like Maharashtra, sugarcane crop, which accounts for barely 2.50 % of the cropped area, consumes nearly two-third of the irrigation water. In spite of increasing the water rate for irrigation purposes periodically since 2000-01, the area under sugarcane in the state has been increasing continuously at a faster pace, which poses different challenges to the policymakers.

Fifth, inadequate information about the operation, maintenance as well as usefulness of drip irrigation is one of the main reasons for its uneven spread across regions in India. Even the adopters do not know fully how much of subsidy is available per hectare for different crops. Owing to poor exposure, farmers are reluctant to invest such relatively large amounts of money on drip irrigation. In fact, many farmers do not know the fact that drip irrigation can also be used efficiently and economically for crops like sugarcane, cotton, vegetables, etc. The extension network, which is currently operated mainly by government agencies, does not seem to be making any significant impact on the adoption of this technology. Therefore, there is a need to revamp the extension network to drip set manufacturers (public and private partnership) in order to improve the quality of the extension service.

Sixth, groundwater is the only source of water being used for drip method of irrigation in India. Since water use efficiency under surface sources (canal, etc.) is very low owing to heavy losses through conveyance and distribution, farmers should be encouraged to use water from surface sources for the drip method of irrigation. This can be done by allocating certain proportion of water from each irrigation projects exclusively for the use of micro-irrigation.

Seventh, one of the important reasons for the low spread of this technology even in the water-scarce area is the availability of highly subsidized canal water as well as electricity for irrigation pump-sets. Appropriate pricing policies on these two inputs may encourage the farmers to adopt this technology.

Eighth, though drip irrigation has been in use in different states since the mid-80s, no agency has a clear idea about the potential of micro-irrigation in each state. Therefore, it is essential to prepare a state-wise and crop-wise potential area for DMI. A detailed estimate on the state-wise potential would be useful to fix the target to be achieved and also formulate schemes for the promotion of the drip method of irrigation.

Finally, state-sponsored schemes are not formulated in most of the states except in Maharashtra and Andhra Pradesh. All other states have been operating schemes mainly with the support of the central government (known as centrally-sponsored schemes), which started in 1990-91. Considering the water scarcity, it is essential to have separate state-sponsored schemes in each state to promote micro-irrigation by following the experience of Maharashtra State.

With regards to future research, more and more research studies need to be carried out pertaining to its economics and adoption using field survey data to strengthen the policy decision and provide feed-back about the issues pertaining to the drip method of irrigation to policymakers. The research findings available at present on drip irrigation are not adequate enough to provide answers to questions such as: Who are the adopters of drip method of irrigation? What are the characteristics of the adopters? Can small and marginal farmers adopt drip irrigation without subsidy? What are the problems of the present subsidy scheme and how to revamp the same? Why do farmers not adopt drip irrigation for cultivating crops like pulses, oilseeds and other similar crops? What is the economic and environmental impact of DMI? Can DMI be used to solve the problem of overexploitation of groundwater? What is the economic viability of different crops cultivated presently under DMI? Unless adequate answers are made available to these questions, we may not be able to make judicious policy decisions to expand the adoption of this water saving technology at a fast rate.

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Water Rights System as a Demand Management Option: Potentials, Constraints and Prospects

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Introduction

This paper examines the potential, problems and prospects of introducing a water rights system as an option for managing irrigation demand. The paper is divided into six broad sections. Section 1 introduces the concept of a water rights system as an option for managing irrigation demand. Different conceptual perspectives on water rights are briefly reviewed and their implications for the introduction of a water rights system are examined. Section two describes various forms of water rights that have existed in different parts of India with some illustrations. Section three examines the rationale for the introduction of a property rights structure, in surface irrigation and as well as groundwater irrigation that has formed the basis of proposals for the introduction of a property rights structure. In addition, the public trust doctrine is also briefly reviewed. Section four reviews the international experience with the introduction of a property rights structure and its efficacy as a tool for demand management. Section five provides a review of the conditions—hydrological, technological as well as institutional—which are needed for the introduction of a water rights system and its smooth functioning. In the light of these conditions, section six examines the specific contexts in which the introduction of such a system might be feasible in the Indian context as a tool for demand management, and concludes with a summary of the main messages of the paper.

Conceptual Approaches to Analysis of Water Rights

Three distinct approaches that have influenced the analysis of water rights can be discerned. These approaches, which have specific bearing on how we approach the subject of a water rights structure from an analytic as well as public policy perspective, are the new institutional economics approach, legal pluralism perspectives, and the socio-technical approach.

New Institutional Economics Perspectives on Water Rights

In the New Institutional Economics, institutions are defined as rules of the game that structure human interaction (North 1990); they could be formal as well as informal. Institutions include law, property rights, social relationships, values and belief systems. They are distinguished from organizations - that are defined as bodies of individuals with a specified common objective. For example, organizations could be political organizations (political parties, governments, ministries), economic organizations (federations of industry), social organizations (NGOs and self-help groups) or religious organizations (church and religious trusts)—(North 1990; 1986; 2006).

Institutions such as property rights are seen as a way of structuring human interaction of a repeated nature. They are seen as a way of reducing transaction costs inherent in human exchange. Transaction costs are the costs of dealing with the market – the costs of information, contracting and enforcement. By providing a structure and predictability to human interaction, institutions reduce the inherent transaction costs. Some economies are understood to perform better than others because they have property rights structures and legal systems that are efficient and, as such, keep transaction costs low (North 2005; 2006).

When this understanding of institutions and property rights is applied in the context of natural resources such as water, the reference is to conventions and practices that structure human interaction with such resources. Agarwal (1999) defines institutions as sets of formal and informal rules and norms that shape the interaction of humans with each other and with nature (without them social interaction would not be possible). Institutional arrangements could thus be defined as rules and conventions, which establish people's relationships to resources such as water, translating interests into claims and claims into property rights. More specifically, water institutions can be defined as rules that together describe action situations, delineate action sets, provide incentives and determine outcomes both in individual and collective decisions related to water development, allocation, use and management (Saleth and Dinar 2005).[1]

From a New Institutional Economics Perspective, thus, property rights in water are seen as an institution that serve as a source of incentives for individual and group behavior governing water use. They serve as a mechanism for avoiding externalities in the use of water and averting what is popularly called the tragedy of the commons (Hardin 1968). They generate incentives for efficient resource use and for avoiding depletion and overexploitation. Thus, they are seen as a means of addressing what is called the 'incentive gap' in Indian irrigation (Saleth 1996; 2005).

Fluid Boundaries: Varying Property Right Regimes

A fourfold classification of property rights is generally understood as: i) distinguishing state property; ii) common property; iii) private property; and iv) open access. Sweeping statements regarding the property rights status of water, however, though often made, are best avoided, as it is the specific context of water use that defines the property rights regime; the property rights regime may change as water flows from one point to another. For instance, in India, water in a river, large dam or reservoir is State Property, by virtue of the Easement Act of 1882. However, when it flows past an outlet on a watercourse serving a group of farmers it is accepted that those farmers have a defined right to use it and, as such, it becomes their common property. But, when it reaches the fields of individual farmers and given the way the farmer's access is defined, it acquires the status of a private property.

A Legal Pluralistic Perspective on Water Rights

As against new institutionalist perspectives, legal anthropological approaches view property rights from a perspective of how different sources of property rights co-exist at the same time

[1] A detailed analysis of institutions, in general, and water institutions, in particular, is provided by Saleth and Dinar (2004).

or confront the same user, as well as the relationship among them. In legal anthropological approaches, property rights are approached from a perspective of legal pluralism. Benda Beckmann F von (1988) reserves the concept of legal pluralism to denote the "duplicate nature of institutions, rules, and processes, as also the relationship between different normative systems." Legal pluralism is an umbrella concept indicating the condition that more than one legal system or institution co-exists with respect to the same set of activities (Benda Beckmann F von 1999). For instance, statutory law may co-exist along with customary law and socially accepted conventions and practices.[2]

Several points merit attention when we approach water rights from a perspective of legal pluralism. First, the premise of legal pluralism shifts focus from the legal or property rights system to the individual. Thus, the focus is not the legal system or property rights system per se, but the individual, who is confronted with different legal or normative systems pertaining to the use of water. Second, a legal pluralistic premise requires the recognition of different bases of legitimacy. State law and property rights emanating from the state have their legitimacy in the state; customary law, conventions and practices, have their legitimacy in a system of social sanction. Essentially, a perspective of legal pluralism sensitizes us to the fact that there may be more than one source of water rights.[3] Customary rights are often found to co-exist along with rights sanctioned by the state. This can, and has often been, a cause of conflict over water. Furthermore, legal pluralism helps us question the premise that no property rights exist. A situation where there are no state sanctioned rights could be interpreted to be a situation of 'no property rights existing', when in practice, there may be a system of rights and mutually constitutive obligations devised and followed by the community, as often observed in community-based systems of irrigation management.[4] Finally, legal pluralism can be applied to a gendered analysis of property rights, in how men's and women's access to water may be socially differentiated.

While new institutionalist perspectives emphasize the need for creating a property rights structure in order to correct the incentive structure facing water users, legal pluralistic perspectives sensitize us to the fact that more than one set of property rights might co-exist. Therefore, any effort at creating a new property rights structure must be cognizant of how it will articulate pre-existing notions of property rights. In this context, there is a need to distinguish between water allocation and distribution, or between concretized rights and materialization of rights. Statutory rights may be granted by the state. However, individuals may mobilize social relationships in order to make these rights more effective. Water rights may be defined by state

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[2] Three major ideas run in the writings on legal pluralism. First, there is a questioning of legal centrism, namely, that all legal ordering is rooted in state law (Merry 1988; Griffiths 1986; Spiertz and Wiber 1996). Furthermore, what is considered to be a legal system is hardly a system because it is not coherent or complete (Spiertz and Wiber 1996). The second idea, which is related to the first, is that of the co-existence of several normative orders. An individual finds himself at the converging point of multiple regulatory orders (Vanderlinden 1989). There is an interplay of plural normative frameworks in society; rules, law and institutional frameworks are independent social resources that actors mobilize to accomplish their ends (Spiertz and de Jong 1992). Third, there is recognition that legal pluralism is all pervasive (Merry 1988; Griffiths 1986). Legal pluralism is present in all societies; the difference being only a matter of degree.

[3] A good synthesis of cases analyzing water rights from this perspective is provided in Bruns and Meinzen-Dick (2000).

[4] Specific instance of water rights systems in community-managed irrigation systems in India are presented later in this paper.

law, but realized through another normative system, based on social relationships. This has been observed, for instance, in the warabandi system of irrigation prevalent in the Northwest Indian state of Haryana (Narain 2003), as also revealed by similar studies in Pakistan (Merry 1986a and b; Meinzen-Dick 2000).

Rights by Prescription and Rights by Negotiation

A useful distinction is provided in this context by Molle (2004), who distinguishes between rights by prescription and rights by negotiation. The definition of water rights by prescription is an approach whereby the state defines the priorities to be given to different uses, while users are considered the recipients of the formalization process. These rights may be permanent, or granted for a number of years; they may be conditional upon productive use or be inalienable. Another alternative is to conceive water rights from the bottom-end users. Because many local, formal or informal rights pre-exist, it would be more apt to construct rights gradually, through step by step negotiation between those parties concerned with the management and use of water. It is important to bear in mind that water rights are not static entities, but are in a constant state of flux. There are several contexts in which water rights are negotiated and renegotiated, and water users deploy a wide range of strategies to extend their water rights or make them more effective. These include political pressure, persuasion, petitions and written applications (see Box 1.) They also include tampering with outlets such as breaking outlet locks and gates (Mollinga 1998).

Box 1. Renegotiation of Water Rights on the Sitapur Minor

The members of the Sitapur Village exercise different forms of power to justify their claim over water. This includes going up the minor head, and making appeals to political and administrative authority. On April 16, 2000, when I arrived in the Sitapur Village, I learnt that a group of village folks had gone up the minor to ask the beldaar to release more water. The water supply at the tail of the minor was only 1 foot, way below the authorized discharge. There was an acute scarcity of water and the farmers complained that their johads (village ponds) were dry and the livestock was dying. I learnt that at that point of time, farmers had inserted siphons at four places along the minor. This had disrupted the supply of water to the village. There was some negotiation with the 'Regulation Beldaa'r who relented to remove one more kadhi; this released enough water to fill one johad.

The farmers in the Sitapur Village also turn to different levels of administrative and political authority to justify their claim over water, though, with little sustained corrective response. They have written and sent petitions to the SDO, XEN and JE (position holders in the Irrigation Department). They have also made representations to the present and previous chief ministers of the state. In September 2000, the Chief Minister of Haryana, O P Chautala, was passing by the village on one of his 'sarkaar aap ke dwaar' (government at your door-step) program tours. A large group of farmers assembled along the minor to stop his fleet of cars and to draw their attention. The usual response of the farmers to how effective this strategy is thus: "for some days, water flows as per the desired standard, then it is back to normal."

Source: Narain (2003)

Socio-technical Perspectives on Water Rights

The socio-technical approach to irrigation developed at the Wageningen University, in the Netherlands (Kloezen and Mollinga 1992). This approach essentially sees water management and distribution practices as socio-technical constructs and phenomena, shaped by the interface of technology and institutions. There are three premises that support this theory — that technology has social requirements for use; technology is socially constructed; and that technology has social effects. This approach has been applied to, among other subjects, situations of irrigation management transfer (Narain 2003; Khanal 2003); analysis of market-oriented reforms in irrigation (Kloezen 2002); the social construction of tank irrigation technologies (Shah 2003); and of canal irrigation technology (Mollinga 1998).

When viewed from this perspective, water rights are seen essentially as a certain configuration of technology or the design of canal irrigation and concomitant social infrastructure and relationships. The relevance of socio-technical perspectives on water rights is that they sensitize us to the fact that water rights do not exist in isolation, but instead are embedded in technology and social relationships. For instance, water rights in the warabandi irrigation system of Northwest India, defined in terms of the time for taking water, are the result of a certain technology for water distribution that seeks to ration out scarce water supplies among a large number of farmers in proportion to the size of their landholding (Malhotra 1998; Narain 2003; Narain, forthcoming). Once a water right is defined in this sense in terms of a time for taking water as laid out in the warabandi schedule, farmers deviate from it by exchanging turns, on the basis of informal relationships (see Box 2).

Box 2. Visit to Kishan's Fields

While I was sipping my tea at the dhaaba (road-side eating joint), a man called Kishan introduced himself. He had 5 kilas (acres) of his own land and had taken 16 kilas of land on contract. We then reached his fields at about 10.45 a.m and started walking towards the point where his field channel took off. His awsara (turn for taking water) started at 10.50 a.m. When we reached the head of his field channel, he showed water flowing to his neighbor's fields. A small embankment of mud lay across the head of his field channel. All he had to do was to break that embankment and insert that mud over the head of his neighbor's field channel so that water would start flowing to his fields instead. They conversed with each other and I started inspecting his fields. Kishan said then that we should go back. I was surprised, I looked at my watch and said "but your awsara (turn for taking water) has started. It is past 10.50. I have come to see you irrigate." "No," he said, pointing to his neighbor, "he is taking my share of 50 minutes today." At this point in time, his neighbor intervened, "next time, I will give him my 50 minutes. Then, he will have a total of 1 hour and 40 minutes to irrigate." I was quite impressed. The entire transaction had taken place in front of my eyes with great felicity and smoothness and I was amazed at how little effort was involved in it.

Source: Narain (2003).

This could be contrasted with water rights in the shejpali system of western India, where farmers apply for irrigation water in each cropping season, and these applications are granted by the irrigation department based on the availability of water stored in the reservoirs.[5] Water rights in these systems take the form of irrigation passes that are sanctioned by the Irrigation Department in response to applications for water received and the availability of water stored in the reservoir. Thus, water rights in the warabandi and shejpali systems take a different form in response to the differing types of irrigation systems, namely the design and characteristics of the irrigation infrastructure, and the concomitant institutional framework for water delivery.

The relevance of these approaches to the analyses of public policy interventions for creating a water rights structure needs to be appreciated. While new institutionalist perspectives that have dominated the current thinking on water rights in India emphasize the creation of a water rights structure to ameliorate the incentive structure facing water users, and have formed the basis of much of the policy prescription in favor of instituting a water rights structure through public policy intervention, socio-technical and legal pluralistic perspectives urge us to be cognizant of existing notions of water rights as embedded in technology and social relationships. Proposals for water rights reform and market creation need to take into account existing notions of property rights, rather than start from a premise that no property rights exist, or that they are ill-defined or insecure. Any new system of water rights that is imposed will articulate with existing systems and notions of water rights. It is important to be conscious of how this articulation would take place, and what its effects would be.

The second significance of this analysis is that it may be in the long run, futile, and perhaps inappropriate to think of 'a' property rights structure for India; instead, it is more appropriate to think of differentiated property rights suited to different technological, social and hydrogeological conditions. Besides, given that property rights are not static entities, but constantly in flux, being negotiated and renegotiated, and that there is a discrepancy between the concretization (or definition) of water rights and their materialization (or realization), it questions the efficacy and potency of a property rights structure as a tool for accomplishing specific public policy goals, such as the management of irrigation demand.

The Indian Experience: Evidence of Water Rights Systems

Water rights systems of various kinds are known to have existed in India for a long period of time under various kinds of community-based and state-managed irrigation systems. These systems have emerged in response to different local, social and hydrogeological conditions, and have existed, in some cases, for centuries. It is important to note that in these systems, water rights are defined differently; this may be in terms of a time for taking water, on the basis of crop water requirements, or family size. Some of them have had an in-built element of flexibility to respond to seasonal variations in water supply, even as crop-water requirements are known to have been the basis for the determination of the water right. A case in point is the phad system, which is known to have existed in western Maharashtra for several centuries (Box 3). In other systems, water rights have been defined in terms of the time for taking water, in proportion to the size of landholdings, as seen in the warabandi system of irrigation prevalent in Northwest India (Box 4), and also referred to earlier in this paper.

[5] A detailed discussion of this process is beyond the scope of this paper and can be found in WALMI (1998a, b), Narain (2003) and Lele and Patil (1994).

Box 3. Water Rights in the Phad System

The community-managed 'Phad Irrigation System', prevalent in northwestern Maharashtra, came into existence some 300-400 years ago. The system operates on three rivers in the Tapi Basin, Panjhra, Mosam and Aram – in Dhule and Nashik districts. A series of bandharas were built in these rivers to divert the water for agricultural use. Variations in the supply of water are managed annually by demarcating the command into two categories. Assured irrigation is so limited that in most years it can be irrigated without much difficulty. In years of water scarcity, irrigation is done by extending the rotation period in summer, with less strain on the system. Division of the command into phads and planting of only one crop in each phad helps in the management of irrigation application. The water requirements for a phad are the same, and the entire area in a phad'can be treated uniformly for water application. Sharing of water among the phads'can also be varied according to different water requirements for different crops. Thus, a phad with a wheat crop can be allotted a higher share of water (per hectare) than a phad with a sorghum crop. The sequence of irrigation in a phad is from head to tail. At the head, farmers receive irrigation water first, and the water application is relatively high. When the upper farmers irrigate, excess flows reach the lower farms. To ensure adequate supply of water to the tail reaches, a second watering to the farmers at the top is not allowed until all farmers along the canal have received irrigation water.

Source: Agarwal and Narain (1997)

Box 4. Water Rights in the Warabandi System of Northwest India

Warabandi, prevalent in Northwest India and Pakistan, is a system of water distribution that is designed so that every farmer is entitled to receive a pre-determined share of water in proportion to the size of his landholding. 'Wara' means turn and 'bandi' means fixation. Thus, warabandi means fixation of turns. It implies a rotational method of water distribution. The cardinal principle underlying the warabandi system of irrigation management is that the available water, whatever its quantum, is intended to be allocated to cultivators in equal proportion to their Culturable Command Area (CCA), and not to meet their total demand. This imposes water scarcity conditions in the command area. The theory of the warabandi arrangement is that each cultivator is assigned a turn, represented by the specific period of time--a time share--and the volume of water available during that slice of time is his to use. This time share becomes a property right legitimized by the state through the creation of a formal and legal warabandi roster for the delivery channel in question. The warabandi share, as a property right, then serves to organize the social relations of irrigation among the cultivators and between them and the irrigation agency.

Sources: Coward 1986; Malhotra 1998; Narain 2003

An alternative basis of allocating water rights has been on the basis of the size of the family, as seen in the Pani Panchayats of western India. An important feature of this experiment was the separation of rights in water from rights in land; the agreed principle was that water sharing would be on the basis of the number of members in each family. Each member would be entitled to half an acre of irrigation with an upper ceiling of two and a half acres for a household. The water rights would not be attached to land. The Pani Panchayats have existed outside a statutory organizational set-up, based on locally evolved norms and regulations regarding water use. Thus, they are essentially self-governing institutions formed to govern water management based on mutually agreed norms. They have existed for sharing water mainly among small and medium farmers belonging to a single caste. Thus, they have been characterized by an element of social and economic homogeneity among their members.

The failure of the Pani Panchayats to define a family or household resulted in making the water distribution rule more favorable to farmers with large families (Keremane et al. 2006). There has been only scant evidence of any landless receiving water since the formation of the first Pani Panchayat in 1979, demonstrating the impracticability of the principle of separating rights in water from rights in landholdings. Furthermore, these Pani Panchayats have been on the decline on account of several factors such as the existence of internal disputes among members, absence of explicit conflict resolution mechanisms and the policies and the lack of support from the government.[6] It is possible to locate many other systems of water rights in India.[7] The existence of such systems is often used as a basis for evidence in favor of introducing and institutionalizing a property rights structure, on grounds that a water rights structure is compatible with the Indian ethos. However, it is important to bear in mind that they emerge in response to specific local social, hydrogeological and technological conditions and, as such, make much more a case for the existence of varying property rights regimes rather than 'a' property rights structure. Furthermore, the reason that they have existed is their compatibility with local conditions, and that does not in itself provide evidence that a property rights structure created through top-down, public policy intervention will meet with the same success and acceptability.

Rationale for a Property Rights Structure

Why is a property rights structure needed? The basic underlying rationale for the establishment of water rights, from a policy perspective, is that a clear definition of who is entitled to use a certain amount of water, with the specification on when and where this is possible, will reduce uncertainty and conflicts (Molle 2004). A water constraint experienced by individual users will compel them to use water more efficiently. And this practice will have a significant impetus when they have the option of an economic exchange for the water thus saved (Saleth 2005). In the Indian context, current debates on water rights in the context of groundwater revolve around addressing the incentive problem associated with overexploitation, the functioning and regulation of water markets and addressing equity issues, both at the intra-generational as well as inter-generational level. In surface water, too, rights in water have been tied to rights in landholdings, and the need to separate the two has been considered necessary from an equity perspective.

[6] The separation of rights in water from rights in land has also been a subject of the agenda for several nongovernmental organizations, such as SOPPECOM in Maharashtra. The separation of rights in water from rights in land, nevertheless, is a subject that requires strong political will that is unlikely to be forthcoming.

[7] A detailed listing is provided in Saleth (2005). See also Agarwal and Narain (1997) and WALMI (1998a, b).

Rationale for Water Rights in Irrigation Management

Though India does not have at present any explicit legal framework specifying water rights, various 'Acts' in existence have the basis of defining such rights (Saleth 2005). Early British legislations did recognize customary water rights of individuals. However, with the Easement Act of 1882 and the Madhya Pradesh Irrigation Act of 1931, the state's absolute rights over all rivers and lakes were firmly established. In surface irrigation, the case for a property rights structure as a tool for demand management has been linked closely to a case for market creation (Narain 2003). The premise is inspired by fundamental neo-classical economics: well-defined, secure property rights in water will, through an invisible hand, lead to a situation where water is allocated to the highest valued uses, and a price will emerge that is a market clearing equilibrium price. Furthermore, this price, when constituted through the interface of the forces of demand and supply, will convey the scarcity value of water (Rosegrant and Binswanger 1994; Meinzen-Dick and Mendoza 1996; Anderson and Snyder 1997). This, in turn, could serve as a potent tool for curtailing demand.

It is argued that excessive resource depletion and environmental degradation are the result of misleading price signals, which result from the absence of markets and secure property rights in resources and environmental assets. Establishment of secure property rights should lead to the emergence of markets and scarcity prices for the resource in question. With exclusive and secure property rights, resource depletion would be internalized (Panayotou 1994). Once the water rights systems are set up, water markets in water-scarce areas will establish the market value of water, which is also a reflection of the opportunity cost of water (Kemper and Olson 2000).

Second, secure property rights are advocated on grounds that they could empower users (Rosegrant and Binswanger 1994). Security of tenure could lead to long-term investments in water saving, cause users to consider the opportunity costs of water and to use it efficiently, and gain additional income from the sale of water and internalize externalities. It would be more responsive to changes in water values as demand patterns and comparative advantage change. Third, it is argued that when water can be made available to meet demand through water markets, it reduces the need for constructing costly supply-oriented infrastructure and leads to a more rational and economically viable allocation of water resources (Kemper and Olson 2000). Markets can allow rapid changes in allocation in response to changing demands for water and can stimulate investment and employment as investors are assured access to secure supplies of water (Thobani 1997).

Institutional Demand for Water Rights

Another reason that the subject of water rights in surface irrigation has acquired some prominence in recent years is in the context of debates on irrigation management transfer. Water rights have been identified as a subject that has been overlooked in the design and implementation of programs for irrigation management transfer (Mollinga 2001). On the other hand, water right is a subject that such programs need to explicitly address. A pertinent issue is: why would farmers come together to form a water users' association unless they see a perceptible difference in how water rights are defined (Narain 2000; 2003)? Does the formation of water users' associations strengthen farmers' claim over and access to water, or does it maintain the status quo?

The case for a property rights structure has been a prominent subject in debates in the realm of groundwater governance and policy for over two decades. Such authors as Shah and Raju (1988) have referred to the need for a well-defined rights structure in the interest of equity among users. Dhawan (1975) has argued for such a structure in the interest of sustainability. Similarly, Moench (1994) has argued for a similar system for the successful functioning of water markets and water user groups. A property rights structure has been seen as a viable alternative to other policy interventions for groundwater management, which have been unsuccessful in their impacts (Narain 1998, 2000; Kumar 2000; Saleth 1996, 2005). These measures have included licensing and credit or electricity restrictions for the construction of wells or spacing norms (Shah 1993). None of these measures have had a significant impact.

There has been a tendency to scuttle licenses issued by the state's groundwater departments for electricity connections by the rich and influential farmers. In the event of credit restrictions, the well-off farmers are known to have resorted to informal sources of credit or to even self-finance their structures. Similarly, when the water table is high enough, in the face of electricity restrictions, the affluent farmers have been known to get away with diesel connections. Besides, these measures have sought to regulate only the establishment of groundwater structures, rather than the quantum of water extracted. The policy and institutional framework for groundwater, then, has been considered not only peripheral to the sector but also regressive in its impact, favoring the pre-emption of the resource by the rural elite.

There are no de jure rights in groundwater; but de facto, all land-owners have the right to groundwater underlying their land. The Easement Act (1882) allows private usufructuary rights in groundwater by viewing it as an easement inseparably connected to land. The Transfer of Property Act 1882 provides that easements (in this case groundwater) can be given to one only if the dominant heritage (in this case land) is also transferred. Conversely, the Land Acquisition Act asserts that if some one is interested in getting rights over the groundwater, he would have to be interested in the land. Thus, groundwater is viewed essentially as a chattel attached to land. There exists, at the same time, no limit to how much water a landowner may draw, in contrast to a legal structure that specifies property rights setting absolute limits to collective and individual withdrawals. Once again, the legal framework is conducive neither to equity nor to sustainability.

Post-colonial efforts at legislation have been made through the Model Groundwater Bills of 1970 and 1992. The central focus of these bills has been in the creation of a groundwater authority comprising essentially representatives of the government and the technocracy for giving clearances for the installation of water extraction structures (Narain 1998, 2000; Kumar 2004). However, once again, they seek only to regulate the creation of water extraction mechanisms, rather than the quantum of water withdrawn. Besides, there has been opposition to the bills on the grounds that like the past record with the system of licensing, they would tend to breed corruption and inequity. It is also felt that such an approach ignores the possibility of successes through localized, participative approaches and adopts a simplistic, centralized approach that fails to consider the wide array of management options suited to diverse sociological as well as hydrogeological contexts (Narain 1998; Kumar 2004). While some states have made certain efforts to tinker with and to implement this legislation, it is felt that even if they would succeed, there would be no significant impact on promoting either sustainability or equity. In 1996, the Supreme Court of India declared the Central Groundwater Board as India's authority that would take custody of her groundwater resource and arrest overexploitation of the resource. After as much as a decade, Shah (2008) notes the inability of the body to register, let alone regulate, the over 350,000 domestic wells scattered even through the capital city.

More recently, the subject of the need for a property rights structure in groundwater has acquired significance in the context of localized struggles for water rights and more so in rights to development. The pre-emption of scarce groundwater supplies for industrial use, such as for manufacturing beverages brought popular attention to the subject of use and ownership rights over water (Drew 2008). This has taken the form of public vs. private ownership of groundwater, as in the case of Plachimada, in Kerala, wherein the Perumatty Panchayat chose to support the tribal women who were conducting an infinite sit-in to stop the loss of an estimated 1.5 million liters of water a day. After filing a Public Interest Litigation in the Kerala High Court, the Kerala Chief Minister ordered the closure of the plant on February 17, 2004. The Perumatty Panchayat has continued to withhold permission of the company to resume operations (Ranjith 2004). Another context in which the subject of a property rights structure for groundwater will assume significance now is in terms of growing rural-urban conflicts over water. With the advent of urbanization, as water is diverted to urban uses, rural water supplies for agriculture will come increasingly under threat; conflicts and social and political unrest will intensify in the absence of well-defined rights to groundwater use.

Water Rights Structure: The Role of Public Trust Doctrine

Given the failure of past efforts to regulate groundwater withdrawals through a wide range of legislative and regulatory measures, and with growing struggles and pressures over groundwater use, a property rights structure has been seen as a viable alternative, for addressing equity, efficiency and sustainability concerns in groundwater use (Saleth 1996). Saleth (1996) advocates a water rights structure specifying individual and collective limits to water withdrawals under which water resources would be held by the state under the 'public trust doctrine'. Under such a structure, the state is seen as a trustee of the country's water resources under a premise of stewardship; equity can then be achieved at the stage of distributing individual and collective water rights, efficiency can be enhanced by permitting the exchange of water rights, and sustainability can be ensured by limiting overall water withdrawals by specifying absolute limits, collectively as well as individually. Under the public trust doctrine, the overall water allocation, regulation, and management are with the state, and community organizations under the influence of the public trust whereas field level water allocation and use are under private hands and market influence (Saleth 2005). The government at the appropriate level has the responsibility to establish the legal framework for the water rights system including formal mechanisms for conflict resolution at the regional level. According to Saleth (2005), a water rights structure could be a rare policy instrument that accomplishes the three policy goals — sustainability, efficiency and equity, simultaneously and effectively.

The International Experience: Some Evidence

Several countries have made a move towards market-based allocation of water based on a property rights structure, as against command and control measures in response to varying levels of physical, institutional and financial scarcity (Venkatachalam 2008). However, there seems to be a difference in terms of the factors that have led to the movement towards an adoption of a property rights structure. In developed countries like USA and Australia, water scarcity is known to have lead to its evolution. On the other hand, in developing countries like Chile, Mexico and Morocco, the move towards a property rights structure was part of overall economic reform processes.

On the whole, the experience of countries such as Australia, Chile, and the western parts of the US suggests that once the Water Rights System is established, economic incentives emerge for the development of more robust but less costly water measurement technologies (Saleth 2005). The experience with these countries also suggests that once the rights over most of the resources are already claimed, meeting the rights of new entrants is met by reallocating the existing rights mostly through markets or state-managed compensation procedures. As seen in Chile, these rights may not necessarily be ownership rights; they could as well be usufructuary rights.

Studies have shown that a move towards a property rights structure does result in increased water use efficiency and productivity and lower transaction costs, even as the outcomes depend on the political set-up, historical factors, institutional and policy aspects (Samad 2005). One critique of the limitation of the functioning of a property-rights based market structure, however, comes from questioning the functioning of property rights and water markets as purely economic phenomena. This is borne out, for instance, by the evidence of market-oriented reform policies in Mexico (Kloezen 2002). Kloezen argues that cost-recovery; financial autonomy and water pricing and marketing need to be seen as socio-political constructs. The behavior of actors in settings of market creation is not purely guided by conditions of economic rationality, but also shaped by social and political factors. In Chile, while formal water markets are known to have improved the economic efficiency of water use and stimulate investment as demonstrated by Thobanl (1997), Bauer (1997) shows how sales in canal water tended to be limited on account of several geographical, local and cultural factors. In general, the Chilean model of water resource management shows the need for a more institutional and interdisciplinary approach to the economics of water (Bauer 2005).

Creating Water Rights: Opportunities and Constraints

Given a convincing rationale for creating a property rights system as a tool for demand management as well as the existence of water rights systems already in different parts of the country, and some evidence in support of a water rights structure from international experience, what supportive conditions are needed to institute such a system, and do these conditions exist in Indian settings? The issue of defining and enforcing such rights in the context of water with its fluid and fugitive characteristics requires indeed specific technical, organizational and infrastructural conditions (Saleth 2005). Reidinger (1994) argues that three conditions are essential— water rights must be clearly specified and legally enforceable, water supplies should be reliable and delivered on a volumetric basis and there must be some form of water user organization.

Hydrological Databases

To begin with, defining quantitative rights requires a very sound knowledge and control of the hydrology of the basin, its water balance and its surface and underground flows (Molle 2004). Data collection and processing must not only be of a high standard but also be made transparent and accessible, so that users may make sense of the share of water that they are able to access. The most immediate technical requirement is to establish a water balance for each appropriately defined hydrogeological unit under use and source–wise disaggregated conditions as well as alternative scenarios. It is believed that meeting this requirement for most areas in India is not difficult, given the availability of information and technical expertise (Saleth 1996; 2005). While the establishment of the water rights system is likely to generate new demand for additional and more refined information, the existence of the necessary technical capacities and organizational preconditions can enable most states to meet such information needs. More than a decade ago, Saleth (1996) demonstrated that India indeed had the technical capability, institutional capacity and the adaptability to implement and monitor such a system and that the technical and institutional capacity would only further improve in the years to come.

Decentralized Organizational Arrangements

Enforcement of a property rights structure, monitoring and conflict resolution at the basin and local levels further require decentralized arrangements such as basin organization, local governments, community organizations and user-based arrangements. In India, there is evidence of local community-based institutions' involvement in allocating and managing water, as seen above. More promise on this is provided by recent efforts directed at management decentralization through water user associations. However, the validity of several of the other conditions that are necessary for the functioning of a property rights structure and the consequent emergence of water markets, as a potential tool for managing irrigation demand, has been widely challenged (Young 1986; Bolding, Mollinga and Straaten 1995; Moore 1989; Narain 2008). It is argued that water markets of the kind envisioned by neo-liberal enthusiasts based on a property rights structure would not emerge in Indian canal irrigation. Several factors are known to restrict trade in water. These inhibiting supply characteristics include mobility, economies of large size, uncertainty and variations in supply and availability of alternative sources of supply. Other factors include high costs of storage and conveyance and high transaction costs relative to likely gains from potential exchange.[8]

Stable, Volumetric Water Supplies

Important constraints emerge from the wide variations in the availability of the water supply in Indian irrigation systems. The definition of entitlements and allotments implies that the corresponding amount of water can be delivered during a specified period (Molle 2004). Depending upon the size of the basin and the degree of technical control on flows, this assumption may be too optimistic. Uncontrolled water pumping or diversion may affect flows; conveyance and control structures may be manual and rudimentary; low water levels and low heads in dams or canals may not allow managers to ensure planned discharges; rainfall and side flows permanently alter the effective flow at different points in the system; and conjunctive use of water blurs assessment of demand and contributes to the deregulating of cropping calendars by allowing farmers to be more flexible.

[8] This should, however, be distinguished from sales of groundwater services to irrigators, as evidenced in the groundwater markets, for instance, in Gujarat. Groundwater markets have emerged as a response to the open access and fugitive nature of groundwater resource, causing farmers to pump large volumes of water for commercial purposes. See, for instance, Shah (1993) and Dubash (2002).

Redesigning Irrigation Systems

Under conditions of protective irrigation in India, where water is 'scarce by design', the possibilities of water markets emerging are very limited (Narain 2003; Narain 2008).[9] In fieldwork in the warabandi system of irrigation in North-West India, for instance, it was found that while there were some sales of canal water among users, they were confined geographically, and were on a very small scale. The basis of a water sale is a surplus; a farmer would choose to sell his water right only after he had met his own requirements. When a farmer's water right is inadequate relative to his requirement, as is the case here, there is no saleable surplus. Thus, the basis for the sale of a water right is limited. Where groundwater supplies are inadequate and/or of an inferior quality, as quite often they are, dependence on canal irrigation shall continue to be high. Thus, while theoretically the argument in favor of property rights reform and market creation may sound neat and appealing, this argument acquires a new dimension when placed in the context of the design characteristics of canal irrigation.

Social Values and Transaction Costs

Apart from economic values, communities associate a certain sense of security and control with water over and above its direct economic significance, which may cause the emergence of a market to be 'sluggish'. Farmers have been found to have a psychological resistance to selling their water share (Narain 2003). It is something that is just 'not done'. Narain found that when a farmer did not need his water share, he chose to lend it instead of selling it. This is because lending his water share created a basis for a future claim, since the borrower was obliged to return it.

The presence of many small farmers and political risks in creating the legal and organizational apparatus and conceptual or information problems in defining water rights in physical and legal terms constitute major challenges in moving to a property rights structure in water (Saleth 2005). Perhaps the most important constraint in this context is likely to be the high transaction costs of dealing with millions of farmers scattered geographically over large areas (Shah 2008). This is where the Indian conditions are most unique, particularly with regard to groundwater irrigation. Shah notes that India's groundwater economy is characterized by some 20 million small well-owners, scattered over a vast countryside, supplying groundwater irrigation service to another 30-40 million marginal farmers. While the volume of groundwater India diverts every year is only a little over twice what the USA does, the number of independent users are over a 1,000 times the number in the western USA. Defining rights also means that there is a political will and a legal capacity to act against those who disregard them, to control new users and limit corruption (Molle 2004). Poor stakeholders may be unaware of their rights, unfamiliar with administrative or legal processes and have an instinctive (and understandable) reluctance to engage in them.

Concluding Remarks

Given that certain conditions are needed for the institutionalization of a property rights structure in water, are these conditions met to the extent that a water rights structure can be

[9] Protective irrigation systems seek to divide a limited water supply over a large area in order to protect large numbers of farmers over large areas against droughts that would otherwise occur. See Mollinga (1998).

successfully instituted? The institutionalization of property rights structure is, in principle, very much possible at the level of user groups in the shejpali system of irrigation prevalent in western India (Gujarat and Maharashtra). The institution of property rights and creation of water markets is technically feasible at the collective or group level, given that it is possible to deliver volumetric supplies of water to farmers and to outlets, for instance on the basis of season-wise quotas; irrigation systems are fitted with volumetric devices such as the V-notch and standing wave flume. Indeed, volumetric water supplies have been tried in several experiments in Maharashtra as part of the programs for IMT (Irrigation Management Transfer).[10] However, given that water rights at an individual level are defined in a strict sense only after the farmers have made applications and these have been sanctioned by the Irrigation Department, it is hard to think of a long-term institutionalization of water markets in these systems at the individual user level.

In the warabandi irrigation system that is prevalent in northwest India, (namely, Punjab, Uttar Pradesh and Haryana), water rights are already defined in terms of the time for taking water, and farmers exchange their time slots to suit their convenience. So, a water rights system is already in place, concomitant and in fit with the physical infrastructure (Narain forthcoming). One critique of this system, however, is that the rights are defined in terms of the time for taking water, rather than the volume, making the system inequitable across head and tail reaches. Thus, the system rations the time for taking water rather than water itself. Any effort at reforming this system from a rights perspective would be motivated more by considerations of equity, rather than those of demand management. Irrigation systems here are fitted with outlets such as the APM (adjustable proportionate module) and the open flume[11], wherein discharges vary with upstream water flows and, therefore, volumetric-based rights are a technical impossibility. In any case, since water rights are defined in terms of time for taking water, rather than volume, and users exchange their time slots to suit their convenience, it is hard to think of a water rights system as a potent tool for managing irrigation demand in these systems.

In South Indian canal irrigation systems, as in Karnataka, Tamil Nadu and Andhra Pradesh, the dominant practice is localization. Localization can be looked at as a rights system, wherein certain plots of cultivated land or farmers have the right to irrigation by virtue of an administrative order. However, that right tends to be rather weak, and not necessarily, actually, experienced as a right by farmers.[12] It is probably better seen as a regulation mechanism for the government, in which respect also it has tended to be weak.[13] Essentially, the 'rights' that localization has established are not enforceable; neither for farmers, nor for the government. Therefore, actual practices take the form of some kind of anarchy at the field level.

Given this context, a study on the Tungabhadra Canal (Mollinga 1998) showed that in practice, there was extensive rule-making at all levels. These rules tended to create de facto rights. The process of negotiated rule-making emerged as the core process - that lead to rights, in whatever way they would be defined or understood. While it is true that rights principles were present in such negotiations, but so were location-based advantages, physical

[10] See, for instance, Lele and Patil (1994) and Narain (2003).

[11] Technically speaking, these are semi-modular outlets, wherein the discharge varies with the upstream water levels.

[12] Personal communication with Peter Mollinga, May 15, 2008.

[13] The exception perhaps would be the early days of localization when farmers actually went to court sometimes for not getting water.

force, management styles of bureaucrats and local relations of power. In these conditions, therefore, it is unrealistic to see 'rights' per se as an important factor organizing irrigation practices, or influencing irrigation demand. As regards groundwater, though the arguments in favor of a groundwater structure are quite convincing and several of the technical and institutional conditions are known to exist in the Indian settings, perhaps the most important constraint is likely to be the high transaction costs of dealing with millions of farmers scattered over large areas. Even as rights-based institutions for groundwater governance are known to have successfully existed in the west, the distinguishing characteristic of Indian settings is the large number of scattered users, extracting water over a large geographical area that is likely to make the introduction of a water rights structure problematic.

In conclusion, this paper has three main messages to articulate. First, that it is perhaps unrealistic to think of 'a' water rights structure in Indian settings, given the diversity of technological, social and hydrogeological conditions. On the other hand, there is merit in recognizing a differentiated rights structure in alliance with local conditions of the kind described in this paper. Second, a rights structure is likely to play a more important role in organizing access to water, namely, defining who gets water, and how much rather than as a means of managing or curtailing irrigation demand, as a top-down public policy measure.[14] Third, the large number of groundwater users spread over large areas, making monitoring difficult, and the design characteristics of Indian canal irrigation systems as described in this paper are likely to pose significant constraints in introducing a water rights structure as a tool for managing irrigation demand.

[14] Here, too, access is likely to be mediated by social relations and other factors, rather than being solely determined by rights themselves, as defined.

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User Organizations as a Demand Management Option: Potentials, Problems and Prospects

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Context and Rationale

In the wake of emerging economic reforms and structural adjustment programs in most parts of the world, the statistic models of development that are followed by the public sector are increasingly subjected to public scrutiny, and for which the irrigation sector is no exception. Since water is the crucial input for increasing crop intensity and productivity, the demand for it has been increasing year after year. Among the competing demands for water, irrigation accounts for 75 % of the contemporary world's total use of water. At present 40 % of all food production comes from 17 % of agricultural land that is irrigated and irrigation water provides employment for about 2.4 billion people (DFID 1997). Globally, the amount of irrigated agricultural lands has increased almost by 2.4 % in the 1970s, to an additional 1.4 % during the 1980s and the late 1990s. It is projected to increase further by 0.4 % per annum for the next 34 years (FAO 2000). The challenge, then, before the irrigation planners is how to manage this growing demand for irrigation, given the finite physical availability of water in each country.

Before we discuss about the suitability of different organizational options necessary for managing irrigation demand, it is better to understand the dynamics that warrant demand management, more importantly in the context of major irrigation projects. Irrigation projects are supposed to have been designed scientifically, based on sound engineering principles, to meet crop water requirements in a given project area, which is called a culturable command area (CCA) in irrigation parlance. The experiences and results distilled from empirical research on a wide range of irrigation systems have shown that the designers and planners laid more emphasis on sound engineering principles for designing and building dams and did not pay necessary attention to the much more important long-term institutional role of water distribution, allocation and management (DAM) aspects. It was, perhaps, perceived that the construction of dams, storing water and releasing it to the fields through a network of canals as end of the problem, taking the timeliness, dependability and equity in sharing water and the consequent flow of benefits are granted with water releases to the field. But in reality that has not taken place.

Inequitable distribution of water has almost become an accepted norm, leading to a total alienation of tail-end farmers, which has created scores of social and economic problems

(Reddy 1995). Irrigation projects should, therefore, be characterized not as hydraulic systems to be run according to engineering principles, but as socioeconomic systems, where all participants – farmers, managers and politicians – presently maximize their private interest with respect to the cost of social goods and activities (Caruthers 1987). Caste, class and factional ties and antagonisms become relevant in the delivery of any goods and services to the community. It is essential to underscore this point, for irrigation systems tend to be viewed as complete in all respects, as mentioned earlier, when the channels reach the fields. In a very important sense, this only marks the beginning of the problem and not its end (Srinivas 1984).

Reforms in the irrigation sector at present should, therefore, be on improving water distribution, allocation and management, which has hitherto been neglected or not given the required attention. Lack of clarity on the roles, rights and responsibilities of all the stakeholders on the one hand and their respective accountabilities on the other, seem to be the root causes for many of the shortcomings and problems in the irrigation sector, more importantly in major irrigation. The successful management of irrigation demand depends upon, among other factors, motivation, commitment, cooperation and mutual understanding of two groups of stakeholders namely, irrigation engineers and farmers. Both groups have developed strong mindsets over time, perceived as appropriate and necessary to optimize the benefits from irrigation. The primary task in the demand management process is, therefore, to transform the mindset of the engineers and farmers, which calls for a thorough understanding of the caste, religion and faction-related dynamics in the community and mobilize them to undertake the task of irrigation management. This is possible only through community-centric approaches, something a local organization or an NGO will be able to do effectively. This is because of the fact that the region needs to integrate the technical, institutional, managerial, social and economic aspects of water resources management. This new approach for sustainable water supply and demand management depends on local involvement, solutions, and knowledge within an overall framework of local planning and operation.

The government will have several advantages in promoting local or community involvement from the inception of a reform process. Normally small water bodies like tanks, natural springs and other such systems tend to be widely scattered and their management by the government becomes cost ineffective because of the huge transaction costs involved in the management and supervision of the day to day operations of the systems. Local communities can understand better the rural dynamics that provide information on customary rights and responsibilities in managing seasonal water demands for different crops depending upon the fluctuations in water availability due to the vagaries of the monsoon. The ability and willingness of the local communities to take on the management of the system and distribution of water depends, however, on several factors, such as organizational capacity for system management and resource mobilization, economic and social incentives to sustain participation and well articulated rights, responsibilities, conflict resolution and other related operational norms and procedures to take care of the demand for water, arising out of fluctuations in the supply due to natural factors.

How to balance demand and supply of water under constantly emerging and difficult conditions is the major challenge before the water planners and managers across the globe, especially in the less developed countries. The policies, institutions and planning procedures in place at present to manage water are not well suited to ensure efficient and equitable distribution of water between inter- and intra-sectoral demands. This is because irrigation projects are constructed and managed by the government departments, because of their heavy capital requirements and the complicated technical inputs that are required. This government-dominated approach may be referred to as the supply-oriented management of irrigation systems. Due to a wide range of political economy factors, the government management of irrigation systems has deteriorated leading to several socioeconomic problems in the rural areas. The need for transferring management to user associations has, therefore, gained importance. For development does not start with goods; it starts with people and their education, organization and discipline. Without these, all resources remain as a latent, untapped potential (Schumacher 1975). Farmers who depend on irrigation water for their livelihoods have a strong incentive to manage that water very carefully. The government agency could never match the discipline that farmers impose on themselves when they manage their own system. Under the demand management approach, users through their associations make management decisions for distributing water, maintaining systems and collecting fees, while government plays a supportive role (Groenfeldt 1996).

The blue print approaches (top down) followed by the public agencies so far have not yielded the expected results in terms of equity, dependability and productivity of irrigation water. The success stories of community participation, which are few and far between, tend to vanish the moment the agency withdraws the incentives, whereas the participatory systems that have evolved through local initiatives and involvement, can be sustained for generations. This is because these participatory systems are built on local knowledge, wisdom, culture and locally available resources. It is in this context the user and community organizations become effective tools for the efficient management of water for irrigation and also for other purposes. This is due to the fact that the structures are based on strong social engineering principles, quite different from the public agency-centric ill-perceived operational rules.

Present Status of User Associations in India

Farmers' participation in irrigation management is not an alien concept in India. Historically, one could trace the trajectories of the evolution of local organizations and initiatives to harvest surface and ground water for irrigation (Reddy 1991). The existence of tank panchayats, spring channels associations (locally called *Kaluva Gonchi* in Andhra Pradesh), management of tank and canal systems (*Kudimarammath* in Tamil Nadu), *Kuhls* in Himachal Pradesh, where a typical community provide *Kuhl* services to 6 to 30 farmers, irrigating an area of about 20 hectares and diversion weirs (called as *Bandharas* in Maharashtra) just to mention a few, were all traditional water harvesting systems that were evolved collectively by communities based on local needs. The community was involved right from the design of the project till the completion of the physical infrastructure, and the projects identified clearly articulated roles and responsibilities for different stakeholders, and operational rules and regulations, in order to enforce user rights.

There are also informal conflict resolution mechanisms, including social sanctions for non-compliance with the agreed roles of individuals and rules of the association. For instance, the *khuls* were constructed, operated and maintained by the village community. At the beginning of each irrigation season, the water tender or water man, who operates the system, would organize the irrigators to construct the head wall and repair the *khul* and make the system operational. The water man plays almost the role of a local engineer. Any farmer refusing to participate in construction and repair activities without a valid reason would be denied water for that season. Subsequently a religious sanction evolved, which was initiated by the community and followed strictly to date without any excuse or favor, irrespective of a person's social and economic status. Such practices are many across the country, called by different names in different states (for details see Sengupta 1991).

Similarly, *eris* (tanks) in Tamil Nadu, were maintained by the local communities. Some historical data available from Chengalpattu District indicates that in the eighteenth century about 4 to 5 % of the gross produce of each village was allocated to maintain *eris* and other irrigation structures. Some lands, called manyams, were assigned to the village functionaries (*Neerugantis* or water men) to maintain the tank system and distribute water. This was the practice even in Karnataka and Andhra Pradesh. This can be termed as the era of the farmer-nature friendly irrigation systems evolution. These systems have been owned, operated and managed by the local institutions effectively and efficiently for generations. Even to this day they are as efficient as they were at the time of starting, maybe even 100 years ago in some cases. With the advent of British rule, and subsequent political economy considerations in the post-independence period, on-farm water problems and reliable supply of water led to enormous expropriations of village resources by the state, which in turn gradually disintegrated the traditional society, its economy and polity.

The traditionally evolved participatory culture seems to have been gradually diluted, due to a whole range of natural, social, economic and most importantly political factors, especially during post-colonial or post-independence period. For instance, tank systems, especially in the southern parts of India, which had a long history of community management, the government took over the responsibility of managing such systems after independence. Given the bureaucratic culture, they were unable to provide timely assistance to maintain the tank infrastructure. And as a result, physical infrastructure deteriorated over a period of time, leading to a gradual reduction in storage capacities of tanks and the consequent reduction in the area irrigated under tanks. Furthermore, due to natural factors like reduction in the runoff (due to changes in rainfall pattern), the widespread implementation of watershed programs in tank catchment areas, siltation and weed infestation of feeder channels, and also encroachment by the neighboring farmers, the frequency of water filling and tanks surplus had come down drastically. The tanks, which used to have a surplus every year, are not filling now even once in 5 years, in some cases not once even once in10 years and in some others even longer periods. The shift from more dependable water availability to uncertain and undependability has had a negative impact on farmer's interest in tank management, and had also resulted in the gradual disappearance of the traditionally evolved demand management strategies. The state governments now have realized the importance of and the need for reviving or restoring community management of tank systems and initiated steps to handover tanks to the user groups.

The process of reinventing the wheel of community management is in progress in several states, like Karnataka, Andhra Pradesh, Orissa and many others. The tank systems are being rehabilitated to the originally designed standards and handed over to the communities, by building the required capacity to operate and manage them on a sustainable basis. The capacity building includes identifying cropping pattern and planning suitable to different levels of water storage in the tanks to ensure effective demand management. The initial indications of this approach are quite encouraging, in spite of some threshold problems and teething troubles.

Groundwater development and lift irrigation offer a wide range of opportunities to tap water for irrigation purposes. Traditionally, dug wells were constructed by the farmers, either individually or in groups, depending upon the size of their landholding, and water lifted through animal-drawn water-lifting devices. These practices are widely prevalent in South India and also in Maharashtra, Rajasthan and other states. For instance, an open well with multiple owners called 'Saza *Kuva'* (*Saza* means partner and *Kuva* means open well) is an important source of irrigation in the Aravalli hills in Mewar, eastern Rajasthan. The construction is generally taken up by a group of farmers with adjacent landholdings, and water is shared on the pro-rata basis of the size of the holding. Protection of well and annual repairs and desiltation is taken up collectively by all the partner farmers. Similar practices are found in Andhra Pradesh. Farmers manage the groundwater in the wells by resorting to an appropriate cropping pattern, depending upon the monsoon and the consequent depth of water available in the well. Water is shared on the basis of the landholding. This is allocated in proportion to the land area owned by the farmer with well as the source of irrigation (Reddy 1994).

Similarly, spring channel irrigation associations in Andhra Pradesh that flourished once, have now become dysfunctional because of the reduced flow in the channels that is created by frequent droughts in several parts of the state. Some of them are, however, still functional with the same efficiency and effectiveness with which they had been working for more than 100 years. The traditional systems evolved through users' initiatives have stood the test of time and continue to function in diverse forms across the country. Because of natural constraints and limitations however, some of them could not be sustained. Even otherwise, the contribution of farmer- managed irrigation systems per se in the country, to the total irrigation potential is very limited. Though the contribution of groundwater irrigation is significantly more, it is mostly owned and managed by the resource-rich farmers.

Given the status of traditionally evolved users' associations and their contribution to the total irrigation requirements, the emphasis now is on farmers' participation in irrigation management in the agency-operated large and medium projects. This is because management of water distribution in large surface irrigation systems in India rests with the Irrigation Departments of the State. Most of the irrigation systems are supply-based, designed for a given cropping pattern, with estimated crop-water requirements. The literature available on irrigation impact clearly brought out the mismatches between the expected and actual impacts of irrigation on economic, social and environmental conditions. The need for and the significance of farmers participation in irrigation management under the agency owned and operated large surface irrigation system was realized all over the world. The attempts were, however, not systematic and sustainable. Except for a few isolated attempts, sustainable efforts have hardly been made due to a variety of political economy factors.

The Irrigation Commission 1972 has expressed concern about the need for the creation of an efficient and effective utilization of potential irrigation. It has, therefore, recommended an institutional set up at the state level to coordinate the activities of different departments as well as those of the user farmers. Based on the recommendations of the Commission, Command Area Development Authorities (CADAs) were constituted at the project level. This is, in a sense, a landmark beginning in India to provide scope for farmers' participation in irrigation management. But not enough attention was paid to the farmers' participation per se in the command areas. As a result, the demand management strategies were hardly adopted in these areas. This has led to inequitable distribution of water, depriving the legitimate right of the tail-end farmers to use irrigation water, and paved the way for the consequent social and environmental problems. For instance, water-related squabbles and litigations among farmers have increased, as have environmental problems like waterlogging, salinity, alkalinity and related health hazards to the rural communities.

Special efforts were, therefore, made in the 1980s in several states in the country to develop demand management, a non-structural approach, in the agency-operated canal command areas. For instance, the warabandi system of water distribution, which was effectively implemented in Punjab, Haryana and Western UP, was also introduced to the Andhra Pradesh and Karnataka later. While it was sustained in the northern states, the impact of the warabandi system in Andhra Pradesh and Karnataka was short-lived. Same is the case in many other states, including Maharashtra. However, Maharashtra made an attempt to organize village level committees for water distribution in the Girna project. But the village irrigation councils established in the project could not function properly and therefore could not be maintained (Lele et al. 1994). Institutional sustainability depends upon establishing sets of ordered relationships among people, which define their rights, creates awareness on the rights of others, and on each others' privileges and responsibilities. Unfortunately, the institutional approaches adopted by several states, have not been sufficiently grounded in social realities; instead they are mostly based on a short-sighted political economy considerations.

The big-bang approach adopted by the Andhra Pradesh to establish Water Users Associations covering all the irrigation systems – major, medium and minor – had raised high hopes of setting direction to enforce participatory irrigation management (PIM). The Government of Andhra Pradesh had passed an Act namely 'Andhra Pradesh Farmer Managed Irrigation Systems Act, 1997' to facilitate the transfer of irrigation systems in the state. While some studies have shown the impacts as promising and encouraging (Jairath 1999), some others have brought out the limitations entailing the successful and sustainable functioning of WUAs (Reddy et al. 2007). The present status and features of irrigation management transfer in India can be seen in Tables 1 and 2. The institutional structure and policies of WUAs are not uniform; they differ from state to state. For instance, in Andhra Pradesh it is based on a three tier structure, i.e., outlet, distributory and the project, with clearly demarcated rules and responsibilities. Though the tier system is introduced in other states, the operational area is fixed. In Maharashtra, Gujarat and Tamil Nadu the operational area is fixed as 500 ha, whereas it is 10,000 ha in Bihar. While O & M responsibility is entrusted to WUAs in all the states, the water tax collection rests with the agency. And in some states the choice to collect money for O & M from the users is left to the WUAs. However, the systems were not rehabilitated fully to the originally designed standards, before handing them over to the farmers or associations.

Table 1. Water users' associations (WUAs) in India.

States	Number of WUAs	Area Covered (ha)
Andhra Pradesh	32	17,388
Assam	30	15,000
Bihar	1	12,197
Gujarat	477	48,500
Karnataka	196	38,400
Kerala	3,432	137,280
Madhya Pradesh	67	62,800
Maharashtra	118	48,095
Orissa	52	27,589
Tamil Nadu	276	13,800
West Bengal	10,000	37,000
Total	14,681	458,049

Source: Palanisami and Paramasivam (2007)

For instance, in Andhra Pradesh O & M grants were promised to WUAs every year. This has prompted the farmers associations to look for government grants even after the systems were handed over to them, instead of exploring different sources of revenue generation for their day-to-day operations. The participation is in a sense incentive-induced. Incentive here is government support for O & M. "It was reported by some farmers that Rs.50,000/- can be spent by the association for canal repairs and maintenance without calling for any tenders or other formalities. This according to them is an incentive, especially for office bearers of the association. If the funds are not made available, the interest in the association will be eroded making it non-functional." (Personal discussions with some groups of farmers in Anantapur District of Andhra Pradesh).

The available literature shows that most of the studies of WUAs in different states have mainly focused on understanding the transfer processes and not necessarily on their benefits and sustainability, particularly in terms of an equitable and dependable supply of water to all the farmers, irrespective of their farm location in the service area of WUA (Singh 2000). Some of the studies have brought out the efficiency of WUAs under private owned systems, especially in groundwater and pump irrigation systems (Shah 1993) highlighting relative advantages. Some other studies have revealed that the WUAs have limited success in terms of participation as well as impact (Brewer et al. 1999; Parthasarathy et al. 2000). While the impacts or experience at the aggregate level are generalized and documented, micro-level observations based on the ground realities in different socioeconomic and environmental settings are not executed systematically.

In order to ensure that WUAs, especially in the agency-managed large irrigation projects, function effectively on a sustainable basis, local dynamics associated with the operation and management at the farm level should be integrated right from the design and formulation stages of the associations. Furthermore, there is an absolute need for integrating the main system management with farm level management strategies. This is because farm level problems often result from water allocation and distribution problems at the main system level, which is beyond the farmer's control. Unless main system management is organized and improved, a key factor for the success of WUAs, on-farm water problems cannot be resolved. More attention should, therefore, be paid towards this aspect, which hitherto has not received the required attention.

Table 2. The status of irrigation management transfer in India.

State	WUA Organization	Transferred Responsibilities	Water Supply	Water Distribution
Andhra Pradesh	Three tiers: • Village (outlet) WUA • WUA for distributory channel Command Project Committee	O & M below the outlet Maintenance of distributory Collection of government irrigation fee	Assured Water Supply through WUAs	Full power, including punishment of rules breakers
Bihar	Three tiers: • Village (outlet) WUA • WUA for distributory channel Command of over 10,000 hectares • Project Committee	Distribution of water to the outlets Maintenance of distributory Collection of government irrigation fee	No power	Full power, including punishment of rule breakers
Haryana	Outlet level WUAs	08 M below the outlet Collection of government irrigation fee	No power	Responsibility limited or no power of punishment
Maharashtra	Contact (Cooperative WUA for minor canal, about 500 ha)	08 M within the WUA areas Payment of fee on volumetric basis to the agency	Assured water supply through contract	Full power
Gujarat	Contact (Cooperative WUA for minor canal, about 500 ha)	O & M within the WUA areas Payment of fee on volumetric basis to the agency	No power	Full Power
Tamil Nadu	Three tiers: • Outlet WUA about 500 ha • System level joint management	Maintenance within the WUA areas Advice on operations at all levels through WUAs and JMCs	Influence over water supply through JMCs	Limited responsibility. No power to punish rule breakers
Kerala	Three tiers: • Outlet WUA • Branch canal JMC • Systems level joint management	Advice on operations at all levels through JMCs	Influence over-supply of water through JMCs	Limited responsibility

Source: Brewar et al. (1999), quoted in Reddy et al. (2007)

Capacity of WUAs for Demand Management

A brief overview of the status of WUAs in the traditional small irrigation systems and the agency-managed large systems presented above leads us to critically examine the possible ways and means of building the capacity of WUAs to meet the emerging and contemporary needs for demand management. While the scope for and scale of operations in small-scale systems is limited, the focus needs to be more on the agency-managed large-surface irrigation systems. It is clear that WUAs in the agency-managed systems are mostly operating on pilot basis except in Andhra Pradesh. The impacts observed so far are limited. Some of WUA are promising and some others are far from ground realities. There seems to be no option, other than WUAs to manage demand for irrigation water, particularly given that the agencies are gradually becoming less and less effective in managing irrigation water supplies, due to a variety of reasons (some of which are mentioned below (see Box.1)).

Box 1. Why State Agencies Are Becoming Less Effective in Managing Irrigation Water Supply?

- Lack of timely and periodic maintenance of water distribution network, including hydraulic structures, has led to non-compliance with the originally designed water delivery schedules at different points of the canal distribution network;
- Violation of the cropping pattern and the consequent non-realization of water duty assumed in the project design;
- Inequitable distribution of water has almost become an accepted norm, resulting in total alienation of tail-end farmers, which has created scores of social and economic problems;
- Productivity of irrigated crops has been much lower than the expected levels;
- On-farm development (OFD) is poor and unscientific;
- Environmental degradation due to increasing waterlogging, salinity and alkalinity problems in the canal command areas have converted hitherto fertile and productive soils into unproductive quagmires;
- Due to low water tariff and an even lower recovery rate, even the operation and maintenance (O & M) costs are not recovered, to keep the distribution system in good condition.

Farmers basically are not interested in keeping irrigation engineers totally off the field and become their substitutes. And it is neither possible nor advisable. All that farmers want is a timely, dependable and adequate supply of water to optimize productivity. However, the water distribution network that has been planned and designed by the irrigation engineers is based on certain water duty assumed for a crop or set of crops. In doing so, they seem to have taken for granted and treated as rational, and therefore expected behavior, the tendency of farmers to follow the designed cropping pattern in a given irrigation project. Any deviation from the designed cropping patterns creates problems of inequity. But in reality, the designed cropping pattern has been hardly followed, and the indiscipline in water use has increased. This has resulted in a 'laissez-faire' system of water use, which the rich and influential farmers exploit to their advantage.

The primary task of ensuring the sustainable functioning of WUAs as effective agents of demand management entails a transformation of the mind-set of the engineers and farmers to meet the requirements of the prevailing situations. This calls for the identification and establishment of a mutually agreeable and facilitative interface between the irrigation department and farmers or WUAS. One of the important aspects that merit attention for establishing an interface is the water distribution system improvement or rehabilitation, as none of the distribution canals and hydraulic structures have the originally designed standards. It must be considered and noted that farmers, to start with, do not generally posses technical skills and financial resources to restore the system to the designed standards, without which efficient distribution and utilization of water remains an elusive concept. The spread and scale of the proposed system of rehabilitation should, to the extent possible, take local conditions and stakeholders' views and suggestions about the ways and means of restoring the system, including the placement of irrigation structures, to ensure efficiency and sustainability are taken into account. This helps to create a sense of accountability and ownership of the system among the farmers, a prerequisite for institutional sustainability, when the system is handed-over to the association.

The traditional wisdom and past experiences show that an institution borne out of users' interests endures for generations, while those created by an external agency (top down blue-print approach) are invariably short-lived with limited success. A set of conceptual themes, like defining water as an economic good, decentralized management, delivery structures, user principles and levels of stakeholders' participation need to be well articulated, informed and implanted in the mind-sets of the irrigation engineers and user farmers. The status of water availability for irrigation, after taking other competing demands into account, should be made clear and the limitations to increase water supply beyond the designed capacities need to be explained to the farmers to prepare their mind-set. The responsibility of supplying a mutually agreed quantity of water at the interface cut off point – a distributory or an outlet, as the case may be – from where farmers or the WUAs take the responsibility of management, should be the exclusive duty or responsibility of the irrigation department. The WUA should be vested with the right to demand for the quantity of water they are entitled to, under the normal monsoon conditions. The absence of commitment to honor this agreement by both the parties makes the WUA unsustainable.

The WUA establishment process should be participatory, based on a logically framed stepwise approach, where entry and exit points for water users, irrigation engineers and allied agricultural extension agencies are clearly spelt out. The concerned stakeholders and agencies must be reconstituted to take charge of the new roles with responsibility, accountability and commitment. The proposed new role models for farmers and government agencies need to be supported by well-articulated, systematic and location-specific change processes that ensure the operational feasibility of the new strategies and plans, in order to facilitate their effectiveness. The reform processes should be broad-based and maintain a balance between political exigencies, social needs and ground realities. It is, therefore, essential and necessary to consider the social mobilization and stakeholder analysis as the beginning or an entry point for the building users' association to manage irrigation water. In order to ensure a built-in sustainability of the new paradigm, the past experiences in the agency-managed large irrigation projects, the socioeconomic contexts where the alleged adverse effects have taken place and the field realities should form the basis and not the formal perspective approach, hitherto followed by the line departments.

The role of farmers or WUAs should be clearly articulated and discussed in the social mobilization process to ensure mutual acceptability. The issues may include, among others, water use priorities, crop planning, sharing of system rehabilitation and maintenance costs, selection of operation and management interventions, with a built-in flexibility to meet the location-specific conditions and requirements. The role and usefulness of a common sense approach, besides a techno-centric professional approach, needs to be given due consideration in order to promote and ensure sustainability. Otherwise, the subsidy-driven approaches to establish WUAs will invariably be short lived and the dependency syndrome among farmers becomes perpetuated.

Some Successful Cases of WUAs

A brief overview of the critical factors necessary for the successful organization of WUAs, especially in the agency-managed large irrigation projects, has been presented in the preceding section. Given the necessary and sufficient conditions for sustainability, it may be useful to examine some of the existing systems. The traditional systems evolved by the farmers, have been maintained in several parts of the country. But the coverage and scales of operation are meager, when compared to the needs of demand management in the contemporary scenario of irrigation projects. Though efforts had been made to transfer irrigation management to the user farmers in the 1950s in some of the countries, it became a national strategy in most of the developing countries only in the 1980s and 1990s. Organized and systematic efforts to transfer irrigation management to the farmers have started first in the Philippines in the early 1980s, particularly the farmer-managed irrigation systems. The strategies and modus operandi were, however, not exactly what they required in other parts of the world, more importantly in the Indian context.

Different countries have followed different strategies. Even within the countries, the approaches and methods were different. The initial success stories reported and publicized seem to be short lived, because of weak organizational foundations. The water rights and corresponding responsibilities of the WUAs and its members were not defined, and also there was no enabling legislation or legal backing to make them functionally effective. Hence this apparent lack of a comprehensive policy resulted in about 225 WUAs, in the mid-1990s, that were created in major and minor irrigation projects, becoming defunct. Keeping the above scenario as a backdrop, an attempt has been made to present some of the existing systems as examples of better WUAs in different socioeconomic and cultural contexts.

In India, the success stories are many among the smallholder traditional irrigation systems. In drought-prone districts of southern India, particularly in Andhra Pradesh there were many groundwater open-well irrigation systems that operated on a time-sharing basis. The gradual decline in groundwater and consequent drying up of shallow open wells has led to the disappearance of a participatory culture (Reddy 1994). The resurgence of some of the systems is, however, worth mentioning as an illustrative example. Anantapur is one of the backward districts in Andhra Pradesh, where participatory open-well irrigation systems were in plenty. Because of natural factors and constraints over a period of time, most of them have disappeared. In recent times some NGOs have tried to revive, and rebuild such practices. For example, an NGO called the Rural Integrated Development Society (RIDS) has tried to organize farmers for the demand management of groundwater for irrigation in one of the villages called Madirepalli, through social regulation. It began in 2003 when the area was hit by a severe drought. There were about 139 tubewells in that village, of which 75 have dried up. Nevertheless, the rat race for digging tubewells continued. The indebtedness among the farmers was on the increase due to failure to strike water, and the investment in the tubewells became unproductive. At this point of time the NGO (RIDS) entered the scene and became a catalyst to rebuild the participatory culture that once existed in the village. Historically, Madirepalli had a track record of sharing surface water flowing in a stream, through a traditional 'Gonchi' system (see Box 2).

Due to resource pressures and other attitudinal changes, the system, which was dormant, if not extinct, needed rekindling. RIDS played the much needed catalytic role. The community was motivated through several rounds of meetings and discussions. There is no irrigation project in the vicinity of the village, nor any reliable surface water resources. The only sources of water for crops, livestock and drinking are the rains and the groundwater. As a result, there has been a heavy pressure on the wells. RIDS prepared a water balance sheet (supply and demand for water) for the village, and placed it before the villagers. The road map was clear – either to go ahead with indiscriminate digging of tubewells and end up in debts and misery or to be wise and share the available water with those who did not have. The initial reluctance of the owners of live tubewells did not last long. The hard facts – that there was not enough water for every one in Madirepalli and that if every other farmer dug out his own tubewell, the water in the live wells would also run out soon – were gradually realized by every one. Subsequently, 'water- haves' and 'have-nots' agreed to come to terms in sharing the available groundwater.

Box 2. 'Gonchi' Systems for Surface Water Sharing

'Gonchi' refers to collective community efforts in bringing water from a stream and distributing the same equally to irrigate a stipulated 'ayacut' area. This system has been in practice in parts of Andhra Pradesh for well over a century. A users association manages Gonchi. The association lays down norms for use and maintenance of the system. One of the major activities is desilting of various channels through which the water is brought and distributed. Water is blocked by constructing a temporary structure and then diverted from the main stream, this helps to take up repairs all along the channels. Users contribute labor or compensate with wages towards the operation.

A natural stream called "Akuledu Vanka" serves a few of the Madirepalli farmers. It receives a reasonable quantity of water, besides seepage from the Tungabadra high-level canal, when water is released into the canal. Villagers have built a separate diversion canal to allow the stream water to flow into their fields by gravity. Generally, paddy is cultivated for one season in these fields.

Water is distributed by placing wooden gates called 'anthams 'across the flow. The water flow is monitored by a designated person called Neerugant; who is compensated for his service by providing a designated share in the harvested crop. The functioning of this system is governed by the rules and norms set by the users association. Violation is curbed by fines and strictures.

Source: Sreenath Dixit et al. (2007), LEISA, INDIA, March 2007, Vol.9; No.1

Villagers agreed to follow the regulations for use of groundwater. The resolutions were passed in the 'Gramasabha', and the following social regulations were accepted by all.

(a) No more tubewells in the village henceforth;

(b) No more growing of high water-consuming crops like paddy;

(c) Every one in the village would do his/her best to protect and augment groundwater resources;

(d) Farmers having water in their tubewells to share a reasonable quantity (enough at least for 0.5 acre) of water with fair neighbor;

(e) Use water saving devices like sprinkler and drip systems for irrigation.

All these resolutions have been written on the walls of the village ‘Chavadi’ (a community centre where villagers gather). These regulations are in force in Madirepalli since 2004, and the impacts are tangible. There is no drinking water issue even in the drought years. The cultivated area has increased from 339 acres in 2003 to 516 acres in 2006, though there was a marginal increase in the rainfall from 255 mm to 297 mm in the respective years. This is due to sharing of water between haves and have-nots, ban on cultivation of paddy and using sprinkler and drip systems. Farmers, 33 in number, who irrigate their 113 acres, have shared water with another 33 farmers, who were able to irrigate 66 acres of dry land. This has become a model village to spread water literacy in terms of awareness on conserving and sharing the available water.

Another surface irrigation system managed by the farmers is functioning effectively in the same district. There are no recorded evidences to show as to when it was started. Some village elders say it is more than 100 years old. The beauty of the system is that, the same rules and regulations which were evolved by the founders are followed even today, without diluting even a single aspect. The source of water for the systems is a natural spring located about 6 kms from the village. Water flows through a ravine called Kutalamadagu *nala* up to the village tank. The tank has a separate sluice to allow the water to the farmer’s fields coming under Kutalamadagu *nala*. The association has fixed a proportional distribution weir to ensure an equitable distribution of water. This has been prepared by the farmers themselves, without any engineering help. *Neeruganti* (water man) will operate the system. The committee will meet before the start of the irrigation season and decide the cropping pattern to be followed by all the member farmers, taking into account the availability of water. Nobody can violate the cropping pattern decided by the committee. Maintenance of the main nala and field channels is the collective responsibility of all the farmers, by contributing labor in proportion to the land owned by individual farmers. Social sanctions are built into the system management rules and regulations. All the farmers should obey and follow the rules strictly. There have been no problems at any time in managing the system. It continues to be the model for the participatory management of water (Reddy 1989).

The story of WUAs and their sustainability in the major irrigation projects of Andhra Pradesh is different. For example, farmer’s organizations known as ‘Pipe Committees’ were first started in one of the major irrigation projects in Andhra Pradesh in 1976, namely the Sriram Sagar Project. The Pipe Committees worked effectively with several advantages to the farmers. Subsequently the ‘warabandi’ system of water distribution was introduced in the 1980s, as a tool for the demand management of water, resorting to the rotational supply of water. This has brought about a lot of discipline to water use and ensured equitable distribution of water even to the tail-enders. But the success was short lived due to a number of socioeconomic problems and also because of the lack of a strong institutional base. The same is the case with the WUAs that started after the enactment of A.P Farmers Management of Irrigation Systems Act in 1997. Though WUAs are legally constituted, their effective functioning and advantages to the farmers are very few and far between.

Gujarat is known for successful functioning of water users' cooperative societies. In the Ukai Kakrapar Irrigation Project, one society, among others, which was formed in 1979, seems to have been working effectively. The society covers four villages with a cultivable command area (CCA) of about 421/hectares. Water is supplied in measured quantity from fixed outlets and the society pays for the quantity of water drawn. Maintenance of the field channels and other structures is the responsibility of the farmers. Farmers contribute labor and also money, if and when required to undertake small repairs. Volumetric supply of water as per the agreement with the society appears to be the main reason for the successful functioning of the society (Pant et al. 1983). Another success story widely quoted in Gujarat is the Mohini water user's society. One of the main reasons for the successful functioning of the society is the homogeneity of farmers. A majority of the farmers belong to one caste. This could be one example to show that homogeneity of caste or community, among others, is one of the factors for sustainability of WUAs and their effective functioning.

Maharashtra is yet another state where water cooperative societies have a long history. Some of the indigenous systems like Bandharas (small diversion weirs), locally known as 'Phad systems', are very popular in Nasik and Dhule districts. They have been successfully working for centuries and are effectively functioning even now. The decision is taken collectively at a meeting of the farmers before the commencement of the crop season, to decide the crop pattern, allocation and rotation of water. Farmers misusing water or not following the rules will be fined. The canal systems running for several kilometers, is maintained by the beneficiary farmers. Contribution to meet O & M expenses are collected either in kind or in monetary terms. Water men, inspectors and watchmen are appointed by the society to regulate and distribute the water supply to the farmers.

'Pani panchayat' is another noteworthy success story quoted widely. The sustainability of an institution created by local initiatives depends mostly, among other things, on the committed leadership of either a group of individuals or single individual. This is a unique system developed in the village of Ralegaon Siddhi in Maharastra, under the leadership of a noted social worker, Anna Hazare. All the households in the village are entitled to a share in the available water, irrespective of the household owning land. This is the household-based equity and not land-based equity. This has happened due to the leadership of Anna Hazare. Though it is acclaimed as the best system, its replication has not taken place. Attempts to replicate the same in some places have not been successful enough. That means, it is purely leader-centric. Unless and otherwise a leader like Hazare is available, this cannot be replicated. Same is the case with 'Tharun Bharat' in Rajasthan. Because of the commitment of Rajendra Singh, it was possible to turn the desert ravines into green pastures. He fought against several odds and problems created by the government, mobilized farmers, sustained their interests and showed the tangible results, so as to motivate farmers and develop their commitment. It is, therefore, important to underscore the necessity of credible leadership to build WUAs on a sustainable basis.

In Karnataka, there are farmer-managed lift irrigation schemes along the Krishna river bed that have been functioning successfully for several years. For example, the Kalpatharu Lift Irrigation Society in a village called Siruguppi in Athani taluka of Belgaum District is run by the farmers very successfully. This is a drought-prone area and even finding drinking water was said to have been one of the biggest problems in the village. Some village elders say "people were reluctant to give their daughters in marriage to this village, because of the scarcity of drinking water." Such was the condition of water availability in the village, though it is about 3 to 4 kms away from the Krishna River.

The farmers were told by the neighboring Maharastra farmers (the village is located in Maharastra border), they are lifting water from the Krishna River for irrigation purposes. A group of farmers visited some of the villages in Maharastra where river pump systems were in operation and discussed with the Maharastra farmers and observed the system operation. Then they called for a meeting of like-minded farmers and discussed the proposed lift irrigation schemes. After ironing out all the initial apprehensions about their technical capabilities for putting the system in place and other related financial issues, they resolved to go ahead with the registration of the society and named it as 'Kalpatharu Lift Irrigation Society'. The initial seed money was raised through personal contributions from the member farmers and the rest of the money was borrowed from a banking institution. An open well at a distance of about 2 kms from the river bed was constructed, and a pump in the river bed was installed to lift water from the river. A big tank, in an area of about 1 ½ acres, was constructed to store water. First, water was to be pumped from the river to the constructed open well, and then from the open well to the tank for storage. Water stored in the tank was to be distributed to member-farmers through the underground pipes, by gravity flow. The entire water collection system from the river to the well and on to the tank was operated through under ground pipes. The piped water distribution system has been laid in such a way that every farmer is provided with a gated inlet to take water. The water inlet is locked and will be operated by the waterman, appointed by the society, on the scheduled day and time of the farmers' turn to take water.

Water entitlements of all the members, their roles and responsibilities, water tax to be paid, clauses of penalty for violation of rules and taking water out of turn or wasting, rights of way for farmers to transport inputs to and outputs from the farms to the village, have all been written down and the by-laws were framed accordingly. The farmer who donated land for construction of the tank will be given water to his remaining land free of cost to the rest of his life. Irrigation schedules, depending upon the nature and type of crops they plan to grow, will be prepared and circulated to all the member farmers. The waterman will operate the distribution systems; the concerned farmer should be present in his field to take water on the scheduled day and time. The waterman will open the lock and allow the water to flow through. After irrigating the said farmer's field, the pipe outlet will be locked and the next farmer in turn will be given water. Farmers have been operating this system for over 20 years and even now it is functioning as effectively as it had been when it first started. The demonstration effect of these systems is very wide. Many societies have come up now after seeing the success and operation of these systems and are themselves functioning well. The environment of the village of today is completely changed. The drinking water problem has been solved and the village micro-climate itself has changed because of the greenery all through the year; thanks to the irrigated agriculture, facilitated by the lift irrigation society.

Participatory irrigation management (PIM) per se has not been successful enough in India, though it has become a wide spread strategy in Asia, Africa, and Latin America. The governments are trying to reduce their role in the large irrigation projects and promoting the participation of primary stakeholders in a number of piloting areas. The results from Maharastra, Gujarat and in a few other states seem to be encouraging. But the scaling up of these success models needs, among others things, political will to introduce a few tough policy interventions to turn over the system to the user association. Otherwise, taking off from the piloting stage is likely to evolve into a mirage.

In various countries where PIM has been adopted as a national strategy, there has been a mixed trend of results. The transfer processes have been relatively smooth and fast. The costs of self-managed irrigation systems have become relatively less. In this context, one of the most successful examples is Mexico (see Box 3). The financial crisis of the 1980s has compelled the Mexican Government to enforce a number of structural adjustment programs. The transfer of management responsibility of irrigation districts to the farmers was a significant reform. This was adopted due to absolute necessity. The government made it clear to the communities that they have to either take on the management responsibility or suffer the consequences due to unreliable water supplies in poorly managed irrigation systems. This tough stance taken by the government made farmers to accept the responsibility of managing their respective irrigation systems.

Box 3. The Mexican Experience

The Mexican Government adopted carrot and stick approach. The carrot was management autonomy and the transfer of mechanized equipment from the agency to the farmers association. The farmers would become the owners of this equipment, and would be free to set their own rules for cleaning the canals, water distribution norms and procedures, and the appointment of the required technical staff. The canal would be theirs on 20 years concessions, which in practice is a transfer of ownership. They have also used a 'stick'. If farmers refused to take over management, the government could offer no assurance that the canal network could be kept in repair. The government in effect threatened to default on its conventional understanding with farmers regarding levels of subsidy in the irrigation sector. Many farmers, particularly the commercially-oriented ones, could not accept the risk that the irrigation infrastructure might collapse. They preferred to take over the management, and with a few exceptions, they have not looked back. They are paying much more for their water without the government subsidy. But the reliability and responsiveness of their new management structure is well worth the prices they pay. For them it has been 'Win' situation, and for the government as well.

Source: Groenfeldt and Sun (1996). Hand Book on participatory Irrigation management. World Bank/EDI, Washington. DC.

The first irrigation district was transferred to the users in 1990. By 1995, more than two-thirds of the country's 3.2 million ha network consisting in 80 irrigation districts, had been transferred to 316 irrigation associations (Groenfeldt 1996). The work involved countless meetings at various levels, from discussions with leaders of producers and marketing associations to one-on-one discussions with users. The transfer program was initially focused on the most productive irrigation districts, with the most commercially-oriented farmers. The important criterion for selecting districts was the potential of the user organization to become financially self-sufficient, with users paying the fees to cover the costs of operations, maintenance and administration.

A few illustrative examples cited above underscore the diverse range of socio-cultural factors, political economy dynamics, institutional and organizational capabilities contributing to the sustainability of different types of irrigation associations. While the traditional associations borne out of the relentless efforts of a few committed local leaders, collective efforts of a community, revival strategies facilitated by NGOs etc., stood the times of test and remained as islands of participatory approaches, the agency-sponsored blue-print top-down approaches, are yet to take off from the piloting phase. The irony here is the need for and importance of users' participation for demand management is gigantic in the agency built, operated and managed large irrigation systems. The present efforts to implement PIM in major irrigation projects is, however, less than a scratch, in the given gigantic task, in terms of scaling up the spread and operation.

Areas Where WUAs Can Manage Water Demand

This is a very broad and difficult question to tackle in the context of India, which is of continental dimensions in spread, endowed with a diversely ranging resource base, socioeconomic and cultural differences, political economy considerations and above all, dominating self-interest of the elite class in rural areas. The strategies should, therefore, be broad based to develop the culture of 'consumerism' cutting across the given socio-political diversities, taking the location or area-specific ground realities into account. While almost all the states have made a beginning to introduce the demand management strategies in the agency-managed large irrigation projects, the success and sustainability is yet to be seen. The prioritization of the regions for rekindling participatory culture as an effective tool for demand management should be based on the status of the resource (water) availability, extent of its utilization, past attempts made to promote user associations and other related factors. In northern states like Punjab, Haryana, western UP, the demand management strategies in the form of warabandi and other systems of irrigations have been implemented fairly well, when compared to southern states.

There are a number of traditional small-scale irrigation systems, as mentioned earlier, successfully managed for generations in the southern states. The demand management through user association in the agency-managed large systems has hardly made any impact. It is, therefore, necessary to promote, user associations in southern states, particularly Andhra Pradesh, Karnataka and Tamil Nadu, for demand management of irrigation water. The frequent inter-state water disputes in these states makes the need for demand management much more significant. Identification of surplus and deficit zones within an irrigation project, taking the existing cropping pattern and crop-water requirements into account, is necessary to plan for demand management. Benchmarking of water delivery status at different points of the water distribution network starting from main canals, distributaries and up to minors and farm outlets is essential. This helps to prepare a road map of water availability and the status of its utilization, which can be placed before the concerned communities to explain the implication of water use and change their mind-set.

Andhra Pradesh has an edge over other states for demonstrating user associations as effective agents of demand management since the state has been performing experiments to introduce participatory management system from the early 1980s. It was started with Pipe Committees and warabandi system, followed by a big-bang approach, under which all the irrigation systems were brought under WUAs. But the impacts are not clear and mixed as revealed by some empirical studies. Furthermore, the present government has taken up irrigation as the main agenda for development under the 'Jalayagnam' program, with a huge investment. It would be more appropriate to study the existing systems in place for demand management, problems and constraints, if any, for their successful implementation.

The estimated water resource available in the state is about 108 bcm (billion cubic meters) of which about 57 % (62.3 bcm) is currently being utilized for irrigation and other purposes. The state comes under a water-stressed category with a per capita annual water availability of slightly more than 1,400 m^3. The total irrigation potential created is about 3.6 million hectares, of which almost 50 % is under major and medium projects. At present, efforts are being made to increase the irrigation potential by completing all the ongoing projects and starting new projects. There is, however, a wide gap-estimated to be at about 0.4 million ha, (22 % of the potential created) between the irrigation potential created and its utilization under the major and medium irrigation projects. This is mainly due to poor systems management and low on-farm water-use efficiencies. In spite of handing over the management to WUAs, the water use efficiency has not improved, and the potential created continues to be under utilized or misused. It is, therefore, important and necessary to reexamine the demand management strategies and formulate new paradigms by considering the experiences in different agro-climatic, socio-political, and cultural contexts.

It is equally important to conduct water balance studies and research on water use efficiency in the Cauvery Basin projects of Karnataka and Tamil Nadu. There are no scientific studies to estimate water requirements of the crops grown and water released or made available at different reaches and locations to judge whether water released at present is adequate or not. Creating an institutional paradigm in these regions to create effective and efficient WUAs will have far reaching impacts on the frequently arising water disputes between the two states. There are allegations and counter allegations about the use and abuse of water by the farmers, and wasting the scarce resource. Benchmarks about the water release and utilization at different locations in the basin should first be established before WUAs are put in place on an experimental basis. Taking the lessons and impacts of these pilot experiments into account, the scaling up of strategies can be worked out to sustain the proposed new paradigm of water management.

Constraints for WUAs in Demand Management

The task of creating effective community-controlled social organizations has become a widely advocated development strategy in many developing countries. While this strategy is espoused by some as a means for the disadvantaged groups to acquire a larger share of the benefits of development, others stress the importance of local organization in sustaining the productive use of land and water resources. This has led several states to experiment with building user organizations as one approach to reduce government expenditures for recurring costs of irrigation system management. Because, irrigation water rates, in general, do not even meet the costs of O&M. Even the low water rates are not regularly and fully paid by the farmers. The inadequate finance has led to lesser and lesser allocations for O&M in successive years and the consequent system deterioration has caused a decline in the delivery of services.

Community organizations are, therefore, inevitable to meet the challenges of water demand management in the future. This calls for designing irrigation systems that are responsive to farmer’s needs, matching supply and demand as closely as possible, with minimum losses of water and providing for flexible cropping patterns. The ramifications of water resources development over the years have given rise to a number of theoretical and empirical questions. It is said that environmental problems like waterlogging, salinity, alkalinity, water-borne diseases and other socioeconomic adverse effects are due to the disjunction between increasingly large-scale complex and modern irrigation network and still largely traditional peasant farm users of that system. The human dimension has almost remained outside the ambit of water resources planning and, therefore, led to a number of avoidable adverse effects. The institutional backup necessary to equip farmers to operate and manage an irrigation system, beyond the main system, has remained far from satisfactory. In order to maximize welfare it is necessary to analyze farmers' perceptions about the potential benefits from user associations and complex processes involved in the operation, maintenance and distribution of water under the newly built management paradigm.

The institutional approach for integrated planning and demand management of irrigation water through WUAs on a sustainable basis has gained adequate ground. As mentioned earlier, the institutions emerging at the grass roots levels on account of peoples' own initiatives to manage natural resources have endured for generations, while those built by the bureaucratic interventions have not been so sustainable. How does the collective action emerge at the local level? What factors contribute for its sustainability? These are the two important issues that need to be addressed. There are various schools of thought which explain collective action. One of the recent ones draw on the institutional economics of local forms of cooperative action to derive generalized principles for collective actions. This analysis uses a formal model derived from the theory of repeated games to challenge the dominant thesis on the unlikelihood of collective actions among rational self-interested individuals. Focusing on costs and benefits to individual actors, incentives and penalties, institutional support demonstrates the economic rationality of cooperation and possibility of cooperative equilibrium outcomes from competitive games (Ostrum et al. 1994; Sengupta 1991). Institutional economic analysis therefore, offers the possibility of the kind of prediction and generalization of theory of cooperative action, which WUAs require in order to generate predictable or excepted outcomes from planned inputs.

The empirical studies in India and at the global level on the effectiveness of community organizations for demand management of irrigation water, especially in the agency-managed large irrigation projects have brought out several limitations and constraints for their sustainability. They could broadly be classified as follows:

(a) Social dynamics of the primary stakeholders.

(b) Technical and design constraints of the irrigation systems.

(c) Institutional and policy constraints.

(d) Political economy factors.

The available literature has brought out clearly how the problems related to the aspects mentioned above have individually and collectively contributed to less sustainability of WUAs created in different irrigation projects.

Social Dynamics

Social engineering encompasses the attitudes, behavioral understanding, cooperation, leadership and other cultural factors of a given community to take up the system management. The agency-sponsored approaches do not normally take this aspect with the required seriousness. The top-down blue-print elite-centric approach of the bureaucracy may lead to immediate short-term gains due to construction and other incentives-induced participation in the initial period, but can never be sustained. Community mobilization, therefore, becomes central for building the new systems management. Awareness building about the relative advantages of WUAs, the roles and responsibilities of various stakeholders to prepare the mind-set of the community to take up challenges is very crucial. This is where NGOs come into the picture - to motivate the community. For, the agency will have neither the required man power nor the ability to do this, under the given bureaucratic set up. The evaluation studies carried out in some of the agency-managed projects have clearly brought out that majority of the farmers who were not aware of the concept of WUAs and its advantages.

Identification of leadership during the social mobilization process is most important as the success and sustainability of an institution depends upon the quality of leadership. There are a number of standing examples, historically and in the contemporary period, where committed leadership has proved to be the most crucial factor for the successful and sustainable functioning of an institution. Stakeholder analysis is necessary to identify the group interests and faction-related dynamics. The need for cooperation and collective approach and its advantages to different stakeholders, their roles and responsibilities to realize the expected benefits have to be clearly told to the community to promote a participatory culture. A road map of the irrigation system proposed to be handed-over to a community has to be prepared, highlighting the existing problems and short-comings in terms of water availability, inequitable distribution of water and irrigation-related squabbles, and then be placed before the community so that they can come out with their suggestions to improve the system management. This will create a sense of involvement and accountability, both of which are crucial for the sustainability of WUAs.

Technical and Design Aspects

Most of the irrigation projects are supply-based. The canals are designed to carry a particular quantity of water, for a predetermined cropping pattern, based on an estimated water duty, by taking the crop-water requirements (Crop delta) into account. The successful demand management depends upon, among other factors, farmers adhering to the designed cropping pattern. Next in line is the appropriateness and conformity of water duty assumed with the field situation. It is natural that there will be wide variations in soil characteristics across a given project, and the uniform water duty assumed may not work. This leads to inequitable distribution of water. What is required is a volumetric supply of water to the community, based on the potential area to be irrigated under a given outlet, minor or a distributory from where WUA takes water. The option about a cropping pattern to be followed should be left to the association. They should, however, be guided with the given quantity of water, what type of crops can be grown and what measures should be taken to ensure water use efficiency. Without a mutually agreed schedule of volumetric supply of water between the irrigation department and WUAs, the sustainability cannot be ensured.

Institutional and Policy Constraints

A paradoxical situation often observed is that the informal user associations work more efficiently than the formal association. Paradoxical because, the formal association created with all the necessary procedures and formalities do not endure, because of improper and inadequate legislative and legal back up, which gives room for political interference. Whereas informal institutions are socially embedded, based on local needs, culture, customs and practices. The legal backup provided for the formation of user associations should ensure a political base, where politics whether local, state, or national-do not interfere in the management. This calls for a strong political will, without which the institutions cannot be sustained.

Political Economy Factors

The agency-created user associations, as mentioned earlier, are mostly incentive-induced. In order to motivate the community, they give financial incentives like providing a grant for construction and repair works and other related subsidies. But the temporal and spatial limitation up to which such assistance will be provided and the scale of assistance are not made clear in the beginning. The community, therefore, expects the assistance to continue and a dependency syndrome develops. This happens particularly in the donor agency supported projects. The ways and means of mobilizing financial resources to meet minor expenses should be properly explained to the community and their capacity should be built. Lack of financial resources, after the withdrawal of support from the government, is one of the main reasons for malfunctioning of WUAs, after the initial success. Politicians try to push their elite clan during the incentive phase as the leaders, to develop user association. The moment that phase is over the politically-supported leaders withdraw, after however, spending the resources provided, and ask others to take up the responsibilities of management. In that situation nobody will come forward, because there are no financial or other resources to manage. This situation tends to create indifferences among members and makes the institution dormant.

WUAs in Demand Management: Potential and Prospects

The National Irrigation policy makes very clear the need for and importance of promoting water use efficiency in the country, more importantly in the agency-managed large irrigation projects. PIM has been accepted as a national policy and the legislation to transfer irrigation management to the users has already been passed in some of the states. But the ground realities observed so far are far from the expected outcomes from user associations. Many states to-day are facing a dilemma regarding the demand management of irrigation water. Dilemma because, on the one hand they are not able to meet the increasing costs of irrigation system management and on the other, the alternatives for taking up management tasks to reduce the burden on the government are found to be not effective enough. In order to reduce the growing dependency syndrome among the communities and to change their mind-set, promoting community organizations is the only alternative. The micro-level experiments of demand management through community organizations, both in the agency-managed large systems and farmer-managed small systems, the results are encouraging in terms of ensuring the equitable and timely supply of water. The replication and scaling up has remained as a challenge.

The scaling up is inevitable and, there is no scope for a second opinion about it. But what is required at present is to take the lessons from the micro-level experiments, identify the constraints and adopt area-specific people-centered approaches by putting flexible policy options in place. The prospects for scaling up user associations depend essentially on the following factors.

(a) Awareness building about the importance of and the need for demand management among the community, by adopting systematic processes for mobilization, capacity, building-technical and managerial skills and cooperation.

(b) System improvement before handing over to the community is the second prerequisite. Most of the canals and irrigation structures have been damaged due to lack of timely and adequate maintenance. The system should be rehabilitated to originally designed standards and handed-over to the user association, because the community will not have the required technical skills and financial resources. The association members or stakeholders should be involved fully in all the processes associated with the system improvement and reconstruction. Their views have to be taken into account.

(c) It is essential to release the designed discharge of irrigation at the interface point for handing-over the distributory, minor or outlet, depending upon the status of water availability. The unit of operation should be a hydraulic boundary. Volumetric supply of water as per the mutual agreement is very crucial. Mechanism for dispute management-regarding water release distribution should be in place.

(d) The sustainability depends upon financial adequacy and stability. The responsibility of water tax collection and the proportion of sharing have to be clearly articulated, informed and recorded. There should be no room for confusion on this account. Awareness and capacity of the association to generate financial resources, other than water tax, through plantation along the canals bund, common lands and other related avenues has to be developed.

(e) Requisite legal back up for institutional sustainability has to be provided. Norms for decentralization of rights and responsibilities, water rights to the association from the irrigation department, water rights to the farmers within the association have to be clearly articulated with built-in penal clauses for not respecting the rights and consequent losses to the farmers due to crop failure.

(f) Integration of main system management with the tertiary systems handed-over to the community is essential to meet the on-farm water distribution requirements.

The sustainability and scaling up of WUAs depends largely on the organic linkages between various factors mentioned above. It is important to strengthen the distribution, allocation and management norms, procedures and plans to ensure effective demand management through user and community associations. This aspect should form as an integral and important component of an irrigation project's design in future. Irrigation projects should transform into social systems after completion of the construction phase.

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