CREATING A POLICY ENVIRONMENT FOR SUSTAINABLE WATER USE

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Abstract: This chapter discusses the historical context of water use, rights, and development, much of which has contributed to the current water shortage in many arid regions of the world. In addition, it attributes many perceived water crises to poor water management instead of an insufficient water supply. Poor water management is discussed in several contexts, including the ecological implications of past water development, social and public health ramifications, and a general underestimation of all costs associated with water development. Recommendations are provided to improve the management of water resources in the future. These recommendations include recognizing that uncertainty about costs and benefits of water management choices must be taken into account by decision-makers, and that incorporating community management of water resources can lead to improved water management. Other recommendations include improving water pricing and allocation systems, such as through a switch from queuing systems to tradable permits; as well as using water pricing mechanisms that incorporate the negative externalities of water quality deterioration. Finally, the chapter provides description of how to improve the cost-effectiveness of policies to improve water quality and quantity through better targeting.

Keywords: water shortages, water management, water pricing, cost-effective water policies

1. INTRODUCTION

Water resources have been the source of environmental services and economic benefit for millennia. Water provides multiple benefits, in both consumptive and nonconsumptive uses. Examples of consumptive uses include drinking water and agricultural production; nonconsumptive uses

E. Wiegandt (ed.), Mountains: Sources of Water, Sources of Knowledge, 305–326.

include water recreation and habitat provision for aquatic species. Historically, an adequate supply of water has not been a constraint in many locations, and institutions and policies have been established to encourage utilization of water. Governments who were rich in resources, but poor in capital, established systems that were liberal in dispensation of water rights for beneficial use. Under this type of system, water is not used where it provides the greatest benefit. Increasing population growth, growing concern for environmental quality, and financial constraints are leading to the realization that water use has to be curtailed and water has to be managed in a sustainable manner for the long run.

As the word “sustainable” can be ambiguous, its meaning in this context should be explained. It requires that water use and resource development take into account the limitations of natural systems, and that the existing stock of the resource not be depleted. Surface water sources are replenished regularly, but the amount of water provided is limited and subject to variability. Groundwater aquifers provide another source of fresh water. While some groundwater aquifers are replenished, others are nonrenewable and their use should be carefully monitored. These supply constraints need to be recognized in any sustainable water management plan. A key element in sustainable water use is the development of new technologies to use water more efficiently and to reuse residual water more effectively.

Many regions have a perception of water crisis because existing water resources are not sufficient to meet growing needs. In most cases, the real problem is a *water management crisis*. Incentives for efficient and socially responsible management of water are lacking. Water projects that cannot be justified economically, and are damaging environmentally, are being built. Users are paying well below the value of the water they use, and are encouraged to consume water. Polluters of water bodies are often not penalized. In looking at the sustainability of water resources, it is not enough to only require a sufficient quantity of water, it is also important that supply be of sufficient quality.

In this chapter, we discuss past trends and their implications for water use. We also discuss necessary components of any water policy that considers future needs. To achieve sustainable water use, water policies and institutions must be reformed. Concerns about adequate water supply can be addressed through better management of existing sources. In this spirit, we will present incentives and policies to improve water project design, water conveyance and pricing, micro level choices, and water quality.

2. PAST TRENDS

2.1. Population Trends, Food Security, and Water

A growing world population is putting increasing pressure on freshwater supplies. Global population has increased from 2.5 billion in 1950 to 6 billion in 2000. As much as half of the world's population lacks adequate water for basic sanitation and hygiene (Sullivan 2002). By 2050, the world population could be 10 billion or higher. In addition to population pressures, there has also been an increase in water use per capita. The combination of these forces has led to worries about the adequacy of water supplies in the future.

We find both good and bad news in addressing this problem. First, the good news—in many ways, irrigation has allowed the world to overcome the potential food supply problems associated with population growth. Worldwide, irrigated land has increased from 50 mha (million hectares) in 1900 to 267 mha today (Gleick 2000). While 17 percent of cropland is irrigated, it produces 40 percent of the food supply, and the value of output per acre is six times the value of output on rain-fed cropland (Dregne and Chou 1992). In addition, there is some evidence that the high productivity of irrigated agriculture has slowed the rate of deforestation. Agriculture is one of the primary reasons for deforestation in developing countries, and increased yields (a change at the intensive margin) have decreased the need to expand the total land under cultivation (a change at the extensive margin). This is particularly important in mountainous regions. The steep slope of this land not only makes it difficult for food production, it also increases its value in conservation. Protection of forests in mountainous regions protects the soil, and decreases erosion and runoff into water bodies.

Now some bad news—there are limits to increasing irrigation water sources. Worldwide water consumption in 2000 is 4–5 times that of 1950 levels. Most of the obvious sources of water have been developed, and many that remain are marginal at best. The costs of developing water for irrigation are increasing and are not uniform across regions. Postel (1999) reviews the result of a World Bank study that shows the cost of irrigation has increased substantially since the 1970s. The study of more than 190 Bank-funded projects found that irrigation development now average \$480,000/km^2. This cost varies by location—the capital cost for new irrigation capacity in China is \$150,000/km^2, while the capital costs in Africa are \$1,000,000–2,000,000/km^2. Mexico's irrigated area has actually declined since 1985 due to lack of capital.

There is also an increased understanding of the importance of freshwater for environmental services, such as ecosystem health, as well as the environmental costs of water projects, such as habitat destruction. Soil salinity is a problem on irrigated arid lands, both reducing productivity and forcing land out of production. In many places with insufficient surface water supplies, groundwater is used as a substitute. While the availability of groundwater has benefited the global food supply, its use as an input has progressed in an unsustainable manner. As much as 8 percent of food crops grown on farms use groundwater faster than the rate at which aquifers are replenished. In 1973, only 3 percent of India's groundwater tables were below 10 m. By 1994, this figure was 46 percent (Postel 1999). Using irrigation in a more efficient manner will be necessary to protect water sources while still meeting goals of food security.

2.2. Social Concerns and Water Development

Social concerns associated with water development include waterborne diseases and displacement of native populations. There have been a number of large dams whose construction contributed to local public health problems, including increased incidences of diseases such as malaria, diarrhea, cholera, typhoid, and onchocerciasis (river blindness). However, there is evidence that many of these cases have been the result of poor planning, and not a necessary effect of dam construction. Often, increased vector breeding occurs in fields and not in the dams and canals (von Braun 1997). Incorporating public health concerns into the planning of a new water project can reduce the impact of the project.

Another negative result of water development has been the displacement of native populations. Between 1950 and 1999, 40–80 million people were displaced as a result of water development. In addition to their physical displacement, it has also often resulted in forced lifestyle changes. Compensation for these forced resettlements has been minimal. Resettlement plans regularly fail to take into account the loss of a viable livelihood in addition to the loss of physical land, often leaving resettled populations worse off than before dam construction. For example, one study found that 72 percent of the 32,000 people displaced by the Kedung Ombo Dam in Indonesia were worse off after resettlement (World Commission on Dams (WCD) 2000). The construction of the Liu-Yan-Ba Dam on the Yellow River in China forced the resettlement of 40,000 people from fertile valleys to unproductive wind-blown highlands. This has led to extreme poverty for many of the resettled people (ibid).

3. WATER PROJECTS

The last 50 years have witnessed the construction of thousands of water projects worldwide. Many of these projects have been built in marginal areas, without consideration of the true cost of construction. It is important that water projects rely on social benefit-cost analysis. In many cases, the estimated costs of construction have been too low. A recent study of 81 large dams by the World Commission on Dams found that the average cost overrun was 56 percent. These costs include only capital costs, and if environmental degradation was also included, the "true" costs would be much greater. In addition, ex-ante predictions of the benefits of water projects have often been overly optimistic. This combination of factors has resulted in observations that the internal rate of return to most water projects is well below the expected rate of return, although most of the return rates are still positive (World Commission on Dams 2000). Only projects with a positive net present value, when all costs and benefits are included, should be considered for construction.

In the past, capital subsidies and low estimates of environmental values have led to oversized projects. There has often been an attempt to include environmental benefits of water development (such as recreation in a reservoir) in a cost-benefit analysis. However, many environmental costs such as habitat destruction or extinction of species were considered immeasurable, and were ignored. Methods of accurately measuring these costs are being developed and improved, and they should be used whenever possible. In evaluating different projects, issues of uncertainty, optimal project design, and future costs must be considered.

3.1. The Importance of Uncertainty

One important issue in water development is that of uncertainty, particularly when making irreversible decisions. Water development requires choices about the location and size of a water project. These choices are made under uncertainty regarding future technology, population size, and environmental preferences. For example, the construction of a large dam will permanently alter the surrounding ecosystem. Traditional cost-benefit analysis looks at the net present value of a project to determine whether or not the project should be built. This type of analysis ignores a third possibility—the option of waiting. If the value people place on the benefits of this ecosystem is uncertain, then waiting to build the project can allow further information to be learned about these benefits. If the benefits of water development are uncertain, the uncertainty can be decreased as further knowledge becomes available.

Arrow and Fisher (1974) and more recently Dixit and Pindyck (1994) develop models that suggest that in these cases the decision-maker may consider delaying the decision about optimal project design to collect more information about the costs and benefits of project construction. They not only look at the question "to build or not to build"; they also consider the importance of when to build. Delaying building a project by one or two periods may lead to the loss of benefits in these periods but will lead to a future gain as more information is taken into account. They show that if the gains from acquiring new information are greater than the foregone benefits of current construction, it is better to delay construction of a new project. The gain from not making an immediate decision is referred to as "option value." In particular, in cases when there is uncertainty about productivity of water as a result of availability of a new technology or as a result of uncertainty about environmental impacts of water diversion activities, the "option value" of waiting may be quite high and there may be significant gain from delay. Because of this, a positive net present value of a benefit-cost analysis is a necessary, but not a sufficient, condition for construction.

Zhao and Zilberman (1999) extend this analysis to consider projects where restoration is costly but feasible. This is more realistic for water development. Dams are being removed from many sites worldwide, and natural habitats are being restored. They find that in some cases, it might be better to construct a new project even if there is a chance it will lead to costly restoration in the future. This could happen if the expected benefits of a project are larger than the expected future restoration costs.

For policymakers, it is necessary to consider not only the expected benefits and costs of developing a water project, but also the potential to learn more information when those benefits and costs are uncertain. If the gains from waiting and learning are high, it might be best to delay the decision until better information is known.

3.2. Project Design

In the design of water projects, it is not enough to only consider the physical construction of the project; it is also important for engineers, economists, and biologists to work together in the project design process. Project design should include both physical aspects and managerial specifications. At a system-wide level, management and storage capacity can be considered substitutes. Designing a management system in conjunction with physical infrastructure may reduce the size of the project and its environmental side effects.

Traditionally water systems have been managed by large bureaucratic agencies, leading to much inefficiency. As discussed by Easter (1986), there has been a shift in recent years from the development of new water projects to better management of existing projects. This has led to an increased reliance on water user associations (WUAs). A WUA is usually comprised of landowners in a small geographical region who are charged with the distribution of water and the collection of costs of provision. Because they manage the conveyance and costs themselves, they have incentives to find ways to do so efficiently. One element that is essential for the success of a WUA is well-defined property rights to water. In cases where rights are ambiguous, monitoring and charging water users an appropriate cost becomes very difficult. The successful use of WUAs for water distribution and cost recovery is used in parts of India, Mexico, and most of Madagascar (among other countries). The growing use of WUAs is a positive step toward improved management, but there is still room for much improvement.

Another aspect of project management is developing uses for recycled/reclaimed water. Often water is not fully consumed in its first use, and can be reused. For example, certain crops are tolerant of water with high salinity levels, and runoff water from other less tolerant crops can be used for some irrigation needs. Treated wastewater from sewage plants can be reused for many industrial water needs. As more technologies are developed, further possibilities will be found for reusing and recycling water in an effort to make the limited supply last.

Water system management should also include sufficient upkeep in maintenance. The lack of maintenance is seen in both municipal water and irrigation infrastructure. Poor management of irrigation systems leads to conveyance losses of up to 50 percent (Repetto 1986). When users of conveyance structures invest in maintenance, they get some benefit because of improved water supply. However, water users downstream also incur a positive externality, which is often not taken into account in maintenance decisions. Economic theory shows that private users under-invest in canal maintenance. This has a few implications for water users. First, canals will be shorter than optimal if based on private interests. Second, there will be overapplication of water upstream, and under-availability of water downstream. Third, improving conveyance will improve the well-being of downstream farmers' more than upstream farmers. There is a need for governments to take charge in developing optimal canal maintenance and pricing. Water prices should not be uniform; they should take into account a user's location on a canal

(Chakravorty et al. 1995). These charges need to take into account transportation costs and inefficiencies in conveyance—the cost of water downstream should be greater than the cost of water upstream.

In the development of new water projects, policymakers must consider all elements of the project, including capital, management, and conveyance. These elements need to be planned jointly, as failure to do so could lead to a higher than necessary reliance on one part of the system.

3.3. Dynamic Costs of Water Development

Many of the costs of developing a water project are not immediate. There are environmental problems that have occurred over time as the amount of land being irrigated has expanded. These costs include increased salinity levels in fresh water sources, and waterlogging and salinization of soil. They also might include future construction of drainage systems to keep land usable for agriculture or decreased productivity in traditional fisheries.

For example, the Aral Sea used to be a thriving site for the fishing industry, employing 60,000 individuals. Between 1962 and 1994, diversions to provide water to grow cotton have reduced the volume of water in the sea by 75 percent. The fishery industry has been entirely wiped out, with many fish species disappearing (Calder and Lee 1995). These costs are more likely to arise in arid locations that are susceptible to water logging and salinization of the soils. In arid regions, there is little rainfall to dissolve the salts in the soil. When too much water is applied without proper drainage, the evaporation in arid climates can quickly lead to high levels of salt in the soil, reducing the yield potential of the land. Estimates are that 20 percent of the irrigated land worldwide is affected by soil salinity, and that 1.5 mha are taken out of production each year as a result of high salinity levels.

In evaluating potential water projects and water project design, it is important to consider future costs, where these costs are broadly defined to include future environmental damage as well as social costs.

4. WATER ALLOCATION AND PRICING

Water allocation systems are a primary source of inefficiency in water use. Existing water rights systems are mostly designed as a “queuing system,” where an order of seniority is established among water users. Most of these systems also have banned the trade of water between users, or the sale of individuals' water rights. A prior appropriation rights system gives a permanent water right to the first person to divert water from a source, while a riparian rights system gives water rights to landowners whose land is adjacent to a water source. It has been shown that a transition to trading, where water is priced according to its opportunity cost, will increase social benefits. The original development of this argument can be attributed to Coase's seminal work entitled *The Problem of Social Cost*. Coase (1960) argues that if transaction costs are zero and property rights are well-defined, then allowing trade of those rights leads to a first-best (most efficient) outcome. These gains from trade increase with water scarcity. However, several of the required assumptions for this argument do not hold with the water industry. For water the assumption of zero transaction costs is incorrect. Water is a difficult commodity to move, and trading is only beneficial when the gains from trade exceed the transaction costs. In addition, this outcome assumes perfect enforcement, which is generally not the case with water use and application.

4.1. Gains from Water Trading

In many places, trade in water is not necessary in normal years. However, during times of drought, the benefits of water trading increase. For example, from 1987 to 1991 California experienced one of the worst droughts in recent history. By 1991, the California Department of Water Resources established the California Water Bank, which bought water from users for $125 per acre-foot and sold them at $175 per acre-foot (prices are at the Delta). During this year, the water bank purchased 825,000 acre-feet of water, with 166,000 acres of agricultural land fallowed to provide a portion of this water. The water bank continued during the dry years of 1992 and 1994, although with lower prices due to the lower severity of the drought. Studies have shown that the California Water Bank provided a significant economic welfare gain to the state (Zilberman 1997).

Another example that shows the potential gains from the introduction of water trading is Australia. Like in Chile, Australia has moved to a water-trading regime, and has decoupled ownership of land from the right to use water. The shift from traditional water rights stemmed from a growing realization that greater flexibility was needed in water rights that water resources are necessary in the natural habitat. A 1994 bill separated water rights from land ownership, and established a water allocation for environmental services and the development of water markets. The results of the change in Australia have been positive, and estimates are that the annual gains from the shift to tradable water rights are $12 million in Victoria, and $60–100 million in New South Wales (ACIL 2003). Despite these gains, there are still some barriers that have been identified as an impediment to the highest possible returns to tradable water rights. One of these impediments is a limitation on the lease of water-use rights. Water rights can be permanently sold in all states of the country, but some states still have a restriction on short-term (i.e., one year) leases of those rights. Another aspect that has been identified as a limitation on the benefits of trading is the lack of an options market in water resources. The elimination of these barriers to a fully functioning water market will only increase the benefits already realized in Australia.

In many places, for trading to become a viable option requires an expansion of existing canal systems. When infrastructure required for the transportation of water does not exist, it makes trades between users close to impossible. Even if the use of trading is small relative to total water use, it could still lead to a large gain in total welfare, especially in times of shortage.

Trading in water, particularly in permanent water rights, can induce long-term investment and development, and reduce uncertainty about future water supply. Trading can also allow governments or conservation groups to purchase water rights from individual users for environmental benefits and conservation.

4.2. Design of Water Trading Programs

In designing a water trading regime, several issues need to be addressed. One of these is the ownership of water rights—the distribution of water rights might be based on a number of criteria, including current use, need, or willingness to pay. The modalities for sale of water rights also need to be clearly specified—whether these rights can be sold on a permanent basis, or only on an annual basis. In 1981, Chile had a major reform in their water law, decoupling water rights from ownership of the land. While there have been many trades since the reform, there have been far more transactions to define ownership of water rights. At the time of the reform, there was a lot of uncertainty about the ownership of much of the water used. Much of the energy since the reform has gone into defining water rights, and some areas have seen 10 times as many water rights approvals as water sales (Bauer 1998). Clearly, well-defined water rights are a necessary condition for welfare-improving water sales.

As mentioned before, third-party effects need to be considered. When using water for irrigation, not all of the applied water is actually used by the plant. Some of the water is runoff, and some is stored in the ground below. Using drip irrigation or better management can increase the water-use efficiency of applied water, but there will always be some loss. Third parties might actually benefit from the availability of the water runoff, and will be affected if a farmer sells their entire water quota. To address third-party effects, individuals should only be allowed to sell the effective water they use, not the total applied water. Several choices need to be made when introducing a water trading program.

One decision is the size of the area to use for a trading region. Limiting trading to within a water basin will decrease third-party effects and lower transaction costs. However, it will also limit the number of potential trading partners of an individual. Another question is if individuals should be allowed to sell their water rights permanently, or to only lease them on a year by year basis. Uncertainty about the future, and particularly the future value of those rights, will lead some to prefer a short-term lease. However, this leads to higher uncertainty for the purchaser, who will be less likely to invest in efficient technology if they are unsure about future water supply. The use of permanent water sales are more appropriate in places with a chronic water shortage, while yearly sales are preferred to deal with drought situations in locations which generally have sufficient water.

Another decision is the type of trading system. Brill et al. (1997) discuss the difference between active and passive water trading schemes. Active trading occurs when a water district assigns water allocations to farmers based on some benchmark, and charges farmers the average price for their allocation. Farmers are then allowed to trade between themselves, so that those with a higher marginal value of water can buy a portion of the allocation of those with a low marginal value of water. Passive trading occurs when a water agency sets both an initial allocation of water per farmer and a price, with the price chosen for the water market to clear. Allocations are set so that the sum of individual allocations equals the total demand, with individual farmers allowed to use either more or less than their allocation, and either pay an additional fee or receive a rebate accordingly.

The details of a chosen trading system are influenced by various considerations. Certain choices are better for existing rights holders, while others will be better for governments or water agencies. Political economy considerations and the feasibility of the system must also be a factor in the choice.

4.3. Water Pricing Systems

There is a problem with many current water pricing systems. They are often aimed at cost recovery, and not at promoting efficient water use. Despite this goal, many water systems do not come close to recovering their costs. Recovery of operation and maintenance costs range from a low of 20–30 percent in India and Pakistan to a high of close to 75 percent in Madagascar (Dinar and Subramanian 1997). The most common means of pricing are per-hectare fees. This leads to inefficient water use, since the marginal cost of applied water to users is zero. Using volumetric pricing with the water priced at the marginal cost of delivery leads to efficient water use because the marginal cost reflects the opportunity cost of water. The marginal value of water in one use should equal the marginal value in another. Concerns about equity can be addressed through tiered pricing, while still retaining volumetric pricing and some level of efficiency. Often, there is no effort to recover fixed costs of water development, particularly in places where capital costs have been financed by international agencies. Attempts to recover fixed costs is usually done by applying a "hook-up" fee, where an individual has to pay a set fee for access to water from a source.

As mentioned earlier, efficiency can be gained with volumetric pricing of water. For efficiency, it is not sufficient to have an invariant marginal price for water. The value of water changes both by season and location. Ideally, we would like to impose a water pricing structure with variation in prices by both of these variables. While this sounds complicated, it is used in many places. Prices can change by time, location, or crop. These varying prices should reflect differences in the costs of supply, specifically conveyance costs and environmental side effects. In many places, volumetric pricing is not feasible due to the high costs of monitoring. It is possible to mimic volumetric pricing by imposing per-hectare fees that vary by the season/crop/irrigation choice.

Regardless of whether volumetric or per-hectare fees are used, it is crucial that these prices reflect the environmental side effects of water use. The use of greener/cleaner application technologies (such as drip instead of gravity irrigation) should be rewarded.

4.4. Groundwater Management

Groundwater suffers from an open-access problem, as an aquifer is accessible to anyone who builds a well. Each individual user affects the quantity of water available to others, but has no incentive to take that into consideration in their pumping decisions.

Groundwater resources are being exploited and being used at unsustainable rates in many areas of the world. For example, India increased pumping of groundwater by 300 percent from 1951–1986. This increase has continued in recent years. In using groundwater, farmers should pay both the direct pumping costs of obtaining that water, and a user fee to reflect future scarcity. Another issue is the subsidized costs of pumping. Many places have very low costs of electricity (the main cost of pumping groundwater). If the cost of electricity is subsidized, the perceived cost of pumping to farmers is below the actual cost. As with surface water, tiered pricing can be used to address equity issues between individuals. One concern is that a higher price of surface water will lead to increased dependence on groundwater resources, as water users substitute groundwater for surface water.

Because of the externality imposed on other water users, the elimination of electricity subsidies still leads to a sub-optimal groundwater price. The theory of exhaustible resources dictates that the price of groundwater should equal the sum of the cost of extraction and the user cost, with the user cost equal to the opportunity cost (Hotelling 1931; Devarajan and Fisher 1981). The user cost measures the loss of future benefits because of depletion and the increase in future pumping costs associated with depleted stock. A first-best solution would be to impose a tax equal to the user cost on every acre foot of groundwater extracted (Shah, Zilberman, and Chakravorty 1993; Howe 2002). However, the monitoring and enforcement of a tax such as this would be impossible given the costs and currently available technology. As discussed in Shah, Zilberman, and Chakravorty, a second-best solution would be to base the tax on the irrigation technology and crop choice.

As mentioned above, it is difficult to accurately monitor groundwater use. Despite this, it is necessary to have some monitoring of groundwater sources. It is possible to either do this directly, with test wells at various locations, or indirectly, by estimating water use based on land allocation choices. The fact that these are substitutes for each other requires a joint management plan of surface and groundwater sources.

4.5. Conjunctive Use of Water Sources

In managing water resources, there are several important differences between surface water and groundwater. Surface water supplies are replenished every year, but they are subject to large variation from year to year. Some groundwater sources can be recharged, while others should be considered a nonrenewable resource. For example, parts of the Ogallala aquifer in the Western United States has not had any recharge in over 1,000 years, and use of existing water is depleting the available reserves. For water management, conjunctive use of surface and groundwater can limit the uncertainty of surface water availability and the overdraft of groundwater. Conjunctive use of the two sources can decrease the risk associated with a stochastic surface water supply. In some cases, the separate management of groundwater and surface water resources has led agricultural producers to substitute groundwater for surface water after laws are passed to protect the environment through the reduced use of surface water. Therefore, the conservation goals of such policies are not achieved, as users substitute one unsustainable pattern of water use for another.

Arvin Edison Water and Storage District (AEWSD), located in California's Central Valley, provides a model of beneficial conjunctive use. AEWSD utilizes underground water banking in their water management plan. In years when they receive large quantities of water, they store some of it underground, providing a net gain in stored water. During dry years, when the water supply is insufficient to meet demand, they can pump this stored water for the growers in the district. Tsur (1997) estimates the value of this supply stabilization by the district to be $488,523 per year, a value equal to 47 percent of the total value of groundwater.

These outcomes show that there is a need to regulate surface water and groundwater jointly, as they are substitutes for each other in many places. Failure to do so can lead to inefficiency in water use.

5. WATER QUALITY AND ENVIRONMENTAL MANAGEMENT

For water systems to be sustainable it is not enough to have a large quantity of water available, it also must be of adequate quality. It should be noted that the definition of "adequate" quality varies by end use. The quality requirements of drinking water are much greater than that of water use in many industrial or agricultural applications.

5.1. Externalities

In economics, an externality is an unintended benefit or a cost imposed on a third-party. For example, producers get some economic benefit from the right to pollute water bodies. However, other users of the water (both for consumptive and nonconsumptive uses) are harmed, suffering a negative externality because of that pollution. If there is no regulation, polluters will ignore these externalities in their decision of how much to pollute. There are several ways that pollution can be decreased to a level that considers these externality costs.

Some of the most often discussed policy interventions are the use of taxes, subsidies, and quotas. Taxes impose a fee per unit of water use or pollution, equal to the damage incurred by third parties. Firms or agricultural producers will then take this cost into consideration when they decide how much water to use in their production decisions. Another possibility is to give firms a payment (a subsidy) for each unit of water they do not use. In this type of payment, the choice of a baseline level is difficult, but crucial for successful implementation. Using historical levels of water use punishes firms that were relatively efficient in their water use before the regulation. A similar solution is to subsidize the purchase of water-saving technologies. While these two policies can lead to the same outcome in a static framework, the long-term effects of a subsidy or a tax are different. A subsidy increases firms' profits, giving others an incentive to enter the market. A tax decreases total profits, and can lead to exit from the market.

Another possibility is the use of quotas, where a maximum level of pollution or water use is allowed, permits are distributed to potential users, and then those users are allowed to trade for permits between themselves. Examples of this include the 1990 Clean Air Act Amendments in the United States, which developed a tradable permit program for sulfur dioxide emissions of power plants. The choice of an appropriate policy depends on a number of factors, including implementation and monitoring cost, transaction costs, and political will.

Water quality management should be based on polluter-pay principles that control disposal of contaminants to bodies of water. When pollution can be linked to a polluter, and its marginal damage is known, a pollution tax equal to the marginal damage will result in an optimal outcome. However, it is often difficult to monitor individual pollution emissions, and to calculate the marginal damage of that pollution. Incentives may be used to encourage adoption of monitoring technologies and pollution abatement technologies to control runoffs and erosion. A major environmental problem is that of uncontrolled water movement, and the resulting soil erosion and flooding that occurs as a result. Better management of forest resources to limit soil erosion is a necessary part of water quality management.

In any policy designed to limit pollution, it is important to minimize the use of direct control. By allowing flexibility among users, efficiency and compliance are improved. The nature of a pollutant affects the choice of the regulatory mechanism. There are two distinctions that must be made with pollution. The first is the difference between point and nonpoint source pollution, while the second distinction is that of uniformity or nonuniformity in damages.

5.2. Point and Nonpoint Source Pollution

In discussing water pollution, it is necessary to distinguish between point source and nonpoint source pollution. The difference is mostly one of technology: point source pollution can be traced to the polluter using currently available, cost-effective technology, while nonpoint source pollution cannot be traced to a single polluter, but only measured in aggregate. To control pollution, a first-best policy is to tax pollution directly. As point source pollution is directly observable, it can be controlled with a single tax per unit of emissions. This requires monitoring each firm. While this can be costly, several solutions are available to help with the cost.

One type of program can include self-monitoring, where firms are responsible for reporting their emission levels to a regulatory agency, and are subject to a fine if they report inaccurately. One example of a program that uses self-reporting is the Environmental Protection Agency's (EPA) Permit Compliance System. This program enforces standards for water pollutants. Shimshack and Ward (2005) show that there is little evidence of strategic behavior by individual firms, and that self-reporting is usually accurate. Another possibility is for the government to take a role in subsidizing monitoring costs. This decreases the cost to individual firms and regulatory agencies.

While it is ideal to monitor and tax pollution directly, with nonpoint source pollution this may be impossible. Shortle and Horan (2001) describe some of the difficulties and developments that have been made regarding the control of nonpoint source pollution. For example, if pesticides are used by farmers and enter the water system, it might be impossible to accurately measure the quantity of runoff associated with each farmer. One method that can be used is a tax of an associated input. Using the example above, while it is difficult to accurately track pollution from pesticide use, placing a tax on pesticides when they are sold is relatively easy to enforce, and will lead to the desired outcome of less pesticide runoff. If different technologies are available to an industry, and some are more polluting than others, taxing either the use or purchase of the "dirtier" technology is another option. Another possibility is to subsidize certain behavior, such as the use of integrated pest management (IPM) or low-tillage crop production. Similarly the protection of forest resources, particularly in mountain regions, reduces soil erosion and increases water quality. Subsidizing those who protect these resources can reduce water pollution. In cases where these programs are not feasible, one option is to impose a lump-sum tax on any operating business. Despite the lower cost of implementation, this option is not a good choice when there is a lot of heterogeneity among firms. If firms are fairly homogeneous, however, it can work well.

In determining the appropriate policy to reduce water pollution, decision-makers must make a distinction between point and nonpoint source pollution, and develop policies that are appropriate to the kind of pollution. This could mean either taxing a pollutant directly, or taxing another input into the pollution generating process.

5.3. Uniform and NonUniform Damages

An additional distinction must be made between pollution damages that are uniform and those which are not. If damages are uniform, the total level of emissions is what matters in determining appropriate regulatory policies. If damages are nonuniform, the policies of pollution control should vary spatially. An example of a pollution problem with uniform damages is greenhouse gas emissions, where an individual firm's emissions are not as important as the combined total emissions from all firms in determining damages. Generally, damages from water pollution vary spatially. For example, a polluting factory that is upriver from farmers and urban communities affects all downstream users who require a clean water source. Because of this, it is not optimal to charge a constant tax on pollutant emissions for all users—those who are in locations where the pollution causes greater damage should pay a higher tax on their emissions.

When damages are uniform, a tradable permit program can be an effective way of limiting total pollution. When damages are not uniform, trading can only be allowed in a small region, or should be otherwise restricted.

5.4. Environmental Services

A public good has some element of non-rivalry and non-excludability in use. This means that one individual can enjoy the benefits of the good without reducing the benefits to another, and that it is difficult to restrict people from these benefits. Environmental services are benefits that accrue from either the preservation or improvement of natural resources. For example, the preservation of a forest sustains biodiversity, acts as a carbon sink, and reduces soil erosion. While environmental services tend to be underprovided by the private sector, they are a growing portion of environmental policy interventions worldwide, with several examples of successful programs in existence.

An example of a program used for the purchase of environmental services is the Conservation Reserve Program (CRP) in the United States. This program pays farmers to set aside crop land to be preserved as natural habitat. Other examples of this type of program are funds to buy wetlands in California or to protect the Pyramid Lake in Nevada. The U.S. Fish and Wildlife Service used a purchasing program of land to protect Pyramid Lake, where the purpose was to acquire the water rights necessary to protect the lake itself. In 1997, Costa Rica established a system of payments for forest environmental services, with hydrological services such as the provision of water for human consumption, irrigation, and energy production explicitly recognized as one of those services. The goal for this program is to eventually be self-sufficient with its funding. This has not been achieved yet, with hydroelectric power plants being the primary beneficiary group to contribute money to the program (Pagiola 2002). Another example of the successful use of an environmental services purchasing plan is seen in Sukhomajri, India (Kerr 2002). In this program, authorities built a system of irrigation water pools to benefit a local village. In exchange for protecting a fragile region prone to erosion, which resulted in the siltation of a recreational water body; the villagers received ownership of the irrigation water provided by the project development. The development of a water market between villagers allowed both landowners and landless peasants to share equally in the benefits of the project, providing an excellent example of how these programs can benefit everyone involved.

As discussed by Viviroli and Weingartner in this volume, mountain regions provide more than their share of freshwater resources. They also find lower variation in these water supplies than those originating in lowlands. Since mountain regions are often the source of water for downstream areas, keeping water resources clean provides a benefit to downstream users. In designing programs to purchase environmental services, the choice of which areas to target is important. As shown in Babcock et al. (1997), this is not always the least expensive land or the most ecologically diverse land. These two indicators are often not independent of each other—it could be the case that the most ecologically diverse land also has the richest soil, and therefore is the most lucrative for agricultural production. Their analysis shows that it is important to try to target spending to get the highest value of environmental benefits per dollar spent. This can be seen in Figure 1.

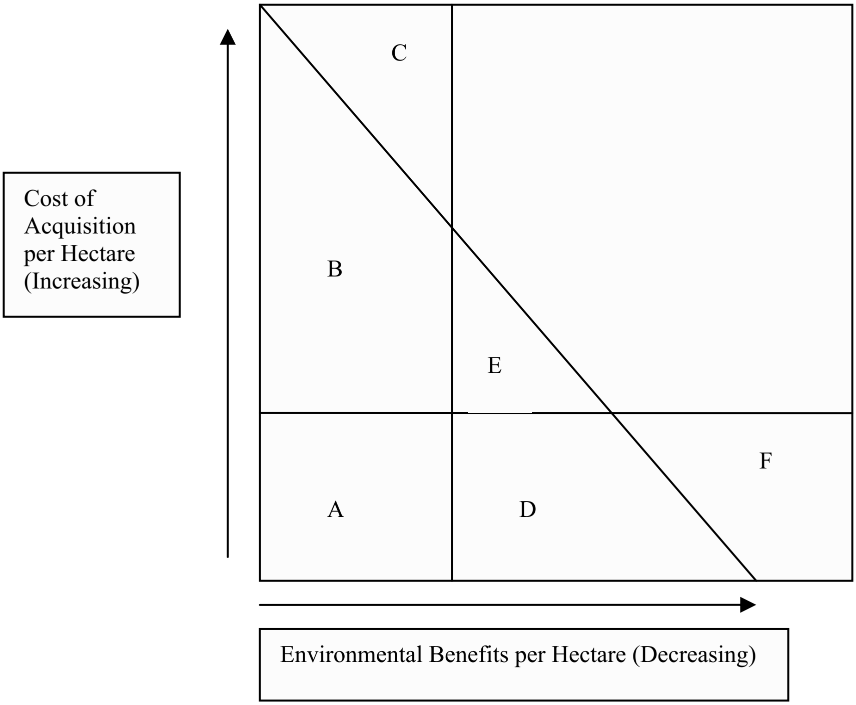

Figure 1: Distribution of Environmental Benefits and Cost of Acquisition per Hectare (Babcock et al. 1997).

In the past, many programs have either tried to focus on acquiring the largest possible area of land, or on saving only the most ecologically important. In Figure 1, the first goal would target regions A, D, and F; while the latter goal would target regions A, B, and C. Babcock et al. argue that with limited funding a program should target regions A, B, E, and D.

Mountain regions provide many environmental services. For example, protecting forests in mountainous regions decreases soil erosion and runoff. Combined with the fact that mountainous regions are often marginal for other activities (agriculture or urban development), mountain regions are a logical target for purchase through conservation programs, and should be targeted in a program where the goal is an improvement in water quality. For any type of program that purchases environmental services, monitoring is crucial to see that purchases are effective.

As policymakers continue to develop programs that pay for the environmental services provided by natural areas such as mountainous and forested regions, they need to develop strategies that target the areas which provide the highest level of environmental service per dollar spent. Failure to do so will waste limited budgets, and provide levels of environmental services lower than the full potential.

5.5. Learning and Information

With any chosen policy, information is crucial. An effective policy requires accurate valuation of the environment and environmental degradation. Monitoring is also necessary to ensure that individuals do not pollute more than they are permitted to. In some cases, pollution is not directly observable. For example, it might be impossible to accurately measure emissions of certain pollutants. In these cases, it is still possible to regulate by taxing the activities that lead to pollution instead of applying direct taxation. An example of this would be to have organic farmers pay a lower price for water than conventional farmers, who cause water pollution when pesticides and fertilizers enter the water supply. Organic farmers, who do not use these items, should not have to pay for the environmental costs of their use.

Unlike the case of perfect information, the seminal work of Weitzman (1974) showed that when environmental benefits and costs are uncertain, the choice between taxes and tradable permits leads to different results. Much has been written since this paper was published, but a major theme is that uncertainty matters in policy development. A program of adaptive management, one that allows policies to change as more is learned, is necessary. Designing effective water policies requires constant learning and updating of knowledge of natural phenomena and human behavior. Development of new monitoring technologies can help to track water pollutants and assign appropriate penalties/rewards. The use of satellite imagery can aid in the spatial analysis of different policies. An example of an agency that currently uses this technology is the Argentinean government. They recently started a program that uses satellite imagery to observe the crops and acreage that farmers have in production, and they are using this information to collect appropriate taxes (Smith 2003). Similar programs could be used to monitor individuals providing environmental services, or to assign appropriate taxes for pollution.

One crucial component of continued learning is policymaker education and interdisciplinary dialogue. In designing policies, we need to recognize the limitations of our knowledge.

6. CONCLUSIONS

In this chapter we have argued that humanity can do much more with the water we have already appropriated from nature. Our challenge is to introduce water policies and management strategies that will lead to sustainability of water resources. We argue that some current practices are sustainable while others are not, and that water resources may be depleted without intervention. The deterioration of groundwater aquifers throughout the world is a repeated example where subsidizing the price of water in the present may lead to resource depletion in the long run. The key elements of reform are the introduction of appropriate pricing and design of effective institutions and incentives that will promote conservation and responsible use of water, and reduce water contamination and pollution.

The policymaking process consists of many separated acts of decisions, and achieving sustainability will require reducing the likelihood of unsound policy choices. Therefore, water development plans need to be scrutinized by a social cost-benefit analysis. This analysis will consider the public and private, as well as the market and nonmarket, costs and benefits of proposed policies. Improved incentives can be used not only to address issues of a sufficient quantity of water resources, but also the quality of the water supply. Taxing polluters for the social cost of their activities will decrease pollution and ensure that pollution only occurs where its benefits outweigh the social costs. Public programs need to be developed to pay for conservation, environmental services, and other public goods. For these programs to work, the development of new technology for monitoring and enforcement are essential and need to be well utilized.

While we have a growing knowledge about policy design, we are also aware that implementation of reform is challenging intellectually and politically. Good science and economics are necessary but not sufficient for achieving water reform which is first and foremost a political act. A successful reform requires political will, leadership, and timing. Reform may be embodied in policy packages that are not ideal but represent major improvements. Reform has to be designed so that possible losers will not master the power to block it. So a reform may include compensations and resource transfers. The design of the reform may need to take into account not only the power distribution between various consumers and consumer groups, but also between government agencies, to overcome barriers by potential losers of reform. History has shown that frequently it is necessary for a crisis situation to occur (such as a severe drought) to develop the political and economic conditions that will lead to changes of policies. It is important that policymakers be well informed so that the opportunity afforded by a crisis can be used to make the best reform decisions.

The implementation of sustainable policies is still hampered by a lack of sufficient information. There is a need to know the parameters of both damage and benefit functions that show the relationship between people's behavior, policy choices, and the natural environment. There is a need to move to more interdisciplinary research efforts that incorporate biological, economic, and engineering knowledge to develop integrated decision-making frameworks resulting in ecologically sound and economically efficient solutions. Improved water policies have a limited capacity to lead to sustainable outcomes, as other policies are also of paramount importance. Water resource use depends on other factors and social trends. Many processes and factors generate pressures on water resources and threaten sustainable use. These include population growth, subsidization of agriculture and other industries, neglect of the risk posed by climate change, insufficient control of urban sprawl, and mining of the ocean or natural resources. Achieving sustainable water policies must thus be part of an across-the-board effort to attain resource sustainability.