8 Water Pricing in Haryana, India

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Introduction

Haryana is one of India's major irrigating states, with approximately 2.9 Mha undersurface irrigation. Water is scarce and irrigation water demand exceeds available canal water supplies. The major challenge facing the responsible government agencies is to manage water scarcity so as to minimize long-term damage to agriculture, fresh aquifers and soils.

It is indisputable that underwatering is pervasive and that, as non-agricultural demands rise, irrigation supplies will come under increasing pressure. Besides water shortages, agriculture is threatened by rising water tables in the western zone (about 52% of the area) and by falling water tables in the eastern zone (about 48% of the area). These proportions do not fully accord with the distribution of saline and fresh groundwater and suggest that brackish groundwater is already used for irrigation, presumably mixed with surface water and/or rainfall. In 1997, about 0.42 Mha were affected by high water tables, with 0.25 Mha totally waterlogged (GOH, 1998). Another source gives some 0.19 Mha affected by salinity and 0.33 Mha by sodicity (Agarwal and Roest, 1996). Interventions that improve on-farm water management reduce canal seepage, and installing drainage systems could help address these problems.

Priority objectives therefore specify the following:

- Increase the productivity of water in the context of declining long-term availability.
- Control abstraction of fresh groundwater to avoid decline and salinization of aquifers.
- Manage saline aquifers so as to reduce or avoid waterlogging and soil salinization.
- Finance adequate operation and maintenance (O&M) expenditures along with justified capital improvements.

Volumetric water pricing is often mentioned to address these problems, but the role it can play in meeting the objectives in Haryana is not clear. The main aim of this chapter is therefore to study the potential role of pricing policy in meeting the above priority objectives. To achieve this aim, the way water is currently allocated will be described and insight will be provided into the price, costs and value of irrigation water in Haryana.

The structure of this chapter is as follows. First, the study area and *warabandi* system that allocates water to all irrigators in proportion to their landholdings are described. Next, the price, cost and value of water are studied. An analytical framework is applied to assess the value of production and contribution of water to that level of production. Then policy recommendations are made and finally conclusions are drawn.

Study Area and *Warabandi* System

Study area

Haryana is located on the Indo-Gangetic plain in north-west India with a climate that is arid to semi-arid. It has an area of 4.4 Mha of which 3.8 Mha is cultivable and 2.9 Mha irrigable (GOH, 2004). The population totals 21 million of which 70% is rural. GDP per head is $660 (32% above the national average) and has been rising in real terms at up to 3% per annum. Agriculture accounts for 31% of GDP and, along with Punjab, Haryana led India's Green Revolution. Grain yields are some 30–40% above the national average and, with just 1.4% of India's area, this small state provides 30% of the national procurement of wheat and 10% of its rice. Gross sown area in 2001–2002 was 6.3 Mha and net sown area 3.6 Mha, giving an overall cropping intensity of 177% and an intensity on irrigated land of about 190–195%. There are three primary sources of water: rainfall, surface water and groundwater.

Annual rainfall averages 545 mm, ranging from more than 1000 mm in the extreme north-east to less than 300 mm in the arid west. Rainfall also varies from year-to-year and from season-to-season. About 80–85% occurs in *kharif* (June to September), and most of the rest in *rabi* (October to February). Evapotranspiration averages about 1550 mm so that irrigation is a prerequisite for successful cropping most of the time over most of the state.

Surface water comes from the Sutlej via the Bhakra canal system and from the Yamuna via the Western Yamuna system. Sutlej and other Indus allocations are regulated by the Bhakra-Beas Management Board (BBMB), which was created under the 1966 Punjab Reorganization Act. This Act and subsequent agreements govern the state shares in the three rivers (Sutlej, Ravi, Beas) assigned to India by the 1960 Indus Basin Treaty. Haryana has yet to obtain its full share and disputes continue, in particular relating to construction of the Sutlej Yamuna Link (SYL) canal, which would allow access to water from the Ravi and Beas. Yamuna allocations are governed by the Tajewala Headworks Agreement of 1954 as modified by the Punjab Reorganisation Act and other agreements.

Groundwater is abundant on the alluvial Indo-Gangetic plain. Recharge in Haryana has risen greatly as a result of surface irrigation. Brackish groundwater underlies up to two-thirds of the state, an area characterized by poor natural drainage, rising water tables and secondary salinization. The balance one-third is underlain by fresh groundwater and is characterized by falling water tables since use exceeds recharge by a considerable margin. By now, there are some 600,000 tube wells that are predominantly privately owned. Well owners commonly sell water to their poorer neighbours after meeting their own needs.

The *Warabandi* System

The irrigation management system in Haryana, as in other states in north-west India and Pakistan, was formalized under the Northern India Canal & Irrigation Act of 1873 (Eastern Book Company, 1982), based in part on earlier Moghul and British practices. Canals are designed based on the 'regime theory' with the aim of distributing suspended silt over the land. Surface supply is intended to be protective (i.e. to spread water over a large area inter alia to guard against famine) rather than to be productive (i.e. to meet full water demands of a specified irrigable area to maximize yields) (Ministry of Irrigation, 1982; Malhotra, 1988; Jurriens *et al*., 1996). Supply is thus well below potential demand and water is rationed in proportion to irrigable area. Although often referred to as the *warabandi* system (literally 'fixed turn' system), *warabandi* is just one component of a complete system with the following main features.

Water allowance

Water is allocated in proportion to land, and farmers are free to use their allocation as they wish. In other words, the cropping pattern is a response to a pattern of supply (crops to water) rather than supply being a response to a cropping pattern (water to crops).

Delivery capacity (duty) is low, being typically no more than 0.15–0.175 l/s/ha at the outlet or perhaps 0.17–0.20 l/s/ha at the head allowing for canal losses. If given continuously, this satisfies the theoretical crop water requirements of no more than 20–30% of the irrigable land in kharif and 35–45% in rabi.

Reservoir operations

Reservoir operations are the responsibility of the BBMB. Subject to the priority normally given to hydropower and other non-agricultural uses, water is delivered to each irrigation canal headwork in line with the shares of the respective states. The seasonal operational plan is updated at least every 3 weeks to reflect actual water conditions.

The main system

The conveyance and distribution system is managed by the Irrigation Department (ID). Main/branch canals are operated with variable flow in response to BBMB allocations and – to a limited extent – demand (see below). Distributaries and minors are either full ON or full OFF, with flow reduction limited at most to 10–15%. When main or branch canals run full (e.g. if river flow exceeds diversion capacity) lower channels also run full.

Distributaries operate in rotation such that the sum of discharges in ON channels equals branch canal discharge allowing for losses. Priorities shift every 8 days so that each distributary has an equal chance of being ON. This design has come to be known as the structured design, with the system structured at the head of the distributary (the point below which flows are proportional and canals run full) (Albinson and Perry, 2002).

Adjustable gates on the main/branch canals support variable flow management. ON/OFF gates at the head of each distributary or direct minor allow canal rotation. Below this point, the system is un-gated with proportional division at each junction point.

Correct discharges in ON canals are critical to successful operation. Levels are monitored twice daily at key points. If flow at the tail falls below the design, action is taken to increase supply and/or close channels to maintain full supply. Canals are closed annually for maintenance, notably to check offtakes and restore cross sections.

Distribution below the outlet

Outlet capacities are based on duty. If the design duty is 0.15 l/s/ha, the capacity of an outlet serving 200 ha is 30 l/s. To ensure that the stream size is manageable by the farmer (in the range 25–40 l/s), *chaks* (outlet commands) are generally limited to between 100–300 ha and typically serve some 50–100 farmers.

All outlets are un-gated and run full when the minor is ON. The full flow in the watercourse is allotted to each farmer in turn on a weekly (168 h) schedule. Turn length is based on farm size. If the *chak* size is 200 ha and duty 0.15 l/s/ha, the farmer receives 30 l/s for 0.84 h/ha of land that he owns. If the *chak* size is 250 ha, he receives 37.5 l/s for 0.67 h/ha. Some limited adjustment may be made to these times to account for losses in the watercourse.

The farmer obtains water at the same time each week (the clock keeps ticking). If there is water, he has the right to the full flow. If not, he loses his turn. Equity is ensured by the rotation of supply to distributaries and the flow in the watercourse – if there is one – is owned at all times by a known farmer. The schedule rotates through 12 h at the end of each crop year to ensure equity in night-time irrigation.

The schedule below the outlet is known as the *warabandi* schedule. Farmers can either arrange this schedule among themselves (*kutcha warabandi*) or request registration by the authorities (*pucca warabandi*). In Haryana, almost all schedules are registered. It is then an offence to take water out of turn. It is also an offence to exchange or sell turns though this occurs in practice. Farmers maintain the watercourse at their own expense.

Groundwater

Groundwater is unregulated and the landowner has the right to exploit any aquifer lying below the surface of his land. In fresh groundwater areas, this means that the individual farmer has no incentive to limit extractions since others may continue to pump; and in saline areas, the farmer has no incentive to install drainage facilities since this would have to serve the whole locality to be effective. These two examples of 'the tragedy of the commons' are critical to understanding groundwater management.

In its essence, this system has survived since its inception in 1886 despite developments that include: (i) independence and partition; (ii) population growth; (iii) falling farm size; (iv) the Green Revolution; (v) the massive growth of mechanized pumping; and (vi) expansion and diversification of an increasingly market-based economy. The system's relative simplicity, transparency and low-cost help explain its robustness (Horst, 1998). Other factors include canal rotation 'which makes it difficult for the farmers to interfere with the "automatic" distribution by the proportional outlet structures on the distributary' (Jurriens *et al.,* 1996), and lack of ambiguity in the *warabandi* schedule – the irrigation turn is in effect a property right in water and farmers tenaciously defend their turn. Rationing does not, of course, meet precise crop water requirements. In Sirsa Circle, for the actual cropping pattern and after allowing for rainfall 'canal supply exceeds requirements by 50 mm (500 m^3/ha) during the winter period and the late-summer shortage is 210 mm (2100 m^3/ha)' (Agarwal and Roest, 1996). In fresh groundwater areas, groundwater can compensate for shortages.

The system does not, of course, always perform as designed, and deliveries may be inequitable both between distributaries or minors and along watercourses (Jurriens *et al.,* 1996). Shortfalls in O&M funds, farmer interference (notably in the outlet) and other factors are all of concern, although farmer interference is more prevalent where farm size and rural power are inequitable or rainfall is higher (or topography and soils are more variable [Berkoff, 1990]). On the other hand, some modifications to system operations may even be beneficial (illegal exchange or sale of turns, main-system-flow adjustments in response to waterlogging).

The system has worked well relative to other systems in India. Both relative agricultural success and a priori arguments suggest that it is well adapted to local conditions (Berkoff, 1990). Up to the 1950s, western Haryana was notoriously vulnerable to famine, yet now the state provides an astonishing share of India's grain and 'is emerging very fast as one of the leading states in the field of horticulture (though horticulture occupies only about 5.2% of cultivable area)' (GOH, 2004). The key indicator is the contrast between potential crop intensity based only on surface irrigation (55–75%) and actual intensity (190–195%) utilizing all three water sources. This contrast is explained in part by underirrigation. However, the main reason is the combined use of rainfall, groundwater and sub-irrigation by capillary rise, all of which have been augmented by surface irrigation. Rainfall, which in terms of volume may be the largest source, is much less productive without irrigation; groundwater and capillary rise reflect surface water recharge; and brackish water causes less damage – whether from irrigation or sub-irrigation – if used conjunctively with surface water and/or rainfall. The original intention of the system designers may have been to provide protective irrigation but the unanticipated spread of mechanized pumping along with sub-irrigation has led to one of the most productive agricultural systems in India, with high yields and a cropping intensity that approaches 200%. The question is, however, for how long, as it leads to dropping of groundwater tables and salinization.

Crop selection in response to supply (crops to water) means that the farmer, rather than the scheme operator, is primarily responsible for planning. In effect, the farmer maximizes farm income subject to his assessment of risk. Water rather than land or labour is generally the scarce resource so: 'farmers underirrigate some crops in relation to full potential evapotranspirative demand, because reductions in yield may be proportionally less than reductions in water applied' (Perry and Narayanamurthy, 1998). With regard to risk, rainfall is unpredictable but free; surface water is predictable within limits but incurs a small additional cost; and groundwater is predictable but more expensive. Groundwater and sub-irrigation may also be unusable or damaging. Farmers thus divide their farm into distinct plots on which they plant crops with differing water needs, allocating water between plots in the light of rainfall with the aim of meeting their implicit objective function. Based on field evidence from the Bhakra command, Perry and Narayanamurthy (1998) conclude that: 'Farmers generally aim to maximise returns to the scarce resource, but due to the uncertainties involved guard against unacceptable risk by reducing the area planted and increasing seasonal water allocations per unit area where supplies are less certain.'

Farmers are intensely concerned with their own welfare and, though there are good farmers and bad farmers, there is little doubt that, in general, they are equipped to perform this planning exercise. But their perspective is limited to their own interests, and this leads to the tragedy of the commons as described above. In fresh groundwater areas, water tables fall and groundwater irrigation on the current scale is unsustainable over the longer term. In saline groundwater areas, water tables rise and agriculture is threatened in complex ways by waterlogging and secondary salinity (Agarwal and Roest, 1996). Any modification to the present management system must also take these externalities into account (section under Recommended Policy Instruments).

Price, Costs and the Value of Water

Price paid for canal water

Charges for surface irrigation are levied on a crop-area basis: that is, rates per hectare vary across crops and are charged according to the area irrigated. The ID records crop areas, excluding those that utilize only rainfall and/or groundwater. Areas irrigated from canals are reported to the Revenue Department, which collects what is due as part of Land Revenue. This is incorporated in the general budget and does not directly determine budget allocations for recurrent costs. The general aim is to cover O&M costs, an objective that is almost achieved by the device of assigning only about one-third of ID recurrent costs to irrigation, with the rest assigned to non-irrigation users who receive priority at times of scarcity.

There is no explicit volumetric charge, although crop area and type are a proxy for volume. Table 8.1 shows crop-based charges ($/ha) along with their volumetric equivalents ($/m^3). The average charge can also be estimated from the total revenue derived from irrigation water charges ($1.00 = Rs 47.00). In 1999–2000, the net area irrigated by canals was 1.44 Mha, generating revenues of Rs 210 million ($4.47 million) (GOH, 2004), equivalent to an average of Rs 145 or $3.1/ha. If total surface water deliveries were about 9.4 Bm^3, this implies an average delivery of 6500 m^3/ha and an average water charge of $0.0005/m^3. This is comparable to the estimates in Table 8.1.

Table 8.1. Haryana: water charges by crop and volumetric equivalents.

	Rice (6,800 m³)		Wheat (4,500 m³)		Sugarcane (10,000 m³)	
	$/ha	$/m³	$/ha	$/m³	$/ha	$/m³
Haryana 2000	3.2	0.0005	2.7	0.0006	4.3	0.0004
Haryana 1999	2.4	0.0004	1.9	0.0004	3.1	0.0003

Costs of water delivery

Surface water costs

Annual recurrent costs of delivering water within Haryana to all users during the period 1996–2000 averaged about $18 million per year. Annual deliveries were about 14 Bm^3, resulting in an average O&M cost of about $0.0013/m^3. This confirms that the Haryana system is low-cost which reflects the highly centralized system of management, the relatively small number of control structures, limited staffing requirements and farmer responsibility for O&M costs below the outlet. This makes no allowance for capital costs, which are very substantial. One-third of the total O&M costs is allocated to irrigation (i.e. about $6 million/year). In 1996–2000, irrigation received an average volume of 12.9 Bm^3/year (92% of the total), implying a cost to irrigation of $0.0005/m^3. This was less than 1/20 of the cost per cubic metre attributable to other users ($0.0107/m^3, given average deliveries of 1.12 Bm^3 and a share in costs of $12 million). In return, non-agricultural users receive a more continuous and predefined service as well as priority at times of scarcity.

The World Bank-funded Haryana Water Resources Consolidation Project (World Bank, 1994) placed emphasis on cost recovery, requiring, first, a clear definition of the costs of system operations; second, political decisions on how costs should be allocated; and third, that charges be raised to cover O&M expenses over 6 years. This process was important in clarifying the situation, raising charges and highlighting the extent to which the ID provides water services to other users (drinking water to villages, industrial supplies, supplies to power stations, water to Delhi and water to other government departments, such as mining, fisheries and forests). Irrigation charges are nevertheless a highly sensitive political issue. In many Indian states, poor cost recovery stems from a combination of both low charges and low rates of collection. In Haryana, however, though rates are low, collection is 90% or more, in part due to collection of water charges as part of Land Revenue. Shortfalls at times of crises (floods, droughts, pest attacks) are usually offset by collection of arrears in subsequent years.

Groundwater costs and charges

Tube well water is charged by well owners at anything between $0.2–1.6/h or at a flat rate of $7.0–15.0/delivery/ha irrigated. The wide range reflects not only differing pumping heads, but also the extent to which tube well owners seek to recoup capital investment, exploit their monopoly powers, etc. (see section under Recommended Policy Instruments). If each delivery amounts to about 1250 m^3, a flat rate of $7.0–15.0 is equivalent to $0.006–0.012/m^3. This compares to an average quoted fuel cost of about $0.005/m^3. It also suggests that at the lower end of this range charges are largely confined to marginal costs (mainly fuel). Whatever is covered, it is equivalent to 10–20 times the cost of surface supplies. The ratio would no doubt be higher if electricity was charged at an unsubsidized rate.

Value of water

Net returns

Tables 8.2 and 8.3 summarize farm budget estimates for the Sirsa district in the western

Table 8.2. Sirsa district: farm budgets – surface water and groundwater.[a] (Based on information from World Bank, 1998 and Aggarwal *et al.*, 2001.)

				Farm costs: surface water			Farm costs: groundwater			Net farm return	
Crop	Gross return ($/ha)	Cropped area (ha)	Gross return ($)	Inputs ($)	Labour ($)	Water ($)	Inputs ($)	Labour ($)	Water ($)	Surface water ($)	Ground-water ($)
Kharif											
Rice	327	0.83	270	55	71	2	55	71	32	142	113
Cotton	406	0.60	263	56	23	1	56	23	16	183	169
Chickpea	161	0.34	55	11	23	1	11	23	5	20	16
Rabi											
Wheat	449	2.00	899	165	82	4	165	82	29	647	622
Mustard	443	0.70	295	10	21	1	10	21	14	263	250

[a]Year unspecified.

Table 8.3. Sirsa district: farm budgets – five farm types, rabi 2000/02 and kharif 2002/03.

	Cropped area (ha)	Gross farm return ($)	Farm costs			Net farm return ($)
			Inputs ($)	Labour ($)	Water ($)	
Farm type 1	16.6	14,380	5,673	1,570	317	6,820
Farm type 2	6.1	5,109	2,020	435	126	2,528
Farm type 3	7.6	5,510	2,162	460	106	2,782
Farm type 4	7.1	3,960	1,987	223	93	1,657
Farm type 5	7.3	3,974	2,070	423	119	1,361

Farm type 1: paddy–wheat belt, head of canal, normal soils, four farms covering a total of 9 ha.
Farm type 2: paddy–wheat belt, middle of canal, normal soils, four farms covering a total of 3.3 ha.
Farm type 3: cotton–wheat belt, head of canal, normal soils, eight farms covering a total of 5.1 ha.
Farm type 4: cotton–wheat belt, middle of canal, normal soils, four farms covering a total of 5.9 ha.
Farm type 5: cotton–wheat belt, tail of canal, problematic soils, four farms covering a total of 5.7 ha.

zone. Table 8.2 is based on information derived from Aggarwal *et al*. (2001) and the World Bank (1998). It assumes that cropping and water use remain the same irrespective of the source of water. This is a simplification since cropping patterns might be expected to adapt to the improved security of supply and, perhaps, to the higher costs and volumetric basis of groundwater. Table 8.3 gives comparable data without distinguishing between surface water and groundwater irrigation, based on a survey of 24 farms in rabi 2001/02 and kharif 2002/03 (Appendix). The farms were divided into five categories on the basis of location in the canal system and type of land.

Despite considerable differences between the two sets of data, the tables confirm that water represents only a small part of farm costs, even in the case of groundwater, and that the costs of other inputs (seeds, fertilizers, pesticides, etc.) and labour are substantially greater. In the case of the Sirsa scheme, for example, the average shares of inputs, labour and water are 78%, 18% and 4%, respectively. Subsidies on other inputs are now limited and their costs approximate to trade-equivalent levels. The labour market is also relatively competitive given seasonal migration from eastern India and, though wages may exceed the opportunity cost of labour, this is becoming less significant as the economy develops. The major distortion in farm costs relative to the economic optimum in respect of irrigation is, therefore, due to low water charges and electricity subsidies.

Apparent returns to water

Tables 8.4 and 8.5 show net returns per unit of water after allowing for all financial costs, including those of water, for the two sets of farm budget data provided in Tables 8.2 and 8.3, respectively. Net returns to water are about $0.04/m^3.

Discussion of price, costs and value of water

Care must be taken in interpreting these data. Expressing net farm returns in terms of the net return per unit of water seems to suggest that the profit over and above financial costs is wholly attributable to water. However, net returns might be similarly attributed to fertilizer or some other input while this profit represents the farmer's return to land, capital and management after allowing for other costs. If water was to be charged at a rate that equalled apparent net returns per unit to water and returns to land, capital and management would sink to zero (or, in the case of family labour, be no more than the going wage rate), which is unrealistic. On the other hand, water is a major constraint to increased agricultural production and Tables 8.4 and 8.5 suggest an extreme upper limit to the returns to water.

Returns to water are 50–100 times the water charge ($0.0005/m^3), implying that water charges would have to rise substan-

Table 8.4. Sirsa district: water use and net returns by crop. (Based on information from World Bank, 1998 and Aggarwal *et al.*, 2001.)

Crop	Water use per hectare (m^3/ha)	Total water use per farm (m^3)	Net returns per farm: Surface water ($)	Net returns per farm: Groundwater ($)	Net returns per unit of water: Surface water ($/$m^3$)	Net returns per unit of water: Groundwater ($/$m^3$)
Kharif						
Rice, paddy	6870	5700	142	113	0.025	0.020
Cotton	4835	2900	183	169	0.063	0.058
Chickpea	2355	800	20	16	0.025	0.020
Rabi						
Wheat	2450	4900	647	622	0.132	0.127
Mustard	3715	2600	263	250	0.101	0.096

Table 8.5. Sirsa district: water use and net returns by farm type, rabi 2001/02 and kharif 2002/03.

Farm type	Average water use (m^3/ha)	Total water use (m^3)	Net returns per farm ($)	Net returns per unit of water ($/$m^3$)
Farm type 1	9,200	152,700	6,820	0.045
Farm type 2	9,310	56,800	2,528	0.045
Farm type 3	6,170	46,900	2,782	0.059
Farm type 4	5,745	40,800	1,657	0.041
Farm type 5	7,425	54,200	1,361	0.025

Note: See Table 8.3.

tially before they had any significant impact on net farm returns, assuming that the water charge can be made volumetric (see next section). As is to be expected, water use was greater in the paddy–wheat than in the cotton–wheat belt, and net returns per cubic metre – at least in the cotton–wheat belt – declined towards the tail and were lower in farms with problematic soils. Table 8.4 suggests that net returns per unit of groundwater on the same basis were 2–10 times greater than groundwater charges ($0.006–0.012/$m^3$).

This means that surface water charges would have to rise very substantially before they have an impact on water use. In other words, water demand at current charge levels under the current system of rationing is almost wholly inelastic. In the case of groundwater, this is less self-evident. Water charges are higher – for the least profitable case, net returns per unit are just double the charge – but water use is discretionary.

Recommended Policy Instruments

The above discussion suggests that water charges have minimal impact on surface water use. The system delivers a rationed supply that is sufficient for a limited part of the irrigable area. Since charges are well below the value of water to the farmer, there is no reason for him to reject any of his share since water can almost always be profitably used to meet the needs of irrigated crops, supplement rainfed crops, moderate underwatering, save on pumping costs or leach salts from the land. It is only if land is waterlogged or flooded that the farmer has reason to reject his share and the ID then often closes higher canals so as to alleviate problems that typically go well beyond the individual farmer. Instances where water cannot be profitably used are thus few and excess water, in any case, may do no harm. Far from rejecting his turn, therefore, the farmer resolutely defends it.[1]

Considerations in groundwater are very different. Not only are the charges made by well owners (much) higher than for surface water but a decision whether or not to turn on a pump is discretionary and does not prejudice access to the resource at a later time. The amount of freshwater extracted is thus a function of demand and not of availability. In areas of conjunctive use, surface water is a relatively stable, if limited base, supply; rainfall is variable and uncertain but free; and groundwater can be fine-tuned to 'optimize' net returns after exploiting other sources. That fresh groundwater is overpumped reflects the pattern of financial incentives, with richer farmers better able to adjust to falling water tables than poorer farmers. If falling water tables adversely affect water quality, then the resource may be lost and this of course then becomes the decisive concern.

In other words, so long as fresh groundwater is freely available, groundwater is provided on a volumetric basis and the amount demanded broadly optimizes farmer net returns subject to anticipated farm-gate prices, input costs, cross-elasticities and numerous other factors. Groundwater use in an imperfect and variable way thus reflects farmer willingness to pay. If conditions change (expected rise in farm-gate prices, electricity subsidies are withdrawn, etc.), the outcome is different. Net farm returns over-and-above financial costs (including water costs) are the farmer's return to land, capital and management and cannot be attributed to water as such. That the groundwater charge is so variable reflects variable spatial, temporal and farm conditions and numerous market imperfections. Even if extractions were to be effectively regulated, for instance to account for the externality costs associated with overpumping and/or salinization, the market would adjust to the new conditions with the price determined by the property rights created rather than by the current conditions of open access.

Surface irrigation is thus supply-driven and consumption is largely unaffected by water charges, while groundwater irrigation – no matter how imperfect – is demand-driven and consumption is a function of alternative water sources (rainfall and surface supplies) and (imperfect) market incentives. Given this background, what is the potential role of pricing policy in meeting the above objectives? The discussion is in two parts: (i) policies that require restructuring of the infrastructure; and (ii) policies that can be implemented with the present infrastructure.

Policies requiring restructuring of the infrastructure

Volumetric charges are often advocated as a mechanism for reducing water use and increasing output per unit of water. They require an infrastructure that can provide differentiated water supply and measurement at the point of sale. In the case of Haryana, they would thus require that the supply-based surface system (including the *warabandi* schedule) be replaced by a demand-based system that allowed water to be delivered in response to willingness to pay. To be effective, demand at the point of sale would have to be elastic with respect to price. At the theoretical limit, the charge would be ideally set such that demand and supply are brought into balance. For surface water in the Haryana context, volumetric charges could be levied at three possible levels: head of the watercourse, head of the minor or distributary and the farm.

Irrespective of how far differentiated supply is taken down the system, water rates must be sufficiently high to elicit a response

[1] If the farmer cannot defend his turn – if rural power is distributed inequitably or law-and-order breaks down – then the system is weakened. Persistent theft by head-enders can also wear the tail-ender down even under normal circumstances. Moreover, if rainfall is higher and the design supplements rainfall in kharif over the full irrigable area, or conditions are more variable than in Haryana, then there will be more instances when the individual farmer will want to reject water and this again tends to undermine this management system (Berkoff, 1990).

if they are to impact on water use. The increase required is in itself politically and socially infeasible. But there are more fundamental objections to volumetric pricing to the farmer. The present system is stable, simple and cheap to operate and this has major advantages for large schemes in developing countries (Horst, 1998). Moreover, the system already provides powerful incentives limiting water use and maximizing output; surface water use per hectare is already low and by Indian standards productive although unsustainable. This is even so if groundwater is saline. Where it is fresh, applications at the margin are charged on a volumetric or quasi-volumetric basis from groundwater. Farmers operate in real time, adjusting groundwater use in response to rainfall, surface supplies and financial incentives. Quite apart from the costs and risks of restructuring the delivery system, it is hard to imagine that volumetric pricing could be more successful.

Levying a volumetric charge at the head of the watercourse, minor or distributary is a less clear-cut issue and in some circumstances there may be a case for creating water user associations (WUAs) and/or organizations operating at the distributary or minor level. If WUAs and/or autonomous agencies are to be financially viable, they may limit demand in response to even moderately enhanced charges and may be willing to sell allotted shares if a market develops at this level. Being closer to the farmer, they may also be in a position to influence on-farm use even without volumetric charges to the farmer. However, the rationale for this has more to do with cost recovery and effective O&M than with enhancing the productivity of water, and where the system is functioning relatively well, as in Haryana, the uncertainties and risks are almost certainly unacceptable.

Account must also be taken of falling water tables, waterlogging and salinity. Declining water tables raise costs and disadvantage poor farmers. More importantly, they can affect quality since deeper aquifers are more saline than shallow aquifers. Rationing of surface water, ceteris paribus, has slowed the process of waterlogging and salinity.

Policies within the present infrastructure

If full volumetric water pricing of surface supplies is ruled out, what potential is there for modifying the present water charge system to reflect quasi-volumetric considerations? Possibilities can again be considered at three levels: main system, watercourse and the farm.

Main system rotation is equitable in terms of irrigable area. Given the homogenous character of an alluvial plain and equitable holding size, this also has the merit of transparency. Even so, differences between sub-commands – notably between fresh and saline areas and also in terms of rainfall, cropping patterns and other factors – could be reflected in differential schedules (Narayanamurthy, 1985). To a limited extent this already happens since the ID closes canals where waterlogging or flooding is acute irrespective of 'equity' considerations. One option would be to devise rotations that provide reliable but lesser supplies to saline areas (to ensure security, minimize recharge and slow the *rise* in the water table); and less reliable but greater supplies to fresh areas (since they already have security, excess deliveries can, if necessary, be recaptured by pumping or, alternatively, may slow the *fall* in the water table). Another option would be to devise schedules to meet differential demands of the predominant cropping pattern, e.g. differentiating between paddy–wheat and cotton–wheat (Narayanamurthy, 1985). This has the potential for bias and would tend to erode transparency. New schedules need to be articulated in a straightforward way.

The distinguishing feature of distribution within the watercourse is the *warabandi* schedule. Farmers have strong incentives to defend their turns and this is a major strength of the system. Trading beyond the watercourse implies a fundamental restructuring of the delivery system (see above) but trading along a watercourse is quite possible and undoubtedly occurs despite being an offence. Losses in the watercourse result in more water being delivered at the head than at the tail so that sale of tail-ender turns to head-enders adds to the surface water available (and incidentally may well be a factor in the inequities recorded in watercourse studies) (Jurriens *et al.*, 1996).

Farmers in any case differ in their resources, skills and wants, which leads to trades that may increase total welfare. Allowing trades along the watercourse is a market mechanism that could, in principle, increase productivity although it impacts on patterns of groundwater recharge and runs the danger of weakening the traditional and accepted system.

Differential crop charges imply a quasi-volumetric element at the farm level. Increased differentials and penal rates for crops that utilize large amounts of water could, in principle, make this approach more effective. However, cropping patterns cannot always be changed – paddy may be the only feasible crop in higher rainfall and waterlogged areas – and political objections would still have to be faced. A more interesting suggestion is made in the Indo-Dutch report (Agarwal and Roest, 1996). If water charges were to be based on the authorized water delivered to the farm rather than on the measured crop areas, they conclude that irrigated areas in saline regions, presumably in kharif could increase from 50% to 85%. Much of the rain-fed part of the farm would be converted to partial irrigation and the annual rise in saline water tables might be slowed – recharge would decline due to underwatering and greater evapotranspiration. As a result, waterlogging problems 'can be postponed by 5 to 10 years'. Of course, farmers even now irrigate crops on that part of their farm that they claim is rain-fed and subsequently mislead or collude with ID staff. Moreover, the act of measuring areas – indeed the whole land revenue tax process – contributes much to conserving the delivery and land tenure systems. Nevertheless, this proposal might receive further consideration.

Conclusions

Surface irrigation water in Haryana is distributed in proportion to holding size irrespective of soil type, crops grown, groundwater conditions or climatological factors. The amount delivered is sufficient in itself for no more than 20–30% of the irrigable land in kharif and 35–45% in rabi, leading to widespread underirrigation. Surface supplies are supplemented by (variable) rainfall and, if water is fresh, by groundwater pumping, so that cropping intensities are much higher than would be possible based just on surface supplies. Nevertheless, water remains a constraint on agricultural output and this is likely to intensify as non-agricultural demands grow. Agricultural production is also threatened by rising water tables in saline groundwater areas and falling water tables in fresh groundwater areas.

Effective rationing of surface supplies provides powerful efficiency incentives in water use, both directly and as pumping responds to variable rainfall and regular surface deliveries. This has been reflected in a remarkable growth in agricultural production despite constrained surface supplies. Moreover, the combination of main system rotation and *warabandi* below the outlet has proven robust and has demonstrated important advantages in terms of equity, transparency, social acceptance and low transactions costs. A shift from an accepted supply-based system to a demand-based system and volumetric pricing would involve major reconstruction of the physical infrastructure and a fundamental reform of accepted institutions and practices. The increase in the level of water charge needed to have a significant impact on water use would almost certainly be politically and socially unacceptable although small annual increments in water charges would be politically more acceptable than intermittent large increases in water charges. Thus, while in principle it might lead to a more responsive irrigation system, it is inconceivable that this could justify the costs and risks involved in making such a change.

More modest reforms of the supply-based system might include revised main system schedules, greater differentiation in area-based water charges, or replacement of area-based water charges by charges based on the water delivered during a *warabandi* turn. Main system schedules could in principle be modified to respond to soil or cropping conditions, for instance to provide more reliable but less abundant supplies to saline areas and vice versa, or to respond to the predominant cropping pattern in different areas. Water charges are presently collected along with land revenue and are based on the area of each crop irrigated by canal water. Charges are low but collection is relatively efficient and makes a reasonable contribution to meeting recurrent costs. Rates could be increased and the levels for different crops further differentiated to encourage planting of water-efficient crops. Alternatively, crop-based charges could be replaced by a charge dependent on the authorized water delivered during a *warabandi* turn, leaving the farmer to decide how best to allocate water on his farm.

Any such reforms need to be introduced cautiously given the risks associated with many modifications of the current accepted system. They would also at best have a modest impact on the long-term problems of falling water tables in fresh groundwater areas and waterlogging and secondary salinity in saline areas. Regulation of groundwater use represents a formidable challenge given the large number of wells and well owners. In the absence of an effective regulatory system, water tables will continue to decline until this is limited by rising pumping costs or deteriorating water quality. Waterlogging in saline areas can at best be slowed by reforms of the type discussed above. The only ultimate long-term solution would be costly investments in drainage and reclamation programmes.

Appendix: Overview of Outcome of the Spreadsheets

The returns to water in the Sirsa district of Haryana State in India were studied (see Fig. 8.A.1), using data on 24 farms. Eight farmers

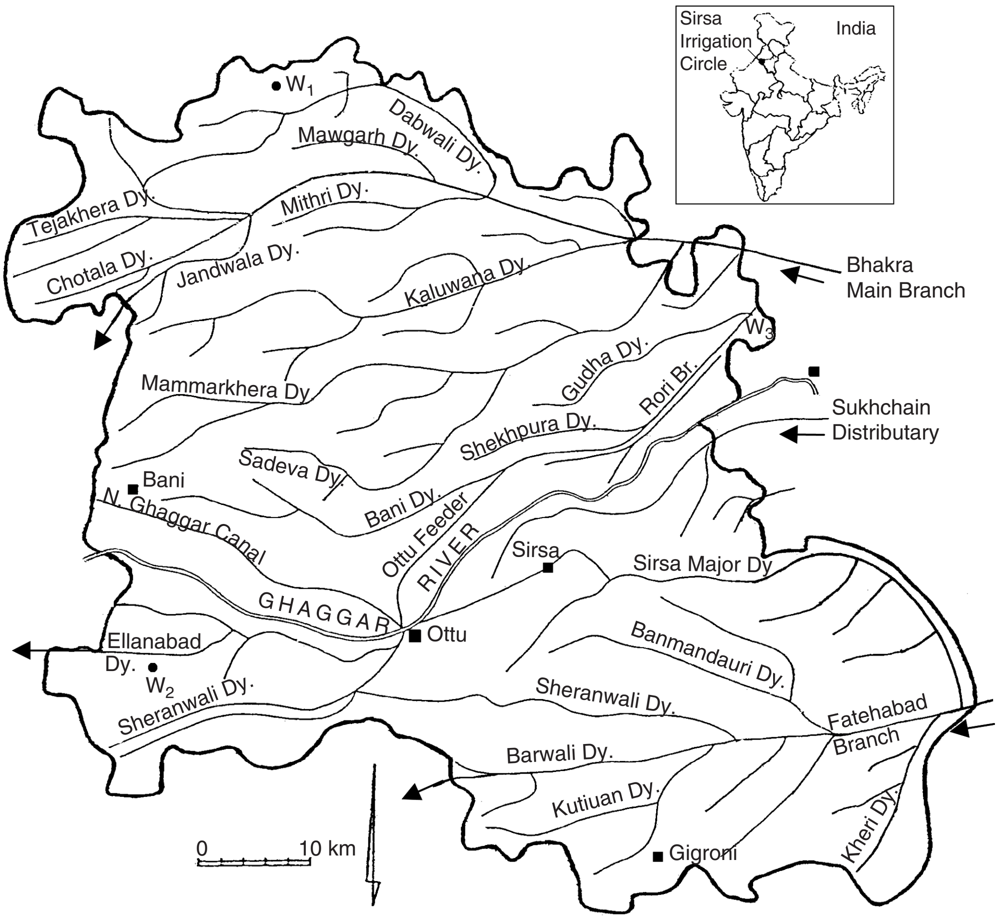

Fig. 8.A.1. Location of the Sirsa Irrigation Circle showing the canal network (Van Dam and Malik, 2003).

were selected from the Ottu Feeder in the paddy–wheat belt (four from Ram Pur Their and four from Sangatpura in eight Burji Ottu villages) along with 16 farmers from the Kasumbi distributary in the cotton–wheat belt in six villages (four from Fulkan, three from Kotli, two from Kanvar Pura, one from Ding, one from Kasumbi and five from Ban Mandori). These 24 farmers were divided into five farm categories on the basis of location in terms of the canal water source outlet and type of land. The data required for the AGWAT spreadsheets pertaining to rabi 2001/02 and kharif 2002/03 were collected from each respondent through personal interviews using structured questionnaires. The results are summarized in Tables 8.A.1–8.A.5. It is important to note that the data are based on an exceptional year, with very low canal water availability and rainfall.

Table 8.A.1. Farm type 1 (paddy–wheat belt, head of canal, normal soils, 4 farms; 9 ha).

Crop	Gross return ($/ha)	Cropped area (ha)	Gross return ($)	Farm costs: Inputs ($)	Farm costs: Labour ($)	Farm costs: Water ($)	Net return ($)	Water: Use (m³/ha)	Water: Total use (m³)	Water: Net return ($/m³)
Kharif										
rice	894	7.88	7,046	3,256	1,155	233	2,403	13,782	108,600	0.020
Cotton	580	0.36	208	112	28	6	62	8,611	3,100	0.020
Rabi										
wheat	857	8.24	7,067	2,293	385	78	4,313	4,927	40,600	0.110
Mustard	655	0.09	59	13	2	1	43	3,333	300	0.150
Total	868	16.60	14,380	5,673	1,570	317	6,820	9,200	152,700	0.045

Table 8.A.2. Farm type 2 (paddy–wheat belt, middle of canal, normal soils, 4 farms; 3.3 ha).

Crop	Gross return ($/ha)	Cropped area (ha)	Gross return ($)	Farm costs: Inputs ($)	Farm costs: Labour ($)	Farm costs: Water ($)	Net return ($)	Water: Use (m³/ha)	Water: Total use (m³)	Water: Net return ($/m³)
Kharif										
rice	880	3.04	2,675	1,188	366	96	1,023	13,816	41,800	0.030
Rabi										
wheat	801	3.04	2,434	831	69	29	1,505	4,934	15,000	0.100
Total	840	6.10	5,109	2,020	435	126	2,528	9,310	56,800	0.045

Table 8.A.3. Farm type 3 (cotton–wheat belt, head of canal, normal soils, 8 farms; 5.1 ha).

Crop	Gross return ($/ha)	Cropped area (ha)	Gross return ($)	Farm costs: Inputs ($)	Farm costs: Labour ($)	Farm costs: Water ($)	Net return ($)	Water: Use (m³/ha)	Water: Total use (m³)	Water: Net return ($/m³)
Kharif										
rice	499	0.10	51	36	5	3	7	10,000	1,400	0.010
Cotton	792	2.96	2,342	918	228	62	1,134	9,460	27,700	0.040
Rabi										
wheat	772	3.37	2,598	974	198	32	1,393	4,154	13,600	0.100
Mustard	443	1.17	519	234	29	10	247	3,419	4,100	0.060
Total	725	7.60	5,510	2,162	460	106	2,782	6,170	46,900	0.059

Table 8.A.4. Farm type 4 (cotton–wheat belt, middle of canal, normal soils, 4 farms; 5.9 ha).

Crop	Gross return ($/ha)	Cropped area (ha)	Gross return ($)	Farm costs: Inputs ($)	Farm costs: Labour ($)	Farm costs: Water ($)	Net return ($)	Water: Use (m^3/ha)	Water: Total use (m^3)	Water: Net return ($/$m^3$)
Kharif										
cotton	659	2.53	1,665	1,002	116	56	492	10,040	25,400	0.020
Guar	410	1.00	410	130	8	3	270	200	200	1.740
Rabi										
wheat	571	2.65	1,512	700	88	27	697	4,491	11,900	0.060
Mustard	423	0.88	373	156	12	7	198	3,750	3,300	0.060
Total	561	7.10	3,960	1,987	223	93	1,657	5,745	40,800	0.041

Table 8.A.5. Farm type 5 (cotton–wheat belt, tail of canal water, problematic soils, 4 farms; 5.7 ha).

Crop	Gross return ($/ha)	Cropped area (ha)	Gross return ($)	Farm costs: Inputs ($)	Farm costs: Labour ($)	Farm costs: Water ($)	Net return ($)	Water: Use (m^3/ha)	Water: Total use (m^3)	Water: Net return ($/$m^3$)
Kharif										
cotton	644	3.12	2,009	1,085	256	81	586	11,795	36,800	0.020
Guar	513	0.79	407	112	10	2	283	253	200	1.800
Rabi										
wheat	476	3.12	1,484	828	152	34	470	5,192	16,200	0.030
Mustard	326	0.23	74	45	4	2	22	4,348	1,000	0.020
Total	533	7.30	3,974	2,070	423	119	1,361	7,425	54,200	0.025

Farms 1 and 2 experienced a shortage of family labour during the peak months of July (transplantation of paddy), October and November (due to harvesting of paddy, sowing of wheat crops and peaking of cotton crop on Farm 1). Both farms also experienced insufficient supply of canal water throughout the year, compensated for by groundwater pumped from tube wells. Highest net returns were found to be from mustard; net returns per cubic metre of water were smaller on Farm 2 than on Farm 1. Farms in the cotton–wheat belt experienced a shortage of canal water in the months of February, March, August, September and October. The cotton crop was more remunerative on Farm 3 than on Farms 4 and 5. The net returns were highest for Guar.

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