Sustainable Water Management for Crop Production

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Abstract

The 20th century witnessed a tremendous growth in food production, especially from irrigated agriculture. Combination of hybrid varieties, agrochemicals and irrigation ensured global food security for billions. Scientists, policy-makers, extension workers and farmers involved in irrigated agriculture have plenty of reasons to be proud. In the 21st century, agriculture faces new challenges. While increasing population requires more food per capita, availability of land and water for irrigation is decreasing. More food has to be produced with less land and water. Despite the fact that agricultural researchers have obtained very high yields for crops at experimental sites, yields from farms remain low due to socio-economic, institutional, and technical reasons. This paper presents major socio-economic and institutional constraints faced by water managers in developing countries.

Introduction

The 20th century witnessed a tremendous growth in food production, especially from irrigated agriculture. Combination of hybrid varieties, agrochemicals and irrigation ensured global food security for billions. Scientists, policy-makers, extension workers and farmers involved in irrigated agriculture have plenty of reasons to be proud.

In the 21st century, agriculture faces new challenges. Like human populations, freshwater supplies are distributed unevenly among and within countries around the world. This discrepancy has already resulted in water scarcity in some countries and regions. The continuing growth of global and national populations and the consequent increase in demand for water, a finite resource, will cause water scarcity in even more countries and regions in the future.

While increasing population requires more food per capita, availability of land and water for irrigation is decreasing. More food has to be produced with less land and water. At present, irrigated agriculture produces 40% of all food, and consumes 69% of all freshwater resources. To meet the projected demand for food, irrigated agriculture will require an additional 17% of freshwater resources. This water is not available. Waters of marginal quality (drainage and sewage) will be used after being recycled to produce food. Such repeated use of water will threaten the natural environment and biodiversity.

In summary, water managers in agriculture will be required to maximize water availability for agriculture, but minimize damage to the environment. Furthermore, they will have to develop management strategies to distribute scarce water resources uniformly across vast irrigated lands in a reliable manner. This overall objective of water managers is hindered by socio-economic and institutional as well as technical and environmental constraints. In the following sections major socio-economic and institutional constraints affecting water management in developing countries are discussed.

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Socio-economic constraints

Land fragmentation

Land rights of farms are handed over from one generation to another resulting in fragmentation of farmlands. This is severe in countries where population growth is high and employment opportunities in non-agricultural sectors are minimal. For example, 62 % of all farms in Pakistan had been divided at least twice during the last century. Four percent of them had been divided more than ten times! Land fragmentation is severe in the Northwest Frontier and Baluchistan Provinces. Smaller farms become economically inviable, and limit farmers' ability or willingness to invest in water technologies. The Hardinath Irrigation System in Nepal, has a large groundwater reservoir. Depth to the water table is approximately 3 meter, and the transmissivity of the aquifer is high (200 - 8,000 $m^2 d^{-1}$). Various studies show that the aquifer can sustain up to 2,500 shallow tube wells, but less than 500 are operational. Despite the abundance of groundwater, only 60% of the land is planted with wheat due to inadequate supply of canal water. Well installation makes economic sense only for farmers with larger holdings and a potential to sell water to others (Brewer and Sharma, 2000).

Land tenure[1]

There are two types of tenurial arrangements, sharecropping and leasing. Sharecropping contracts are mostly on a 50-50 basis, whereby the yield and costs of agricultural inputs are divided equally between the landowner and the sharecropper. The sharecropper is responsible for labor and other activities. The landowner, if not absentee, remains in control of non-daily water course activities and of water rights, including selling and purchasing canal and tube well water. In leasing contracts, the water and usufruct rights shift to the lessee. Factors influencing motivation for a certain tenancy strategy and its impact on water management are discussed below.

When landowners have several landholdings, they may be less interested in the land when the soil type is less suitable for growing preferred crops, or when canal water supply is poor. They may then opt to lease the land. The size of a holding also determines whether land is owner-cultivated or not. Plots too small for efficient farming, such as through the division of holdings with inheritance, especially if less than one acre, tend to be leased or sharecropped out. Landholdings too large to cultivate alone, will also be (partly) given under tenancy.

Making investments on land with low soil quality for cultivation is less beneficial. Landowners may be more inclined to give these fields on a sharecropping contract. On the other hand, if the tenant has the means, he will take land of good quality on tenancy.

The availability of canal water also plays a role, as a sufficient and regular supply of canal water is beneficial for the soil, the crop, types of crops that can be grown and less money on tube well water is spent. Tenants prefer to take land with good canal water, or with tube well water supply. Involvement in tenancy arrangement offers more flexibility in canal water supply to farmers, especially for lessees, who have full water rights. Taking land on tenure is a way to consolidate landholdings and water rights by sharecropping and leasing in nearby plots.

Tenants tend to take less, or equal, care of soil and irrigation management practices as owner-cum-cultivators. Leasing tends to increase degradation of lands, as lessees aim to get high yields and income. Sharecropping contracts do not have favorable conditions for optimal use of water markets, as they do not have full water rights, which lead to less flexibility in irrigation practices.

[1] This section of the paper is based on a report published by Terpstra (1998).

Water markets

Water markets are an allocation mechanism based on an initial allocation of water rights. As a result of the confrontation between water supply and water demand, water is reallocated between users at an equilibrium price determined by the market. Requirements of well-functioning water markets include water scarcity, and well-defined and transferable water rights (Strosser, 1997).

Brewer and Sharma (2000) and Raju and Brewer (2000) observed two ways of groundwater marketing. The first, is the sale of pumping service and the second is the rental of pump sets to owners of bores. A key point in this market is that water is not valued as such. Price of the service is usually fixed for the area at informal meetings among tube well owners. In general, payment is requested immediately either as cash or as diesel. Water is transferred from the well to the buyers' fields, through earthen channels. To minimize conveyance losses, most buyers buy water from the nearest seller. Although, owners install wells to meet their groundwater requirements, most well owners sell water to their neighbors. In many instances, a well is pumped more for others, than for the owner's main use. Smaller farmers, who could not afford to make immediate payments, will therefore suffer. Furthermore, groundwater through trading will be available only to those who own farms near existing wells.

Strosser (1997) observed very active surface and groundwater markets in Punjab, Pakistan. In cases of high unreliability in canal water supply, high conveyance losses, and cheap access to groundwater resources of good quality, farmers intensively develop canal water markets. The impact of existing canal water markets on agricultural production was difficult to estimate. Short-term flexibility is a very important element of such transactions. But, the impact of tube well water markets on farm income was significant and estimated at 40% of the actual gross income.

Institutional constraints

The term "institutions" in its popular usage, is usually understood as referring only to "organizations", but basically refers to sets of "rules", which serve to define and underlie the organizations. Viewed in this way, irrigation rules, both formal and informal, become as important as organizations in the improvement of irrigation performance (Bandaragoda and Firdousi, 1992). Therefore, institutional constraints include organizational constraints and the rules under which such organizations function. A number of countries are attempting to overcome the institutional constraints by enacting new rules, or by establishing new organizations.

In many countries, a number of government organizations is directly or indirectly involved in distributing water to farmers. For example, in Pakistan, at the national level, the Indus River Statutory Authority (IRSA) is responsible for the enforcement of the water apportionment act of 1991. In collaboration with the Water And Power Development Authority (WAPDA), the Provincial Irrigation Departments (PID) are responsible for all aspects of planning, design, construction, modernization, and rehabilitation of irrigation and drainage works. Funding for capital works is provided through Provincial Finance Ministries (PFD). The Revenue Departments (PRD) assess the water services fee, and the Planning and Development Departments (PP&D) of the provinces approve major rehabilitation works. In summary, IRSA, WAPDA, PP&D, PFD, PRD, and PID play a role in delivering water to farmers. Once the water is delivered to the farms, the Provincial Agricultural Departments advise the farmers on how to manage the water on-farm. Drainage works are similarly operated and maintained by the Provincial Irrigation Departments. This includes surface drains, subsurface (tile) drains, and drainage tube wells. Charges for drainage services are generally not levied, though provisions exist for small charges.

In many countries, developed as well as developing, the irrigation sector is in financial difficulty, and in consequence the long-term sustainability of food security is precarious. The quality of irrigation services has deteriorated over time. Maintenance of works is inadequate and the conditions of infrastructure are deteriorating. Charges levied on farmers for irrigation services are inadequate to meet operation and maintenance expenses, in part because the charges and recovery rates are too low, in part because the irrigation departments are inefficient and over-staffed. As a result, productivity is far below potential, salinity and water-logging are spreading, over-exploitation of fresh aquifers is widespread, and excessive use is being made of poor quality groundwater — to the detriment of the soils and the long-term productivity of the sector.

The problems of inadequate financing and management of irrigation systems have been recognized worldwide and for some decades have prompted reforms in the irrigation sectors. Increased management and financial responsibilities for irrigators have been a central feature of all of these reform programs. In some cases, complete irrigation systems are to be transferred from government agencies to farmer organizations, while in others, joint management between farmers and government irrigation personnel is preferred. In some systems, joint management is envisioned as the reformed *modus operandi*, while in others it may be pursued as a transitional stage towards complete management transfer. The partial turnover of some system components and management functions, the joint management of others and the retention of yet others with government agencies have been considered as well.

In smaller systems, complete system transfer is recognized as a feasible option, as in some cases of IMT in Nepal or the Philippines (Sijapati, Prasad and Laitos, 1998; Mishra and Molden, 1996; Lauraya and Sala, 1995). In larger systems, upper level structures (main canals, barrages, reservoirs) frequently remain with government irrigation agencies and lower (secondary and tertiary) level structures are or will be under joint or farmer management as in the USA, the Philippines, Egypt, Pakistan, Sri Lanka, India, Colombia and Mexico (Merrey, 1996; Svendsen and Vermillion, 1996; Vermillion and Garces-Restrepo, 1998; Kloezen, Garces-Restrepo and Johnson, 1997). The degree and level of farmer/water user control over physical structures, O&M activities and finance vary considerably among systems and countries. Although there is no deterministic relationship between system size and mode of institutional governance, there is a tendency for larger systems to be controlled by government or semi-government organizations (Merrey, 1996; Hunt, 1988).

In Pakistan, the search for solutions to the problems outlined has resulted in 1997 in the passage of the Provincial Irrigation and Drainage Authority (PIDA) Acts in the Punjab, Sindh, Baluchistan and Northwest Frontier Provinces. Under these acts, Provincial Irrigation and Drainage Authorities will be formed, which will be responsible for irrigation-related functions carried out by Provincial Irrigation, Finance, Revenue and Planning & Development Departments. An Area Water Board will be established to manage water at the primary canal. Farmers would be organized to take over operation and maintenance of secondary canals. Farmers would be responsible for levying charges for irrigation and drainage services, with the proceeds divided among the PIDAs, AWBs and farmer organizations to reflect costs at each level.

The success of institutional reforms in the irrigation sector will depend on a number of pre-and post-conditions (Vermillion and Johnson, 1995). The pre-conditions include:

* A firm, consistent long-term political commitment to the policy,
* Clear water rights with compatible water distribution arrangements,
* Legal and political recognition of new organizations, including their right to raise revenue, enter into contracts and apply sanctions,
* Benefits exceeding costs and being proportionally related to farmer investments.

The restructuring cannot be sustained, unless the support services to the new organizations, especially as they evolve from single purpose organizations to multiple function commercial organizations, to assist them in

resolving conflicts and technical problems. Very often, the degrees to which the pre-conditions exist in a country vary considerably, resulting in a slow and a painful transformation.

In conclusion, the purpose of this paper is to illustrate the existence of non-technical constraints on water management and sustainable crop production. Despite the fact that agricultural researchers have obtained very high yields for crops at experimental sites, due to socio-economic and institutional constraints, the yields from farms remain low. Investments need to be made to overcome these constraints in developing countries to ensure food security for all.

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