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Irrigation Water Management Economically

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Abstract

The post-World War II era saw a significant increase in irrigation activities that contributed greatly to the massive growth in agricultural production that enables humanity to feed its multiplying population. However, a distinction must be made between the overall positive contribution of irrigation and water to agricultural productivity and economic well-being, and a great deal of misallocation and mismanagement of the resources that accompanied the expansion of irrigation. In many cases, water resources were too much; there was excess spending on capital; And significant costs in terms of loss of ecosystems, extinction of fish species, and pollution of water sources. This research provides an economic perspective on the contribution of irrigation and water resources to past agricultural development and future water resource management.

Water use efficiency is affected by decisions taken at many levels. In this research, we first analyze the shortcomings that can occur at different levels of water management. We start with a discussion of the use of irrigation water by the individual, and then we turn to the importance of regional water management. Then we discuss the importance of dynamic considerations about the future and the role of interregional management. Together, these departments provide an economic framework for designing water institutions and policies to improve the allocation of water resources and prevent some of the current deficiencies in water resource systems. The second part of the research provides an overview of the benefits and costs that have been achieved through agricultural water and irrigation projects in developing countries. There is a dearth of posterior integrated evaluations of these projects, so we grouped the parts together, gathering data with conceptual arguments.

Keywords: Developing Countries; Economic; Irrigation; Water Management; Water Resources

Overview

The previous century saw unprecedented growth in irrigation projects globally. The use of piped irrigation has reduced the cost of using groundwater, and large reservoirs and canals have been supported to achieve food security. Worldwide, irrigated land increased from 50 million Maha (million ha) in 1900 to 267 Maha today, most of which is in developing countries [Gleick (2000)]. There is currently 75% of irrigated land in developing countries. Irrigation has increased the area of cultivated land and yields on existing agricultural land. It also allowed the cultivation of double crops, and reduced uncertainty about the water supplied by the rain.

And in the continent of Asia, it benefited a lot from irrigation. The countries with the largest irrigation area are China, India, and the United States, which consistently contain about half of the irrigated land in the world. Other regions like Africa have little land under irrigation. The global total shows a significant increase in irrigated land, with nearly doubling in a 30-year time frame. In addition to that, we find that the percentage of irrigated crop cultivated lands varies greatly between regions. For example, in Asia in 1995 it had 32.4% of all agricultural land under irrigation, while in Africa it was only 6.1%. Also, some countries, such as the United States and China, had their share of arable land in irrigation relatively stable between 1965 and 1995, while in India this proportion almost doubled.

While there is little land for irrigation in certain regions of the world, such as Africa, in some cases, there is a large amount of potential irrigated land. One interesting thing to note is that the ratio of actual land to potential irrigated land is much greater in Asia than in Africa and South America. One of the conclusions we can draw is that future expansion in the irrigated area is limited in Asia, but there is great potential in other developing regions of the world. However, the distribution of potential irrigated land has a great deal of variation. This disparity in Africa and its implications for development and food security are discussed in more detail in Rosegrant and Perez (1997).

An important concern for the future is the limited supply of fresh water. Recent years have seen a decrease in the number of water projects built around the world, due to environmental and cost concerns. Most of the areas that are good sites for water projects have already been developed, and more is known about the negative environmental impacts of building large dams and poorly managed irrigation systems. Evidence of this change can be seen in projects funded by the World Bank. There has been a shift from developing new irrigation projects to improving existing irrigation facilities. Examples of this type of competition in water supply in the Aral Sea region sponsored by the World Bank and IWMI [Murray-Rust et al. (2003)].

Water resources are not distributed evenly around the world, and arid regions will continue to struggle with water supplies. In addition, a growing population in developing countries is expected to increase total food demand in the next century. Those in developing countries eat more meat products, and the demand for cereal crops increases as feed for livestock as a result. The International Food Policy Research Institute estimates that to meet demand in 2025, global cereal production will have to increase by 40% compared to 1995, and it will be better to manage existing water systems, along with the use of more efficient irrigation techniques in the coming decades. Thus, in this part of the research assessing the performance of irrigation systems in the past and providing a direction to reform the water system for the future...

Multiple Dimensions of Water Management

Water use efficiency is influenced by decisions at several levels of management but to explain some of the choices made at each level, and options that affect the efficiency of the entire water system. When choosing the optimal system design, it is important to use the reverse induction approach, and base the system design on the expected responses at the district and farm level.

Partial water management options

The efficiency of irrigation systems is determined by farm-level options, which include land allocation options between crops, the extent of irrigation of these crops, the use of non-aqueous inputs, and the type of irrigation techniques. These options are interlinked, and the full modeling of these choices is likely to be complex, so here we discuss land allocation between activities. First we address the choice between rainfed and irrigated agriculture, then we move to choosing a specific irrigation system.

Allocation of land for irrigation at the farm level

There are extensive literature on technology adoption that is useful for analyzing the choice of irrigation areas [Feder, Just and Zilberman (1985); Vader and Amalie (1993)]. To a large extent, this literature assumes that farmers avoid risks and are constrained by the availability of credit. Approving irrigation reduces risk and increases yield, but requires additional investment. The expected net profit per acre under irrigation is greater than rainfed agriculture. Consequently, irrigation will increase because the gain from irrigation is large, the impact of reducing irrigation risk is greater, costs of irrigation smaller, and credit less restrictive. From this result, we can conclude that support for investment in irrigation financing is likely to increase the area under irrigation, especially with increased yield gains and reduced risks from irrigation.

Choose irrigation technology at the farm level

Farmers have no choice to grow crops on rainfed lands. In many places, precipitation is not enough to grow any crop. In these cases, the farmer cannot choose irrigation or not, he / she must choose the type of irrigation technology to be employed. Conventional irrigation methods, such as flood or groove, use gravity to distribute water over a field. These methods have low adoption costs, but are also relatively ineffective in water use. Modern technologies such as partial spraying or drip irrigation have high adoption costs, but direct water delivery to the crop and water use is more accurate than traditional techniques. To discuss the efficiency of different types of irrigation technology, we will use the concepts of "effective water" and "applied water". Applied water is the total amount of water that a farmer uses in the field, while effective water is the amount of water actually used by the crop. The difference between the two is due to evaporation and runoff, and irrigation efficiency is the ratio of the effective water to the water used. In addition to irrigation technology, land quality characteristics such as the slope of the earth and the ability to retain water in the soil affect the efficiency of irrigation. Theoretical and experimental studies have shown that the increase in water prices is positively correlated with the adoption of precision irrigation technology [Caswell and Zilberman (1985, 1986); Dinar and Yaron (1992)].

According to Caswell and Zilberman (1986), under reasonable conditions, modern irrigation techniques increase yields and provide water in most cases, but the gains from this technology are reduced as the quality of the land improves.

Because the differences in the ability to hold water lead to differences in the effective price of water, as the actual price falls under traditional irrigation as the quality of the land improves. Therefore, the relative gains of converting to micro irrigation are less with high quality land. Except in cases where the initial ground quality is very low, this is a productivity gain that will also be associated with water supply. Adoption occurs when the effect of microprocessing yields and providing prices is greater than the fixed cost of technology, and therefore we expect modern technology to be adopted first in sites with low-quality lands such as steep hills and sandy soils. Another nontrivial consequence of the analysis is that the availability of effective irrigation technology can actually lead to a net increase in water use in a particular area. This is because there are two types of effects from the availability of effective irrigation; Those on the fringe margin and those on the wide margin. On the intensive margin, farmers who adopt effective irrigation technology are likely to reduce total water use; however, there can also be a change in the wide margin. Low-quality landowners often find it not profitable to farm using traditional irrigation methods, because the effective water price is high when the irrigation efficiency is low. However, modern irrigation technology increases the efficiency of water use, which reduces the price of effective water. This can make it profitable on farmland that has been left under irrigation by floods, and both intense and intensive changes in water use must be evaluated with a change in the price of water or the availability of technology.

The increase in water use efficiency reduces unused water, and therefore with drip irrigation, the problems of water accumulation and water saturation decrease. Caswell, Lichtenberg and Zilberman (1990) explain that when a drainage sanction is applied, the adoption of drip sprinkler irrigation is likely to accelerate. These technologies provide increased productivity as well as lower negative externalities, and their adoption will be enhanced by improving water pricing and introducing exchange fees, and providing the right incentives for farmers to adopt effective irrigation can be a triggering effect on water use. Switching from groove or sprinkler irrigation to drip systems reduces water applications by up to 35% [Schoengold, Sunding and Moreno (2005)]. The global use of drip irrigation is twenty-eight times from the mid-seventies level, but it still represents less than 1% of the irrigated area in the world, while sprinkler irrigation is used 6% of irrigated land [Postel (1996)]. Improving water efficiency is not just about agriculture, industrial and residential water users can do a lot as well to improve water efficiency. Thanks to the technologies available today, farmers can reduce demand for water by 10 to 50%, industries by 40-90%, and cities by a third without sacrificing economic output or quality of life [Postel (1996)].

Water productivity

An important factor in determining the response of farmers to the change in water prices is the form of the function related to production production with water inputs. After Caswell and Zilberman (1985) we determine the output per acre (Y) as a function of effective water (e), where effective water is the amount that the plant uses. This is equivalent to the product of the water efficiency efficiency applied.

Some early work on water productivity was performed by Hexem and Heady (1978), who use field trials in the United States to estimate yields as a function of inputs including water and fertilizers. One of the commonly used production functions in economic literature is the Cobb-Douglas production function in the form $Y = Ae\delta$, with the condition that $\delta < 1$. While some work has shown that this representation is reasonably accurate at the aggregate level, economic evidence has shown that this is a poor representation of the yield response to water at a more minor level. There is evidence that the quadratic function, such as $Y = a + be - ce2$ where a, b, $c > 0$, is a better representation of the water productivity. This functional model has the characteristic that, above a certain level of input use, yields begin to decrease. With extreme weather shock, such as floods, while these values may be possible from an engineering perspective, designing appropriate policies that provide the right incentives for individuals to change their behavior is difficult. As such, these are difficult to achieve reduction levels in practice, and it is easy to see how the crop field is washed, and the benefits of that additional water are negative. Berck and Helfand (1990) demonstrated that different options for functional forms of production can be reconciled around the heterogeneity of land quality.

In addition to the theoretical work done on the functional form of water productivity, experimental work was done to estimate the returns from water in several locations. One study of the Sir Darya River basin found that the average return on water in the region is \$ 0.11 / m3. However, this value varies significantly across the region, and the use of water in non-saline areas is five times higher than in saline areas [Murray-Rust] et al. (2003)]. The relationship between high yielding varieties (HYV) and water productivity was also worked out. Since HYV increased the marginal product of water, it was also found to stimulate investment in irrigation.

Low-efficiency irrigation techniques

Effective irrigation techniques do not necessarily require high capital cost for adoption. Examples from water-scarce areas show farmers 'versatility in adapting to limited water supplies. One example is the settlement of agricultural land. Agricultural land areas have been used for thousands of years as a means to increase the efficiency of applied water. A flat surface reduces water flow and increases the water use efficiency of the plant. Another method that has been used is to place clay pots below ground level near the roots of tree crops. Porous clay allows water to slowly drip from the pot, and provides a steady supply of water to the tree. Another example of low-cost irrigation technology is the use of village tanks in India. Traditionally, villages in India collected rain water in tanks, with each village.

Existence of a system that determines how water is divided between users, and who is responsible for maintaining the system [Whitaker, Kerr and Shenoi (1997)]. The low-capital drip irrigation system that is used in parts of India has also been developed. This system uses simple perforations instead of emitters and fabric filter. Although much less capital investment is required than most drip irrigation systems, they are remarkably effective in water use [FAO (1999)]. The use of drip irrigation can reduce the bucket, a method by which water is connected via drip tubes to a dropping bucket, using water by up to 50%.

Regional allocation of water

At the regional level, there are many aspects of water management that must be addressed to improve the overall efficiency of the water system. We will first discuss the initial options that were made around the system, including the location and size of the water project, as well as the importance of project financing. Then we move on to discuss important management options for existing systems, such as transportation, water circulation and water pricing.

The primary economy for mega water projects

In the decision to construct a new water project, the project benefits must be compared to costs. Mega water projects in the western United States were some of the first government funded projects that required benefit and cost analysis before approving the project. International water projects funded by international agencies such as the World Bank require such studies before approval. In addition to the site's decision, the size of the dam and the transportation system must also be chosen. Economic theory has an insight into choosing the optimum size of a dam, while dams provide many benefits by providing irrigation water, hydropower and flood protection. The full costs of construction are often overlooked, both in the decision to build a dam and in choosing the size of the water project. External factors associated with construction are often overlooked entirely, reducing the perceived marginal cost of development. And development costs are often subsidized, either by governments or international agencies. In these cases, the perceived costs of water development are lower than the real private costs.

The costs of building a dam can be divided into two categories - direct capital, construction costs, and external costs. The marginal direct cost of building the dam is shown, while the marginal social cost appears. The difference between these two curves represents the external factors associated with the dam construction. These external factors include environmental costs such as the destruction of natural habitats and land degradation, and other costs such as the loss of well-being of the displaced population. Now let's say building is supported. Because of the support, the cost to developers is often much lower than full private costs, the dam capacity will be very large, and the marginal benefit of the water provided will be very low. If the full social cost of dam construction is taken into account, it is also important to take into account the relationship between storage capacity and other components of water delivery. The benefits of water development are three activities - transport, management and storage capacity. To some extent, these three activities can be considered alternatives to each other. When subsidies lower the relative cost of storage capacity, there is an excessive investment in storage capacity and a lack of investment in the transfer and management of irrigation systems. While it is clear that irrigation and water development has provided tremendous benefits, the omission of real costs has led to the construction of large dams, often in unsuitable locations for the development of the water project due to fragile landscapes and ecosystems.

Transportation Systems Management

The construction of water transmission systems is an important component of the overall efficiency of the system, as better management of transportation systems reduces the need for new water projects. Many canal systems were built at a time when the costs of creating an efficient distribution system were greater than the additional benefits, and there are various ways to improve water distribution. For example, lining of canals is one way that can limit the amount of water lost during transportation. Another problem is poor maintenance of existing canal systems - over time there is degradation, which leads to increased amounts of lost water. Poor management of irrigation systems results in transport losses of up to 50% [Repetto (1986)]. Inefficiency also stems from lost water evaporation in the channels and reservoirs.

These problems have a disproportionate impact on downstream users of the water system, which creates equity problems among different water users. Keeping the Channel System in one location has benefits for local users. However it has lost its benefits to all downstream users of the water system. Because of this, channel maintenance provides a positive external effect, as the social benefit of channel maintenance is greater than each user's private benefit to water. If these positive externalities are ignored, there will be little investment in channel maintenance, leading to an inefficient water transmission system. Chakravorty, Hutchman, and Zilberman (1995) show that without teamwork (which leads to ideal investment and transportation), channel systems would be shorter than optimal, with overuse of water near the source and lack of application far away. The move to optimal transportation will expand the channels and production and will actually reduce the rate of land lease that is upstream, although the overall lease is likely to increase.From the development of new water projects to better management of existing projects. This has resulted in increased reliance on WUAs. WUA is a group of farmers who collectively manage and distribute the available water supply together. The transition to water resource management is encouraged by water users as a means of achieving this, improving transportation systems, cost recovery and water efficiency. In various places, water user associations have been present alongside state-run irrigation systems for many years. Evidence indicates improved yields, improved transport structures, more efficient maintenance and more reliable supply with water user associations. One of the important questions for economists is the effectiveness of different management strategies for a common resource.Irrigation system. In a study of farmers-managed Mexican irrigation systems, Dayton Johnson (2000) examines the incentives an individual provides to provide collective maintenance work under different WUA distribution rules. He believes that due to the high costs at the system level, the system in which work requirements are distributed and water allocation proportionately may not be optimal. The best system is an equal system with work requirements and water distribution, with the possibility of circulation among members. It was also found that economic inequality among water users is positively correlated with the relative distribution rule, which is evidence that wealthier land owners can press for a higher share of total water supply.

One of the countries that mainly use water user societies to manage irrigation systems is Madagascar. A 1990 decree required water users to pay for the irrigation infrastructure, and the result was an average cost recovery of 80-90%, much higher than most developing countries [Rabemanambola (1997)]. Another country with increasing use of water users' associations is India. Since seeing a drop in irrigation performance, Andhra Pradesh, India has created over 10,000 WUAs covering 3.7m of land. As Dayton Johnson's findings indicate, some level of equal land holdings appears essential to the success of the Water Users Association. Pakistan, where in many areas there are few landowners, has been less successful in forming water users' associations. In Hubei, China, one of the goals of becoming a water user association is financial independence. Water users' associations are required to purchase the water they use, giving them an incentive to conserve and use water efficiently [Easter (2000)].

The political economy of water system management

Understanding the policies underlying water resource development and management is crucial for future improvement. The work done by Rosser and Zusman (1991) shows that when policymakers place unequal weights called "political power" by (Rosser and Zusman) on different interest groups, the resulting pricing and allocation methods are economically ineffective. Rauser (2000) is expanding this model to include a multilateral bargaining model based on the Nash-Harsani bargaining framework. This model shows the trade-offs between different interest groups interested in distributing water. One of the reasons given to explain the mismanagement of transport structures in many public irrigation systems is called "political economy for neglect." This theory says that if agencies fail to provide them with the necessary maintenance their irrigation system will be rescued by a donor agency, and there will be less incentive for them to provide effective levels of maintenance. This situation is described in many public irrigation systems. Funding for the initial costs of project construction usually comes from agencies such as the World Bank or the Asian Development Bank. This funding often depends on the recipient country managing the irrigation system so that the revenue covers the operating costs of the system. However, countries also know that if they fail to properly maintain irrigation systems, international agencies will provide additional funding. This provides an incentive for the public agency to neglect to provide adequate maintenance and create a cycle of reliance on external financing.

Another explanation for mismanagement and low quality service was discussed in Spiller and Savedoff (1999). Their paper looks at how government opportunism affects efficient water supply. Their paper focuses on countries in Latin America, but many conclusions have general implications. They discuss the emergence of low-level and high-level balances in providing water service. A low-level equilibrium indicates the state where the government wants low water prices to keep its citizens happy. When water is supplied either by public agencies, or private agencies that can be partially controlled by the government, water prices are kept artificially low.Unless you get support from other sources, this results in limited service and poor infrastructure, and generally undesirable to pay higher prices for the water service that they consider to be ineffective and of low quality. While it does not increase social well-being, the low-level balance is stable. For a high-level balance, with a high price of water, a well-maintained quality water service improves social welfare. However, in cases where the government is short-sighted and controls water service, it may not be stable. In their analysis of Latin America, Spiller and Savedoff identified several countries in each category. Honduras and Peru are examples of countries with low-level balances, while Mexico, Chile, and Argentina have high-level balances.

Moving from water rights to water markets

Water rights systems In most parts of the world, the price that water users pay is much less than the marginal value of a water product as input. Current estimates of the ratio of water charges to farmers' benefits range from 26-33% in Korea to 5% in Nepal [Repetto (1986)]. Given the low price that users pay, the demand will greatly exceed the water supply if allowed. Since water resources are scarce, and the price that users pay is less than the input value, the water should be allocated using a non-market mechanism. In many parts of the world, water is allocated using the "queuing" system [Easter (1986); Chambers (1988) of the Indian Peninsula; Lee (1990) for South America]. Queue systems use either a historical or spatial basis to assign an order to users of the water system. The pre-assignment system and the beach rights system are two of the most common types of queuing systems. The pre-assignment system is based on the principle of "first in time, first in right". Seniority in water rights is granted to the first person to divert water for beneficial use. The riverbanks rights system gives any landowner who has land adjacent to the water source the right to use that water. Also common are restrictions to trade within the catchment system.

In these systems, the major rights holders or users of flowing water have little incentive to invest in water-saving irrigation technology, as they are guaranteed by a stable water supply. These types of systems were established at a time when water was abundant, and governments wanted to provide a catalyst for private development and innovation. However, water in many systems has now been overly allocated, and better management is necessary to optimize the use of a limited resource. The transition to trade and markets imposes restrictions on trade in water, which leads to inefficiency in the distribution of water, and there is no economically effective type of system, as water is not used in the activity where it gets the highest marginal value. Economic efficiency dictates that if the transaction costs are low, either water markets or negotiable permits are the best way to allocate water supplies [Burness and Quirk (1979); Coase (1960)]. These systems ensure that rare water flows to the user, who earns the most marginal value from the water.

With the prior allocation system, the demands of large rights holders are fully met before small rights holders receive any water. If the water is not very scarce, the costs of water circulation transactions may be greater than the benefits. However, as the demand for water expands over time and the shadow value increases, the benefits of trade will outweigh any transaction costs. Evidence for this is evidenced by observations that in developed countries that allow water circulation, commercial activities increase dramatically during droughts. Also, as Johansson (2000) discussed [citing the works of Renfrew and Sparling (1986), Shah (1993), Anderson and Snyder (1997))], Informal water markets were frequently developed under conditions of water scarcity.

There are alternative water trade mechanisms to take into consideration when introducing repairs. The first option is whether to use a transferable permit system or transfer ownership of water to government agencies that will sell it on the market. Water users with higher rights prefer transferable rights systems because they are able to earn the associated rents. The water agency may prefer water markets, because it earns revenue from water sales, and can use the revenue to improve service and management of water supplies. Brill, Hutchman and Zilberman (1997) distinguish between active and passive water markets. In the case of negative water markets, water users buy and sell water to a regional water authority that controls water supply and transportation. In the case of active markets, agents trade among themselves. Negative markets are more appropriate within regions, especially among water users who serve the same tool, while active markets are appropriate between regions.

Another option is whether individuals are only permitted to lease the right to use water on an annual basis or allow full transfer of property rights. In rare droughts, leasing water rights to those with a high willingness to pay may be a better option than permanent sale. In places with chronic water shortage, the rights holder may be in a better position to sell those rights. In addition, the permanent sale of water rights secures a future water supply for users. This could boost capital investment in land that will not occur with unconfirmed water supplies. The third decision is whether to allow out-of-basin circulation among water users. When water users in one pool are allowed to circulate, transaction costs, especially third-party costs and environmental costs will be lower. If water users are allowed to circulate their rights outside their water basin, concerns about the effects of the third party should be addressed. These may be third parties to individuals who use flowing water or deep water from the ground, or environmental benefits that accumulate by providing the remaining fresh water. Addressing these issues may require determining the amount circulated in effective water, not water used by the individual. Easter and Baker and Tzur (1997)....

Examples of countries that have moved to water markets are Chile, South Africa, and Australia. Chile is perhaps the most well-known example of such a transformation on a national scale. In 1981, Chile reformed its water law, thereby changing the nature of water rights. After the change, water rights became completely separate from land ownership, and they can be bought, sold or rented freely. The government now has little control over water use, and most administrative decisions about transportation and maintenance systems are made by private water users' associations. An interesting result of the shift to water markets in Chile is that a few transactions have been observed in practice, while most transactions are combined with the sale of land, and the right to water is rarely sold separately from land rights. Part of the reason for this is the depreciation of the land without water rights. There are also institutional reasons - at the time of repair, there was a lot of uncertainty over ownership of much of the water used. Much energy since the reform went to water rights limitation, and some regions have seen water rights approval times like water sales. Well-defined water rights are clearly a necessary condition for improving water sales. In some cases, though, the initial water distribution is not far from optimal. However, even if only a small percentage of the total water used is sold and these are final sales, the impact may be significant if the profitability in the productivity of this water is significant. Ultimately, as water rights are better defined, new actors enter the system, and conditions change, transactions increase.

Another example of a country with a major change in water law is South Africa. In 1998, the new South African Water Act changed ownership of water from private to public; however, farmers still have special rights to use certain amounts of water. Water transmission between users is permitted, although certain administrative policies must be followed. Nieuwoudt, Armitage, and Backeberg (2001) discuss case studies of two agricultural regions to highlight factors that could either lead to or hinder an active market for water trade. They found that despite the costly administrative requirements, the Lower Orange River region has an active market for water trade. Reasons for this include water scarcity and a heterogeneous group of water users. Some farmers in the area grow table grapes, a high-value crop, while others grow wine or raisins, which give them a lower price. Since the marginal value of water is greater for table grape growers, the benefits of trading outweigh the transaction costs. In the second area (Nkwaleni Valley), an active commercial market failed to appear. Despite water scarcity, none of the water users were willing to give up their water rights. The farmers in this area are fairly homogeneous, and they all grow a mixture of sugar cane and citrus. While some are willing to buy more water, if available, none of them wants to sell it. One of the obvious effects of these results is that for water to circulate successfully there must be homogeneity among potential water users.

Australia also moved to the water trading system, and separated land ownership from the right to use water, similar to Chile. The shift from traditional water rights stems from the growing awareness of the need for greater flexibility in water rights, and in particular, water resources are essential in natural habitats. A 1994 draft law separated water rights from land ownership, and set aside water allocation for environmental services and water market development. Results the change in Australia has been positive, and it is estimated that the annual gain from converting to negotiable water rights is $ 12 million in Victoria, and $ 60-100 million in New South Wales [ACIL (2003)]. Despite these gains, there are still some barriers identified as an obstacle to the highest possible returns to negotiable water rights. One of these barriers is a limitation on the lease of water use rights. Water rights can be permanently sold in all countries of the country, but some countries still place restrictions on short-term lease contracts (i.e. for one year) for these rights. Another aspect that has been identified as restrictions on trading benefits is the lack of an options market in water resources. Removing these barriers for a fully functioning water market will only increase the benefits that have already been achieved in Australia.

Water pricing systems

The costs of providing irrigation water include a fixed O&M cost and a variable cost that depends on the amount of water supplied. In addition, there is a capital cost for constructing a water project. There are many pricing systems used to recover some or all of these costs. In most countries, revenue received is less than the cost of providing irrigation water for users, and often does not attempt to recover the initial capital costs. Recovering O&M costs range from a low of 20-30% in India and Pakistan to a recent high of 75% in Madagascar [Dinar and Subramanian (1997)]. In some regions of India, receipts fail to cover administrative costs for collection [Saleth (1996)].

Water pricing systems can be designed to provide an incentive for water users to adopt water conservation techniques, or to change the area of cultivated land. It provides an incentive to reduce water use, while a hectare fee provides an incentive for intensive farmland cultivation. Some of the most common pricing systems are hectare fees, increase or decrease block rates, and volumetric fees. These rates can be fixed or dependent on the region and time of the year. Many systems combine these; For example, charging one hectare for water, then reduced fees for the water that is connected. This is the type of pricing system used in Brazil for irrigation water. Most irrigation water is measured in Brazil, and the irrigation law requires that the price of irrigation water be a total of two fees. One hectare is designed to pay off the capital costs of the project, which are calculated using a 50-year repayment period and a subsidized interest rate. Volumes are designed to pay for the operation and maintenance costs of the water project. However, the revenue from this is unpredictable and practically fails to cover the costs of the water projects [Todt de Azevado (1997)].

Inaccurate volumetric measurement is one source of inefficiency in water pricing stemming from an inability to measure the amount of water an individual uses. In many areas of the developed and developing worlds, the cost of installing measuring devices to accurately measure water use by individuals is prohibited. Various pricing systems have been developed as an alternative to volumetric pricing. Mostly, developing countries use water fees per hectare, if they charge a fee. One country that uses pricing for each region is Pakistan. In Pakistan, water fees are charged per unit area, and vary across region, crop and season. However, the difference in prices across crops is not related to either water requirements or the profitability of the crop. Other countries, such as Egypt and Indonesia, do not impose on farmers anything for the water they use but require farmers to maintain and operate the irrigation canal system. The most frequently used pricing scheme depends on the delivery time of the water. This system can approximate the volume scale using an expected amount per minute or hour.

Supporting water delivery costs while precision irrigation technology can significantly reduce water use, their adoption is minimal. One of the reasons for this is that the price of irrigation water in general does not reflect the value of water scarcity. Irrigation and water subsidies are provided in many areas, and the price often does not reflect the cost of delivery, not to mention the shadow value of a scarce resource. An example of ineffective pricing can be seen in India, where from 1983 to 1986, the estimated labor expenditures for major water projects were 2.2 times the total revenue received from water users [Saleth (1996)]. Using data from 1987, a study in six Asian countries showed that irrigation fees as a percentage of total cost ranged from 1.0% to 22.5% [Repetto (1986)]. Eliminating subsidies on water delivery will enhance the adoption of precision for irrigation water, which will reduce water use, increase yields, and reduce external environmental factors such as water registration and salinization.

Improving pricing and water theft is another benefit of the improved water pricing policies discussed by Ray and Williams (1999). Their paper explains the prevalence of water theft on the common channels in India. Upstream water users can steal water destined for downstream users, and penalties, if any, are usually a form of bribery for the inspector. Their analysis uses a linear programming model to show the effects of different pricing policies on farms along the canal. Elimination of price and water subsidies increases social welfare, but the gains are not uniform along the channel. Without water theft, farmers at all points along the canal have higher revenues at subsidized prices. However, when water theft is taken into account, farmers lose at the head of the canal, while those in the middle earn from converting to unsupported water and production prices. Those at the end of the channel are better off with a little support, but the loss of price improvement for them is minimal.

Groundwater management

Groundwater as an open resource. When the ownership rights to a natural resource are not precisely defined, there is often a problem with open access for many individuals. In cases where the resource is limited in supply, resource users will not take into account the implications of their use for future availability and resource cost for other users. The open access problem is one of the biggest obstacles to optimal management of groundwater systems. Since groundwater is rarely regulated, anyone has the ability to drill a well and pump water for personal use. However, since the same groundwater level is available to many users, each user causes an external impact on others, as a greater level of water abstracted reduces the availability of other users in the future.

Supporting the costs of pumping groundwater .One of the obstacles preventing effective management of groundwater is support for pumping costs. The main cost of pumping groundwater is the energy required to raise water to the surface. Electricity is subsidized in many countries, reducing the marginal cost of pumping, and leading to increased groundwater abstraction. Two countries support the costs of electricity are India and Pakistan, and this support is part of the reason for the overdraft of groundwater that occurs in these countries. From 1951 to 1986, the use of tank irrigation decreased slightly in India, while the use of canal irrigation and well irrigation increased significantly. Reservoir and canal irrigation depend on surface water, while well irrigation depends on groundwater supply. The area of land under the irrigation of the canal increased from about eight thousand to fifteen thousand hectares, while the land under good irrigation increased from six and a half thousand twenty thousand hectares, an increase of more than 300%. This is partly due to the technological improvements that make drilling wells and pumping water easier, but also due to the lower costs paid for pumping water. Electricity users pay a low flat rate, which almost eliminates the marginal cost of pumping groundwater [Whitaker, Kerr and Shenwei (1997)].

Introducing groundwater pricing efficiently Because of external factors imposed on other water users, eliminating electricity subsidies still leads to a lower price than groundwater. The theory of exhaustible resources dictates that the price of groundwater must equal the sum of the cost of extraction and the cost of the user, with the cost of the user equal to the opportunity cost [Hotelling (1931); Devarajan and Fisher (1981)]. The first best solution is to impose a tax equal to the user's cost on every acre of extracted groundwater [Shah, Zilberman and Chakravorty (1993); Howe (2002)]. However, monitoring and enforcing such a tax would be impossible with the cost and availability of the technology currently available. As discussed in Shah, Zilberman, and Chakravorty (1993), the second best solution is to base the tax on irrigation technology and crop selection.

Among the allocations of the water sector

One area is the interaction between agricultural water users and other sectors, such as urban and industrial groups. Often there is not only poor water distribution between farmers, but also between sectors. With limited water supplies, competing interests among user groups become important. Of these three sectors, agriculture uses the black share in the water supply, despite the fact that it often earns the lowest marginal value for water. As the population increases, pressures also provide a sufficient amount of water for domestic and industrial purposes, causing conflicts between sectors. This has been true for over 100 years in places like California. In Chile, developing cities such as Santiago bought water the rights of agricultural users to supply urban residents. However, the appropriate solution to the issue between sector allocations is more complex than simply transferring water from agriculture to the urban sector. For example, a study of Hyderabad, capital of Andhra Pradesh, India, found that improvements in urban water pricing structure could lead to more efficient allocations of urban water, eliminating the need for costly transfers from the agricultural sector [Saleth and Dinar (1997)]. Also, differences in water quality requirements exist between sectors. Much of the water used in agriculture will require more treatment to be used in other sectors.

Using unconventional water sources

With conventional water supplies scarce, there is an increased use of non-traditional water sources. These include wastewater reuse and recycling, and ocean water desalination. In the western United States, parts of Africa, and countries in the Middle East, there has been growth in the use of treated wastewater for industrial, agricultural, and commercial uses [Gleick (2000)]. Reclaimed water may be produced at a cost of 30 to 40 cents per cubic meter and will be able to compete with other water sources in Israel and Jordan. In Israel, partially restored water is widely used in the production of industrial crops such as cotton. Crops that can withstand salt water are able to reuse water that was initially applied to crops that cannot tolerate salt. Another option is desalination of ocean water. Although still very expensive, desalination has begun to use in scarce water areas such as North Africa and the Middle East, and 7,500 desalination plants in the world can produce 0.1% of the world's water use [Weber (1991)]. Rhodes and Dinard (1991) present results that suggest that for crops such as cotton and some vegetables, yield levels can be maintained if high-quality water is used early in the life of the plant and more salt water is applied at the end of the season. Their approach will enable water planners to take advantage of wastewater and other low-quality water, but still requires maintaining water stocks of various qualities. Amir and Fischer (2000) explain that farmers in the Jezreel Valley in Israel use high-quality freshwater and brackish water to produce crops. The arbitrary policy of limiting the production of low-value crops like cotton increases the average return on water, but it also limits the ability of producers to make optimal use of both types of water sources. This guide demonstrates that there is a benefit in having multiple properties of water available for different end uses. However, this option requires an assessment of the economic trade-off between the cost of separate storage and the cost of bringing water quality to the highest level.

Temporal aspects of water

Dynamic thinking and uncertainty

The water project is planned not only for one period, but for many years. Dynamic considerations include interest and future cost calculations, selection of the appropriate discount rate, and population growth. Because of the high population growth rate in many developing countries, it may be preferable to choose a greater water capacity than the current demand. One source of uncertainty comes from expectations about future water demand. It is often difficult to accurately forecast future water demand from a newly developed irrigation system. If the developers assume that the demand for water inputs will remain constant after the water project is established, the chosen level of supply may either be too high or too low. Demand for water can drop for a number of reasons after building a water project. One reason is that crop yields in irrigated areas are higher than in rainfed areas, and higher benefits per unit of water may reduce overall water demand.

Another factor is the choice of irrigation technology. If farmers adopt a more reliable micro-irrigation technology, this may also reduce total water demand after building the water system. There are also several reasons for a possible increase in water demand. Many water projects are built in countries with high rates of water population growth, which can increase demand for water. The resulting water and employment projects can increase immigration to the developed region. In addition, arid regions that are unproductive are able to grow crops after water development, which leads to increased demand for water for agricultural uses. While the direction of the shift in water demand is unclear, if future future demand for water is assumed, the resulting dam size is usually suboptimal.

Arrow and Fisher (1974) and recently Dixit and Pindyck (1994) have developed models that indicate that in these cases decision makers may consider delaying decision-making on the optimal project design so that more information can be learned. Delays in building one or two projects may lead to a loss of benefits in these periods but will lead to future gains as more information is taken into account. This work demonstrates that if the gains from obtaining new information are greater than the previous benefits of the current construction, it is better to postpone building a new project. Gains from the option to not make an immediate decision are referred to as the "option value". In particular, in cases where uncertainty about water productivity as a result of the availability of new technology or environmental uncertainty impacts of water diversion activities, the value of the waiting option may be very high and there may be significant gains from delay. Because of this, the positive net present value of the benefit cost analysis is necessary, but it is not a sufficient requirement for construction.

Waterlog and exchange

Solving the problem of water saturation should combine two elements - an efficient drainage system and the use of more efficient irrigation technology. Various details regarding the development of a exchange management plan were discussed in Dinar and Zilberman (1991). Construction of the drainage system can reduce the levels of water saturation in the soil. A well-functioning drainage system can allow the otherwise depleted soil resource to become sustainable over time. Despite its effectiveness, it does have its own problems. Construction of the drainage system can be very costly, and the effluent must be deposited in an area where the saline water will not have negative environmental impacts. It may be preferable to combine a limited drainage system with the use of effective irrigation technology, which reduces the need for drainage and warehouse storage of water [Chakravorty, Hutchman and Zilberman (1995)]. While sanitation and water saturation are problems in many regions of the world, quantitative data on the prevalence of these problems are not widely available to all regions. However, regions like Asia and South America have very good data available. In China, 24.6 million hectares are susceptible to waterlogging, with drainage equipment over 20.3 million hectares. In the former Soviet Union, 12% of crop land has been depleted, although this varies from 6% in the Russian Federation to more than 100% in the Baltic States. 3 In Mexico, more than 5.2 million hectares of land were drained for agriculture, along with 1.3 Million hectares in Brazil, figures that account for 19.1 and 2.0% of arable land, respectively.

Interregional options

Conflicts and cooperation on water

In many places, water sources cross political boundaries, and agreements are necessary to determine not only the division of water between groups of users, but also the permissible activities and levels of pollutants in that water. Dialogue and international agreements are necessary in many areas to protect both allocation and water quality levels from freshwater resources. While it has often been said that disputes over water supplies are more likely to occur with increasing populations, and that current freshwater supplies have been excessively allocated, the work done by Wolf (1998) indicates otherwise. Wolfe found that the number of agreements to cooperate in water management was much greater than the number of conflicts. Additionally, Wolf sets the conditions for an armed conflict to appear on the water, and finds that there are few potential sites that meet the criteria.

Joint cooperation is necessary to maintain or improve water quality, as well as agreements on allocation of quantity. There are many examples of inter-regional cooperation to improve water quality. For example, in 1972, Canada and the United States signed the Great Lakes Water Quality Agreement. This agreement has made both countries responsible for activities that affect water quality in the Great Lakes region. This agreement, and the ongoing dialogue that it began between nations, was at least partially responsible for the dramatic increase in the quality of the waters of the Great Lakes [Potts and Mulledon (1996)]. Another example of such an agreement between different countries is the Chesapeake Bay Agreement, designed to improve water quality in the Chesapeake Bay. This agreement was signed by the state of Maryland, Virginia, Pennsylvania, and the District of Columbia. It was designed to reduce nutrient levels in water by 40% less than the 1985 standard [Bockstael and Bell (1998); McConnell & Strand (1998)].

Trade and the concept of "virtual water"

Water scientists have traditionally assumed that the annual per capita requirements for water are 1,000 cubic meters [Gleick (2000)]. Just looking at the numbers, this requirement leaves many developing countries suffering from severe water shortages. For example, percapita annual water supply in Jordan is only 100 m 3. However, the requirements for 1000 m3 are average in quantity, and assume self-sufficiency in food production, especially in cereals for feeding humans and livestock. There is great homogeneity and the availability of water ranges from 5000 m 3 in Canada and Northern Europe to 100 m 3 in Jordan. Trade can ease some water restrictions. Countries with limited water resources may produce high-value goods for export that will enable them to purchase grains that use water heavily but cheaply. Thus, hydrologists present the idea of virtual water. For example, if each acre of feet of water that is placed in tomatoes earns $ 500, while each acre of water that is placed in wheat earns $ 20, then a foot that is used to grow tomatoes is worth 25 acres of feet of wheat. The idea of "virtual water" is that if a community can generate enough value (by using the available water) to obtain 1,000 cubic meters of food, that community has enough virtual water. This can be achieved if water is scarce and countries focus on exporting non-agricultural commercial products or growing crops of high value for export (such as flowers or products) and then using the revenue to import basic crops such as grains. Although water itself is not tradable across countries, this allows countries to replace trade in goods produced with water available to them for direct trade in water. An example of a water-scarce country with a transformation into a high-value crop wing is Yemen. Yemen has actively pursued a policy of subsidizing imported grain products instead of supporting its own production, and thus imports three quarters of the cereal crops. Between 1970 and 1996, agricultural land used for cereal crops decreased from 85% to 61% of cultivated land, while the share of cash crops increased from 3% to 14% [Ward (2000)].

Benefits and costs of irrigation

Benefits of irrigation

The contribution of irrigation to agricultural productivity

The increase in irrigation water supplies has been useful in feeding the population of developing countries in the past fifty years. Irrigation water has increased food security and improved living standards in many parts of the world. Fifty years ago it was common to hear fears of food shortages and mass starvation, and while malnutrition remains a concern in many countries, the reason is not the global food supply is insufficient. Indeed, in the early 1990s, nearly 80% of malnourished children lived in countries that produced a food surplus, which is evidence that the cause of malnutrition is a lack of sufficient income by families to buy food, not a lack of supply [Organization Food and Agriculture (1999)]. A report issued by the International Food Policy Research Institute showed that between 1967 and 1997 global cereal production increased by 84% by the time the population increased by 67% and malnutrition among children under five years of age in developing countries fell from the overall rate of more than 45 % To 31% during this period. India, a historically poor country, had no major famine since the sixties. There are a number of reasons for this increase in food production, including high-yielding varieties of seeds and increased fertilizer use. However, the role of water development in providing irrigation water for farmland was also important. Benefits include expanding food supplies, stabilizing water supplies, protecting against floods, and improving the well-being of some indigenous people.

Expanding the Food Supply

Irrigation and expansion of agricultural lands.One of the benefits of water projects is the expansion of the land base that is feasible for agricultural production. Many high-quality soils have a Mediterranean climate and receive rain during the winter months when it cannot be used to produce crops. For these areas, the development of reservoirs allows water to be stored during the rainy time of the year, then used for cultivation during a dry part of the year. The channels allow the transfer of water from water-rich areas to arid regions, where they can be used to produce crops.

Irrigation and higher yields .There is indisputable evidence that irrigation of land leads to increased productivity. One acre of irrigated farmland equals several acres of rainfed agricultural land. Globally, 40% of food is produced in irrigated land, making it up to only 17% of cultivated land. The value of irrigated farmland production is estimated at $ 625 / ha / year, compared to $ 95 / ha / year for rain-fed farmland and $ 17.50 / ha / year for pasture. In Asia, yields of most crops increased by 100-400% after irrigation [FAO (1996)]. Irrigation allows farmers to apply water at the most advantageous times of the crop, instead of submitting to the irregular timing of precipitation. A recent study using Indian production data from 1956 to 1987 shows that irrigation affects total factor productivity (TFP) beyond the input value of water [Evenson, Pray and Rosegrant (1999)].

Irrigation and dual farms of land .Another benefit of reservoirs is that the stored water can be used in the dual cultivation of fields. There are many tropical and subtropical regions that are warm throughout the year and have monsoon rains for part of the year, but remain dry for the other part of the year. ***Capacity to store water*** .The rainy season for use in the dry season can allow farms to move from one harvest per year to two or three. An example of this occurs in the central plain of the main island of the Philippines. This region has a rainy season from mid-June to November, and more than 70% of the total precipitation falls in a 4-month period. Storage systems allowed the area to have two agricultural seasons per year - the first mainly relying on rain water, with irrigation water being used to supplement dry times, while the second, from December to May, relied almost entirely on irrigation water [Ferguson (1992)]. Although statistics are generally not available, there is anecdotal evidence that expansion in the cultivation of double crops allowed the conservation of land for nature, rather than developing it for agricultural production.

Luxury Improvements

Irrigation, employment opportunities, and income.Employment opportunities increased in many regions after the development of irrigation systems. This can happen because additional work is needed in agriculture and harvesting for new lands being brought into production, for double cropping land, or for industries that support agricultural production. An example of this occurred in Porleitar, Nepal. The construction of the large public works project during the 1980s doubled the total demand for labor in the region, improving productivity and welfare. Production potential increased by 300% and income increased by 600%, resulting in increased food security for indigenous people [FAO (1999)]. A 1997 study in Kenya and Zimbabwe showed that the average net increase in irrigation income was $ 150- $ 1,000 per family farm [FAO (1999)]. Agricultural productivity growth has a multiplier effect, providing benefits to the non-agricultural sectors as well. Using data from India, Hazell and Haggblade (1990) show the value increases non-farm production by 2.19 times the value of increases in irrigated production.

Irrigation and land values in an area are a function of the productive potential of the land. The development of irrigation systems allows farmers to grow higher yields than current crops, or more profitable cash crops. Because of this, the benefits the landowners can have for significant irrigation development. An example of this can be seen in the land supported by the Loskop irrigation scheme in South Africa.

Irrigation Supply Stability

Building a water storage and transportation system reduces the risks associated with random rain. Farmers are better able to plan their crop patterns with reliable water supplies. Growing certain crops, such as tree crops, requires ensuring an adequate supply of water and may not be an economically logical option for farmers before developing water. Irrigation also allows farmers to apply water at the most advantageous times of the crop, rather than succumb to the diversity in rainfall.

Environmental Benefits

Irrigation and deforestation. The expansion of agriculture is the main cause of deforestation in developing countries. For example, between 1975 and 1988 the forest area in northeastern Thailand decreased by about 50% due to growth in cassava production [Siamwalla (1997)]. Increasing food production in a region requires extensive use of existing agricultural land or expansion of cultivation on new farmland, and over time, increased production is necessary due to the increase in population, higher living standards, and increased meat consumption. The use of high-yielding crop varieties increases production on existing farmland, and irrigation is an essential input for many high-yield crop varieties in production. While deforestation is still an important problem worldwide, one can expect that without the benefit of irrigation, the forest cover left today will be less than what we observe.

Benefits of Joint Use of Groundwater and Surface Water

There is a large body of literature on the benefits of the combined use of surface and groundwater [Burt (1964); Fisher and others. (1995)].These benefits accrue due to the different nature of the resources. Surface water and extraction costs are usually lower, but subject to fluctuations in supply. Groundwater pumping can be costly, but it does have reliable supply.In aquifers with recharge, use of surface. During high rainfall years, water can recharge the existing aquifer and reduce future overdraft from groundwater supplies. In underground recharging reservoirs, the availability of surface water for irrigation can be an alternative to non-renewable groundwater. In either case, the associated use of the two sources can reduce the risks associated with the random surface water supply. The Arvin EdisonWater and Storage District (AEWSD), located in central California Valley, provide a useful example of connectivity. AEWSD uses groundwater banking in their water management plan. In humid years when they receive large quantities of surface water, they store some of it underground, and then they pump this stored water during dry years, when the surface water supply is insufficient to meet the demand of the area. Tsur (1997) estimates the value of this supply stability by the region at $ 488,523 annually, which is equivalent to 47% of the total groundwater value.

Flood Control Benefits

The main purpose of building several dams is flood control. While floods are rare in many areas, they have high costs when they occur. Floods can do massive damage -

destroying property, killing people, and destroying environmental families. Dams were useful in reducing these costs. The World Register of Dams shows that 17.3% of large dams reported flood control as a major objective. Most of these dams are in developed countries (the United States, Europe, and Japan make up a large proportion of the total); But developing countries shared some of these benefits as well. One difficulty in measuring the value of the benefits of flood control for a dam is that the benefits are probable. When the dam is built, it is impossible to predict which years the floods will occur, and the extent of the damage the floods will do. Because of this, the proposed cost-benefit analysis of the dam should use an expected value in favor of flood control. As Krutilla (1966) discussed, a dam that reduces the likelihood of flood damage to zero would not be feasible in cost-benefit analysis, conventional or economically optimal, given the necessarily high costs.

Irrigation costs

Despite the many benefits, there have also been many negative impacts of water projects. There were financial, environmental, and social costs for developing water systems. Environmental problems include family destruction and low water quality while social costs include displacement of indigenous people, and an increased incidence of waterborne diseases that affect this population.

Capital Costs

The cost of building a dam and irrigation transportation system is often millions of dollars. In deciding whether a project is worth doing, it is important to weigh the expected benefits against the expected costs. The capital costs of constructing water projects have been consistently reduced. A recent study of 81 major dams by the International Commission on Dams found that the average cost was over 56%. In addition, the advance expectations for the benefits of water projects were overly optimistic. This combination of factors has led to observations that the internal rate of return for most water projects is much lower than the expected rate of return, although most rates of return are still positive. This result varies by region. The average investment costs of irrigation projects in West Africa averaged more than three times the irrigated hectare of projects in Asia. West Africa did not use double crop cultivation methods and was poorly managed for water supply. For this reason, the return to most West African projects has been negative [Matlon and Adesina (1997)].

Additionally, yield rates have decreased over time. Postel (1999) reviews the result of a World Bank study showing that the cost of irrigation has increased dramatically since the 1970s. The study of more than 190 projects funded by the bank found that irrigation development now averages $ 480,000 per square kilometer. This cost varies by location - the capital cost of the new irrigation energy in China is $ 150,000 per square kilometer, while the capital costs in Africa range from 1,000,000-2000,000 per square kilometer. There are few reasons for this increase in the cost of irrigation development. The best sites for water projects are already developed, and those that are still increasingly expensive. Improved knowledge about the environmental impacts of dam construction also led to the requirements of detailed environmental impact reports before approval of several projects.

Environmental Costs

Destruction of families Building a large dam causes changes in the river's ecosystem. There are changes in current flow, water temperature, and water quality. These changes affect the plants and animals that live in the river basin area. Types of fish that live in warm water may not live in cold water under the dam site, or species that thrive in flowing water may not live in the reservoir's still waters. Preventing the migration of native species.Many river systems are used by migratory fish species such as salmon. During her life, salmon species are raised up the river, swim down the river, and eventually return to the top of the river for mating and reproduction. Building large dams can block the roads these fish use, and affect their reproductive behavior. This affects the sustainability of fish species and those whose livelihoods depend on fisheries. One example is the Puerto Primavera Dam in Brazil. The construction of this dam has impeded the migration of local fish species, and has led to an 80% reduction in upstream fishing [WCD (2000)]. It lacks not only affects the health of the species, but also the well-being of people who depend on fish species for their consumption or livelihood.

Dynamic Costs Of Water Resources

The development of irrigation projects allowed crops to be produced in drylands. This has had many benefits, including expanding output and increasing land values. However, there were environmental problems that over time expanded the area of irrigated land. These costs include increasing salinity levels in freshwater sources, waterlogging, and soil salinization.

Increased salinity levels in freshwater supplies Evolution of irrigation can increase salinity levels in existing lakes and rivers. This occurs when the water that previously collided with the freshwater lake is diverted, or when the water withdrawal from the river is very large. With less fresh water available, the lake level will decrease, and the water will evaporate, the salt content of the lake will increase. With a river basin that flows into the sea, if the water withdrawal is very large, salt water from the sea can back down to the river basin. Over time this can lead to changes in the environmental balance of a river or lake and the species that support it. One of the areas where irrigation has led to an environmental disaster lies in the Aral Sea between Uzbekistan and Kazakhstan. The ecological balance of the habitat was destroyed and an industry using many citizens was destroyed. The rivers that feed in the Aral Sea are Amu Darya and Sir

Darya. The area has been a site of irrigated agriculture for centuries. In the last century, the region has become a major producer of cotton, an export crop of the USSR. In 1956, the Kara Kum Canal, a project on water to be used to increase cotton supplies, was completed. Between 1962 and 1994, the volume of water in the sea decreased by 75% and the level of sea salinity increased from 10 to more than 100 grams per liter. This affected the wildlife that lived in the area. The Aral Sea used to be a thriving site for the fishing industry, employing 60,000 people. The industry has been completely wiped out, with the disappearance of many fish species [Murray-Rust et al. (2003); Calder and Lee (1995)]. Another example occurs in the Periyar River Basin in Kerala State, India. In this river basin, the dam system increased the freshwater withdrawal from the river. For this reason, sea water enters about 20 miles above the river system during the dry season, resulting in a seasonal closure of factories that rely on river water [Ribeto (1986)].

Waterlogging and salinization of land Waterlogging and salinization is two problems related to land productivity that occurs frequently. Salinization occurs when the salt content in the soil increases, affecting the productivity of the land and limiting the crop's choice of crops. This is a special problem in arid or semi-arid lands. In dry areas, there is little rain to melt the salts in the soil. When water is applied without proper drainage, evaporation in arid climates can quickly lead to high levels of salt in the soil, reducing the yield potential of the land. Another type of problem that can occur in irrigated land is known as "waterlogging". This can happen if a layer of rock forms a barrier through which water cannot escape, and over time, water can accumulate and reach the root zone of plants, making agricultural production impossible. Water saturation ultimately leads to salinization of the soil, as the water evaporates and the salt content in the soil increases. It is estimated that 20% of irrigated land worldwide is affected by soil salinity levels, and that 1.5 million hectares are excreted from production each year as a result of higher soil salinity levels. The costs for this are great. One estimate is that salinization costs world farmers $ 11 billion annually in lost income [Postel (1999)]. However, this estimate does not include the general equilibrium effects of the increase in the price of production due to lower output, so it should be considered the upper limit. The Indus Basin in Pakistan is one of the sites where the problem of waterlogging and soil salinization is a serious problem. In Pakistan, about 38% of the irrigated area is submerged in water. The problems are worse in the Sindh region of the Sindh Basin, which contains more than half of the area affected by waterlogging and soil salinization. This region has experienced a 40-60% decrease in crop production as a result of these problems [Wambia (2000)].

Low sediment and nutrient levels in water .One of the benefits of river systems is the sediment and nutrient movement. Sediments moving downstream can replace soil erosion, and provide beneficial nutrients for farmland downstream. Construction of a dam in the river system can lead to trapping sediments and nutrients behind the dam, leading to deterioration in the quality of the final river system. One example is the Nile in Egypt. Traditionally, the Nile will sink every year, water the banks of the river, and replace eroded soil with new sediments. New deposits not only prevented the earth from eroding, but also added nutrients to the soil. Since the construction of the Aswan Dam in southern Egypt, most sediment has been trapped in the river behind the dam and has not been released towards the mouth. There were some problems due to this. The lack of sufficient sediments causes erosion in the Nile Delta coast by 5-8 meters per year, and removing a natural source of nutrients requires farmers to increase their use of fertilizers.

Water Supply Contamination .Water supply contamination can occur from agriculture from several sources, including animal waste, or the flow of fertilizers and pesticides. Domestic animal water contaminated with water can cause diseases such as diarrhea, hepatitis, or typhoid fever. More than a third of the world's population lacks access to basic sanitation and most of these live in developing countries. More than half of China's population consumes water that exceeds the maximum permissible limits for human and animal waste, and it is estimated that 80% of diseases and one third of deaths in developing countries result from the consumption of polluted water. Since agricultural runoff is an unspecified source of water pollution, its regulation poses difficulties. Compared to source pollutants, controlling non-source pollutants is more difficult, as individual emission levels cannot be measured directly, which limits the choice of policy tools [Shortle and Horan (2001)]. Pollution control from an unspecified source must be achieved through an indirect procedure, which necessitates the second best result in efficiency. One possible policy may be to support irrigation techniques, which leads to a decrease in agricultural drainage flows. Support for modern technology will lead to higher adoption rates and less agricultural drainage.

Social Interests

Waterborne diseases .In many places, large dams and irrigation projects have been blamed for public health problems, including increased cases of diseases such as malaria, diarrhea, cholera, typhoid, schistosomiasis, and river blindness. The high levels of snail hosts in irrigation canals led to an increased incidence of schistosomiasis in the Senegal River Valley and Niger River Basin [Matlone and Addisina (1997)]. However, there is evidence that many of these cases were the result of poor planning, and not of the necessary impacts of dam construction. Vector breeding often occurs in fields, not in dams and canals [Von Braun (1997)]. Incorporating public health concerns into planning a new water project can reduce the project's impact. For example, the new reservoir could be an attractive breeding ground for mosquitoes, which could lead to the spread of malaria. Using nebulizer to control pests can reduce this risk. In areas where this risk has been ignored, such as the Senegal River Valley and the Kou Valley in Burkina Faso, there has been an increased incidence of malaria in the regions. In addition, there were areas where cases of malaria and other waterborne diseases actually decreased after the development of irrigation projects.

There is other evidence that the effect of irrigation on public health was demonstrated by the work of public health researchers, who found a set of results when studying the effect of irrigation development on disease incidence. A study from the Tigray region of Ethiopia compared the incidence of malaria in villages near dam sites (less than 3 km) to villages at similar heights away from dam locations (more than 8 km) [Ghebreyesus et al. (1999)]. In their studies, they compared the incidence of the disease at different times of the year in children under the age of ten. In all cases, the incidence of malaria was greater in the at-risk villages than in the control villages, and this difference was statistically significant. However, Ijumba and Lindsey (2001) reviewed several studies from Africa and found that irrigation development does not always lead to a high incidence of malaria, and it can actually reduce incidence under certain conditions. They found that this result varies by location, and while irrigation development increases malaria infection in highland regions where the population lacks any immunity, in many parts of sub-Saharan Africa irrigation development can reduce malaria infection. Ijumba and Lindsey (2001) also discuss other factors that affect malaria infection and are also closely related to the development of irrigation systems. One of the factors is population migration. Development of irrigation systems .The resulting employment opportunities may lead to an influx of people, and many of them may lack any resistance to malaria. This factor can partly explain the incidence of malaria due to the development of irrigation in specific locations. Another factor is the increase in wealth, which can be the result of irrigation development. Increased wealth allows access to antimalarial drugs and prevention technologies such as mosquito nets. This factor is one of the explanations for the low incidence of malaria observed in some locations after the development of irrigation.

Displacement of indigenous people .The development of water projects in the past century has displaced 40-80 million people. In addition to their physical displacement, this also often led to a forced change of lifestyle in 1990, displacing 26 to 58 million people in China and India (two major dam-building countries). Compensation for these forced relocations was minimal, if at all. Resettlement plans regularly fail to account for the loss of viable livelihoods as well as the loss of tangible land; leaving the resettled population in a worse position than before the dam was built. For example, one study found that 72% of 32,000 people displaced by the Kedung Umbu dam in Indonesia were worse off after resettlement [WCD (2000)]. Liu-Yan-Ba Dam on the Yellow River, the largest river in China, is building 40,000 people from fertile valleys to unproductive heights raised by wind. This has resulted in extreme poverty for many resettled people (WCD (2000)).

Excessive Use of Groundwater Resources

Irrigated agriculture depends on ground and surface water. Most large-scale irrigation projects divert surface water, but a large percentage of new irrigated land in the past century is from groundwater pumping. In many situations, groundwater resources are renewable and renewed by rainstorms. Sometimes, as in the case of the Libyan Desert, aquifers are not replenished as fossil water is extracted. It is estimated that Libya's plan to extract 2.2 km 3 of the desert aquifer depletes the aquifer within 40-60 years [Postel (1999)]. Worldwide, about 8% of food crops on farms that use groundwater grow faster than groundwater aquifers [Postel (1999)]. For example, the Punjab region of India is rapidly depleting its groundwater reserves. Punjab is a major production area in India, and most of the crops produced are cereal grains, such as rice and wheat. The past two decades have seen groundwater levels drop at 25-30 cm per year. At depths of groundwater less than 15 meters, commonly used tube wells will not work, and the well must be abandoned. The percentage of land has increased since the level of groundwater is less than 10 meters from 3% to 46% between 1973 and 1994. 5 This excessive use of groundwater .The future of the region and the national goal of food security threaten, and in some areas such as Jakarta and Bangkok, intense groundwater withdrawal leads to the sinking of the ground level above the aquifer. In Bangkok, a third of the city is below sea level. Lower ground level has increased flood damage and increased costs of flood protection [Barker and Molle (2002)].

Another problem that can occur with clouds on coastal underground reservoirs is the infiltration of sea water into the aquifer. If groundwater is drawn from the aquifer to a sufficiently low level, sea water from the adjacent ocean can enter the system; Increased level of salinity in freshwater remaining in the aquifer. For irrigation that relies on available groundwater, this can limit the choice of crops to those that can withstand high levels of salinity from the applied water. One of the areas where this problem is represented is the Gaza Strip between Israel and the Mediterranean Sea. Gaza is totally dependent on groundwater for fresh water supplies. Increased pumping reduced levels of aquifers located in Gaza, and allowed seawater to leak. Citrus crops, which have traditionally been a source of revenue for the region, are intolerant of high salt levels in water, and there has been a decrease in both yield and quality of the crop. In some parts, high salinity levels were forced to switch from citrus crops to other salinity-tolerant fruits and vegetables.

Conclusion

Irrigation was the source of over 50% of the increase in world food production during 1965-1985 [Gardner (1996)] and more than 60% of the value of Asian food crops came from irrigated land [Hinrichsen (1998)]. Irrigation in the last half of the twentieth century exploited most opportunities to divert water and, in some cases, it took advantage of non-renewable water resources. The environmental benefits of adequate freshwater supplies for ecosystems are better understood now than they were 50 years ago. Despite growing concern about the effects of water projects from third parties, there is a challenge to increase food supplies by at least 40% in the next fifty years, due to the growing population and changing preferences. Increased productivity should not come through expansion of water, but rather through increasing the productivity of existing sources. It can be accomplished by reforming water design and management systems. In particular, the reform should include increasing reliance on cost-benefit analysis for water projects, focusing on appropriate design and management of transportation facilities, and the use of mechanisms that determine the price of water to represent marginal costs for extraction, user costs, and environmental costs. Correcting these institutional problems is an essential step in improving water quality and increasing effective water supplies.

The increased use of Water Users Associations (WUAs) is a positive step towards improving water management systems. Experience in water trade suggests that it can improve efficiency as long as attention is paid to third-party impacts issues. Water quality issues should be further addressed through incentives to reduce pollution. Current technologies allow yield maintenance while significantly reducing water use, but technology may be expensive and many are in its infancy. New wireless technologies and improved power for computers that can reach even the most remote areas may suggest that the challenge for research is to develop affordable water use management technology by the poor, as well as mechanisms to enhance the adoption of these technologies. Effective policies, water pricing and management are one of the major challenges facing society now.

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