‘Get the Price Right’
Water Prices and Irrigation Efficiency

Economists are right when they point out that irrigation water prices are absurdly low compared with their scarcity value, and that at such low prices there is no incentive to conserve. However, it does not follow that raising water prices is the natural next step for developing countries such as India. There are two broad reasons for this conclusion: first, in the near to medium term, canal water prices probably cannot be raised to the point where they significantly affect water demand. The negative impact on farm revenues would be too drastic and the policy would not find broad public support. Second, low water prices are often not the main reason behind the farmers’ water-inefficient crop choices. Moreover, farm-level inefficiencies appear not to be the most significant ones on existing canals, nor are water prices the most significant prices driving irrigation demand. A better first step would be to enforce simple allocation rules – such as per-hectare rations – that would make the scarcity value of water immediately obvious. The analysis in this article is based on a study of one canal system in Maharashtra.

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Much of the world’s fresh water is wasted. Governments are shying away from the answer: to price this valuable substance correctly. [*Economist,* March 23, 2000]

I
Introduction

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 [Repetto 1986]. However, growing populations, higher cultivation intensities, increasing urbanisation, and, of late, environmental concerns, have all combined to put pressure on global water resources. Irrigation is by far the largest consumer of fresh water, and the realisation that this water is scarce and getting scarcer has forced a widespread re-thinking of the ‘cheap water’ policy. Elementary economic theory says that 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 with low efficiency methods such as flood and furrow, does not repair his field channels, and over-waters his standing crop. It has therefore been argued, especially since the Dublin Principles of 1992,[1] that the price of irrigation water should rise or that water markets should be established, so that on-farm water use at least approaches its scarcity value.[2] The larger point is that water is an economic good and not a birthright, and wasteful water use can best be combated by introducing market discipline into this sector.

Higher prices for irrigation water have been under consideration – and partial implementation – in several countries, including India, for some time [Daines 1985; Dinar 2000, Table 1.1]. Most country reports on water sector reforms mention the need for volumetric pricing and higher water prices. This would require the removal of flat, per-unit-area water charges, which is the current allocation rule in most agricultural sectors, India included. Alternatively, it is argued that farmers should be allowed to sell their allocated water rights to higher-value uses both within and outside the agricultural sector. Such trades would be economically efficient for society and in the farmer’s interest. Tradable water rights have been implemented in Chile, Australia and to a lesser extent in Mexico.

In this paper I examine the hypothesis that, in order to induce irrigation efficiency at the farm level, water prices should be raised. In the next section, I lay out the rationale for opportunity-cost water pricing, citing modelling and empirical evidence in its favour. In Section III. I bring out the (often implicit) assumptions under which higher water prices at the farm level can in fact increase irrigation efficiency. Section IV briefly describes the system of canal irrigation in Maharashtra, India, and introduces the case study canal. In Section V I show that when the assumptions of Section III do not hold – and they do not in many developing countries – water prices may have only limited impact on irrigation efficiency. I draw on a model of the Mula canal in Maharashtra as a concrete example.[3] The case study is not meant to be ‘representative’ of canal irrigation all over India; rather, it illustrates the role of water prices in a context that shares many features with other canal-irrigated regions of India. Finally, I analyse a different price policy – specifically, support prices or procurement prices[4] for particular crops – as an alternative means of conserving water. I do not claim that higher water fees cannot induce water conservation, but that they will do so only under certain preconditions. If these preconditions are far from ground reality, then higher water prices will not be the best way to conserve water or increase its productivity. Enforceable allocation rules may be more feasible, and output price policy changes more effective, at least in the near term.

I should note that cost recovery rather than efficient irrigation is another important reason for charging higher water prices. Many developing country governments are debating higher water prices as a way to recover the operating costs of canal systems, rather than as a way to reflect its opportunity cost. India's own National Water Policy of 2002 makes reference both to cost recovery as well as to 'rational pricing' [GoI 2002]. Most international lending agencies, economists and water policy analysts see cost recovery as just one step towards the larger goal of efficient water allocation. The rationale for cost recovery is financial, whereas the rationale for efficient pricing is economic. It is quite possible to raise water prices to the point where administrative costs are covered, and still have them be significantly lower than the opportunity cost of water. In fact an adequate per-area-irrigated flat fee (that cannot induce efficiency) can cover the operating costs of a canal system. Similarly, efficiency-inducing water trades can, and do, coexist with massive subsidies at the system level. The role of water prices for cost recovery is not addressed in this paper.

II
Opportunity-cost Pricing: The Evidence

If water prices rise to reflect its opportunity cost, a profit-maximising farmer could have any or all of four responses [Gardner 1983]. He[5] can demand less water and leave some land fallow. He can cultivate all his land but stress the crop a little, thus maximising his output per unit of water rather than output per unit of land. He can diversify out of thirsty but low-water-productivity field and fodder crops into water-efficient crops such as vegetables. And finally, he 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 per cent. The conclusions of both econometric analyses and mathematical programming models imply that farmers would respond to price-induced water scarcity in all of these ways.[6]

Much of the literature on water prices is from the agriculturally rich, but water-short, western US. Using agronomically derived production functions for cotton, Ayer and Hoyt (1981) show that farmers in Arizona and New Mexico would 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 for the western US. Caswell and Zilberman (1985), using an econometric analysis of several California water districts, find that the probability of adopting drip irrigation technologies for perennial tree crops increases with increased water prices, amongst other factors such as land quality and crop type. Kanazawa (1988) asks: what range of price increases will induce conservation? For the Westlands Water District he finds that a three- to five-fold rise would take the price of water to its shadow value and beyond that, farmers would conserve.[7]

It should be noted that in most of these studies on water prices, the response of water use is rather low within observed price ranges. Only when the price is projected to rise significantly, by a factor of five, or even 10, is the water demand price – responsive. 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 it is cheap and feasible to substitute other inputs, such as labour, for water. Levy (1982), a proponent of regulating water use through the price mechanism, agrees that the price elasticity of water is high when water is readily substitutable and when its share in total production costs is high. I shall revisit these points later in the paper.

Programming models, which are not restricted to observed price ranges, can yield more elastic water – demand estimates. Many of these confirm the existence of low elasticities at low prices. In a modelling exercise, Weinberg et al (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. Hooker and Alexander (1998), in a programming model of San Joaquin valley, show that water demand is inelastic over a substantial price range, and steps towards conservation are taken only at certain threshold water prices. However, Howitt et al (1980) have argued that including a demand function for the crop itself – not just one for water – should generate higher own-price elasticities. (Higher water prices should raise the cost of production which is passed on as higher product prices to the consumer, thus lowering the demand for the product and finally bringing down the derived demand for water.)

Implementing water trading – as opposed to implementing higher water prices – is another way in which market forces can be brought to irrigation. Several agricultural regions of Australia are experimenting with intra-basin water trades, such as on the Murray-Darling Basin.[8] Spot markets are common in California, and inter-district water trades, though less frequent than spot trades, do occur [Haddad 2000]. In the developing country context, informal, intra-watercourse trading is active on some Indian and Pakistani canals [Bandaragoda 1998]. Such trades are generally considered 'illegal' but they occur nonetheless. Short-term sales of groundwater are even more common – indeed groundwater markets in Gujarat have functioned for many years [Shah 1993; Dubash 2002].

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 formalised water rights, and allowed water sales to be separated from sales of land. These reforms have reportedly led to more land under high-valued fruits and vegetables, less land under pasture, and a greater than 20 per cent increase in water use efficiency [Rosegrant et al 1995]. The Chilean case has been cited as a model for other developing countries, though some authors dispute the extent to which the Water Code should be given credit for the subsequent gains in productivity [Bauer 1997].

For the rest of this paper, I focus on water price policy rather than water trading as a tool for water conservation and irrigation efficiency. Informal trades notwithstanding, as of today, water markets are not a serious part of irrigation policy discussions in India.

III
What Does It Mean to 'Get the Price Right'?

The claim that increasing irrigation water prices is an effective means to irrigation efficiency is much more than a generic statement about downward-sloping demand curves. It contains many embedded assumptions[9] which need unpacking. These are:
(i) Water costs are significant in the overall crop budget, and as a fraction of crop net revenues. If not, the net effect of price increases may be so small that the water demand function will barely respond.[10]
(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.[11]
(iii) Farm level inefficiencies are significant in relation to overall system inefficiencies. If not, the farm may not be the place in which to look for water savings.
(iv) Farmers irrigate using wasteful methods and/or grow low-water-productivity field crops because water is so cheap. If field crops are grown because local food or fodder markets are thin, or farmers over-irrigate because their water deliveries are erratic, water price signals may not have the expected effect.
(v) The changes to the infrastructure that may be necessary to implement volumetric pricing, such as measuring devices, channels for conveyance, managerial and administrative changes, etc, are not prohibitively expensive. If they are, any gains from more efficient water use will be neutralised by these implementation costs.

The last item relates to the difficulties of implementing higher water prices on account of institutional or infrastructural barriers. It has borne the brunt of the criticisms levelled at water price reform and water markets in the literature to date. 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 [Molden 1997], and the possible third party effects of water reallocation through pricing or trade [Rosegrant and Binswanger 1994]. The income losses that farmers could face – especially small and marginal farmers – have also been critiqued on grounds of social equity. In this paper I approach water prices as a means of water saving not from the point of view of a social planner or the government, but from the point of view of the incentives of the farmer – the actor who is supposed to do the saving.

I examine an Indian canal system – the Mula canal in Maharashtra – to ask: How effective are higher water prices as a means of curtailing a farmer's water demand, even if transaction and infrastructure costs are not constraining? Using a detailed, farming systems model of a median-sized farm, I analyse:
(i) whether higher water charges are the most feasible way to induce farm level efficiency;
(ii) whether farm level efficiency is indeed as dismal as it is generally thought to be; and
(iii) whether water prices are the most relevant prices in a farmer's cropping decisions.

The price and input use data for the model, the pattern of water delivery over the agricultural year and the technical coefficients are all from my own eight-month long fieldwork on the Mula over 1991-92.[12] The net irrigation requirements and the yield responses to water are from studies done at the Mahatma Phule Agricultural University at Rahuri, Maharashtra.

IV
Irrigation in Maharashtra and on the Mula Canal

Canal irrigation in Maharashtra is a demand-based system. Before the start of the irrigation season, the farmers who want water submit a demand statement which specifies the land they will irrigate and the crops they will grow. Depending on the water availability that year, the requests are fully or partially granted. The goal of major canal systems in India was to ensure a reliable supply of foodgrains over a large area, even in drought-prone regions, to reduce the risk of famine and the dependence on food imports [Daines 1985]. Accordingly, canal command areas are rather extensive.[13] Annual grains and oilseeds are favoured for irrigation, while water-consuming cash crops such as sugarcane need a special 'sanction' (unless they are raised exclusively on groundwater). Dug wells are common along canal-irrigated tracts. Most of the Maharashtra plateau is underlain by basaltic rock; this basaltic layer keeps the water table high but the usable volume of groundwater low [Dhawan 1986].

Canals in Maharashtra are fed by water stored in reservoirs, and are run on an 'on and off' basis [Gandhi 1981]. Only a subset of the watercourses is full of water at any given time. Each watering turn is called a 'rotation'. To compensate for the locational advantage of head-reach farmers, canals are operated from tail to head. When a watercourse has its rotation due the last field is watered first, and the irrigation turns move up the channel rather than down it. This system is known locally as 'shejpali'.[14]

Traditionally, a farmer could irrigate until his field was 'adequately' wetted. Over time, and especially whenever irrigation demand exceeded the supply, this system came to be seen as too loose. From 1977 on, the operational rules of major canal systems have gradually been modified to a pre-set number of irrigation hours per hectare of land within each watercourse. Only the land and the crops for which the farmer has placed a demand are entitled to water, and this demand could differ from season to season and even from rotation to rotation within a season. The fixed irrigation entitlement, proportional to the area irrigated, is influenced by, but is not identical to, the 'warabundi' system of north Indian canals.[15] It appears that this modification has introduced greater accountability and predictability in an otherwise over-flexible system [Datye and Patil 1987].

The Mula canal system in western Maharashtra has an irrigable command area of 80,000 hectares; the soils are medium-deep loams to dark clays; the average annual rainfall in the command is less than 600 mm; the median landholding is between 1.6 and 2 hectares, and even small farms produce crops for the market. The primary crops are sugarcane (a thirsty, lucrative cash crop), wheat and groundnuts, followed by sorghum, chickpeas and some cotton. Over the last decade, sunflowers have grown in popularity. Millet, a coarse grain that was once widely grown and eaten in the region, now occupies less than 10 per cent of the gross cropped area. The arrival of year-round water has made other crops more profitable [Lele and Patil 1991].

Water is allocated on the Mula canal according to the modified fixed-turn system. As described above, it contains elements of Maharashtra's traditional shejpali system, and of the warabundi method of north Indian canals. As under warabundi, canal water is supposed to be delivered to farmers according to a pre-set rotation schedule – starting about the third week of July (unless it is still raining) and continuing through mid-June. As under shejpali, it is up to each individual farmer to place, or not to place, a water demand for each rotation of each season. The normal rotation interval – meaning, the interval between two successive irrigations for any farm – is 21 days. Between March and June, when midday temperatures peak and the soils have no residual moisture, this interval is shortened to 14 days.[16] Each hectare is given a fixed duration of irrigation, e g, 10 hours per ha for a head-end farm and longer if the farm is at the tail-end.[17] In practice these durations are 'flexible' (sometimes intentionally, and sometimes unintentionally, so).

The Mula is, in many ways, a typical south Asian canal. The water supply is more generous and more predictable at the head of the system than at the tail; upstream and downstream cropping patterns reflect both the soil variability and the uneven water delivery of the region; water often does not reach the fields on time; much of the water released into the system is 'lost' in transit, or at least unaccounted for; 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 a loose attempt to link water charges and volumes. The command area has several shallow wells, which are largely recharged by canal seepage, and which supplement canal water supplies. The water from these wells is also cheap, because electricity for farm use is subsidised.[18] Irrigation professionals who are familiar with Indian canals will recognise many of these features even if they have never been on the Mula.

V
The Farming Systems Model

In this section, using a mathematical programming model written in GAMS, with numerical parameters calibrated to the upper-middle reaches of the Mula canal, I explore the role of canal water prices on the water use of a hypothetical median-sized farmer. Throughout India, Maharashtra included, canal water is charged at a flat per-hectare rate. For modelling purposes, I have assumed that canal water is priced per hectare-cm and have converted the relevant per-hectare charges to per ha-cm equivalents.[19] The 1.6 ha farm in the model is endowed with a male and a female adult, a specified allowance of canal water in each irrigation rotation, and a dug well. The farmer can irrigate from the canal, from the well, or from both.[20] He is assumed to be profit maximising,[21] so the objective function maximises the total on-farm profits over the agricultural year, subject to the constraints of land, family labour, and the water available from the canal and the well.

The farm is modelled as a linear programme with eight crops (year-long sugarcane; monsoon sorghum and millets; winter wheat, sorghum and chickpeas; and summer season early-sown and late-sown groundnuts) over one agricultural year. With year-round irrigation, the same piece of land can support two, or even three, crops a year. Data on the technical coefficients, output prices,[22] input prices for hired labour, fertilisers, draft power, etc, and the demand and supply constraints for family labour and water are from field observations and cost-of-cultivation surveys from 65 farm households. The resource constraints for labour and water are separately specified for each 14-21 day period to accommodate the water delivery schedule from the canal and the seasonal nature of the agriculture.

As more water is made available per hectare, the yields of most crops increase, but at diminishing rates [Hillel 1987]. To keep the model linear and yet allow the production functions to exhibit diminishing returns, the concave water response functions for each crop are broken up into between four and six linear segments. A crop with a lower water availability than its net irrigation requirement[23] is treated, in effect, as a separate crop with a lower water requirement, a lower yield and lower labour use. Crops have critical periods when water shortages cause a disproportionate fall in yields, and which cannot be reversed by adequate irrigation at other times. For wheat, for example, the most water-sensitive stages are crown root initiation and pre-flowering. To reflect plant physiology as accurately as the data allow, the rotation-wise water requirements take into account any critical growth stage a crop might have. The final model has 36 crops from which the GAMS solver can choose.

The model entitles the farmer to a limited amount of canal water, proportional to his irrigated acreage, at very low crop-specific prices. This approximates the modified rotational water allocation rule on the Mula canal. The farmer may use all, part, or none of his canal water entitlement in each rotation. The model thus reflects the voluntary demand structure of the shejpali tradition as well as the per-hectare quota of warabundi. In order to analyse the effect of higher canal water prices, three further assumptions have been made. First, in addition to the cheap and limited canal water entitlement, the farmer can buy all the extra canal water he wants at a higher price. In effect, the farmer has access to a cheap baseline block of water and a second, higher priced tier over and above the baseline entitlement. Second, the farmer can use canal water to irrigate his sugarcane crop, even if he does not have an official 'sanction' for this crop.[24] These assumptions are deviations from the actual irrigation rules – farmers are (officially) restricted to their baseline quotas most of the time and crop zoning (officially) allows only some farmers to raise sugarcane on canal water. But the effect of water prices on irrigation efficiency cannot be isolated if physical quotas and crop zoning rules are binding constraints on the farmer's decisions.[25] And finally, the model represents an 'average' year, without price and yield fluctuations. This assumption has been added to keep the model – which is already rich in agronomic detail – tractable.

Are Water Prices the Most Feasible Way to Induce On-farm Efficiency?

Canal water prices are heavily subsidised for the farmers on the Mula – so much so that water costs are insignificant in relation to the crops' per hectare revenues. The surface flow rates in Maharashtra vary by crop so as to reflect the crop's water requirement as well as "the ability of the crop to bear it" [Pawar 1985]. In 1985, water charges were supposedly fixed at 6 per cent of the average gross income for food and non-cash crops and at 12 per cent of average gross income for cash crops. In practice they have fallen far short of this goal. For example, water costs for sunflowers in the data collection period were 0.8 per cent of its (average) gross margins[26] per hectare; for winter wheat this figure was 0.6 per cent; for summer groundnuts 1 per cent; and for sugarcane 1.2 per cent. Sugarcane, the most water-intensive of these crops, and the one to which critics of low water prices regularly refer, was in fact the least subsidised in terms of its charge relative to crop gross margins.

All the (previously cited) evidence on own-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 hectare water prices means that the marginal cost of water is zero for each crop. It is true that higher water fees for water-consuming crops might induce a farmer to switch over to less water-intensive crops, or even to withdraw from farming altogether. However, prices would have to be raised by several hundred per cent before water costs reach even 5 per cent of a crop's net revenues.

An alternative proposal would be to physically ration the water given to agriculture, and to each irrigated hectare. That is, no second tier of canal water could be bought. Recall that all the ways in which a farmer could respond to higher water prices – fallowing land, switching crops, etc – require him to lower his total or his per-hectare water use. Rationing would directly force him into a lower, and potentially 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 ask:

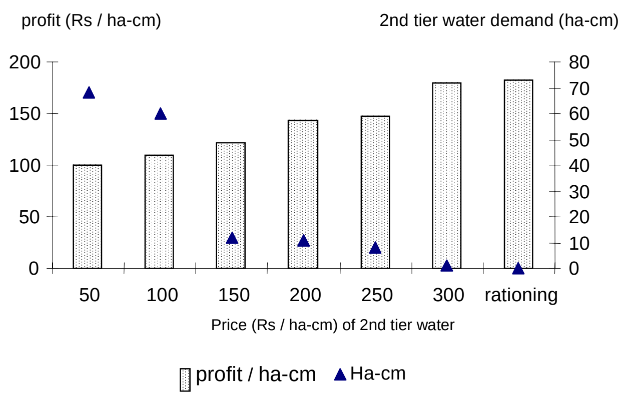
– At what price are the farm-level irrigation demands comparable with and without water rationing?

– Can we estimate the net revenues per unit of water applied[27] under various water price and crop choice scenarios?

Figure 1 plots the net revenues per unit of water, the price of canal water and the on-farm water demand from running the model at successively higher water prices. The X-axis shows the price per unit of any canal water demanded over and above the cheap baseline entitlement. The secondary Y-axis shows the model solution for the farmer's additional water use at the relevant price.[28] The primary Y-axis plots the net revenues per unit of water applied, from the canal and the well, on the farm.[29] Sugar cane is the crop with the highest annual water requirement, and agronomic experiments show that sugar cane has low returns per unit of water used, but high returns per unit of land [Rath and Mitra 1989]. Hybrid grain varieties and oilseeds generally yield higher revenues per unit of water applied. Therefore a water efficient cropping pattern should have less sugar cane and more seasonal crops such as wheat.

In each price scenario, the farmer is allowed a cheap but limited volume of canal water (the baseline) which he can apply to any crop. In the rationing scenario, this is all he is allowed. The model solution shows that, when a farmer's canal water is constrained by proportional allocation rules, a 1.6-hectare plot would have 0.56 ha of sugar cane (which has a growing season of 12 to 14 months), and a winter-summer cycle of wheat followed by groundnuts on his remaining land. (This wheat-groundnut cycle is indeed common on the upper-middle reaches of the Mula). If he can buy all the extra water he wants beyond the baseline entitlement, he grows 1.6 ha of sugar cane if the 'second tier' price is Rs 50/ha-cm.[30] He grows less and less cane as water prices rise, and finally replicates the rationing crop pattern when the incremental price is Rs 300/ha-cm. At Rs 150/ha-cm the water demand has dropped sharply (Rs 150/ha-cm represents a more than 10 fold increase over the average price of the baseline water block). By Rs 300/ha-cm the net returns to water are comparable to those under rationing. A sixfold price increase was needed to induce this level of conservation.

Figure 1: Canal Water Prices and Net Revenues Per Unit of Water



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 to price increases in water or electricity [*Economist*, 'Power Struggle', November 1, 1997, p 4], especially since such price hikes are usually unaccompanied by better or more reliable services. Price increases of even half this magnitude would have to be introduced in stages, and over time, at least in democratic regimes which are less able to implement swift policy changes [Dinar 2000].[31] Nor would the urban population support rapid price increases, out of fear that their food costs would rise, or that national food security would be compromised. As Sampath (1992) points out, urban consumers of cheap food benefit at least as much from subsidised irrigation water as do the farmers. In short, in this region, significant price increases could be politically infeasible, and feasible price increases could be economically insignificant.[32]

Finally, water fee collection on the Mula, as on most Indian canals, is poor. Pawar (1985) estimates that major irrigation systems recover about 67 per cent of their expected annual fees and minor systems recover just over 50 per cent. The irrigation department's own (unpublished) records show that, from 1977 to 1990, fee collections on the Mula ranged from a low 15 per cent of the expected annual total to a high of 64 per cent. Had the uncollected balances been rolled over from year to year in the accounts, these percentages would have been even smaller. If canals in India have been unable to recover their annual operation and maintenance costs, the state's inability to collect water fees is at least as much to blame as are the low water charges themselves. [33]

Are Farm-Level Inefficiencies a Significant Part of System Inefficiencies?

If higher water prices 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 water management and farm-level inefficiencies.

Farmers on the Mula canal – and in much of Deccan India – do flood irrigate their sugar cane and grain crops, and they do allow water to spill beyond the borders of their fields. Rarely do they channel their water carefully through their furrows, or put a lot of labour into land preparation and levelling, as farmers trying to conserve water would do. The field channels are usually poorly maintained, allowing seepage and runoff losses, as even casual observation will reveal. These losses increase non-linearly down the system – seepage and evaporation reduce the flow rates to the tail-end, and the slower flowing water then seeps out at an even higher rate.

It is now well understood that these local seepage and runoff 'losses' are not necessarily lost to the basin. Bromley (2000) critiques the notion that irrigation water should be optimally used on the individual farm, and recommends that canal water be priced recognising that it is a common property resource and that optimality is a system-wide concept. In a pioneering paper Frederiksen (1992) distinguished farm- and project-level efficiency from system-level efficiency and argued that it was worth investing in irrigation efficiency in the lower reaches of a basin but not necessarily upstream. This is because seeped water re-enters the system as return flow where it has instream uses or recharges the water table or can be diverted again. Thus the water 'saved' in one part of the system, through price incentives or other means, may not be a net saving at all system-wide [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 in the dry intervals between canal deliveries, has a very high marginal value.[34] The farming systems model shows that, in the parched month of May, one additional inch (2.5 cm) of well water had a marginal value equal to 1/12 of the profits from a hectare of groundnuts.

But let us assume, for the sake of argument, that most of the seepage and runoff is irretrievably lost. What fraction of these losses occurs at the field level? Large canal systems in India consist of one or two main or major branches, then several distributaries that further divide up into minor branches, and finally a network of watercourses and field channels. Irrigation takes place at the level of the watercourses and field channels. Actual transmission 'losses' are not measured (or at least, are not published) regularly in India, especially downstream of the distributary outlets. However, transmission losses on four canal systems of Maharashtra – just from the main canals to the distributary heads, have been estimated at between 10 per cent and 59 per cent [cited in Rath and Mitra 1989].

The irrigation department of Maharashtra measured the rates of flow down the length of the Mula canal to estimate its transmission losses – without taking into account any return flows – in the mid-1980s.[35] The cumulative measurements of conveyance, evaporation and other losses[36] along the canal were as follows: From the reservoir to the distributaries the flow had dropped by 35 per cent; from these to the minor heads by 42 per cent of the flow released from the reservoir; and from the minors to the farms themselves by 65-70 per cent. That is, the farmer can be given price 'incentives' to be efficient with only 30-35 per cent of the irrigation water diverted from the reservoir. This is all the water that he has control over.

Are Farmers Inefficient in Their Water Use because Water Is Cheap?

Locational asymmetry is a well known phenomenon along major gravity-flow systems such as the Mula. Downstream farmers get less water than do their upstream neighbours, and to make matters worse, their water deliveries are often delayed. 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. In spite of the more frequent water supply in the hot season, this is a period of great stress. The clayey soils of the Maharashtra plateau are normally water-retentive but by April they are dry and cracking, and pan-evaporation rates can be as high as 15 mm a day [Lele and Patil 1991]. Despite these conditions, planned and actual water deliveries move further and further apart as they proceed down the canal. Table 1 shows the actual delivery intervals for one particular watercourse in 1991. This was not even a tail-end watercourse.

Many farmers openly admit that they take extra water and flood their fields generously when the water finally arrives. "I just grab as much water as I can" said a sugar cane farmer. "The government says that's wasteful, that other people need water too. But what else can I do?" And in the words of a smaller farmer, lower on the system, "The canal water is like the rain. It may come, it may not come, it may come late. If it comes, we are happy. But my brothers and I, we can't rely on it."

Farmers who not know when to expect water, or have to plan for long dry intervals between irrigations, can be forced into stress-tolerant, possibly low-valued, field crops. This is especially true of downstream farmers and of farmers without access to supplementary groundwater. The irrigation literature frequently implies that low water prices cause farmers to grow low-productivity crops such as alfalfa and coarse grains, and that higher water prices would make them switch to, e g, vegetables and finer cereals. Water is cheap, and crops with low returns to water are grown, but such observations do not establish causation. An equally plausible hypothesis is that higher-productivity crops (such as groundnuts or sunflowers) need a steady supply of water at regular intervals, whereas crops such as millets or sorghum can make do with less water, less precisely timed.[37] To understand the effect of delays in the water delivery schedule, the original farming systems model was modified as follows:

(i) The wells were taken out, so that the impact of canal water deliveries could be evaluated from the perspective of the most vulnerable farmers – those without supplementary groundwater. These farmers are entirely dependent on the canal, either because they are too poor to have a well or because their local hydrological conditions cannot support a well with reliable yields.

(ii) The arrival of water in a specific rotation was delayed, but compensated for in the next rotation. Therefore the annual water deliveries are unchanged from the original model.

(iii) Quantity restrictions remained in place – the farmers were not entitled to canal water over and above their baseline allocations. The baseline water price was kept low.

Three versions of the model were run, with delivery delays in March, April and May respectively. In each case only one rotation is delayed and the model treats the delay as anticipated. In reality, delays can be approximately known in advance (from

Table: Example of Irrigation Delivery Intervals on the Mula Canal

Winter Irrigation No	Interval (Days) (Planned = 21)	Summer Irrigation No	Interval (Days) (Planned = 14)
1	Not applicable	1	Not applicable
2	18	2	20
3	26	3	18
4	31	4	24
5	27	5	34
6	24	–	–

Figure 2: Water Delivery Regimes, Crop Patterns and Profits

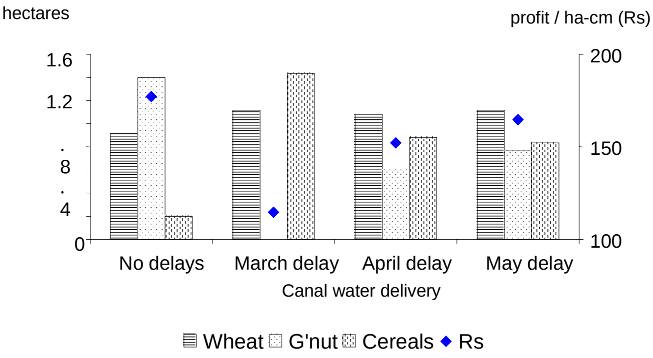
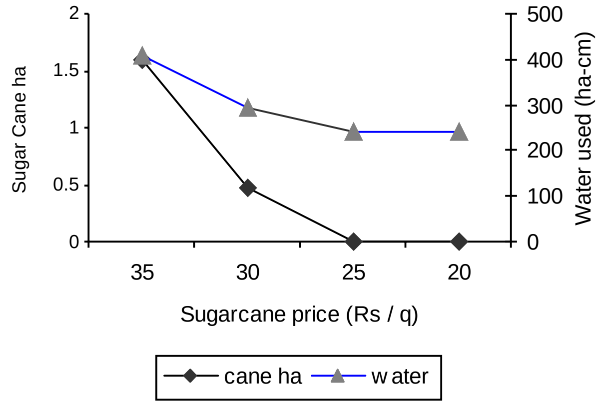


Figure 3: Optimal Sugar Cane Area and Annual Total Water Use on a 1.6 ha Farm; Varying Sugar Cane Prices



past experience), or genuinely unexpected. In the second case, the effect on yields and revenues can range from a significant drop in yields to total crop failure. In the first case, which is modelled here, the farmer can adjust his crop choices from the start. The model solutions therefore represent the best case delay scenarios. The solutions are explained in some detail to illuminate the connections between water deliveries and crop choices.

Figure 2 compares the cropping patterns and the net revenues per unit of water on a 1.6 ha farm under the planned water delivery schedule, with those under late water arrivals in March, April and May. The water delivery regime is shown on the X-axis. The optimal cropped areas under wheat, groundnuts and coarse cereals (millets and sorghum) under each regime are plotted on the primary Y-axis. These areas add to over 1.6 ha because of multiple cropping over three seasons. The returns per ha-cm of water are shown on the secondary Y-axis. The model, as always, allows the farmer to grow sugar cane along with cereals and groundnuts. However, there is no sugar cane in these model solutions – not because of risk aversion or a desire for food security, but because of the high and year-round water needs of cane. With canal water rationing in place and no well, sugar cane is not a viable option on most parts of the system.

Farmers without wells on the Mula command overwhelmingly preferred a winter-summer rotation of wheat (average gross margin Rs 7,500 at 1992 prices)[38] and groundnuts (average gross margin Rs 10,000). The coarser cereals (gross margins between Rs 2,000 and Rs 4,500) were mostly grown on rainfed land or if the water supply was inadequate for a larger groundnut crop.[39] The model solution with no water delays reflects this ground reality, with its wheat and groundnut dominated cropping pattern. If the farmer expects a long dry spell in April or in May, he opts for a smaller groundnut crop and a larger cereal crop – as well as a drop in his water productivity. But a delay in the month of March is the most damaging of all. March is not a particularly water-demanding month, but it is when groundnuts are planted, and when a pre-sowing wetting is really critical. Figure 2 shows that an irrigation delay in March cannot be made up by extra water in April, and that the farmer is forced into a monsoon-winter rotation of coarse staples followed by wheat – a low-value combination. Land records show that this monsoon-winter food-grain pattern was common in this region before the arrival of canal irrigation.

If farmers over-irrigate as a hedge against future shortfalls, or accept low returns to land or water because their canal water deliveries are untimely, they are not going to become efficient as a result of higher water prices. To what extent farm level inefficiencies – which certainly exist – are significant in relation to, or are themselves a response to, main system inefficiencies is a very important question. Irrigation water prices can affect only that water over which the farmers have some control, and only those inefficiencies which are caused by low water prices. Without tighter main system management, higher water fees – if collected – will lower farmers' net revenues, and could have only a marginal impact on overall water use efficiency.

VI
Water Prices Versus Crop Prices as a Means of Conserving Water

Finally, if we must look to the price mechanism as a way to induce water efficiency, we should ask if water prices are the most relevant prices in the farmer's cropping decisions. On the Mula canal, sugar cane is the cash crop of choice for both large and small landholders. The cane-crushing mills, which are given a subsidy per tonne of cane processed, guarantee a high support price to sugar cane producers. There is relatively little price risk with cane compared to sunflowers or groundnuts. In 1992, the average farm-gate price reported from this area was Rs 35 per quintal.[40] The support price guaranteed by the state of Maharashtra was Rs 29 per quintal. The average producer's cost, calculated from my own cost-of-cultivation surveys, was just above Rs 21.

Sugar cane 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 for its low labour requirements compared to relatively water-efficient crops such as vegetables, oilseeds or spices. The programming model of the representative farm was run again, this time keeping canal water prices at their low baseline values, allowing the farmer to buy as much water as he desired at those low prices, letting him choose to irrigate from the canal, from his well, or from both, and parametrically varying the price of sugarcane. The difference between this model and the version that varied canal water prices is that, in this version, first- and second-tier canal waters are the same price. This model specification allows us to analyse the role of sugar cane prices in the absence of high water prices or water quantity constraints.

The model solution shows that had the government not supported the price of cane, or subsidised the cane-crushing facilities, it would have been unprofitable for the farmers to grow sugar cane (Figure 3). When sugar cane prices, shown on the X-axis, fall, the area under cane, plotted on the primary Y-axis, and the total water used on the farm (on the secondary Y-axis) both drop sharply. A 14 per cent drop in the price of cane triggers a 28 per cent drop in the total water demand[41] – the equivalent response would have required a nearly fourfold rise in the price of canal water charged at sugar cane rates. At cane prices of Rs 25, even at low water prices farmers would switch completely to a cycle of winter wheat followed by summer groundnuts. That represents a water-conserving choice not induced by higher water prices.

Maharashtra is the second largest sugarcane producing state in India, contributing about 14 per cent of India's sugar cane by cane weight. It has approximately 12 per cent of India's cropped area under sugar cane and 81 per cent of the cane crop is under irrigation [Pant 1999]. If the government did attempt to remove the support price, it would find a powerful, well-organised and hostile opponent in the cane-processing lobby [Attwood 1985]. Sugar cane growing farmers, too, would be up in arms. As I have earlier argued, drastic rises in water prices may not be feasible, either – at least not over a short time period. A discussion on the comparative politics of higher water prices versus lower sugar cane prices is beyond the scope of this paper. Clearly neither policy would be easy to implement. But the analysis presented here indicates that, if we want to use price policy to reduce the demand for irrigation, or to induce efficient crop diversification, output rather than water prices are a much more direct route.

VII
Conclusion

Economists are right when they point out that irrigation water prices are absurdly low compared with its scarcity value, and that at such low prices there is no incentive to conserve. However, it does not follow that raising water prices is the natural next step for developing countries such as India. From the perspective of the farmer who is supposed to save the water, I have suggested that there are two broad reasons for this conclusion. First, in the near to medium term, canal water prices probably cannot be raised to the point where they can significantly affect water demand. The negative impact on farm revenues would be too drastic and the policy would not find broad public support. Second, low water prices are often not the main reason behind the farmer's water-inefficient crop choices. Moreover, farm-level inefficiencies appear not to be the most significant inefficiencies on existing canals, and nor are water prices the most significant prices driving irrigation demand.

A better first step would be to enforce simple allocation rules – such as a per-hectare ration – that would make the scarcity value of water immediately obvious. This step, while hardly simple, could be more feasible than raising prices because quantity restrictions are already the basis of water allocation on most Indian canals. The rules are rather loosely followed at present [Wade 1982, Ray and Williams 2002], but a concerted attempt to implement them better would be perceived as fair, and would have the support of middle- and tail-end farmers. There is considerable field evidence that water users' associations could be helpful in implementing such rules [Wade 1988, Ostrom et al 1994], though such associations are no guarantee against inefficiency [Vermillion 1997]. Physically rationed water shares that are transparent and enforced could also free up water to be transferred to urban areas, or to increase the number of farmers with access to canal water, or to meet environmental needs.

Proponents of water pricing reform certainly recognise that the price mechanism is always embedded within an institutional framework, and that all allocation mechanisms, including the price mechanism, have to be designed specifically for their physical, social and institutional contexts [Saleth 1997; Johansson et al 2002]. Yet over the last two decades, and especially since the Dublin Principles declared water to be an economic good, the literature on water sector reform has largely been focused on the need for higher water prices and more water trades. This focus has been reflected in influential newspapers such as the *Economist*, which wrote in its most recent survey of water, that "the best way to deal with water is to price it more sensibly" (July 17, 2003). In this paper, drawing on a farming systems model and a case study of the Mula canal in Maharashtra, I have argued that water is in fact cheap, and that may indeed be a problem. But unless the prerequisites for effective price signals are in place, which they frequently are not, we cannot conclude that 'getting the price right' for irrigation water is the 'best way' to deal with overuse and inefficiency. EPW

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Notes

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1 "Water has an economic value in all its competing uses and should be recognised as an economic good" is one of the four Dublin Principles from 1992 [Solanes and Gonzalez-Villarreal 1999].
2 The 'right price' of a resource to an economist is one that reflects its scarcity value, or its opportunity cost in its next best use.
3 I focus on canal water prices rather than groundwater prices for two reasons. First, many analysts believe that canal water is used more inefficiently than groundwater [Dhawan 1988]. And second, canal water prices are administratively set and so can be changed through public policy, while most irrigation wells are privately owned and there are no user fees for the water withdrawn (e g for Maharashtra see the Sukthankar Committee Report 2001, p xiv).
4 'Support prices' are minimum prices that (usually) governments guarantee to farmers. These protect the farmer against low open-market prices. 'Procurement prices' on the other hand are prices at which a farmer must sell a portion of his crop – usually to the government. These protect not the farmer, but the government and consumers, from potentially high open-market prices.
5 I use the term 'he' throughout the paper to refer to individual farmers, because most of the farmers I interviewed for this research were male. There are, of course, both male- and female-headed farm households throughout India.
6 There are no controlled experiments that have tracked the response of farmers to progressively higher water prices while holding other key variables (more or less) constant. Therefore the water pricing literature is largely made up of cross-sectional statistical analyses and modelling exercises.
7 These field studies measured water diverted, not water consumed. Therefore the production functions used in such research could overstate or understate the yield response to water actually taken up by the crop. Molden (1997) points out that the marginal and average values of water should really be calculated as a function of water consumed. This distinction also has implications for how farm-level efficiency and system-level efficiency are measured, as I discuss later in the paper.
8 For details see www.mdbc.gov.au.
9 These 'embedded assumptions' can be considered prerequisites for water

prices to be an instrument of irrigation efficiency. I use the term 'embedded assumptions' following Basu (2000: 249) which makes the point that strong assumptions are often built into models without explicit acknowledgement – in addition to the explicitly noted assumptions. I am arguing here that in many water policy documents, the conditions in this section are 'embedded assumptions'.

10 If there are cheap and readily available substitutes for water, then this conclusion need not hold [Levy 1982].

11 But they can aid in cost recovery, or force farmers to withdraw from agriculture altogether.

12 Updating the price data in 2002 made no difference to the model solutions, therefore I have carried through this analysis with the original prices from my fieldwork.

13 The command area is the area within gravity flow reach of the canal system. The irrigable command area (ICA) is the land that is actually expected to receive water within the command area. On average, major canal systems irrigate half of their official ICA.

14 The word is derived from' shesh' (last) and 'pali' (turn).

15 The northern canals are fed by perennial rivers and are run continuously all year. Every hectare in the canal command gets a few hours of water every week, on the same day and at the same time [Gustafson and Reidinger 1971]. This period is the fixed ('bundi') turn ('wara'). Every farmer in the irrigable command area is entitled to water in every rotation, he need not submit an official 'demand'.

16 The 14-day rule applies only to those parts of the canal system that are entitled to summer-season water. In the 1990s the right and left branch canals were allowed summer water, whereas a third branch, Pathardi, was restricted to an eight-month supply.

17 The longer per-hour irrigation allowance at the tail end of the canal system is an attempt to compensate for the lower flow rate at the bottom third of long canal systems. The AI/DC ratio, which is the planned area irrigated per day cusec, is higher at the lower reaches and along the distributaries than at the higher reaches and along the main canal. (A day cusec is the volume of water flowing at 28.3 litres a second for 24 hours).

18 How to charge for groundwater is an ongoing debate in irrigation policy circles in India. Electricity is cheap and wells are often not metered. The irrigation department knows that the wells within a canal command are recharged by canal leakage and it frustrates them that farmers don't pay for groundwater. An obvious option is to raise electricity prices and meter the wells. Even if this were politically simple, which it is not, farmers could counter high electricity prices by switching to diesel-operated pumps. Diesel is subsidised too, but raising diesel prices would affect several other sectors (tractor power, transportation, residential electricity generation, etc).

19 Without this volumetric charge assumption, the marginal price of water would be zero, and the model solution would not respond to varying prices. Water prices in the model are lowest for grains and pulses, higher for summer seasonals such as groundnuts, and highest for sugar cane – reflecting the ground reality.

20 In keeping with the geo-hydrological conditions of the Maharashtra plateau, the model well is shallow. The water column varies with the season, and is lowest in the summer when crop water needs are at their peak. I am grateful to K R Datye and the researchers of CASAD, Pune, for sharing their seasonal water table measurements with me.

21 A profit-maximising farmer is by definition risk neutral. The literature is divided on whether risk neutrality or risk aversion is a more realistic assumption when modelling the small farmer. My fieldwork on the Mula convinced me that risk neutrality was the more appropriate assumption for a median-sized farmer.

22 All prices are quoted in 1992 rupees; US $1 = Rs 30 approximately.

23 The net irrigation requirement (NIR) is the crop-specific and location-specific water required for maximum yields, over and above effective rainfall and stored soil moisture. The seasonal NIRs for the crops are: sugar cane 190 cm, monsoon millets 25 cm, monsoon sorghum 30 cm, winter sorghum 38 cm, winter wheat 47 cm, gram 30 cm, groundnuts 70-80 cm. These figures are from Mahatma Phule Agricultural University and are averages calculated from three separate estimates.

24 Another interpretation of this assumption is that there is only very loose enforcement of the crop zoning rules or the sugar cane sanctions. So once the canal water arrives, the farmer can use it as he wants. There is quite a lot of unsanctioned sugar cane on the Mula canal, and many farmers do in fact supplement their well-irrigated sugar cane crops with canal water.

25 This issue is often blurred in the literature on water prices. If price-based and quantity-based rationing occur together, the physical limit rather than the price could well be the relevant constraint to water use [Perry 1996].

26 Gross margin means revenues minus variable costs, on a per-hectare basis.

27 'Net revenues per unit of water' means the annual total on-farm profits divided by the annual total quantity of irrigation water used.

28 The X-axis shows the incremental price of canal water for quantities above the baseline ration only. The average price of irrigation water for the farmer depends on the precise mix of baseline canal water, second tier canal water and well water he uses. The primary Y-axis shows the average value of water used on the farm – computed annually over all crops and using all three water sources. Ideally we would like to compare the marginal price of water to its marginal value, but this rises and falls each month for each crop and could not be shown on a graph. We could also run this model for a farmer without a well, so that canal water prices would affect only canal water demand. But since most median-sized farmers of this region do have wells, and the use of well water is affected by canal water availability, such a model would not have yielded a realistic cropping pattern.

29 My assumption in the model is that the farmer's objective function is to maximise his total farm profits, not the output or economic returns per unit of water used. However, 'more crop per drop' or 'more value per drop' are the objectives of water efficiency in agriculture, which is what we are concerned with here.

30 In 1991-92, if a farmer placed a special request for summer season canal water for his standing sugar cane crops, the official charge for that supplement was Rs 150 per acre with a planned irrigation depth of 3". This translates to Rs 50 per ha-cm, hence the choice of Rs 50 as the starting price per unit of above baseline water. Supplementary water needed for other crops such as wheat or groundnuts was priced even lower.

31 I raised the issue of raising irrigation water prices (to cover the annual operation and maintenance costs) at the Command Area Development Authority for the Mula canal. The response of the chief engineer was brief: "You must be mad."

32 This situation is not unique to India. Recent work on the Gediz canal in Turkey [Ray and Gül 1999], and the Zayandeh Rud basin in Iran (Perry 1996) had similar implications. Of course modest and feasible fee hikes could aid in cost recovery, but that is no guarantee of efficiency in irrigation.

33 During my fieldwork, new canal water rates were proposed for the state of Maharashtra. They were only modestly higher than the existing rates, but some farmers on the Mula were unhappy with the proposal. When I mentioned this to the sub-divisional officer with whom I worked, he seemed genuinely surprised. "Why are they angry? They don't pay us anyway."

34 The number of wells in the 360 ha study area went from 22 to 183 within 15 years of the canal being extended to the region.

35 The exact date is unclear. I obtained these data from unpublished reports at the offices of the irrigation department, government of Maharashtra, in Ahmednagar.

36 'Other' upstream losses include illegal water diversions, mostly for unauthorised sugar cane or for irrigation outside the official command area. Illegal irrigation is often not efficient, but, if it goes unchecked, it cannot be made efficient through higher water prices [Ray and Williams 2002].

37 Other plausible hypotheses exist – e g, field crops or coarse cereals are grown because of labour constraints, or a shortage of cash or credit to buy inputs for the more profitable crops, or are needed for home consumption if the local grain markets are thin. In this section I analyse only the effect of irrigation delays. It can also be argued that poor farmers are risk averse, that they choose crops with low returns to water and/or land rather than higher productivity crops whose yields may fluctuate. The model solution shows that even risk-neutral farmers could choose to grow crops with low returns to water/land with untimely water supplies.

38 The figures are location-specific, of course.

39 Groundnuts are summer crops and coarse cereals are monsoon crops. Nevertheless, they are often in competition for the same piece of land.

If groundnuts are sown early then the land can be cleared in time for the monsoon or 'kharif' grain crop. If they are sown late then there is too short an interval between harvesting the summer crop and sowing winter ('rabi') wheat to support a kharif crop. The model solutions accurately reflect the Mula farmers' preference for the wheat plus late-sown groundnut crop cycle.

40 A quintal is equal to 100 kilograms.

41 Though this hypothetical farm is endowed with a well, the model solution shows that the 28 per cent drop in water demand is entirely from the canal. Well water is cheaper than canal water used for sugar cane, so the profit-maximising farmer uses up his well water before buying canal water. Similarly, canal water is the first source of water he cuts if he reduces his overall demand. As the farmer switches out of sugar cane altogether, canal water for seasonal crops and well water can be used interchangeably since they cost about the same.

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