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Farm-level incentives for irrigation efficiency: some lessons from an Indian canal

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In the name of food security for the nation and poverty alleviation for the rural population, every developing country provides its farmers with irrigation water at a fraction of its delivery cost. However, the realization that fresh water is scarce and getting scarcer has forced a widespread re-thinking of this "cheap water" policy. A farmer who pays next to nothing for water has no incentive to use it efficiently. He uses it to grow low-value field crops, irrigates carelessly using flood and furrow methods, does not repair his field channels, and over-waters his standing crop.

It is therefore argued, in developing and developed countries alike, that the price of irrigation water should be raised to reflect its scarcity value. This policy is now under consideration in Morocco, China and in parts of India.[1] Alternatively, farmers should be allowed to sell their water shares to higher value uses both within and without the agricultural sector. Such trades would be economically efficient *and* in the farmer's interest. Tradable water rights have been implemented in Chile, and to a

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[1] Water policy analysts in India are debating higher water prices as a way to recover the operating and maintenance costs of major canal systems. This is quite different from prices as an incentive to irrigate efficiently. It is quite possible to raise prices to the point where administrative costs are covered, and still have them be lower than the opportunity cost of water. Similarly, farm-level efficiency-inducing water trades can co-exist with massive subsidies at the system level.

lesser extent in Mexico. In short, water is an economic good and not a birthright, and wasteful water use can best be combated by “getting the prices right”.

In this paper, I examine the hypothesis that, in order to induce efficiency at the farm level, water prices should be raised or water trades should be facilitated. In the first section, I lay out the rationale for opportunity-cost water pricing, citing modeling and empirical evidence in its favor. In Section 2 I bring out the (often implicit) assumptions under which market-like forces can in fact increase irrigation efficiency. In Section 3, drawing on a case study from the Mula Canal in western India, I argue that these assumptions do not hold on existing canal systems in many developing countries. Therefore water prices (or tradable water rights) are not the best way to save water or increase its productivity. Transparent and enforceable allocation rules may be more feasible, and output price policy changes more effective, at least in the near term.

1. Opportunity-cost pricing: the rationale and the evidence

If water prices rise to reflect its opportunity cost, a rational farmer should have any or all of four responses (Gardner, 1983). She can demand less water and leave some land fallow. She can cultivate all her land but stress her crop a little, thus maximizing her output per unit of water rather than her output per unit of land. She can diversify out of thirsty but low-value field and fodder crops into low-water-using but lucrative fruit trees and vegetables. And finally, she can invest in efficient irrigation technologies, such as sprinkler and drip systems, which allow a larger fraction of diverted water to be used consumptively by the plant. Even a simple change such as shortening the length of the irrigation furrow could raise field-level irrigation efficiencies by up to 10%. There is evidence from theoretical and mathematical programming models that farmers do respond to price-induced water scarcity in all of these ways.

Much of the recent literature on water prices and water markets is from the agriculturally rich, but water-short, western USA. Using agronomically derived production functions for cotton, Ayer and Hoyt (1981) find that farmers in Arizona reduce the water applied as its price rises from $0.5 per acre-foot to $5 per acre-foot. Using Census of Agriculture data for several crops, Ogg and Gollehon (1989) derive downward sloping, albeit rather price-inelastic, demand functions for irrigation water. Caswell and Zilberman (1985) show that the probability of adopting drip irrigation technologies for perennial tree crops increases with increased water prices, amongst other factors.[2] In a modeling exercise, Weinberg, Kling and Wilen (1993) show that as water prices offered to the farmer rose from zero to $50 an acre-foot, water-intensive crops were no longer optimal, and irrigation water applied fell.

It should be noted that in most of these studies on water prices, the response of water use is rather low within the observed price ranges. Only when the price is projected to rise significantly, by a factor of five, ten, or sometimes more, is the water demand price - responsive.[3] The consensus appears to be that the water demand curve for agriculture is inelastic at low water prices. The elasticity is high when water prices are already high, and when water is more a substitute for, than a complement to, other inputs. I shall revisit this point later in the paper.

In the developing country context, informal, intra-watercourse trading is active on north Indian and Pakistani canals (Bandaragoda, 1998). Such sales are generally illegal, but they occur nevertheless. Short-term sales of groundwater and of water directly pumped from canals are quite common.

Tradable water rights refer to longer-term commitments, for an entire growing season or more. The most celebrated case of tradable water rights comes from Chile, where agrarian reforms and the Water Code of 1981 formalized water rights, and allowed water sales separately from sales of land. These reforms have led to more land under high-valued fruits and vegetables, less land under pasture, and a greater than 20%

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[2] Field studies can measure only water diverted, not water consumed. Therefore the production functions used in such research could overstate or understate the yield response to water applied.

[3] Programming models, which are not restricted to observed price ranges, are more likely to yield elastic water – demand estimates. Including a demand function for the crop itself should also generate higher elasticities (Howitt, Watson and Adams, 1980).

increase in water use efficiency in Chilean agriculture (Rosegrant, Gazmuri and Yadav, 1995). The Chilean case has been cited as a model for other developing countries.[4]

2. The assumptions behind "getting prices right"

The claim that "getting prices right" is an effective means to irrigation efficiency is much more than a generic statement about downward-sloping demand curves. It is based on many assumptions:

i. Water prices are significant in the overall crop budget, and as a fraction of crop net revenues. If not, the income effect of price increases may be so small that the water demand will barely respond.[5]

ii. There is a volumetric link between what a farmer pays and what he receives. If water is charged by the hectare, as it usually is in developing countries, its marginal cost is zero and higher prices cannot induce efficiency.[6]

iii. Farm level inefficiencies are significant in relation to overall system inefficiencies. If not, the farm level may not be the place in which to look for water savings.

iv. Farmers do not diversify into high-value crops and irrigate using wasteful methods *because* water is so cheap. If low-valued crops are grown for other reasons, e.g. for own consumption, or because farmers face labor constraints, price signals may not have the expected effect.

v. The changes to the physical infrastructure that are necessary to implement water trades or volumetric pricing, such as measuring devices, channels for

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[4] It should, however, be noted that both land and water rights in Chile were regularized over a relatively short period (see Bauer, 1997). It is not obvious from the literature to what extent the Water Code should be given credit for the subsequent gains in productivity.

[5] The substitution effect could be high, in which case the own-price demand for water could be elastic even at low prices.

[6] This assumption also implies that that the system should not physically ration the water *as well as* charge higher prices. If it does, this physical limit rather than the price is the relevant constraint (Perry, 1998).

conveyance, etc., are not prohibitively expensive. If they are, any gains from trade will be neutralized by these implementation costs.[7]

vi. Tradable water rights can be allocated and enforced without high transaction costs; and third party effects, if significant, can be countered. If not, these costs and potential losses will overcome the benefits of trade or local water savings.

The last two items relate to the difficulties of implementing higher water prices or tradable water rights, and they have borne the brunt of the criticisms leveled at water markets. Many reservations exist about the inadequate physical infrastructure of canal systems in developing countries, the administrative cost of introducing volumetric pricing (Perry, 1996), the difficulty of measuring water consumed rather than water diverted, and the possible third party effects of trade (Rosegrant and Binswanger, 1994). Such reservations are entirely justified, but I shall focus on assumptions i, iii and iv. These assumptions do not relate to implementation, but rather to the effectiveness of price incentives *per se*.

I examine an Indian canal system – the Mula Canal in Maharashtra – to ask: How effective are higher water prices, either imposed on or offered to the farmer, as a means of curtailing his water demand, *even if transaction and infrastructure costs are not constraining*? I analyze whether higher water charges are the most feasible way to induce farm level efficiency; whether farm level efficiency is indeed as dismal as it is generally thought to be; and whether water prices are the most relevant prices in a farmer's cropping decisions.

The data and modeling results I report below are from my own fieldwork on the Mula, carried out over eight months in 1991/1992. These results are more relevant for the analysis of water prices than of tradable water rights, because so little is known about how such rights might work in this region.

3. Farmer incentives on the Mula Canal

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[7] It does not matter for the analysis whether these costs are paid by the farmers, the government, or both.

The Mula Canal System in western India has an irrigable command area of 80, 000 hectares. The primary crops are sugarcane (a thirsty, lucrative cash crop), sorghum, wheat, chickpeas, and groundnuts. Of late, sunflowers have grown in popularity. The Mula is a “typical” Asian canal in that the water supply is better at the head of the system than at the tail; water often does not reach the fields on time; and the farmers pay a (small) per hectare charge for the water they receive. This charge varies by the crop and the season, so there is some attempt to link water charges and volumes. The command area has several shallow wells, which supplement canal water supplies. The water from these wells is also cheap, because electricity is subsidized.

Water prices and irrigation efficiency

Canal water prices are heavily subsidized for the farmers on the Mula – so much so that water costs are insignificant in relation to the crops’ per acre revenues. For example, water costs for sunflowers are 0.77% of its (average) net profits per acre; for winter wheat this figure is 0.59%; for summer groundnuts 1%; and for sugarcane 1.12%.

All the (previously cited) evidence on price elasticities suggests that water demand will not respond to price increases when the base price of water is so low. In addition, the existing system of per acre water prices means that the marginal cost of water is zero for each crop. It is true that higher water fees for low-value or water-consuming crops might induce a farmer to switch over to less water-intensive crops. However, it is clear that prices would have to be raised by several hundred percent before water costs reach even 5% of a crop’s net revenues.

An alternative proposal would be physically to ration the water given to agriculture, and to each irrigated acre. Recall that all the ways in which a farmer could respond to higher water prices – fallowing land, switching crops, etc. – are a result of lowering her water use. Rationing would directly force her into a lower, and presumably more efficient, water use pattern. By comparing the farmer’s crop choices under low prices with rationing, and under successively higher water prices without rationing, we can see at what point the farm level irrigation demands are comparable. We can also estimate the net returns per unit of water applied in various water price and crop choice scenarios.

Using cost-of-cultivation data from the upper-middle reaches of the Mula Canal, and a mathematical programming model written in GAMS, a median-sized farmer's profits were computed under different canal water prices.[8] Figure 1 plots the net returns per acre-inch of water applied on the farm (Y-axis) against the price of canal water for sugarcane (X-axis).[9] Sugarcane is the crop with the highest water price and the highest water requirement. Agronomic and crop-cutting experiments show that sugarcane has low returns per unit of water used, but high returns per unit of land (Rath and Mitra, 1989).[10] Therefore a water-efficient cropping pattern would have less sugarcane and more seasonal crops such as wheat or sunflowers.

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[8] For modeling purposes, I have assumed that water is priced per acre-inch. Without this volumetric charge assumption, the model solution would not respond to varying prices.

[9] Only canal water prices for sugarcane have been varied. Canal water for other crops is cheaper. In addition, the farmers supplement canal water using shallow dugwells. However, these wells contain very little water in the hot weather period, when crop water needs are at their peak.

[10] This explains the popularity of sugarcane on the Mula. Profits, of course, are normally measured, and maximized, per unit if land and not per unit of water.

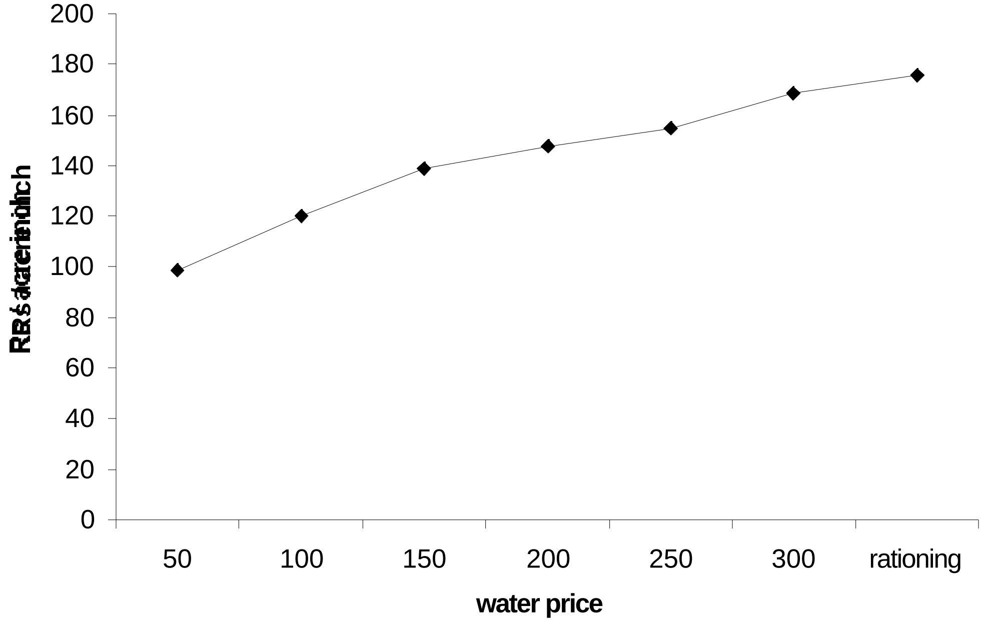

Figure 1. Water prices for sugarcane v. net returns to water applied

In each price scenario, the farmer is allowed a cheap but limited canal water "ration" which she can apply to any crop. In the rationing scenario, this is all she is allowed. The model solution shows that, when a farmer's water is rationed according to simple, proportional allocation rules, a 4-acre plot would have 1.4 acres of sugarcane (for 12 months), and a winter-summer cycle of sunflowers followed by groundnuts on her remaining land. If she can buy all the extra water she wants over and above that allocation, she grows 4 acres of sugarcane at a price of Rs 50/acre-inch,[11] less and less cane as prices rise sharply, and finally replicates the rationing crop pattern at a price of Rs 300/acre-inch. At this point, the net returns to water are high and comparable to those under rationing.[12] A six-fold water price increase was needed to induce this water-conserving response.

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[11] In 1992, US $1 = Rs 30 approximately. Rs 50 is slightly higher than the canal water price for sugarcane during the hot weather season (in 1991).

[12] It may appear puzzling that the net returns to water are sometimes lower than the price per unit of canal water for sugarcane. The X-axis shows the price of canal water for sugarcane only. The Y-axis shows the *average value* of water used on the farm – computed annually over all crops and using

For the near future, such severe water price hikes are unlikely to be suggested, let alone implemented. Farmers are numerous, and they vote. They object vociferously even to small price increases in water or electricity (Economist, 1997).[13] Nor would the urban population support significant price increases, out of fear that their food costs would rise, or that national food security would be compromised. In sum, significant price increases are politically infeasible, and feasible price increases are economically insignificant.[14]

The net returns to water shown in Figure 1 give an (admittedly crude) indication of the price that farmers would have to be offered to sell a part of their water allotments. The average value of an acre-inch of water ranges between Rs 100 and Rs 175 (see Fig. 1).[15] At any price above its average value, the farmer could consider selling some water and growing a little less cane. In fact, the offer price would have to be even higher because a farmer who gives up water loses the insurance that this water provides in the event of a drought, or a sudden shortfall.[16] There are no studies to show how much water would be demanded at these prices, but Rs 100 an acre-inch is already a higher rate than is paid by municipalities and cane-crushing factories within the Mula command area.[17] However, farmers towards the tail end of the canal may accept lower prices, where water supplies are already uncertain and only low-value crops can be supported.

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variously priced waters. The *marginal value* of water rises and falls each month for each crop. The model solution shows that, as expected, the farmer uses additional canal water for sugarcane only when its marginal value is greater than its price.

[13] I raised the issue of higher water prices (for cost recovery reasons) at the Command Area Development Authority for the Mula. The response of the Chief Engineer was brief: “Are you mad?”

[14] This situation is not unique to India. It is true of most agriculture-based economies. Recent work on the Gediz Canal in Turkey (Ray and Gǒl, 1999), and the Zayandeh Rud Basin in Iran (Perry, 1998) had strikingly similar findings.

[15] Marginal values of water in agriculture vary sharply from month to month, or even week to week. Therefore this comparison is best made with average values.

[16] As an added complication, if water is sold separately from the land, the land could lose value. The value of irrigation water is frequently capitalized into the value of the attached land.

[17] Non-irrigation withdrawals from the Mula reservoir amount to 7% of the irrigation withdrawals.

Main system management and irrigation efficiency

If water prices or water trades are expected to improve irrigation efficiencies, it seems reasonable to ask how inefficient water use at the farm level really is, and what the relationship is between water prices, main system management and these inefficiencies.

Farmers on the Mula Canal do flood irrigate their sugarcane fields, and they do allow water to spill beyond their irrigation furrows. But it is now well understood that these seepage and runoff “losses” are not necessarily lost to the basin. Wells in the command are recharged by seeped water, and return flows have instream uses or can be diverted again lower down. The water “saved” in one part of the system, through incentives or other means, may not be a net saving at all (Seckler, 1996). Of course, some return flows become saline and unusable. On the other hand, water which recharges a well over which the farmer has complete control, and which can be used between canal deliveries, has a very high marginal value. In the Mula command, well water in the parched month of May had a marginal value equal to 1/12 of the profits on an acre of groundnuts (Ray, 1997).

Even if it is assumed that most of the seepage and runoff are irretrievably lost, a sizable fraction of these losses does not occur at the field level. Cumulative measurements of conveyance, evaporation and other losses on the Mula Canal were as follows: From the reservoir to the distributaries, 38%; from these to the minor branches, 42%; from the minors to the field channels, 75% (WALMI, 1984). That is, the farmer can be given “incentives” to be efficient with only 25% of the irrigation water diverted from the reservoir. This is all the water that he has control over.

These “loss” figures are for the canal overall -- they would be lower upstream and higher downstream.[18] In addition to lower volumes delivered, farmers along the bottom third of the canal have unpredictable water supplies. Planned and actual deliveries are further and further apart as they proceed down the canal, and farmers

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[18] In particular, “other” upstream losses include illegal water diversions, mostly for unauthorized sugarcane or irrigation outside the sanctioned command area. Illegal irrigation is not a loss, but, if it goes unchecked, it cannot be made efficient through higher water prices (Ray and Williams, 1999).

openly admit that they take extra water when it finally arrives. They are also forced into low-valued, water stress-tolerant field crops, because they do not know when next to expect water. For example, water from the Mula Canal is supposed to arrive at 21 – day intervals for the winter crop season, and 14 days apart in the summer. Table 1 shows the actual delivery intervals for one watercourse in 1989/90. This was not even a tail-end watercourse.

Finally, water fee collections on the Mula, as on most Indian canals, is poor. The Irrigation Department's own (unpublished) records show that, from 1977 to 1990, collections ranged from 15% of the expected annual total to a high of 64%. Had the uncollected balances been rolled over from year to year, these percentages would have been very much smaller.[19]

Winter irrigation #	Interval (in days)	Summer irrigation #	Interval (in days)
1	Not applicable	1	Not applicable
2	18	2	20
3	26	3	18
4	31	4	24
5	27	5	34
6	24		

Table 1. Irrigation delivery intervals on the Mula Canal, 1989/1990

To what extent farm level inefficiencies, which certainly exist, are themselves a response to main system inefficiencies is a very important question (Wade and

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[19] In 1991, new water rates were proposed for the state of Maharashtra. They were somewhat higher than the existing rates, and the farmers on the Mula were unhappy with the proposal. When I mentioned this to the Sub-Divisional Officer with whom I worked, he was astonished. "Why are they angry?" he wanted to know. "They don't pay us *anyway*."

Chambers, 1980). Water prices can only affect that water over which the farmers have some control, and those inefficiencies which are caused by low water prices. In the present situation, higher prices (if collected!) are likely to lower farmers' net revenues, but have only a small impact on overall water use efficiency.

Output prices and irrigation efficiency

On the Mula Canal, sugarcane is the cash crop of choice for both large and small landholders. The cane-crushing mills, which are given a subsidy per ton of cane processed, guarantee a high support price to sugarcane producers. In 1991, the farm-gate price reported from this area was Rs 35 per quintal. (By 1996, this figure had risen to Rs 39). The procurement price guaranteed by the state of Maharashtra was Rs 29 per quintal. The average producer's cost was just above Rs 22.

Sugarcane is popular for its high and certain returns to land (the cane-crushing factories pay farmers more than the government support price), for its resistance to pests, and its low labor requirements compared to water-efficient crops such as vegetables, oilseeds or spices. The programming model of the representative farm was run again, this time keeping the water price low, but parametrically varying the price of sugarcane. The model solution shows that had the government not supported the price of cane, or subsidized the cane-crushing facilities, it would have been unprofitable for the farmers to grow sugarcane (Fig. 2). When sugarcane prices (the X-axis) fall, the acreage of cane (the primary Y-axis) drops sharply. At cane prices of Rs 25, even at low water prices farmers switch completely to a more water-conserving cycle of sunflowers followed by groundnuts (Ray, 1997).

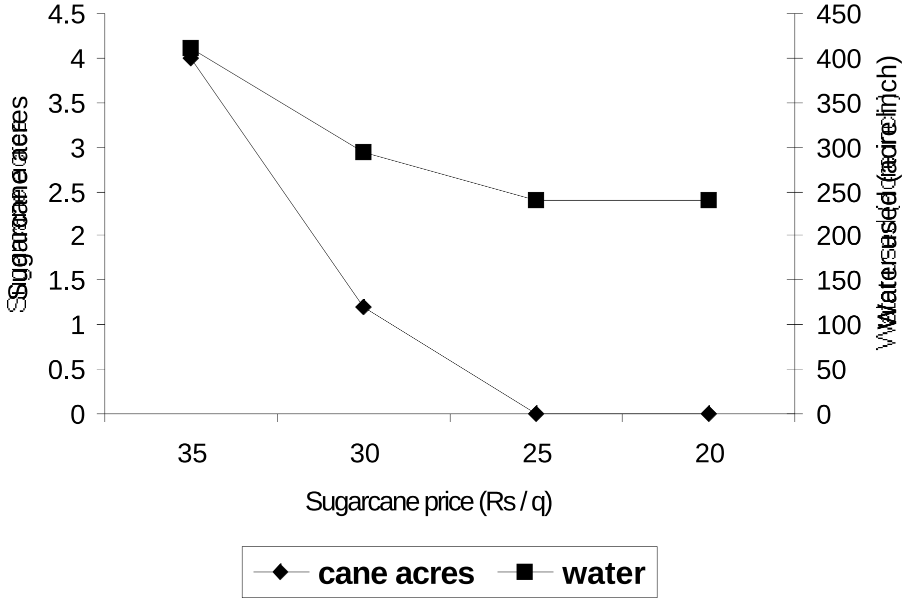

Figure 2. Optimal sugarcane acres and annual water use on a 4 acre farm; varying cane prices; low water prices

Maharashtra produces about 14% of India's sugarcane (by cane weight). If the government did attempt to remove its support price, it would find a powerful, well-organized and hostile opponent in the cane-processing lobby (Attwood, 1985). Sugarcane growing farmers, too, would be up in arms. As I have earlier argued, drastic rises in water prices also appear politically impossible. But if we want to use price policy to reduce the demand for irrigation, or to induce efficient crop diversification, output rather than water prices appear to be a more direct route.

4. Conclusion

In this paper, I have drawn on a case study of the Mula Canal in India to argue that, at this time, water price policy and/or a system of tradable water rights are not the most effective ways to increase irrigation efficiencies. Irrigation water prices are absurdly low compared with its scarcity value, and voluntary water trades are in principle desirable. However, it does not follow that raising water prices and establishing water markets is the natural next step for developing countries such as India. This is true even in the absence of prohibitive institutional and physical infrastructure costs.

I have suggested that there are three broad reasons for this conclusion. First, water prices cannot feasibly be raised to the point where they can affect water demand and use; second, farm-level inefficiencies are not the most significant inefficiencies, at least on existing canal systems; and third, low water prices are frequently not the reason behind water-intensive and inefficient crop choices.

A better first step would be to enforce simple allocation rules on existing canals. Enforcing these rules would compel many farmers to make do with less water, and would make its scarcity value immediately obvious. This step, while by no means easy, could be more feasible than raising prices because proportional allocation is already the distribution principle on modern Indian canals. The rules are rather loosely followed at present. But a concerted attempt to implement them would be perceived as fair, and would have the strong support of middle and tail end farmers on the canal. Physically rationed water shares and transparent water rights are also a prerequisite for future water markets.

A second, and related, step is to focus the management efforts of Irrigation Departments in India (and elsewhere) on tightening the operation and maintenance of the main canal system. At this point, incentives for their staff members to operate efficiently are at least as urgently needed as those for farmers.

References

Attwood, D.W., 1985. 'Peasants versus capitalists in the Indian sugar industry: the impact of the irrigation frontier.' *Journal of Asian Studies*. **45**: 59 - 80.

Ayer, H., and P.G. Hoyt, 1981. 'Crop Water Production Functions: Economic Implications for Arizona.' University of Arizona, Tucson, Technical Bulletin # 242.

Bandaragoda, D.J., 1998. ‘Design and Practice of Water Allocation Rules: Lessons from *Warabundi* in Pakistan’s Punjab.’ Research Report no. 17. International Water Management Institute, Colombo.

Bauer, C.J., 1997. ‘Bringing water markets down to earth: the political economy of water rights in Chile, 1976 – 95.’ *World Development*. **25**: 639 – 656.

Caswell, M. and D. Zilberman, 1985. ‘The choice of irrigation technologies in California.’ *American Journal of Agricultural Economics*. **67**: 224 – 234.

Economist, 1997. ‘Power Struggle.’ November 1, p. 44.

Gardner, B.D., 1983. Water Pricing and Rent-seeking in California Agriculture, in T.L. Anderson (ed.), *Water Rights, Scarce Resource Allocation, Bureaucracy and the Environment*, p. 83 – 113. Ballinger Publishing Company: Cambridge.

Howitt, R.E., W.D. Watson and R.M. Adams, 1980. ‘A re-evaluation of price elasticities for irrigation water.’ *Water Resources Research*. **16**: 623 – 628.

Ogg, C.W., and N.R. Gollehon, 1989. ‘Western irrigation response to pumping costs: a water demand analysis using climatic regions.’ *Water Resources Research*. **25**: 767 – 773.

Perry, C.J, 1996. ‘Alternative Approaches to Cost Sharing for Water Service to Agriculture in Egypt.’ Research Report no. 2. International Irrigation Management Institute, Colombo.

Perry, C.J, 1998. ‘Charging for Irrigation Water -- Issues and options in Iran.’ Project Report. International Irrigation Management Institute, Colombo. (forthcoming).

Rath, N., and A. Mitra, 1989. ‘Economics of irrigation in water-scarce regions: A study of Maharashtra’, *Artha Vijñana*, **31**.

Ray, I., 1997. ‘A Farming Systems Analysis of Irrigation Institutions.’ PhD dissertation, Stanford University.

Ray, I., and S. Gδl, 1999. ‘More from less: Policy options and farmer choice under water scarcity.’ *Irrigation and Drainage Systems*. **13**: 361 – 383.

Ray, I., and J. Williams, 1999. 'Evaluation of price policy in the presence of water theft.' *American Journal of Agricultural Economics*. **81**: 928 - 941.

Rosegrant M.W., and H.P. Binswanger, 1994. 'Markets in tradable water rights; potential for efficiency gains in developing country water resource allocation.' *World Development*. **22**: 1613 – 1625.

Rosegrant, M.W., R. Gazmuri and S.N. Yadav, 1995. 'Water policy for efficient agricultural diversification: Market-based approaches.' *Food Policy*. **20**: 203 – 223.

Seckler, D., 1996. 'The New Era of Water Resource Management: From "Dry' to "Wet" Water Savings.' Research Report no. 1. International Irrigation Management Institute, Colombo.

Wade, R., and R. Chambers, 1980. 'Managing the main system: canal irrigation's blind spot', *Economic and Political Weekly*, Sept. 27, p. A-107 - A-112.

WALMI, 1984. *Mula Evaluation Study - 1976 to 1981*. Unpublished. Water and Land Management Institute, Aurangabad.

Weinberg, M., C.L. Kling and J.E. Wilen, 1993. 'Water markets and water quality.' *American Journal of Agricultural Economics*. **75**: 278 - 291.