Demand management in a basin perspective: is the potential for water saving overestimated?[1]

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Abstract: Water Demand management has received much emphasis from development agencies in the last decade. The concept stemmed from a growing awareness of the externalities of large scale water resources development and of an assumed state of wastage in the use of water by many sectors, notably agriculture. The paper examines critically the scope for saving water in water short basins. It argues that because of the closing/closed nature of such basins, the gains that can be achieved through demand management have been much overestimated. It shows that demand management interventions result in some users being able to increase their water use to the detriment of downstream users and that most interventions result in spatial shifts of water use rather than savings. Water pricing is often proposed as a way to curb water use but its introduction in irrigated agriculture is shown to be problematic. The economic argument for re-allocation to higher value uses is distinct from the discussion of water savings in this paper and is not considered in any detail. The paper also suggests that supply management remains indeed the most effective way to reduce water use, and that in many cases supply augmentation cannot be avoided.

1 Introduction

After decades of development of large scale infrastructure, including the construction of 45,000 large dams and the expansion of irrigation facilities, the water sector has encountered growing costs and environmental externalities that have generated increasing political opposition. At the same time, it has become common knowledge that the use of water is very often characterized by high levels of losses. In developing countries urban water supply is reported to have losses by leakage between 30 to 40% on average. Surface irrigation is also known to incur heavy losses and one can frequently read that two thirds of the water diverted never reaches the plant (e.g. FAO 1998, WRI 1998). Numerous analysts in the water profession have therefore embraced and popularized the concept of demand management (Hamdy *et al.* 1995, Winpenny 1997; Brooks 1997; Frederick 1993) and made the case that its application would be a primary means to solve the current water crisis. Water demand management (WDM) is defined as a "policy that stresses making better use of existing supplies, rather than developing new ones" (Winpenny 1997), and uses a set of incentives that include price incentives, subsidies, quotas, conservation measures, treatment and recycling, awareness raising or

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educational programs. “Better use” encompasses conservation measures to raise efficiency in use, but also reallocation to uses with higher economic and/or social benefit. For Gleick (2003), such efforts combined with decentralization and participation of water users define a “soft path” approach.

The alleged co-existence of water scarcity and wastage is troubling, and in some regard contradictory. Taking river basins as the unit for water management, we may define the degree of closure of a basin by the percentage of runoff that flows out of the basin without being depleted by some use or committed to downstream needs (including environmental services, dilution of pollution or control of salinity intrusion in estuaries). Water short basins are typically basins that are closing, that is where most or all available resources are depleted, at least during some part of the year. Basins with severe problems of scarcity, such as the Yellow, Colorado, Rio Grande, Nile, Amu Darya, Syr Darya, Cauvery or Lerma-Chapala, are all closed basins, at least during large part of the year.

Section 2 of this paper first argues that basins where water is scarce and where users are competing tend to be precisely basins which are closing. The assumed wastage that may occur locally disappears when viewed at the larger scale of the basin. The implication is that local interventions to ‘save’ water are likely to alter the flow regime and impact on other users. Gains in local efficiency in most cases eventually amount to reallocation. This is shown through examples drawn from several countries. Section 3 examines the potential of water pricing for managing demand in the irrigation sector and concludes that this potential has been largely overstated. While WDM is highly desirable, it is unlikely to be a sufficient response and empirical evidence suggests that supply management is usually preferred. Section 4 offers some conclusions.

2 Saving water in closed basins: a contradiction?

There has been widespread recognition that focusing on relatively low irrigation efficiency at the on-farm or secondary levels can be totally misleading (Frederiksen 1992; Keller et al., 1996; Perry, 1999; Molden and Sakthivadivel, 1999). By adopting a basin-wide perspective, it becomes clear that what appears as a loss at a given point flows back to the river or an aquifer and is often recycled by other users further downstream, provided there has been no significant deterioration in water quality. Closed or closing basins correspond to areas with major constraints of water scarcity where water savings are most needed: the *very definition* of a closed basin, however, seems to preclude the possibility of such savings. In closed basins, any decision to further tap existing water (through diversion, pumping from watercourses, drains, or wells) at a given point of the hydrological cycle is almost certain to impact on existing users and/or the environment. What is stored, conserved or depleted at one point dictates what is available at another point further downstream (Molle 2003). Whenever an individual, a village or the State taps a new source or increases the abstraction of an existing one, this is tantamount, in reality, to a mere reallocation: in other words, one may be almost sure to be robbing Peter to pay Paul, as the following examples illustrate.

The Los Angeles/San Diego urban area is a well-known water-thirsty area that relies of interbasin transfers, particularly diversion from the Colorado river. The case of the lower Colorado, where an alleged “win-win” agreement between Southern California Metropolitan Water Authority (MWA) and the Imperial Irrigation District (IID), which took place in 1998, is a good example. This celebrated arrangement includes the lining of the All-American Canal (AAC) by MWA and the usufructory right to an estimated 100 million m^3 (Mm^3) conserved through this intervention granted to Los Angeles (CGER 1992). In fact, it is apparent that the so-called “savings” are detrimental to the recharge and quality of the aquifer that is tapped by Mexican farmers on the other side of the border in the Mexicali

Valley (Cortez-Lara and Garcia-Acevedo 2000). From a total of 100 Mm^3, 30 Mm^3 are captured by the La Mesa drain (which has been excavated to control the level of the aquifer) and 70 Mm^3 recharge the aquifer. The aquifer is tapped by individual and federal wells that irrigate a total of 19,000 ha, to which must be added 800 ha irrigated by the La Mesa drain. However, because of the increase in salinity estimated at 21.9 ppm/year, it is likely that negative impacts will eventually affect an area of 33,400 ha (Cortez-Lara 2004). The decrease in groundwater resources also renders the future supply of the growing urban areas more critical (Castro Ruiz 2004).

Congress has lauded the lining initiative at AAC since 1988, but the misgivings of the Mexican side have never been addressed. Officially, the measure is said to be in accordance with the Colorado compact, which only deals with surface water, and therefore conform to existing legal arrangements. Focusing on the American side of the deal only allows decision-makers to picture the arrangement as a win-win situation and even to state that the "agreement was possible in part because there are few externalities" (Briscoe 1997). Win-win hydrologic situations in water short basins often have a forgotten or conveniently overlooked "lose" element, especially when surface-groundwater interactions are ignored.

Molle and Miranzadeh's (2004) case study in central Iran sheds light on the multi-level interconnectedness of water users in a closed basin. The Zayandeh Rud basin covers 41,500 km^2 in the center of Iran. Its historical and economic significance is attached to the city of Isfahan, with its rich and millenary history. The Zayandeh Rud originates in the Zagros mountains, where rainfall and snow are rather abundant, and traverses arid areas to empty into Gavkhuni swamp. While rainfall in the catchment of the dam averages 1,700 mm, Esfahan only receives 130 mm per year (Murray-Rust et al. 1998). The Gavkhuni swamp, at the downstream point of the river basin, is a natural salt pan, surrounded by sand soils and dunes. Water entering the swamp area is extremely saline, with EC values as high as 30 dS/m during periods of low flow (Salemi et al. 2000).

The river is regulated by the Chadegan reservoir built in 1970. This reservoir also receives water diverted from the adjacent Khurang basin through three tunnels. Irrigated schemes with a command area of approximately 160,000 hectares have been developed around Esfahan and are supplied with reliable water during 8 months of the year (March to October), allowing double-cropping in a large part of the area. However, in many cases these modern schemes were superimposed on ancient systems consisting of run-of-the-river canals (*maadi*) and sometimes qanats. The main valley also used to receive sub-superficial sideflows and run-off from lateral valleys in early spring. These flows have now been reduced or lost because of the development of agro-wells and storage facilities in these valleys. Water released from the dam is diverted to cities and to irrigation schemes at different points, while return flows come back to the river or replenish aquifers that are in turn tapped through wells.

The study shows the high level of interconnectedness of users via the hydrological cycle due to upstream/downstream and surface water/underground water interactions. What villagers did in one part of a lateral valley – drill wells, enlarge and extend qanats, harvest rainfall, etc - impacted on other users; reservoirs constructed by the state modified the hydrology of the valley and reordered the water regime; "green belts" of irrigated trees around the city tapped groundwater that would otherwise flow to the river bed; wells competed and eventually did away with most qanats; increased abstraction resulted in lower and more saline flows to the downstream areas and the partial drying up of the swamp. Conservation at the village level (lining of canal) only led to having more water spread and depleted locally, to the detriment of users further downstream.

Because of the closed nature of the basin, all interventions had an impact on third parties, not least the environment (Gavkhuni swamp) and future generations (due to mining of the aquifer, which Murray Rust *et al*, assume will be so depleted as to no longer be a resource by 2025). Unchecked individual initiatives may add up and have significant impact at the macro level. Macro-level interventions, in return, critically alter the hydrology and existing water-sharing arrangements. In such a process, local and global interventions tend to conflict, and control over water to shift toward the state, as traditional initiatives are overwhelmed. This has critical implication for water allocation and the definition of water rights.

Delhi is a sprawling city that draws its water supply mainly from the Yamuna river, but also from an unknown number of wells (Ruet *et al.* 2002). Treated water is to be piped to Delhi, at a time where the capital is reaching 15 million dwellers and consumes 742 Mm^3/year, against a real demand estimated at 1,200 Mm^3/year. Since Delhi has no right on water of the Yamuna, the negotiations on the allocation of the river flow between the concerned states is a delicate issue. A MOU signed in 1994 attributed 725 Mm^3 out of 12 Bm^3 to Delhi. The Sonia Vihar water treatment plant, which is to treat 635 million litres of water (232 Mm^3/year) from the Ganges river daily, has been inaugurated in June 2002. Water is taken off the Upper Ganga canal, which serves large irrigation schemes north of Delhi, stored in a tank, treated and conveyed to Delhi through a giant 3.25 meter-diameter pipeline. In order not to impact on irrigation supply, the canal has been lined to avoid seepage and make use of the "losses". It was soon discovered, however, that this seepage was the direct source of supply of hundreds of wells further downstream. This situation can be found in most of India, where use of surface and groundwater has developed to the point that the latter has now surpassed the former.

A case study by Sakthivadivel and Chawla (2002) in the the Lakhaoti Branch irrigation system, not far from Delhi, demonstrated how monsoonal flows can be captured for use during the dry season, using subsurface reservoirs for storage, without the construction of a dam. Infiltration losses in the rainy season are stored in the aquifer and used by farmers for a second crop. Reduction of water supply to wells along the Upper Ganga canal has raised protests from farmers relying on groundwater in the vicinity of the canal and emotional statements from social activists who see food security in the area threatened (Shiva *et al.* 2002). Just like in the Imperial Valley case, redirecting seepage losses to cities was seen as the best way to increase supply without affecting existing uses but the "losses" were eventually found to be already tapped by other users.

There are numerous other examples of such situations, and the problem described above also occurs at a smaller scale. When a farmer has access to a given amount of water and invests in micro-irrigation, he usually uses the portion of water saved to expand his area if this possible or alternatively, if he used to be water-short, he may increase supply to his plants. In both cases, the net amount of water depleted by the farmer increases. While this particular individual may benefit from the change, the replication of this situation on a larger scale leads to a significant reduction of return flows, both superficial and underground, and to a diminution of supply to users who were tapping these flows. In many cases, it also leads to the reduction of low flows to the detriment of the environment. Even the suppression of return flows of low quality water in the Jordan Valley is eventually detrimental to the Dead Sea and paves the way for costly plans of sea water transfers to stem further decline in water levels.

A study of the Kairouan plain, Tunisia, looked at the behavior of farmers using groundwater (Feuillette 2001). The aquifer is reached between 25 and 75 m but has been gradually dropping since 1970 because of overexploitation. While a well allows irrigation of 6 ha on average, the introduction of micro-irrigation leads to a better control of application and higher efficiency. As a result, the net impact of water-saving technology is not to relieve pressure on the aquifer but, on the contrary, to allow the expansion of irrigated crops. As a consequence, percolation losses are reduced and the amount of water depleted by evapotranspiration increased. The water saved by a farmer has been readily used on his farm and overexploitation remains undiminished.

Similar situations have been observed in various places like Valencia, Spain (García Mollá 2001), where drip irrigation has not reduced application rates, and in Maharashtra, India (Regassa Namara, pers. com.): different types of micro-irrigation have been introduced and successful farmers have been able to grow cash crops like banana and to expand their cultivated areas. The level of water depleted had thus increased because of crop change, increase in cropping intensity, and expanded area, all this at the cost of an exacerbation of aquifer overexploitation. More generally micro-irrigation tend to be correlated with groundwater, because supply is both more secure and already pressurized. This means that contrary to common belief, which sees micro-irrigation as a water-saving technology, its implementation can result in greater water depletion.

When a basin closes the gradual and growing interconnectedness of users is also induced by their adjustments to scarcity. Users and managers are far from passive and respond in many ways. Farmers aim to optimize benefits from their total water resources – rainfall and groundwater as well as surface and drainage supplies. They respond to rainfall and develop conjunctive use, dig farm ponds or wells, reuse water from the drain and often invest in pumping devices to access alternative sources of water. They shift cropping calendars, adopt cultivars with shorter cycles, improve water application at the farm level and sometimes invest in micro-irrigation. Irrigation managers are led to establish rotations or quotas. Dam managers come under pressure to avoid dam releases that are in excess of downstream requirements and often improve management. The cases of the Chao Phraya river basin, Thailand (Molle 2004), and of several schemes in China (Loeve *et al.* 2003) exemplify such changes; these are often unnoticed because of the tendency to focus on state-designed policies and to overlook endogenous adaptations, such as the widespread construction of on-farm storage to collect natural runoff and store canal supplies (*ibid*). They all lead to the tapping and appropriation of whatever flow is accessible by a multitude of users over the basin.

The evidence, therefore, is that in closed basins where pressure on the resource makes conservation most needed, there is little –if anything- to be saved. This statement, of course needs some qualification since there are notable exceptions. If percolation losses and return flows from irrigation are degraded in terms of quality they might be unfit for reuse and therefore losses by percolation or direct run-off should be minimized. This applies, for example, to the Jordan Valley and in major parts of the Indus basin where groundwater is saline, although saline sinks or lakes are considered to have environmental value. Another caveat concerns the costs incurred by possible successive pumping operations. Users near the coastline also have nobody downstream: according to WRI (1996), 40 percent of cities with populations over 500,000 are located on the coasts and the return flows from these areas cannot be utilized. In practice, wastewater from coastal cities is either treated and reused in peri-urban agriculture or flows to the sea untreated, where it contributes to controlling salinity intrusion, as in Bangkok and Manila. In other words, return flows of coastal areas may not be tapped again and they are often negligible because downstream areas in the basin tend to be the most water short. As cities grow very big, the large volume of fresh water they attract will inevitably increase the return flows available and may reverse this general situation.

These specific cases notwithstanding, closed basins offer little scope for significant *real* overall water conservation. The implication for demand management in general and water conservation in particular is that potential changes in users' behavior simply amount to - reallocation between users, often with unexpected third-party impacts, and not to real savings.

When we look more in detail at the empirical situations alluded to in what precedes, slight differences seem to emerge. In the first case, savings are achieved by a particular user (such as farmers in the Tunisian case), for example by shifting to micro-irrigation, and the water saved is used by the same user to expand his activities. The depleted fraction is likely to increase and return flows are reduced. The change is cost-effective and beneficial for that user but equity decreases and scarcity increases elsewhere in the basin. In the second case, conservation reduces local losses and the corresponding savings are then tapped by a particular user (the Imperial Valley case). This amounts to a reallocation of water from users already tapping return flows to the "conserver". The reallocation can be explicit and therefore allow compensation, but in most cases it is not and is masked by the fuzziness of the hydrologic cycle. Stress and benefits are shifted spatially. The overall economic benefit may, or may not, be higher than the costs, but in all cases the question of access, equity and right to water is posed.

Overall, it must be noted that when constraints/incentives applied to users do reduce abstraction of water are effective, the problem of the impact of reduced return-flows on third parties using these flows remains. Raising water charges to instil awareness of its scarcity is often advocated as a means to regulate abstraction and demand. The following section examines the effectiveness of such policy in surface irrigation.

3 Regulating water use: demand or supply management?

Apart from the conservation interventions reviewed in the preceding section, WDM is concerned with constraining the amount of water diverted/abstracted by users. Several types of incentives are possible, including pricing, subsidies or taxes, campaigns to raise awareness, etc. However, policies generally center on the necessity to raise the price of water, so that users may get incentives to reduce use and to direct it to the most economically beneficial activities. Another widely applied and pragmatic method to control use is the definition of quotas or allotments to the different users. This relates to the management of supply rather than to that of demand. This section argues that if WDM through pricing is often effective in domestic supply, it is not the case in the agricultural sector. Fixing quotas appears to be more efficient and straightforward and allows maintaining a certain degree of formal equity, providing the administrative arrangements for doing so are transparent and properly administered.

Building on the recognition of water as an economic good in the 1992 Rio and Dublin Conference, many economists and development banks have promoted the use of prices and markets as a way to regulate water demand and to put it in line with available supply (Tsur and Dinar 1995; Bhatia *et al.* 1994; Thobani 1997; Dinar and Subramanian 1997; Johansson 2000). The argument is that if the price in irrigation is almost nil, farmers will be encouraged to use a very large quantity before its marginal productivity becomes zero, consuming much more water than accepted standards and needs. This is explained to the layman by the parallel drawn with domestic supply: if tap-water is free, we might leave our tap on continuously and our neighbor might water his lawn lavishly. Conversely, if the water rate is set high, we will try to control our tap and reduce our monthly bill. These examples are familiar to the point of banality. However, it is important to remember, that for a farmer, too much water is as much of a problem as too little, and therefore there are defined limits which contain over-irrigation. A cursory perusal of the literature shows that the correlation between water wastage and underpricing has become axiomatic, as echoed by James Wolfensohn (2000) who states that "the biggest problem with water is the waste of water through lack of charging".

Recently[4], however, a readjustment of the hopes that had been placed in economic instruments in general and pricing in particular has taken place. Tellingly, perhaps, the word "pricing" is absent from the Bonn conference 27 recommendations for action, issued in December 2001, and the use of economic instruments in managing water is not referred to in the 2002 Stockholm statement "Urgent action needed for water security". More significantly, a recent policy document from the World Bank admits that "pricing promotes efficiency and conservation… but [that] there are few successful examples because of the economic and cultural difficulties of putting a value on a natural resource" (Pitman 2002). In 2003, the Bank's new water resources sector strategy (World Bank 2003) acknowledges the "yawning gap between simple economic principles… and on-the-ground reality". Analysts have pointed to several constraints and shortcomings, both at the theoretical and practical levels (see Small *et al.* 1989; Perry *et al.* 1997; Sampath, 1992, Molle 2001; Savenije and Van der Zaag 2002, Bosworth *et al.* 2002). Some of these arguments are reviewed briefly here.

The impact of prices on water use is conditional upon having a direct relation between the volume used and the cost to the user. The problem of metering is well known as the major objection and constraint to the application of pricing as a tool to change water use practices. For historical, technical, and administrative reasons a very small portion of irrigation schemes in the world have volumetric measuring devices at the individual level. Even in the European Union, this case is quite rare, although it has been ubiquitous in Australia for more than 40 years. Historically, irrigation has developed based on tapping plentiful water and quantitative aspects were not a great concern. In addition, with surface water, in contrast to a piped network, installation of measuring devices in surface irrigation is often neither easy nor are measurements trusted when they are carried out. Such structures are easy to tamper with and the transaction costs of enforcing, monitoring, and collecting information are clearly beyond the capacity of most irrigation agencies in the South. Despite the principle that pricing "applies only when water charges are levied volumetrically - an exceedingly rare situation in the developing world", Svendsen (1993) notes that "the argument is frequently invoked as though it applies to all allocative situations."

In the absence of volumetric pricing, many analysts have remarked that the argument that prices "keep [the] farmer aware that water is not a free good, but [that] it has been provided at high cost and must not be wasted" is in fact likely to yield the opposite result, with farmers' determined "to get as much as possible of the thing for which they have been taxed" (Moore 1989; see also Davis and Hirji 2003). Gerards (1992) provides a clear and concise overview of the difficulties of establishing the notion of "payment for service and service for payment" in Indonesia when irrigation fees are administered as part of land taxation.

A second major constraint to the effectiveness of pricing on conservation is the fact that at low prices the elasticity of water use in irrigation is very low or nil. In other words, when the cost of water is, say, 1-5% of farmers' income, significant relative increases will not affect behavior (assuming that the charge is volumetric). This is both common sense and confirmed by empirical evidence and modeling exercises (de Fraiture and Perry 2002; Abu Zeid 2001, Malla and Gopalakrishnan 1995; Perry 1996; Gibons 1987; Ogg and Gollehon 1989; Berbel and Gomez-Limon 2000).

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[4] In 1986, however, FAO and USAID (1986) already found that " water charges policies are unlikely to have any significant impact on the efficiency with which each individual farmers use water except in those extremely rare cases where at the same time: a) water is scarce, 2) the irrigation system delivers water on a demand basis (response to ad-hoc requests); c) water deliveries are measured."

The conclusion of most authors is that actual water charges have no impact on behavior (nor would they have if they were volumetrically based), and that raising them –tenfold or more- to find a degree of elasticity is economically and politically impossible. In the great majority of cases, even if charges were raised to cover full O&M costs they would still be too low to have significant impact, in particular where water is rationed. Given the sensitivity of pricing issues, it is unreasonable to imagine that charges will ever be significantly higher than O&M costs, especially where smallholder agriculture is dominant and the opportunities for economies of scale are very limited. It is unrealistic to imagine that many governments would take the economic and political risks to define fees at deleterious levels, well above O&M costs, only for the sake of 'encountering elasticity'[5].

In Australia (Victoria), where volumetric charging and measurement are the norm, charges are set to recover O&M and capital replacement costs and minimizing seepage to high saline water tables is a priority. Even so, Bethune *et al.* (2004) show that water savings alone are insufficient incentive to invest in further water conservation, as the costs of salinity and water table control externalities are not included in the current water price. At the same time further significant increases in water charges would be politically naïve.

Another argument is whether losses in irrigation schemes are due to farmers. Only the losses incurred at the farm level can be reduced by a change in farmers' behavior (irrespective of whether this is induced by prices or not). In large-scale gravity irrigation schemes, these losses amount commonly to 50-70% of the water delivered at the head of the network (Davis and Hirji 2003). Depending on several factors, such as system layout, soil types, topography, and management, the share of these losses varies. For the case of the Mula Canal in India, Ray (2002) estimated that farmers as a whole receive only 30-35% of the amount of water diverted from the reservoir. This means that whatever improvement in management that farmers make concerns no more than one third of the water released, which drastically reduces the potential quantitative impact of such improvements. Regarding farmers' practices themselves, there is a crucial point which is generally ignored by analysts who paint farmers as the main culprits for the wastage of water. A large part of the losses is due to poor system management that is to the mismatch between supply and demand that results in excess flows at some points of the scheme and insufficient flows at others. These losses are due to poor management and scheduling or to inadequate design and poor hydraulic control structures (Meinzen-Dick and Rosegrant 1997). These causes remain largely independent of the users themselves and any subsequent wastage is because supplies are not in line with needs. Setting substantial water charges is possible only if supply is predictable and assimilated to a service. As Small (1987) aptly observed, "it is likely that once this prerequisite exists, the amount of "wastage" will be greatly reduced, thus lowering the potential efficiency gains from any subsequent attempt to introduce water pricing" at the level of the farmer. The final balance between losses in farmers' fields and in distribution varies considerably and requires proper investigation and description before policy measures are introduced for conservation.

There is a major implicit contradiction between the existence of water scarcity and the alleged evidence of lavish or wasteful use of water. Tap water may be wasted because it is abundant (at an individual level) and because the possibility to "leave the tap open" exists and does result in wastage. The same may happen in irrigation schemes (the farm turnout is left open and allows continuous and free flow to the paddy fields, for example) but this is generally observed in schemes that are not water

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[5] This is, however, advocated by several authors: see Brooks (1997): "Most would argue that… water tariffs should be designed to encourage conservation, not just to recover costs (which implies that pricing should be high enough to move into the elastic portion of the demand curve)".

short. An irrigation scheme located in a water short basin is likely to receive water based not on farmers' demands but on available supply. In such conditions, water will generally be distributed by rotations, excess return flows will be limited, and supply will often fall short of the potential demand (that which would satisfy all users if water was abundant). This in turn can lead to attempts to manipulate scarcity.

There are two very common situations where wasteful irrigation practices may coexist with basin level scarcity. The first situation is that of irrigation schemes with inequitable patterns of distribution because some farmers are able to abstract more than their share - and often more than they need (if supply is by gravity) - without being checked. This problem is one of scheme (internal) management and will not be eased or solved by charging for water. The second situation is one where a user, despite being located in a water scarce basin, is able to divert a handsome volume of water, indirectly compounding the situation of other users. This may occur when a specific area enjoys particular political support, or has a legal right to a large amount of water and is insulated from the surrounding reality. Both problems can be commonly observed in warabandi systems in Northern India and Pakistan and have been extensively documented in the literature in the past. At the same time similar problems are not thought to be found in other countries such as Israel, Jordan and Morocco, where rationing systems have been imposed. These problems are political, legal, and managerial, rather than a question of balance between supply and demand.

Thus, the reasoning suggesting that profit-maximizing farmers are led to increase their use of water until its marginal product is zero does not apply simply because sufficient water is not available to users without restriction. Domestic and irrigation supply cannot be treated in the same fashion and general theoretical thinking across the board is misleading.

Exceptions to this can be found in contexts where distribution of irrigation water is akin to tap water. A good but rare example is the Canal de Provence, in Southern France. Another exception is the case of groundwater, where users have access, in the short term, to more water than they need and where the cost of abstraction is often quite significant. In such cases, there are incentives both to grow crops for which water requirements are lower (but only if this entails no reduction in net income) and also to save water at the plot level. Farmers who pump groundwater should not waste much water at the plot level because of the costs incurred (Bos and Wolters, 1990) but again, this rule has significant and widespread exceptions, as discussed by Shah *et al.* (2004), when the cost of energy (rural electricity supply and sometimes diesel) is very cheap or free.

All these points, to which can be added the difficulties to measure and monitor use, and to recover charges, explain why there is hardly any case in the literature that demonstrates that charging for irrigation water is instrumental in saving water. Charges may have other functions, such as cost recovery, but this is a different matter. This stands in contrast with the emphasis put on WDM in the literature and policy-making. In fact, evidence from many countries, including those with absolute water scarcity like Israel, Jordan, Iran, or parts of Morocco, suggests that supply management is adopted in the great majority of cases. Quotas, reasoned according to the characteristics of each locale, appear as the easiest and most efficient means of reducing consumption. Regulation through prices would be tantamount to putting financial pressure on users and eliminating those who have less capacity and capital to adjust. Such a mechanism is obviously politically very unattractive. Quotas, or reasoned reductions in supply, have two overwhelming advantages: first, they ensure a degree of transparency and equity in the face of scarcity; second they are directly effective in bringing use in line with available resources. This adjustment by users is made easier if supply is gradually, rather than abruptly, decreased and if that supply – even if reduced - is predictable. When water is pressurized and metered like in an urban network, a combination of quotas and sharp increases in prices beyond it appears as a good option (as in the case of Israel). All in all, the "visible hand of scarcity" appears a much more effective and "implementable" solution than that of the "hidden hand" of prices or markets.

4 Conclusions

None of the preceding discussion is meant to deny the need for more efficient management and regulation of water use. The examples given, however, show that conservation in water-short situations is often tricky, sometimes counterproductive, and generally amounts to reallocating water. This reallocation is often invisible because it occurs through complex surface and underground hydrological fluxes, and because it is masked by the inter-annual variability of supply. Even the introduction of micro-irrigation, commonly held as a water-saving technology, has been shown to commonly lead to increased water depletion. Reallocation may or may not be desirable, depending on the point of view and the scale adopted. Changing scale draws us from a mere question of cost-effectiveness of water-saving technology into a wider and thornier question of water allocation, rights to abstract water and regulation of its use. Failure to recognize this point leads to further third party impacts and environmental degradation, since the most likely results of focusing on local efficiency rather than on basin allocation are growing scarcity for downstream users; the mining of aquifers; and the reduction of low flows below sustainable thresholds. Thus, interventions that may seem justified in view of a local cost-benefit analysis, in reality have negative impacts on other parts of the basin and are likely to be both inequitable (as they alter the pattern access to water) and financially flawed (when externalities are taken into account). One may wonder, for example, if the huge investments in micro-irrigation in the northern plains of China are sound, given the closed nature of the basins.

Acknowledging that the scope for real water savings in water short basins is limited does not mean that efficiency in use is not an issue. Use in the domestic and industrial sector, for example, is amenable to real savings in that wastewater is often not reusable and, in addition, often degrades the quality of river flows. When water is treated, such savings are all the more economically beneficial because of the costs incurred in restoring water quality. However, sticking to the common perception that water use in agriculture is overly wasteful is likely to lead to ill-conceived interventions. Failing to recognize that water management is to be addressed at the basin level, more so when scarcity is severe, perpetuates misunderstanding about water problems and inspires flawed responses. The ubiquity of the image of conventional irrigation as a backward practice, marred by efficiencies of 30-40% among both officials and technicians is puzzling and daunting. It takes no account of the remarkable adjustments that users faced with water scarcity have made in the last two decades, not least the pump revolution that has allowed conjunctive use, access to aquifers, and recycling of water (Molle *et al.* 2003).

Water pricing, heralded as a crucial means to reduce water consumption, has been oversold. A host of reasons explains why there are so few, if any, convincing cases where high prices have curbed the use water in large-scale surface irrigation. Rather than raising prices to deleterious levels, a both socially and politically unattractive option, it was observed that the reasoned rationing of supply can generally be a more viable solution.

In conclusion, we may observe that the complexity of hydrologic macro-micro interactions makes it hard for the state alone to reorder the basin water regime by policy or by legislation. Because of the growing prevalence of third-party impacts and reallocation in closed basins, constructing a sound and sustainable water regime demands a very high degree of understanding and control on water fluxes; it also demands multi-level governance patterns that allow interest groups to negotiate arrangements that bring more certainty, social value and equity to the sharing and allocation of water.

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