

Module 9: Investments in Agricultural Water

Irrigation and drainage systems have traditionally been the largest subsector for World Bank agricultural lending, and they remain important to improving agricultural productivity and reducing poverty in many countries. However, the context has changed, and irrigation and drainage systems are now seen as part of a broader range of investments that improve the availability of soil moisture for plant growth. “Agricultural water management” broadly defined in this way is just one input to a complex set of determinants of agricultural profitability and household livelihood decisions, which in turn have complex interactions with other rural social and policy issues. Decision makers must consider these broader issues in the design and implementation of agricultural water projects.

Rationale for Investment

Agricultural water development is essential to meeting the world’s food and fiber needs

The World Bank’s rural strategy, *Reaching the Rural Poor*, recognizes that water is an essential input into agricultural production, as well as the basis for livelihoods of rural communities and a major influence on the quality of other natural resources. Efficient agricultural production for local and export markets will become increasingly important for economic growth and poverty reduction. Over the past 30 years, the world’s net irrigated area has increased by almost 60 percent, from less than 170 million hectares in 1970 to over 270 million hectares in 2000 (FAOSTAT 2002). In developing countries overall, agriculture accounts for more than 85 percent of water utilization (IWMI 2001). Globally, irrigated agriculture represents only 17 percent of total land cropped but provides 40 percent of the world’s food.

The strong demographic push to food demand is expected to continue, and it is anticipated that irrigated agriculture will provide close to two-thirds of the additional food needed over the next 25 years. In addition to relying on intensified irrigation systems and better use of water in rainfed agriculture, there is still some potential to expand irrigated area, which could increase by up to 20 percent (40 million hectares) over the next 25 years. The resulting risks for the environment and for society will require careful management, however. Growing water scarcity will have to be managed as well, with a strong need to further improve water productivity and strengthen the use of demand management approaches. In many river basins, intersectoral competition for water resources is a critical challenge that will need to be addressed.

Most gains will come from areas where agricultural water is already managed

The expansion of irrigated area slowed from two percent a year in the 1960s and 1970s to hardly one percent in the 1990s, and water is increasingly unavailable for irrigation. Given present land and water resource constraints and the shortage of potential areas for new development, most production gains must come from better utilization of existing irrigated areas. This challenge is great, as physical deterioration, outdated infrastructure,

or inadequate institutional arrangements have caused current systems to perform below expectations. While there has been some institutional reform, national and local irrigation organizations need modernizing and improved management.

A poverty focus is needed

Through expansion and productivity increases, agricultural water management has also contributed to poverty reduction, yet much more could be done. In particular, the rainfed areas where most poor people live have been largely bypassed by the green revolution and by public investment in enhanced water management. New investment in agricultural water must address poverty reduction by focusing on the adoption of efficient water management practices and technologies suitable for smallholders (such as the treadle pump) and on research and scaling up of alternatives to conventional irrigation (such as water harvesting and *in situ* rainwater conservation).

Private investment needs a conducive environment

Public investment in agricultural water is justified where it is efficient and pro-poor, but there is also great scope for governments to promote private investment, both by large-scale commercial operations and by smallholders. Private investment requires an investment climate providing security for investments, including secure land and water tenure. Governments can also promote public-private partnerships to reduce risks.

Agricultural water investment has to fit within broader development policy and a water resource management framework

The complexity and political sensitivity of water issues have important implications for agricultural water investments. Water is seen as a strategic input in food security policy and in poverty reduction strategies. It is also a key environmental resource. In addition, water is an input to other sectors and has to be managed within an integrated framework, especially where it is scarce. Water is also often a transboundary resource, and optimal management requires planning at an international, basin-wide scale.

The benefits of agricultural water

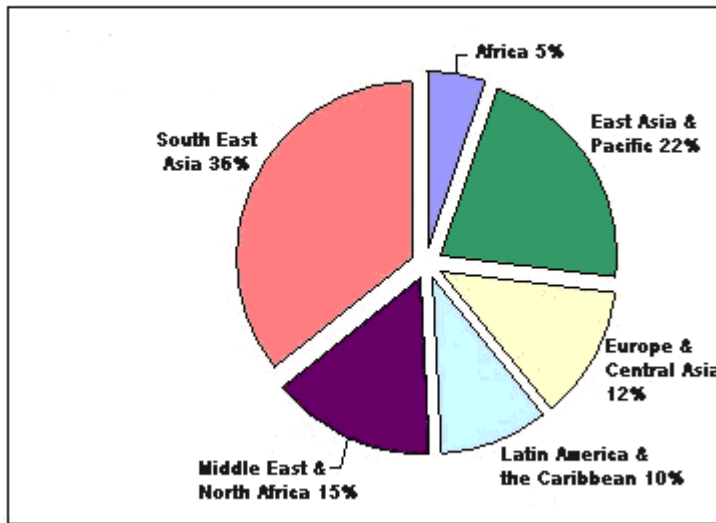
In many regions, irrigated agriculture is the main source of rural employment. Typically more productive than rainfed agriculture, irrigated agriculture reduces risks associated with climatic uncertainty. Investment in irrigated agriculture can benefit the poor if they are included in the design of projects, if they participate in the management of irrigation systems, and if they are exposed to new economic opportunities through the development of markets.

Past Investments

Drop in World Bank lending, but a broader range of delivery mechanisms

The Bank has lent approximately US\$20.7 billion for irrigation and drainage investments since 1980, with commitments differing widely among regions (figure 9.1). Lending for the subsector has varied considerably and decreased in recent years, dropping from US\$1,040 million per year during 1994-96 to US\$891 million per year in 1997-99, and US\$490 million per year in 2000-02 (figure 9.2). This reduced level of funding still represents about 27 percent of the total allocation to the agriculture sector and 10 percent of total rural lending. The number of projects remained stable from 1999 to 2001 but is roughly one-half of that of the 1980s and early 1990s. In addition to financing full-scale irrigation and drainage projects, an increasing amount of investment in irrigation and drainage is being provided as part of community-based development, natural resource management, and other projects.

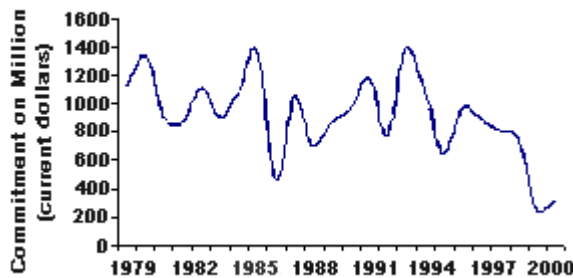
Figure 9.1 Regional distribution of active irrigation and drainage projects, January 2006



Source: ARD Agricultural Water Portfolio Review

Declining investment opportunities, but some high-potential openings

Figure 9.2 Bank investments in irrigation and drainage (1979-2002)



Source: World Bank internal documents

The historically high level of investment in irrigation can be attributed primarily to the large potential gains from greater agricultural productivity and to the reduced weather-related risk to production. Opportunities for profitable new investments are more difficult because of increasing costs, such as water extraction and distribution; new environmental and social costs not previously recognized in irrigation

projects; a growing need for drainage investments; and falling commodity prices. There are, however, significant opportunities for small-scale and supplementary irrigation, and niche markets for high-value irrigated produce are growing fast.

Shift from large-scale irrigation to smaller schemes, community empowerment, and a reduced role for government

Agricultural water investments are changing to respond to changes in the global environment and experience with previous projects (box 9.1). In the 1970s and 1980s, investment typically involved large irrigation and drainage schemes with considerable infrastructure development. In the 1990s, investment often supported system rehabilitation and management and, more recently, small irrigation schemes under community-driven development projects. Increased water scarcity has shifted the focus from exploitation of water resources and building infrastructure to improvement of water use efficiency. Accordingly the Bank has shifted toward smaller investments, focused on poverty reduction and community empowerment. Associated with this is a greater emphasis on markets, the private sector, and water user associations in managing irrigation. At the same time, the limitations of the public sector as investor and economic manager and the greater efficiency of the private sector are now well recognized. This has led to a redefinition of roles, with the public sector focusing on regulation and pro-poor policy and investment.

Box 9.1 Some shortcomings of past investments

Water pricing and water service

On many past investments in irrigation systems, it has proved impossible to recover operating and maintenance costs from farmers, with the result that services have been underfunded and have deteriorated, and improvements in productivity and farmers' incomes have been below target. If systems are to deliver quality service, they have to be profitable enough for farmers to earn an adequate surplus, and arrangements for financing operation and maintenance costs have to be clear from the outset. The optimal arrangement is a farmer-managed scheme with full financial autonomy. If subsidies are required, they need to be transparent and reliable.

Need for more pro-poor approaches

Although recent projects have focused on poverty reduction objectives, fewer than half include data on poverty issues. Project appraisals must now analyze poverty impacts, and monitoring systems must measure long-term impacts on employment, incomes, and other determinants of poverty. Monitoring investment impacts on small-scale farmers, women, and minorities needs to be improved in future irrigation and drainage projects. New small-scale drip irrigation and sprinkler systems (and appropriate drainage systems), and technologies for cultivating high-value crops offer opportunities to improve productivity of assets of the poor.

Source: World Bank 2003

Key Issues for Future Investments

Eleven key issues and the need for a holistic approach

Issues related to agricultural water investments are highly interrelated, and there is a need for a holistic approach.

Maximizing impacts on poverty reduction. Projects will require greater emphasis on targeting the poor, focusing on their empowerment, and designing appropriate regulatory systems. Project design and implementation need to consider the following:

- Does external support improve access to water specifically for smallholders, enabling them to improve their agricultural production, incomes, and food security?
- Are the opportunities optimally used to strengthen the access of the resource-poor to irrigated land?
- Are smallholders protected from expropriation without compensation, and is more equity in resource rights being achieved by linking water rights to the land user?
- What priority is given to women's access to water and land, and what is the impact on their incomes?
- Are poor people being included from the start in planning, and are they empowered by strengthening of their cooperative negotiating powers?
- Does irrigation provide benefits for the landless, such as employment?
- Is access being improved to inputs, markets, and other institutions (van Koppen 1988)?

Need for a profitable business environment. Investment in agricultural water can only be viable and increase farmers' income where water is provided in a business environment that gives farmers the incentives and support services to bring yields to commercial levels and market their production profitably. Complementary investments in financial services, research and extension, input supply, and market development may be needed to diversify and intensify production systems and to increase productivity and profitability.

Multiple interests in water and the need for integrated resource management. Competing interests may result in conflicts over water allocation and use. The main water subsectors, namely agricultural water, water supply, hydropower, flood control, and environment, have increasingly adopted a cooperative approach to water management. But there is still room for improvement in cross-sectoral planning and coordination, as only modest progress has been made in integrating water management activities within river basins. Stakeholder participation in these processes of water governance is vital. Irrigation agencies need to establish links with appropriate basin agencies and various interests (agricultural, urban, industrial, and environmental) to prepare seasonal water management plans with clear water allocation rules. This will ensure that decision makers consider the potential impacts that seemingly desirable activities may impose on other interest groups. For example, while there may be agricultural benefits from more efficient farm water use, it may have negative consequences for rural households that rely on seepage and runoff for their domestic water requirements.

Need for institutional reform. Sustainable water management improvements require significant adjustment in institutional arrangements. Past irrigation investments have performed poorly because a workable institutional model was lacking. Little has been done to restructure irrigation agencies or expand private sector participation. A few

countries, such as China and Mexico, have emphasized financially autonomous utilities that sell bulk water to users. Key institutional issues include transparent and effective regulatory frameworks (water rights and irrigation laws), land tenure, and decentralized irrigation and drainage management. In large-scale irrigation, simple models of construction and rehabilitation have not created efficient and sustainable schemes: what is needed is broader “system modernization” approaches, which combine investment with a decentralized, participatory, and financially self-sustaining institutional model. Addressing these issues will require improved interaction between ministries of agriculture, finance, planning, and environment, and donor support provided through program lending and sector wide approaches.

Need for secure tradable land rights. As land ownership is typically a prerequisite for water rights, an effective land administration system should ensure that land rights are secure and tradable. Smallholders, especially women, have less secure land rights even though they are often the main users. If social, economic, and gender equity are to be enhanced and private investment, especially smallholder investment, promoted, land administration systems need to include mechanisms that recognize traditional and formal rights to land.

Capacity building. Training and technical assistance are required for building capacity of individuals and institutions, such as local governmental bodies and public sector water agencies, and to reform irrigation and drainage policies and their organizational structures. The World Bank Institute and other capacity-building partners, such as the IWRM International Network for Capacity Building (CAPNET) may provide support. Strengthening university curricula on irrigation systems operation and management is also needed.

Water pricing and cost recovery. A key policy issue is water pricing and cost recovery (box 9.1). Covering system operation and maintenance costs is clearly essential, and where water is scarce, managers and users need to develop incentive frameworks aimed not only at recovering costs but also at promoting efficient use.

The need for water rights. Established water rights—especially tradable rights—should improve water productivity and promote investment. However, on large schemes where quantities are uncertain and service delivery weak, attribution of legal rights is hard, and development of firm entitlements, often at the group level, should form part of modernization programs. Some countries—Jordan, for example—have successfully introduced formal rights by developing over time a flexible legal framework of entitlement and transfer, with capacity building. They have also formalized existing informal markets. In countries where there is acute competition for water, a forum for water users, including the resource poor, should be established to negotiate management plans and policies and regulations, such as a national water act, in order to protect all parties.

"Real" water savings. Experience in China and elsewhere has shown that, if projects concentrate only on improvements to physical irrigation and drainage systems, they may improve water use efficiency but may not result in much "real" water savings, because losses return to groundwater aquifers or downstream surface water systems and become available for other users and are not lost to the hydrologic system (box 9.2). Even if individual systems are inefficient, overall basin efficiency may be quite high in such areas. Improvements in water use efficiencies by upstream users might reduce the amount of water available for downstream use. However, "real" water savings

result from reductions of nonrecoverable losses such as evapotranspiration or losses to nonusable water bodies such as saline aquifers or the ocean. Thus for water quantity management the starting point needs to be the water balance (hydrologic cycle) to provide the basis for allocation of water.

Emphasis on productivity improvement. Although the pace of technological change in agricultural water management has slowed, the scope for efficiency gains remains enormous. Efficiencies worldwide are well below technical maxima, pressurized systems and protected agriculture still occupy only a small area, low-value staples predominate in cropping patterns, and agricultural yields and farmers' incomes are well short of potential. Productivity can be enormously improved—for example, through improved management practices that minimize evapotranspiration, such as cropping patterns, cultivation methods, timely availability of inputs, and soil-moisture management. New investments may be needed in areas such as crop genetics and nontraditional crops such as horticultural, flower, and fodder crops. Technology adoption is best promoted by encouraging the development of profitable product markets. Investment may be required to improve marketing infrastructure to respond to changes in market opportunities.

Sustainable natural resource management. Many countries are at the limit of water resources development, and pressure on land and water is intense. Overabstraction of groundwater is leading to a drop in water tables and decline in quality. Salinization and waterlogging have affected 30 million hectares worldwide, and a further half a million hectares go out of production each year—as much farmland as new irrigation creates.

Box 9.2 China: the Hai Basin

Development of China's Hai Basin (mainly due to irrigation) has resulted in annual evapotranspiration (ET) that far exceeds sustainable levels. Annual outflow to the Bohai Sea is about 5 billion cubic meters but would need to be about 9 billion cubic meters to provide adequate environmental flows. In addition, about 9 billion cubic meters of groundwater are overexploited annually. Increasing the outflow to the sea and eliminating overexploitation of groundwater would require ET in the basin to be reduced by about 13 billion cubic meters per year. Conventional water conservation programs have worsened the situation by increasing ET. The Global Environmental Facility (GEF) Hai Basin Integrated Water and Environment Management Project, presently being prepared, seeks to use a new approach by managing basin water resources in terms of ET, and by seeking "real" water savings that reduce ET to sustainable levels. Remote sensing and ET data systems will be key tools for providing accurate estimates of actual ET, thus making it possible to plan and manage water resources on a sustainable basis.

Source: Olson 2003

Drought and floods, exacerbated by climate change, have a heavy impact on agriculture, and particularly on the poor. In many countries, watersheds are degrading under multiple uses, and water allocation and use for agricultural purposes cause downstream externalities and lead to conflicts with other uses, including the need for water for environmental functions.

Future agricultural water development must identify environmental externalities (both positive and negative) related to management and address these in the design and implementation of projects (box 9.3). As an example, improving the marginal productivity of water use may require increased nitrogen fertilizer application, which may contaminate nearby wetlands, resulting in loss of biodiversity. An alternative approach might use legume crops, such as alfalfa, clover, and soybeans, in crop rotations for nitrogen fixation. Technological and managerial innovations from an effective research and extension system can, with cooperation of the different groups, help resolve conflicts over resource use. The development of such mechanisms is a key investment area for the Bank.

Box 9.3 Environmental management issues

- Improving management of water sources, return flows, and drainage to avoid damaging wetlands, mobilizing salts and agricultural chemicals, downstream pollution, and waterlogging.
- Regulating and monitoring extraction of water for irrigation to ensure sufficient environmental stream flows and to avoid “mining” groundwater aquifers.
- Establishing appropriate rules/standards for use of low-quality water in irrigation.
- Creating a supporting environment and capacity for adaptation to climate change.
- Adopting environmental planning in the design/modernization of new/existing irrigation and drainage schemes.

Source: IWMI 2001

Future Priorities for Investment

Future investment priorities start first and foremost with *farmers’ needs*—above all, access to assured water supplies, for which farmers need to have a say in the management of the irrigation system. Farmers’ needs set the reform priorities: irrigation modernization, user empowerment, water rights, and demand-driven investment. For profitable farming, farmers also require access to efficient input and output markets and to cost-effective technology. Thus farmers’ needs also set the priorities for agricultural policy, especially on the two critical fronts of market development, and research and technology transfer.

The need for a holistic approach

Agricultural water investments must recognize the political sensitivities relating to water access and use, as well as the multiple and competing interests regarding its allocation. Many factors—policies, institutional change and investments—need to be *integrated* to achieve efficient outcomes in all aspects of agricultural water management, from modernization of large-scale irrigation to rainfed agriculture. The sequencing and prioritization of change processes need attention, too. At the macroeconomic level, policies and programs for water resources, agriculture, and environment need to be

integrated. At the local level, investment needs to be based on profitable and sustainable farming and on workable institutional arrangements.

Agricultural water management has to be placed within an *integrated water resource management context* through integrated and participatory planning that assesses trade-offs and ensures optimal use of water at the basin scale. Cross-sectoral planning and cooperation and a basin-wide perspective are important, and objectives set should be time specific, realistic, and measurable.

Need for ownership, capacity building, and institutional development

Establishing leadership and ownership (from farmer to politician) and building capacity (organizational and managerial skills, and databases) in agricultural water projects, and related reforms of policies and organizational structures, are important for sustainability of investments.

Investment in agricultural water infrastructure

Need for infrastructure investment. For investment in agricultural water infrastructure, which is identified as a priority in the Bank's rural strategy, there are three vital considerations: ensuring that physical investments are matched with a viable institutional and financial model; ensuring that investments are driven by market considerations and are profitable for farmers; and ensuring that the objective of reliable water supplies is achieved.

In large-scale irrigation, priority should be given to modernization. In large-scale development, priority should be given to making better use of existing infrastructure through "modernization," which should be based on current and future market prospects and water service needs rather than those needs for which the system was initially designed. Modernization combines investment and institutional reforms, aiming at a sustainable, efficient, and demand-responsive water delivery service through an integrated package of selective physical upgrading, agronomic improvements, and institutional changes. The institutional changes typically include a reduction in the role of governments in management and financing, combined with service decentralization, agency accountability, scheme financial autonomy, and user involvement throughout. Irrigation modernization is a process, often implemented over a relatively long period, with changes sequenced and integrated according to local needs.

In *small- and medium-scale irrigation*, the best options for improving profitability are through community-driven approaches, investment financing mechanisms, and participatory irrigation management.

In all cases, investments need to be *financially sustainable* and not require continuing subsidy. They need to be *market-linked*. Access to information and markets for agricultural inputs and products, agricultural credit, farm roads, and telecommunications services, are basic requirements for profitability.

Need to improve reliability of supplies, including new infrastructure. Improving reliability of supplies and services may require development of new storage facilities. The resulting improved reliability will foster innovative investments that may otherwise not occur because of high production risks associated with unreliable supply.

Investment in smallholder agricultural water for poverty reduction.

Increased attention must be given to the potential for reducing poverty through the systematic factoring in of poverty and gender concerns to agricultural water programs. Investment in irrigation and other agricultural water management projects can be effective in reaching the poor, but care is needed to ensure a pro-poor element in programs, as a purely market-driven approach will favor the better off. Where possible, agricultural water investments should be targeted at poor areas, and projects should be designed with the needs and capabilities of the poor in mind. Promoting technologies and services tailored for smallholders is likely to have greater impact on poverty reduction. Such technologies include treadle and small-engine powered pumps, low-cost drip/sprinkler systems, technologies for groundwater extraction, water harvesting and soil moisture conservation techniques, watershed management approaches, and training and technical advisory services specifically for smallholders.

The private sector has much potential to provide management and marketing services for smallholder irrigation but is constrained by the high costs associated with transactions with small-scale producers. Rural producer organizations may be a means of overcoming this scale-related problem and thereby encouraging private sector provision of services to small-scale producers, for example group contracts for marketing. Another route is public-private partnerships to develop promising new technologies and to create demand, as has been done successfully with treadle pump technology in several countries.

Investment in institutions

There has to be a move towards new institutional arrangements which give more responsibility and say to farmers, engage the energy of the private sector, and reduce government's role. The emphasis should be on decentralization, financial viability and accountability of water service providers, empowerment through rights and responsibilities of water users and their organizations, the use of incentives to reflect societal values, and innovative mechanisms to bring in the private sector.

Role of government. As discussed above, the role of government is changing, and investment will be needed to strengthen core government functions, such as: establishing the policy framework within which the private sector can function; regulation of land and water rights and markets; integrated water resources management; environmental

protection; research and technology transfer; and rural infrastructure. Governments need also to set an incentive structure that incorporates principles of equity within the context of customary rights and that provides for recovery of operation and maintenance costs as the basis for quality water service and scheme sustainability.

Broader engagement of other stakeholders and water user associations. As a complement to this more strategic role for government, there are options for broader engagement of other stakeholders in a process of decentralization and inclusion. These options range from corporatization of irrigation management agencies through increased accountability of service providers, to development of user associations, and to public-private partnership in the development and management of irrigation schemes, an approach now being piloted in the Middle East and North Africa Region. At the farmer level, there is a central role for participatory approaches and farmer empowerment. Investment quality can be improved by participation at every level, bringing the voices of the rural poor to such areas as policy making, technology development, and drought management. Community-driven development approaches can also be excellent vehicles for ensuring that investments match farmers' needs and local institutional capacity. Water user associations are increasingly important for irrigation management and can also undertake other activities, including the provision of extension, technical, and marketing services. Associations should normally take over smaller schemes quickly, but transfer of larger schemes should take place only once water user associations have achieved financial autonomy.

Investment in productivity

A focus is required on ways to increase *water productivity* through a combination of pro-business policies, institutional changes that empower the farmer, technological improvements, and investments to intensify and diversify agricultural production and increase farming profitability. There is an agenda for both international and national *research and technology transfer* on water productivity, wherever possible in partnership with the private sector, and on agricultural water management for rainfed farming.

At the farm level, productivity improvements can best be obtained through an integrated approach to the different inputs to the production system—soil, water, and agronomy. Examples include integrated water-saving approaches to on-farm water management; supplementary irrigation and surface-groundwater conjunctive use; combined water and soil fertility management; and integrated approaches to combating drought, salinity, and floods. The clear message is that water-saving technology for profitable investment exists in abundance, but its adoption requires knowledge, reliable water service, and an economic environment that provides undistorted incentives, manageable risk, and market access.

Investment in environmental aspects of water management

To meet demand, there has to be both intensification and expansion of irrigation, and approaches to achieve these goals have to be at once practical and sensitive to

environmental concerns. Environmental concerns need to be mainstreamed into all aspects of water management and agricultural policy, and options have to be worked out for managing possible trade-offs, using participatory approaches and new methodologies to make sure that concerns are assessed and that responses enhance the economics and sustainability of investments.

Some specific investments can have very positive environmental impacts, including investments in drainage, watershed management, and groundwater management. The unplanned mining of groundwater, for example, has severe costs, which investment in management can greatly reduce. For most countries the best immediate options are to strengthen existing groundwater rights and promote self-regulation, supporting this strategy by eliminating energy subsidies and promoting water use efficiency. With these tools, countries may move toward more “planned” depletion, allowing a less water intensive economy to develop without severe shock or negative impacts on the poor.

Scaling up Investments

Readiness for scaling up

Economic viability, a healthy positive cash flow for the farmer, and institutional and financial sustainability of scheme management are the hallmarks of an investment model that is ready to be scaled up. Where government subsidy is involved, investments must be accompanied by clear plans for eventual phasing out of support and for the financial independence of the system.

Monitoring and evaluation of agricultural water developments is essential not only to adapting current programs but also to scaling up. Systems must measure the full range of benefits—economic, environmental, and social. Key outcome indicators relate to production per unit of water use, real water savings, and changes in land use. Impact indicators focus on incomes, poverty reduction, and system sustainability. Systems also have to measure the benefits from multifunctionality of agricultural water and from the multiplier effects of direct and indirect income and wealth creation in the local and national economy, which are often greatly underestimated.

Best practice approach

Improved analysis through monitoring and evaluation and through specific studies will provide a basis for identifying key elements of good practice and innovative approaches for scaling up. Thematic guidelines are also needed with reference to irrigation investment and (1) poverty reduction, (2) the context of increasing water scarcity and competition for water, (3) impacts on the environment, and (4) policies for enhanced private sector investment.

Use of safeguards

Investments will need to conform to World Bank Safeguard guidelines, as summarized in box 9.4. Safeguards can be viewed not as a constraint but as an aid to investment. Effectively, they help by integrating environmental and social issues into projects and by supporting participatory approaches and transparency.

Box 9.4 Key safeguard policy issues for irrigation and drainage investments

- Environmental Assessment (Operational Policy [OP]/Bank Procedure [BP] 4.01)—an Environmental Assessment is required if a project may have potential adverse environmental risks or impacts.
- Safety of Dams (OP 4.37)—dam safety measures and/or reviews and safety inspections are required if an investment involves construction of a large or high hazard dam or is dependant upon an existing dam.
- Natural Habitats (OP 4.04)—protection of natural habitats (land and water areas where most of the original plant and animal species are still present) is required for an investment with potential to cause degradation of the natural habitat.
- Projects in International Waterways (OP 7.50)—the Borrower must notify other riparians of any proposed investment involving a body of water that flows through or forms part of the boundary of two or more countries.
- Involuntary Resettlement (OP/BP 4.12)—a Resettlement Action Plan is required if an investment results in physical relocation; loss of land or access to land or other assets; or impacts on livelihoods due to restrictions on access to parks or protected areas.

Source: World Bank, Operational Manual

Selected Readings

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.

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Investments to Empower Farmers to Manage Irrigation and Drainage Systems

Water user associations (WUAs) are important for empowering farmers to manage irrigation and drainage systems and offer potential for reducing costs and improving irrigation services. The optimal size and allocation of responsibilities to such associations is a complex issue dependent on local conditions and capacities. The impact of farmer management of irrigation systems on agricultural productivity may not be substantial if this is not accompanied by investment in physical infrastructure to improve the quality of services. Empowerment of smallholders, and particularly women, also requires investment in water user association capacity. Irrigation agencies need to provide support to develop sustainable user associations.

Following rapid expansion of irrigated agriculture worldwide from the 1950s to the 1980s, many governments found it difficult to manage recurring costs and collect water charges for irrigation. This led to deterioration of infrastructure, shrinkage of irrigated area, poor distribution and wastage of water, waterlogging, and salinity (Vermillion and Sagardoy 1999). Many governments transferred management responsibility to local water service providers, such as WUAs or cooperatives, expecting this transfer to reduce financial burdens on government and help increase the productivity and profitability of irrigated agriculture, since users were expected to operate systems more effectively to meet their own needs. While these transfers have been successful in some cases, in many countries financial considerations continue to dominate the debate on empowering users in irrigation management (box 9.5).¹

Box 9.5 Mali: success story

The Office du Niger in Mali, known for many years as an example of an irrigation system with a heavy financial burden, is now seen as a success story. The Office was created during colonial times to produce cotton, but in the 1950s cotton cultivation was abandoned because of waterlogging, and rice became the dominant crop. In the 1980s the Office was restructured to focus on both institutional and technical issues. The paddy processing and marketing functions were privatized, and activities now focus on the essential functions of water services, planning, and maintenance. Improved water delivery and land levelling enabled the adoption of transplanting methods and high-yielding varieties, increasing paddy yields from 1.5 to 6 tons per hectare.

Although there are no formal user associations, farmers are represented in decisions on use of water fees through their elected delegates, who are members of joint committees, each covering about 5,000 to 8,000 hectares. These committees decide on the annual maintenance program, budgets, and procurement, while day-to-day management remains the responsibility of the Office. This approach matches the capacity level of the farmers and may be a suitable model for other low-income countries with a low level of literacy.

Source: Couture and Lavigne 2000

¹ See the IAP, “Mali: Institutional Reform to Focus Public Role on Essential Public Goods.”

Empowering Water User Associations—Alternative Approaches

Commercial associations of farmers, common in Latin America, are legal entities that can enter into contracts and have power to enforce rules and regulations. They are responsible for water distribution, fee collection, maintenance, conflict resolution, and representing farmers in discussions with public agencies. Farmer members are not directly involved in the management of systems, as the associations hire professional staff for this. *Social associations*, common in Asia, rely on direct participation by all members and daily interaction for decision making, monitoring, and sanctioning. These associations are involved in maintenance activities by providing labor and in some cases by collecting irrigation service fees. This model is most appropriate in socially cohesive societies with small landholdings and simple irrigation technology.

The question of optimal size for user associations in large-scale irrigation systems with a large number of small-scale farmers is very complex. Expert opinions vary widely—from 40 hectares to a few thousand hectares—depending on whether the key performance objective is the extent of cooperation on irrigation activities or financial viability of the associations.

A multitiered organization is now considered an appropriate model for schemes with small-scale farmers. Base-level user groups send representatives to the higher-level organization that allocates water among the user groups and negotiates any conflicts. In turn, these units may federate into a higher level, with an apex-level organization for the entire system. This approach has been used in Nepal since the early 1990s. In contrast to the gradualist approach used in other Indian states, Andhra Pradesh opted for a “super big-bang,” top-down approach to reforming its irrigation sector. After new legislation in 1997, elections created over 10,000 user associations for all major, medium, and minor irrigation schemes, and six months later created user committees at the level of secondary canals.

Benefits

Typical objectives of transferring management to WUAs include:

- Eliminating recurring government expenditures for operation and maintenance.
- Reducing the rate of deterioration of irrigation infrastructure.
- Providing transparency in management and accountability of the irrigation service provider to water users.
- Increasing farmers’ incomes and the productivity of water.

Commercial associations have been very successful in improving the recovery of recurrent costs and stopping deterioration of infrastructure through better maintenance and equipment. However, despite widespread adoption of management transfer programs, there is still inconclusive and conflicting evidence on their impact on agricultural performance (box 9.6). In most large-scale projects, institutional reforms alone may not improve the productivity of irrigated agriculture and promote crop diversification; physical improvement of the system may be needed, and it generally requires user participation. In Latin America, raising agricultural productivity is most challenging

under systems managed by irrigation agencies according to well-established rules, such as delivery of water to users on prearranged schedules.

Box 9.6 Approaches to irrigation management

Participatory irrigation management (PIM) involves users in irrigation management. The irrigation service provider may be a financially autonomous utility or a local entity. It is generally governed, at least in part, by farmers who are involved in key decisions on water resources management, irrigation water delivery, annual budgets, priorities for maintenance and rehabilitation, and personnel.

Irrigation management transfer (IMT) reassigns responsibility and authority from government agencies to NGOs. IMT is about replacing the government—not just working with it—as is the case with PIM. IMT may include all or partial transfer of management functions, and it may be implemented at subsystem levels or for entire irrigation systems. Farmers may hire technical and administrative staff or even contract other organizations to manage the system.

Source: Authors

Policy and Implementation Issues

Policy reforms. Several policy issues must be addressed before embarking on institutional reforms: What functions should be transferred to what organizations? How will irrigation operations and maintenance and rehabilitation be financed after reforms? What policy and legal changes need to be made to support the reforms? What changes should be made in public agency mandates as a result of the transfer?

Scope of group activities. Water user associations often expand their mandated activities to include input supply, marketing, research and extension, and credit programs. There is a good argument for undertaking these activities, which increase the system's productivity, but they can easily overstretch group management capacity.

System rehabilitation. The most contentious issue is whether physical infrastructure should be rehabilitated before or after management transfer. Farmers may be very reluctant to take over responsibilities for systems in poor condition, given the lack of funds for O&M and the need for even greater funds for rehabilitation. If the government undertakes rehabilitation before transfer, this reinforces a perception that it is a government system and that government will finance future rehabilitation. However, Mexico used financing of rehabilitation works as a bargaining tool to promote transfers that were not very economically attractive to farmers.

Land rights. Secure land rights, providing either ownership or secure tenancy, are necessary before users can be expected to invest in irrigation systems.

Boundaries. There is a consensus that WUAs should be based on hydraulic boundaries (that is, at the level of minor or distributary canals) to perform efficiently. For historical reasons in some countries, however, user organizations are based on administrative boundaries.

Sustainability. Few WUAs have been able to achieve 100 percent cost recovery for operation and maintenance costs or have funds for construction. Using traditional user associations to strengthen large, agency-managed irrigation systems has met with little success. Users have no incentive to cooperate if water delivery is too erratic or if a rigid delivery schedule is imposed—frequent deficiencies of large-scale systems. Social associations developed to provide cheap labor for maintenance or to collect water fees are often weak.

Lessons Learned

There is no “one-size-fits-all” approach to empowering users in irrigation management (box 9.7). In the early 1990s, Mexico’s experience and its successful replication in Turkey and Albania raised great interest. The Mexican model is known as the “big-bang” approach because it covered about 3 million hectares and was completed in three to four years, in contrast with the gradual piloting approach used in most Asian countries. One advantage of the Mexican approach is the limited number of associations (about 400), which reduces efforts required for transferring procedures, training, and monitoring. Obstacles to replicating the “big bang” approach are unsecured land tenure, low productivity of irrigation systems in many countries, and, in some cases, the high level of technology required.

With the irrigation management transfer (IMT) approach, where irrigation management is transferred to an NGO, stakeholders may have conflicting interests, such as tensions between farmers at different ends of canals; wealthy farmers who pay bribes for extra water may resist the formation of strong water associations; farmers may favor taking over management, but irrigation department staff may resist for fear of losing jobs and revenue; and government finance and planning departments may promote IMT to reduce the burden of financing irrigation.

Box 9.7 Key elements of a successful management transfer program

- Absence of strong opposition to irrigation management transfer (IMT) by bureaucracies and local elites.
- Supporting legislation and support services for local water service providers.
- Capacity to create (or alter) local organizations to take over water management.
- Irrigation infrastructure suitable for management by farmers organizations.
- Clear land and water rights.

Source: Authors

With the transfer of responsibilities to users, the role of irrigation/water resources agencies changes to that of providing technical guidance, managerial, accounting, and financial advisory services; assisting with dispute resolution; and monitoring performance of associations. Agencies may focus more attention on river basin planning, surface and groundwater resource management and allocation, and environmental monitoring, and enforcement. But agency reform may result in a drastic reduction in

staff—frequently the cause of resistance to reforms—unless staff can be deployed to other tasks.

Recommendations for Practitioners

Before making investments in irrigation and drainage projects, it is essential to determine whether water users are motivated to take over responsibilities for management and whether there is likely to be resistance from third parties (staff of the present managing organization or influential water users) (box 9.8). For low-income countries, the Mali experience is a good example because it combines user monitoring of maintenance spending with the handling of the finances by the agency.

- Decision to transfer responsibility to users must be made at the highest government level; otherwise, management transfer programs adopted under donor pressure may fail. Such transfer requires legal action in the form of a decree or legislative act, such as the *Agreement of Transfer* between the government and the association, defining mutual obligations, and the *By-laws of the Association*, defining rights and obligations of the association and its members.
- Time-bound lending conditions for official development assistance often conflict with the time required to implement social reforms needed to ensure the effective empowerment of users. In Turkey, a transfer program was initiated first and then a Bank project later contributed to financing maintenance and office equipment for the water associations.
- Involving farmers in irrigation management should be part of an overall irrigation reform program that includes irrigation agency reform and improvement in service delivery functions.
- Adequate infrastructure is essential to ensure that institutional and policy reforms lead to effective and efficient irrigation systems so that is water delivered in a reliable and measurable way.
- Technical change must complement management reforms to improve the efficiency and productivity of irrigation systems, and farmer organizations with irrigation governance responsibilities may act as the catalyst for this modernization.

Box 9.8 Potential investments

- Study tours and exchange visits.
- Assistance in forming user organizations through support to government agencies, community organizations, or NGOs.
- Gender analyses and planning for women's participation in water user associations (WUAs).
- Assistance in changing legislation.
- Assistance in changing the roles of government agencies.
- Training of user organizations (accounting, operation, and maintenance).
- Special equipment for maintenance.
- Office equipment.
- Rehabilitation and upgrading works in severely deteriorated systems.

Source: Authors

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Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.

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This investment note was prepared by Herve Plusquellec, with input from Walter Ochs, Safwat Abdel-Dayem, Ariel Dinar, and other irrigation and drainage specialists in the Irrigation and Drainage Network of the World Bank.

Investments in Irrigation for Crop Diversification

Farmers' efforts to diversify production are frequently hampered by inadequate irrigation systems. If diversification results in high-value crops being grown, irrigation system investments may be more economically viable as a result of the higher returns and the increase in water use efficiency. Diversification in irrigated agriculture often requires new or improved technologies for water delivery and drainage, with investment needed to modernize water control so as to increase the flexibility of water delivery and drainage. To ensure that farmers benefit from agricultural diversification, investments are required in marketing and processing facilities and services, such as research, extension, and credit, and incentive structures to facilitate growth of high-value crop production.

Adoption of high-yielding crop varieties during the green revolution, combined with rapid expansion of irrigated areas from the 1960s to the 1980s, resulted in a significant increase in food production, especially rice production in Asia. Surpluses resulted in a decline in grain prices in domestic and world markets, and in response to this, farmers sought alternatives to cereal cultivation. Other factors spurring crop diversification include the availability of advanced irrigation technology; development and adoption of improved high-value crops; increased domestic and regional demand for fruits, vegetables, and livestock products; growth of private agribusiness in processing and marketing; and removal of distorting policies that favored selected crops.

However, many farmers in rice-based agricultural systems experienced severe problems in diversifying to other crops, constrained by deficiencies in irrigation infrastructure and management at the farm level and by a poor policy environment and lack of support services for diversification. Because of the importance of rice, many issues discussed in this note deal with diversification of rice-based cropping systems. The lessons learned are also valid for increasing productivity of other irrigated agricultural systems.

Irrigation, Drainage, and Crop Diversification

Water delivery. Paddy and nonpaddy crops require different irrigation management. Both excess water and deficits adversely affect yields of nonpaddy crops, whereas rice does well with continuous irrigation and/or field-to-field irrigation, which has been the dominant method of irrigation in most of South and Southeast Asia. Basin irrigation, the method used for irrigated rice, is also used for other crops, such as groundnuts, maize, and soybeans, but is not suited to crops sensitive to wet soils or to soils that form crusts. Delivery of irrigation water to nonpaddy crops at discrete, variable intervals with precise flows is more complex than continuous delivery for rice. Flow rates must be carefully controlled to irrigate nonpaddy crops whether surface or pressure systems are used.

On-farm irrigation and drainage networks. Many irrigation projects designed for rice production have a low density of irrigation ditches and farm drains. Such infrastructure is sufficient for field-to-field irrigation, but nonpaddy crops require direct plot access to irrigation and drainage that provide intermittent water supply and prevent soil saturation affecting crop production. The density of the tertiary system required for nonpaddy crop

cultivation depends on factors including land slope, nature of soils, farm size, mechanization, and method of on-farm water application.

Land consolidation. Construction of a dense on-farm irrigation and drainage system needed for crop diversification cannot reasonably be implemented where farm plots of random shape are scattered throughout the irrigated area. A land consolidation program is often needed as a basis for a cost-effective layout for an on-farm irrigation system suited to efficient water management. Farm plots should be rearranged in a geometric grid that determines the layout of irrigation and drainage systems and farm roads. In Morocco since the 1960s, planning for new irrigation systems has started with a land consolidation program that regroups individual farmers' small plots into rectangular blocks of about 30 hectares. In Japan, Korea, China, and Taiwan, where diversification is common, irrigation systems were developed systematically in conjunction with land reform, providing irrigation and drainage access for each plot and crop. Failure of land consolidation programs has been common, and political commitment—sometimes supported by external stimuli—has been important in driving land reform.

Drainage. Improving drainage reduces waterlogging and salinization, allowing a wider choice of potential crops and encouraging crop diversification. Complementary on-farm drainage facilities for fast removal of excess water and lowering of the water table may need to be installed and integrated with the main drainage system. Some farmers provide these facilities with rudimentary but costly systems of dual-purpose field ditches and raised beds—a technique widely used in delta areas in Southeast Asia. These systems, while effective, take up considerable productive land area.

Soil management. In many cases, conversion of lands from rice to nonpaddy cultivation can be done only at considerable cost as the high clay content of heavy soils that are excellent for rice cultivation results in low infiltration rates and poor suitability for other crops and impose large power requirements for land preparation. Diversification from rice to other crops therefore has greatest potential on lighter soils.

Benefits

Agricultural diversification creates opportunities for higher and more stable rural incomes through more efficient use of resources and the exploitation of comparative advantage. Diversification generally implies a shift from cereal crops to other field crops or high-value horticultural crops (box 9.9). These may require less water but offer opportunities for greater employment, higher incomes, and more value-added processing.

Box 9.9 India: Uttar Pradesh sodic lands reclamation project

In 1993 an estimated 1.25 million hectares of land in Uttar Pradesh was completely barren due to sodification. Another 1.25 million hectares of low-yielding salt-affected lands covered about 10 percent of the net cultivated area of the state. A Bank-supported project to rehabilitate these lands introduced technology that included drainage, incentives, soil amendments (gypsum), tubewells, and institutional components. Within six months of beginning reclamation, productivity and income began to increase. Farmers began to diversify by planting high-value crops, both nontraditional (guava, Cape gooseberry, sunflower) and traditional (mustard, sugarcane).

Source: World Bank 2002

Two Bank projects—a success in Brazil and an unsatisfactory result in Thailand—illustrate the importance of irrigation system design, access to markets, and farmer training in enhancing crop diversification. In Thailand in 1977 at appraisal time, it was expected that during the dry season about half of the Lam Pao Scheme under the Northeast Irrigation Project II would be cropped with high-yielding rice varieties, with the rest under peanuts and mung bean. Over 20 years later, the cropping intensity during the dry season averages about 32 percent. Dry season vegetables are produced mostly near the larger canals. Expansion of diversified irrigated agriculture is constrained by the lack of tertiary canal service to individual fields, the unreliability of canal water, seasonal migration of rural labor to urban centers, and poorly organized markets in the area.

In Brazil, the Upper and Middle São Francisco Irrigation Project, appraised in 1985, consisted of rehabilitating seven public schemes and constructing a new scheme, “Formosa.” Irrigation systems were designed to provide high quality of service to each user, with the possibility of adopting sophisticated pressurized farm applications. The expected area of crop diversification was greatly underestimated at 13 percent as the area now devoted to fruit crops (mainly banana and mango) averages 61 percent in the rehabilitation sites and 32 percent in the new scheme. Improved market access via a new highway to Brasilia greatly enhanced prospects for output growth in Formosa, and the project has generated considerable off-farm employment.

Policy and Implementation Issues

Equity in diversification. Diversified crop production can have major impacts on employment and stimulate off-farm economic development, and these can be important contributors to poverty reduction. However, opportunities for farmers to diversify are not always equal as irrigation and drainage infrastructure can be costly, especially some microirrigation equipment and infrastructure. Wealthier farmers are better able to finance such investments, assume risk, and access the considerable knowledge and information services required for successful diversification.

Groundwater development. Deficiencies in water delivery from surface irrigation systems have spurred farmers to tap other sources of water, primarily from drains and

groundwater (box 9.10). This has sometimes led to overexploitation of groundwater resources, posing a major threat to health and the environment. A decline in groundwater levels increases pumping costs, affecting sustainability of groundwater supplies and the profitability of new cropping systems.

Box 9.10 Groundwater and crop diversification: “farmers vote by drilling”

During the last 20 years, with low development costs, there has been great increase in use of groundwater resources for irrigation. Canal water distribution is often erratic or based on rigid scheduling, and large variations between planned and actual allocation of water hamper cultivation of nonpaddy crops. Farmers quickly realize the potential operational advantage of groundwater over surface water. Groundwater development in Thailand has largely solved water supply problems. In a project in Phitsanulok, farmers’ access to groundwater, provides freedom over crop calendars and choice of crops, as they plant at the time best for their own situation and markets and can water crops at the frequency and duration most suitable to their crop and soil characteristics.

Source: Mainuddin, Loof, and Abernethy 2000

Complementary investments. Irrigation and drainage investments alone are seldom sufficient to increase agricultural diversification. Complementary investments in roads, research and extension, markets, and financial services are necessary to increase productivity and to maximize the impact of agricultural diversification on poverty and incomes.

Lessons Learned

Agricultural diversification is an evolutionary process that requires the support of appropriate policies, technologies, infrastructure, and services. Constraints include limited technologies for alternative crops, irrigation water supply and management deficiencies, poorly developed agricultural markets, weaknesses in research and extension, and unfavorable government policies (Barghouti, Garbus, and Umali 1992). In Japan, South Korea, and Taiwan, the unique role of rice in the agricultural economies of these countries has made it difficult to replace. Social, cultural, and food security considerations have led to heavy government protection for rice farmers.

Crop diversification in irrigated rice systems occurs at a pace determined by markets and policies. Private investment generally grows gradually, as farmers gain experience with new markets and production systems. Market information systems and market access are critical to promoting diversified cropping. Diversification is most advanced where farmers have easy access to reliable water in river delta areas and alluvial areas, where there has been explosive development of groundwater resources. In other surface irrigation systems, diversification will remain constrained if investments support only urgently needed rehabilitation and do not upgrade irrigation infrastructure to meet the requirements of a diversified agriculture.

Recommendations for Practitioners

Diversification in irrigated areas requires improvement of main canals and distribution systems and construction of a tertiary (on-farm) irrigation and drainage system to meet precise water delivery requirements of diversified crops. This may need to be complemented by reorganization of farm boundaries, land consolidation, and improvements to main drainage and flood control systems.

Improvement of irrigation and drainage facilities is a prerequisite to crop diversification but should be complemented by other support services. Governments should encourage investment for the modernization of marketing facilities and more generally by investing in improved roads, communication systems, and storage (box 9.11). Extension programs with information on irrigation, agronomic practices and economics help farmers decide which crops to grow. An assured and stable market, and readily available inputs and credit, are also essential to sustain crop diversification, as demonstrated in the Middle East and North Africa (box 9.12).

Box 9.11 Potential investments

- Modernization of the water distribution system to provide reliable and flexible delivery.
- Tertiary and on-farm development (including irrigation, drainage system, and farm roads) serving each farm plot.
- Microirrigation.
- Greenhouses, tunnels, and mulching.
- Marketing and food processing facilities.
- Extension and financial services

Source: Authors

Box 9.12 Middle East and North Africa (MENA) Region: diversification

The agricultural sector in MENA countries has witnessed remarkable change and modernization, especially in the irrigation subsector, which benefited from a variety of recent advances in water management, crop improvement, marketing, and processing. Changes were often led by private companies that introduced modern production technology, such as plastic houses, tunnels and mulches, improved hybrid varieties, drip irrigation systems, soluble fertilizers and herbicides, modern market information systems, and refrigerated transport equipment for long hauls.

Source: Authors

Before initiating a crop diversification program, detailed studies should determine the quality of irrigation service and its suitability for diversified crops, assess the potential markets, and assess the available level of services and technology. In-depth diagnosis of the irrigation system should go beyond an evaluation of the indicators of hydraulic, financial, agricultural, and environmental performance to cover problems such as obtaining credit, access to markets, and participation by women and poor people in their efforts to diversify.

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Investments in Waterlogging and Salinity Control

Salt movement by rising water tables in surface irrigation, and by pumping brackish water from groundwater systems, can lead to land salinization and reduced crop productivity. The primary investments in waterlogging and salinity control involve irrigation and drainage infrastructure and improved irrigation water management to control seepage losses from canals and reservoirs. This is vital where natural leaching of excessive salts from the soil is not adequate and where geological conditions lead to salinity in irrigated areas. Proper management and provision for subsurface drainage in irrigation systems can address salinity problems and enhance productivity and sustainability of irrigation systems.

Waterlogging and salinity problems often require some form of drainage to allow sustainable agriculture production. This must be an integral part of irrigation system investments. However, poor irrigation and agronomic practices have led salinity, sodicity, and waterlogging to affect 40-50 percent of the world's 270 million hectares of land currently under irrigation. Drainage investments are needed to control waterlogging and salinity on 60-85 million hectares of currently irrigated lands. This investment can yield significant economic benefits (box 9.13).

Waterlogging

Waterlogging occurs when soil pores stay filled with water, resulting in oxygen deficiency that impairs root growth and a plant's ability to absorb nutrients. Rice plants are an exception, as they transfer air to roots and are able to grow well even when roots are submerged for long periods. Irrigation systems are vulnerable to waterlogging at critical locations such as irrigation supply canals and seepage from reservoirs. Low areas within a command area are vulnerable if farmers on higher ground do not practice good water management. High water tables result from deep percolation and lateral underground water flows. Some soils develop high water tables due to low drainage porosity, whereas others maintain high water tables because of low water-transmitting properties. Slowly falling water tables may affect plant growth even when levels eventually fall below root zones.

Salinity

Box 9.13 Egypt: economic impact of drainage

Egypt's National Drainage Program (1992-00) Implementation Completion Report rated drainage components highly satisfactory and estimated an economic rate of return of 19 percent. Drainage is one of the most important investments for raising agricultural productivity in a country with limited water resources and high population growth. Drainage is estimated to have increased production in 1998-99 as follows:

- Seed cotton 95,000 tons
- Rice 240,000 tons
- Wheat 380,000 tons
- Maize..... 1,050,000 tons

The annual contribution of drainage to the Gross Domestic Product was estimated at US\$0.9 billion or 8 percent of agricultural value added.

Source: Ali, van Leeuwen, and Koopmans 2001

Soil salinization is a concern for irrigation systems in arid and some semiarid climates, and some temperate or tropical areas close to oceans or saltwater tidal areas. Salts in the temperate and tropical climates are leached from soils profiles over time, but in arid and semi-arid climates salt builds up due to higher evaporation rates. When irrigated areas are developed in arid climates, soils often must be artificially leached before cropping can begin. In semiarid climates some natural leaching takes place during rainy seasons if adequate drainage is provided.

Irrigation water also contains naturally occurring salts leached from soils of the catchment area or the recharge area of an aquifer. Salt accumulation in soil depends on irrigation water quality, irrigation management, and adequacy of drainage (Hillel 2000). Land salinization initially results in a lowering of crop yields or vegetative growth followed by appearance of salt patches. It can progress to a barren salty landscape if action (such as drainage) is not taken to leach excessive salts from the soil.

Sodic soil is closely related to saline soils. Applying irrigation water to areas with abundant salts (common in arid and semiarid areas) and more than 15 percent exchangeable sodium leads to the formation of sodic (or alkaline) soils. Low chloride and calcium content in some soil and/or irrigation water can cause clay particles in the soil to adsorb sodium and magnesium salts and swell. The soil then loses its structure and permeability, water infiltration is hindered, and plant roots/soil organisms are deprived of oxygen. The solution to sodic soil problems is the use of soil amendments, such as gypsum, leaching, and drainage (box 9.14).

Investment Needs

Irrigation water management is the important first step in controlling waterlogging and salinity. This involves controlling water to minimize losses, thus controlling deep percolation and runoff. Investments may involve improved surface irrigation systems (such as furrow irrigation, border irrigation, or basin irrigation) or pressurized systems (such as sprinkler, drip, and microirrigation), or precision land leveling. All require credit or financial assistance, plus extension and training for successful establishment, operation, and maintenance. Improving irrigation efficiency often requires that conveyance and distribution systems be modernized to provide the right amount of water at the time needed by the crop (for example, in China, the number of irrigations was reduced from five to three, which did not significantly affect wheat yields as water was supplied at critical growth times).

Box 9.14 India: Sodic Lands Reclamation Project

Sodification of soil left 1.25 million hectares of land completely barren in Uttar Pradesh so the Sodic Lands Reclamation Project (approved in 1993) helped provide sustainable solutions to the complex problems. Keys to success were farmer participation, incentives, and improved technologies. Farmer groups made major decisions and did virtually all the work, and smallholder receipt of clear titles to land provided incentives to make the barren lands productive. Farmers successfully used a package of technology involving a strict process of soil testing, digging surface drainage, building tubewells, applying gypsum, leaching and flushing with good quality groundwater, good crop husbandry, and regular flushing of salts from link drains.

Source: World Bank 2002

Seepage control is needed, where seepage from canals and reservoirs causes waterlogging or salinization. Investments to control seepage generally involve canal lining. Farmers, through WUAs, are usually responsible for lining their own (tertiary) canals, whereas governments are generally responsible for the larger canals. Many canal lining systems have joints that transmit large quantities of water to the seepage areas. These rigid canal lining systems may improve hydraulic transport of water in the supply canal but do not provide adequate seepage control unless a flexible geo-membrane is properly installed under the canal lining. Seepage control from dams is also important for dam foundation safety, and modern lining techniques use geo-membranes to prevent seepage from small- and medium-size reservoirs. Interceptor drains are used to collect and route seepage water to supply canals.

Box 9.15 Egypt: drainage

Adequate drainage has mitigated the effect of the irrigation-induced waterlogging and salinity in Egypt, which has invested about US\$3 billion (in FY2001 dollars) since the 1970s to provide drainage for 2 million hectares. The government and farmers have shown strong commitment to the program, adopting appropriate technologies, improving irrigation systems, transferring management to water users associations, and adopting a well-functioning system of cost recovery. Egypt has a cropping intensity of 230 percent, and crop yields for wheat, rice, and cotton are among the highest in the world. Improved drainage accounts for 15-25 percent of crop yield increases. Reuse of drainage water in irrigation contributes to making overall water use efficiency in the lower Nile River Basin one of the highest in the world.

Source: World Bank 2002

Drainage investments are critical to remove excess water from irrigation systems and to control waterlogging and salinity (box 9.15). Surface drainage can control runoff from rainfall, but subsurface drainage is critical to prevent root zone waterlogging and salinization. When poverty reduction is an important goal, and for larger systems, governments make initial investments with some sort of cost-sharing/cost recovery arrangement, as in the case of Egypt² and Pakistan. In commercial agriculture, drainage investments are often borne by farmers and user associations.

Subsurface drainage can be provided by deep open drains, horizontal pipes, or tubewells. Open drains normally must be 1-2 meters deep and therefore take a significant amount of cropland out of production. Subsurface pipe drains minimize loss of land, are readily accepted by farmers, and although initial investment costs are higher, the cost of operation and maintenance is much less. Tubewells are also used for drainage, particularly where groundwater quality is good and water transmission properties of the substrata are adequate. Tubewell irrigation, however, can draw excess salts from below the root zone and create water-quality problems.

² See the IAP, “Egypt: Improving Agricultural Production Through Better Drainage.”

Surface drainage through constructed channels or waterways is important to remove excess water in humid areas. Shaping land surfaces is often necessary to provide uniform water infiltration and to minimize ponding, particularly with surface irrigation. These investments are often financed by credit to farmers from private sources, but poverty reduction objectives may justify subsidies, cost sharing, or government financing.

Biodrainage has not been used extensively in large-scale projects, although it has promise under the right conditions. Biodrainage removes excess groundwater through transpiration by vegetation with high water use, such as eucalyptus trees (box 9.16). This maintains groundwater levels below the root zone of crop plants. Other advantages are wind erosion control, elimination of drainage water disposal problems, low investment cost, and ecological benefits. Disadvantages are that biodrainage areas use potential cropland, do not remove salts, and may interfere with water use by crops (FAO 2002).

Box 9.16 Pakistan: biodrainage in the Punjab

Evaluation of biodrainage project examined an irrigated area of 18.2 hectares with 4 hectares of six-year-old eucalyptus trees planted at 1,340 trees per hectare. The surrounding area was planted to cotton, rice, and sugarcane. The average water table depth under the trees ranged from 1.4 to 2.7 meters, and in the irrigated crop area surrounding the plantation was 1.1 to 2.1 meters. Soil salinity remained below critical limits in the plantation. Water table drawdown resulted in the groundwater moving as a front toward the eucalyptus plantation area and improved environmental conditions in the surrounding area.

Source: FAO 2002

Benefits

Economic benefits from control of waterlogging and salinity include improved crop productivity, greater sustainability, and opportunities for crop diversification for higher income and lower risk reasons. For the India project, even without accounting for incremental revenues from horticulture or benefits from improved education, health, and family income, the rate of return was estimated at 28 percent.

Social benefits primarily relate to poverty reduction, though other improvements in rural quality of life can be significant, such as a reduction of mosquito-breeding areas, improved storm water control, and improved access to fields.

Environmental benefits can include maintenance of wetlands, elimination of barren saline areas, and enhanced habitat and aesthetic values. Care must be taken when installing drainage facilities to protect existing wetlands and mitigate any damage. Disposal of drainage water from saline land can be a problem for downstream users.

Policy and Implementation Issues

Sustainability of irrigation systems in arid and semiarid zones is unlikely if waterlogging and salinity problems are not controlled. Drainage needs must be evaluated when irrigation projects are initiated. Monitoring and evaluation of water tables and water quality changes in existing systems are critical. Irrigation budgets must have adequate

financing for such monitoring and for correcting problems that are detected. Decisions on when to undertake drainage work require realistic information from baseline studies, projections, or models, especially for newly irrigated land.

Institutional considerations should be addressed as early as possible in planning for waterlogging and salinity control. Water user associations facilitate participation of stakeholders, which is especially important early in the planning process. Arrangements for monitoring and evaluation of water tables, water quality, and soil quality changes are necessary on a continuing basis, as changes in cropping systems, water supply, seasonal water variation, and chemical use all impact groundwater levels and quality.

Environmental implications should be explored through environmental assessments, baseline studies, and monitoring of environmental changes. Plans for mitigation of environmental problems should be developed early in the project design phase. All investments to control waterlogging and salinity should seek to enhance environmental resources and develop policy packages to protect the environment.

Lessons Learned

Get to the source. The first priority is to find and eliminate (or reduce) the sources of excess water, such as seepage from canals and overirrigation, as this minimizes the drainage needs.

Disposal of drainage water. Investments in proper disposal or reuse of drainage water are most important to minimize environmental concerns over water quality in downstream areas. However, water treatment is expensive and normally not feasible for irrigation systems. Systems for reusing drainage water are sometimes worth consideration, and they might include using drainage water from salt-sensitive crops for salt-tolerant crops, and then from these for more salt-tolerant varieties of trees, and finally diverting water to solar evaporators for crystallized salt collection.

Tubewells for drainage. Public drainage tubewells are impractical when pumped water is too saline for irrigation use, especially if farmers are expected to pay for operation and maintenance.

Recommendations for Practitioners

Controlling waterlogging and salinity requires investments involving (box 9.17):

- Timely provision of drainage for irrigation schemes based on sound

Box 9.17 Potential investments

- Credit and financial services to enable farmers to invest in on-farm drainage and water management improvements.
- Monitoring and evaluation systems for water tables and water quality.
- Surface, subsurface, or bi drainage control measures.
- Environmental impact studies of irrigation and drainage investments.
- Strengthening of water user associations to allow participation in planning and implementing drainage and salinity control measures.
- Seepage control measures for dams, reservoirs, and canals.

Source: Authors

investigation and planning during the project design phase.

- Use of participatory approaches so that inputs from stakeholders are provided during all phases of implementation.
- Investments to minimize drainage needs, such as effective canal lining and good on-farm irrigation water management.
- Consideration of environmental impacts to avoid water quality problems for downstream users.

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This investment note was prepared by Walter Ochs, with input from Herve Plusquellec, Safwat Abdel-Dayem, Ariel Dinar, and other irrigation and drainage specialists in the Irrigation and Drainage Network of the World Bank.

Investments in Shallow Tubewells for Small-Scale Irrigation

Shallow groundwater supplies provide a basis for small tubewells providing both domestic and irrigation water. Water supplies for garden areas and small fields are pumped using human or animal power, but mechanized pumps are becoming common in all parts of the world. Small engines constitute about two-thirds of shallow tubewell costs, but they can be used for other purposes such as powering boats, hand tractors, and other farm machinery. Shallow tubewells contribute to diversification of cropping systems and improve economic and social conditions. Problems arise, however, if tubewells overexploit the groundwater supply or contribute to salinization of groundwater. Evaluation of groundwater supply and quality, regulation of tubewell establishment, and technical support to farmers are essential for sustainable tubewell systems to contribute to poverty reduction.

Tubewells are a cost-effective source of irrigation water for many small-scale farmers, where groundwater is close to the surface (less than 20 meters deep) and soils are productive. These wells can irrigate up to 5 hectares, depending on the soil, crop, and water conveyance losses. The technology is not complicated, and acceptance by farmers and poor rural communities is rapid. Tubewells can be one of the better investments for poverty reduction, and they are already common in many parts of the world, particularly in Asia and Africa.

Shallow tubewell irrigation generally results in some form of crop diversification for home or local consumption or for export. Niger, for example, has developed a good export market for green beans shipped by air to Europe, with much of the production related to shallow tubewells. Conjunctive use of tubewell water (mostly shallow) to supplement inadequate supplies of surface water or water that is not available when needed to optimize crop production, is also common in many countries, particularly in Pakistan and India (box 9.18).

Investments

Shallow tubewells can be drilled by hand with simple soil auger-type tools, by power rotary drilling, or with a drilling method called jetting or washboarding. The wells represent a relatively inexpensive way of supplying water for drinking and irrigation. In Bangladesh, wells are typically hand drilled even to depths of 60 meters and cased with galvanized iron or plastic pipe that is slotted to allow water to enter while keeping the aquifer material out of the well. Wells are normally equipped with centrifugal surface-

Box 9.18 India: groundwater wells

About one-half of the total irrigated area in India depends on groundwater wells, and about 60 percent of irrigated food production is based on groundwater. In 1994, there were 10.5 million dug wells and 6.7 million shallow tubewells in India. The number of shallow tubewells roughly doubled every 3.7 years between 1951 and 1991. Groundwater irrigation results in at least a doubling of yield compared to surface-watered crops. However, some states in India are facing severely declining water levels due to overexploitation.

Source: Singh and Singh 2002

mounted pumps with 5 to 10 horsepower diesel engines. Each well can provide enough water to irrigate about 4 or 5 hectares.

In the semiarid Sahelian Zone of southern Niger, groundwater depth is 6 to 8 meters and annual rainfall of 400-800 millimeters replenishes groundwater by about 500 million cubic meters. Most villages have at least one dug well for domestic water supply and some irrigation. Some tubewells have been installed with 3 to 5 horsepower portable gasoline-powered pumps, hand-operated pumps, or bucket and rope bailer systems. Irrigated area supplied by these tubewells is about 0.3 to 0.5 hectares, depending on the lift encountered and the water losses during transport to the field.³

Benefits

Shallow tubewells provide substantial poverty reduction benefits by increasing water supplies for domestic use as well as gardens and crops. Increased production and family incomes lead to improved diets and better health. Engines used to pump tubewells represent about two-thirds of the cost of the tubewell. As these engines are also used to power boats, hand tractors, and other farm machinery, they improve the quality of life in rural communities and are a low-cost way of providing economic benefits in poor areas with high groundwater levels (box 9.19).

Box 9.19 Nigeria: National Fadama Development Project

Nigeria's Fadama Project is centered on developing small-scale irrigation by extracting shallow groundwater with low-cost gasoline-driven pumps for tubewells. About 30,000 hectares were irrigated using the complete tubewell-pump package and with 30,500 pumps distributed to farmers. The project had a positive impact on farmer income, significant poverty reduction, and an estimated economic rate of return of 40 percent. Additional benefits involved the development of a simplified well-drilling technology, training of farmers to help other farmers construct wells, infrastructure for transporting and storing products, establishment of a Fadama User Association, and development of an extensive monitoring and evaluation system. The improved welfare of Fadama farmers can be attributed directly to the project.

Source: World Bank 2002

Negative environmental impacts of overexploiting groundwater can be avoided if tubewells are not installed too closely. Increased production from tubewells also reduces pressure on more marginal lands and increases land values, thus providing incentives for conservation.

Benefits from tubewells can also impact water markets. In Pakistan, for example, tubewell owners are sometimes active water sellers to neighbors. Well productivity, delivery potential, and the cost of operation and maintenance have a significant impact on the price of water.

Policy and Implementation Issues

Sustainability. Tubewell irrigation systems can contribute to the sustainability of an

³ See the IAP, "Niger: Tailoring Irrigation Technology to Users' Needs."

agricultural area, but evaluation of groundwater hydrology is important to ensure sustainability of shallow tubewell projects. Overpumping of groundwater from shallow aquifers by large numbers of wells clustered in a small area can have negative impacts on the water supply of neighboring tubewells. This can also lead to severe consequences such as lower water tables, declining water quality, soil compaction, and increased soil salinity (box 9.20). Policies to control density of wells in accordance with the groundwater recharge potential are critical to sustainability. It is normally the responsibility of government to monitor and evaluate groundwater and develop rules that control wells.

Box 9.20 China: water overexploitation in Ninjin County

Groundwater is now the major source of irrigation in Ninjin County, because less water is available from the Yellow River. A rapid increase in irrigated area has resulted in overexploitation of groundwater resources, causing serious environmental problems. The density of tubewells has reached more than one per 5 hectares, and average depth to water level in the wells has increased from 3.7 to 7.5 meters over the last 30 years. About one-tenth of the wells go dry during the summer. Farmers have reduced on-farm losses by using plastic tubing to carry water to their farms, but they still use an inefficient method of basin irrigation. Application of water is about twice the standard volume for North China, and irrigation accounts for 30 percent of total production costs.

Overexploitation of groundwater has resulted in a progressive decline in profitability due to an increase in suction lift, and less (and poorer quality) water. The salt content of groundwater is contributing to an increase in soil salinity. Wheat, a major crop, is moderately salt tolerant, but maize, the other major crop, is moderately salt sensitive and can fail if irrigated twice using saline groundwater. The county thus faces a critical groundwater recharge problem, and the present situation is unsustainable. Reversing this trend will require adopting water-saving technologies, changing cropping patterns, and enforcing laws and regulations, or reducing the number of wells.

Source: Zhen and Routray 2002

Water quality. The quality of groundwater is important because deterioration from salt or mineral build-up can affect its usefulness. Government policies should require evaluations of groundwater quality and the likelihood of changes in quality over time, prior to installation of wells. In Bangladesh, high arsenic levels in water have become a major health problem and are blamed in part on expanded use of shallow tubewells. Water quality evaluation is also important to minimize future maintenance costs, because poor-quality water can increase encrustation and corrosion. In dry climates, tubewells tend to recycle irrigation water, and in more arid climates, salts leached from the crop root zones tend to degrade the water. Thus in time the water extracted declines in quality and contributes to soil salinization, as seen (for example) in large portions of the Indus River Basin in Pakistan.

Lessons Learned

Public-private division of responsibility is important in formulating policy for shallow tubewell development. Tubewell investments are typically private goods that should be the responsibility of those who will benefit from the investment. The public sector role

should generally be limited to establishing a conducive policy and institutional environment for investment. Direct subsidies for tubewell drilling and operation are best avoided unless there is a compelling poverty reduction argument for the subsidies. One-off matching grants may be applicable in situations of high poverty and poorly functioning financial markets.

Water user associations are appropriate for shallow tubewell schemes, because they can help control overexploitation and provide an opportunity for joint maintenance of wells and pumping equipment.

Surveying, drilling test wells, water sampling, and water level monitoring are useful to build a database and track long-term trends. The rational management of groundwater resources is difficult without a basic understanding of the distribution and yields of aquifers and their vulnerability to pollution and overdraft. These monitoring activities are generally a government responsibility, but local authorities or communities can carry out some of the work.

Legislation and regulations are generally needed to control groundwater exploitation, yet lack of political will, lack of awareness among some farmers, and even active farmer opposition and lobbying have been major constraints to implementing this type of legislation in many countries. Important issues to consider for national or regional legislation are:

- A system of licensing for extracting and using groundwater.
- Registration of existing groundwater users, and penalties for not complying with licensing provisions.
- Arrangements to protect rights of shallow tubewell users from more influential farmers who are able to drill and power deep wells that lower the water table and prevent access to water from shallow tubewells.

Training and extension are critical to facilitate good installation, operation, and maintenance of tubewells and for the development of local capacity for maintaining and repairing wells and pumping equipment. To optimize the benefits of tubewell investments, extension and training will be needed for irrigation water management, improved agricultural technology, and marketing systems.

Recommendations for Practitioners

Successful shallow tubewell systems require government promotion and regulation to ensure that tubewell investments are legally protected from overexploitation by excessive drilling or by other users of the same aquifer (box 9.21). Experience with shallow tubewell projects emphasizes the need for investments to:

- Evaluate the groundwater hydrology and management to be certain that the groundwater recharge potential is in balance with anticipated water usage.
- Monitor groundwater quality to ensure suitability for irrigation, and make realistic projections on the water quality change with time.

- Establish monitoring systems and laws and regulations to ensure sustainable development and operation of tubewell irrigation systems.
- Ensure provision of technical assistance, training, and extension services to help farmers properly install, operate, and maintain the systems to optimize agronomic benefits. Marketing of products that are new or more abundant in the area may also require advisory services.

Selected Readings

Asterisk (*) at the end of a reference indicates that it is available on the Web. See Appendix 1 for a full list of Websites.

Box 9.21 Potential investments

- Evaluate groundwater resources and quality.
- Reform policy and regulations to govern shallow tubewell development and operation.
- Strengthen water user organizations to manage shallow tubewell systems.
- Develop systems for monitoring water table depth and groundwater quality.
- Provide financial services to enable producers to finance:
 - Drilling tubewells by hand, power rotary drilling, or jetting.
 - Pump set with engine, hand pump, or bailer system.
 - Small canals or pipe to distribute water to fields.
 - Microirrigation such as drip or minisprinkler (if justified by crop value).
- Provide training and extension to help farmers install, operate, and maintain shallow tubewell systems.
- Provide guidance in irrigation water management, agronomy, and marketing through extension and training.

Source: Authors

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China: Consumptive Use in Water Resource Management for Productivity, Equity, and the Ecology

Historical irrigation development in the southern part of the Xinjiang Uygur Autonomous Region in northwestern China has resulted in a severe reduction in downstream flows and in negative environmental impacts. The Tarim Basin is a desert climate (50 millimeters annual rainfall), and the water source is principally high mountain snow and glacier melt into tributaries of the Tarim River, as well as some groundwater that is recharged, mainly from irrigation.

What's innovative? Using the concept of beneficial consumption of water in a comprehensive basin-wide assessment and strategy that improves the ecological balance and resource use equity, without compromising productivity.

In the past, irrigation development in the Tarim Basin involved continual expansion of irrigated area without consideration of the ecological balance or of other users (including downstream users) affected by reduced water supply. Attempts to restrict water usage were perceived by farmers and irrigation technicians as a regulatory measure that would result in decreased productivity and production potential.

Project Objectives and Description

The Tarim Basin II Project was designed to implement a system of sustainable water resources development and management. The project has the potentially conflicting objectives of increasing downstream flows to preserve the environment of the lower reaches of the Tarim River, while increasing the incomes of upstream farmers who depend on irrigated agriculture. The project has supported the establishment and strengthening of the Tarim Basin Water Resources Commission (TBWRC), with overall responsibility for water resources management in the basin. TBWRC has set quotas for water use in the tributary sub-basins and has implemented a system to monitor and enforce the quotas. In addition, physical and management measures on the main Tarim River will deliver more water downstream.

The project is based on the concept of “beneficial consumptive use,” in which knowledge of the hydrological process and a basin-wide approach are used to optimize the availability and use of water to meet the objectives of increased production and productivity, equitable access across the basin, and long-term preservation of the hydrological and ecological balance.

Water consumption in the upstream sub-basins is presently at the limit allowed by the quotas established and enforced by TBWRC, so no additional water is available; in other words, total ET in the sub-basins is fixed at present levels. ET was divided into three components for project planning and management purposes: (1) consumptive use (CU) related to human activity (mostly in irrigated agriculture); (2) beneficial ET (BET) from trees and green areas along rivers and in and around oases; and (3) nonbeneficial ET

(NBET), mostly in low-lying areas with high water tables (including areas of salinization) and evaporation from nonecologically beneficial water surfaces. In the sub-basins, water consumption is about equally divided between CU, BET, and NBET, and there is considerable opportunity for improvement in water resources management and development. The improvements need to concentrate on preserving BET, reducing NBET, and maximizing the production and particularly the value of production per unit of CU.

The project includes various components focused on increasing productivity as well as restoring the Tarim River Ecosystem, such as:

- Canal linings to reduce seepage in areas where most of the seepage goes to NBET.
- Conjunctive use of surface and groundwater to allow groundwater to be used during low river flow months in the spring. This strategy reduces the need for high-evaporation surface reservoirs and lowers the water table in field areas to reduce capillary flux and NBET from ground surfaces.
- Land improvement that involves land leveling to reduce water requirements and drainage systems to lower water tables, thereby reducing NBET and increasing yields.
- Establishing and strengthening WUAs that receive and pay for water by volume, and thereby conserve water that previously was excessively applied and contributed to high water tables and NBET.
- Agricultural practices, such as growing higher value crops with the adjustments in cropping pattern, improved cultivation techniques, and improved seed.

Benefits and Impacts

Under the project, more than 300 million cubic meters of water have been delivered to a 300-kilometer stretch of the lower Tarim River known as the “Green Corridor,” where no river waters had flowed for 30 years prior to 2001. The TBWRC now has a firm commitment to deliver 300 million cubic meters annually to this area. Strong institutional mechanisms, and the combination of establishing and enforcing quotas for the sub-basins and a commitment to deliver water annually to the lower reaches of the Tarim River, provide a solid foundation for sustainable water resources management and future development in the Tarim Basin. The new basin-wide and holistic approach of the project has resulted in a major shift in mentality of farmers and irrigation institutions. People are beginning to see that an ecology- and equity-based water use approach that decrees limits on use through quotas does not have to compromise production and incomes.

Lessons Learned and Issues for Wider Applicability

The Tarim Basin II Project has shown that, with a solid mix of institutional and technical measures and with strong political will, it is possible to meet the objectives of making more regular water deliveries downstream, while increasing incomes in upstream sub-basins through well-planned interventions. With comprehensive ecological knowledge it

may be possible to find symbiotic strategies that serve several objectives, such as improved productivity, improved ecology, and equity of resource access.

Country	China
Project Name	Tarim Basin II Project
Project ID	P046563
Project Cost	US\$272.6 million
Dates	FY1999 – FY 2005
Contact Point	Douglas Olson The World Bank, 1818 H Street NW, Washington, D.C. 20433 Telephone (202) 473-9227; Email: Dolson@worldbank.org

Egypt: Improving Agricultural Production Through Better Drainage

Approximately 97 percent of Egypt's population live and work on only 4 percent of the land, under conditions of extremely low rainfall. An estimated 3.5 million farmers cultivate average holdings of 0.85 hectare, making agriculture the largest employment sector. Farming is made difficult by an irregular and insufficient supply of irrigation water, and a rise in the water table following completion of the Aswan High Dam in 1970. This increased the irrigation potential of the area but also caused waterlogging and increased salt content of irrigation water. Given the extremely limited water and arable land resources of the country, efficiency of resource utilization is critical for agricultural productivity.

What's innovative?

Improving agricultural drainage, an often neglected technical solution, may sometimes be as critical for enhanced productivity as irrigation.

Project Objectives and Description

Through a series of projects—called the National Drainage Program—the World Bank and partners, such as the German Development Bank and the Netherlands Government, are working with the Government of Egypt to introduce gradual reforms to introduce technologies and improve the management of irrigation and drainage systems. Goals are to enhance agricultural productivity and the incomes of smallholder farmers by improving drainage conditions, reclaim land lost to waterlogging and salinity, and improve the institutional capacity of the Egyptian Public Authority for Drainage Projects (EPADP). An additional objective is to redress the negative environmental effects of discharging untreated industrial and domestic waste into open drains.

In Phase I of the program, 302,400 hectares of irrigated farmland were targeted for drainage, improved technical design, and system management. A second phase, yet to begin, will target another 336,000 hectares of land, and will involve technical training and institutional reforms. Project activities include:

- Subsurface drainage development, renewal, and rehabilitation.
- Open drain rehabilitation.
- Institutional support to EPADP and for the development of an Environment Management Plan. The project also has provision for social and participatory activities in two project areas.

During National Drainage Program I, EPADP organized farmers into drainage associations (Collector User Associations, CUAs) to facilitate interface with the end users. By 1999, 2,269 CUAs were formed. NDP II will continue the development of CUAs. Additionally the project will develop two pilot schemes to explore the potential of integrating irrigation associations (Water User Associations, WUAs) with CUAs.

While the immediate need is for drainage system improvement, the projects are also focusing on creating institutional and community mechanisms for the long-term development and maintenance of drainage systems and the systems for cost recovery. Beneficiaries pay for drainage investments over a 20-year period with no interest charged, effectively amounting to about 45 percent of the cost in real terms.

Benefits and Impacts

All major objectives of the first phase of the project have been achieved. Over 248,000 hectares have been provided with new subsurface drainage. Including renewal areas, subsurface drains have been installed on more than 311,000 hectares. On this area, yields of major crops increased by up to 20 percent. Estimates show that improved drainage accounts for 15 to 25 percent of this yield increase. Many farmers switched to higher-value crops as a result of this project, particularly in the Nile Valley and the Delta region. Reuse of drainage water in irrigation, guided by appropriate criteria and guidelines, has resulted in one of the highest water use efficiencies in the world. The second phase will benefit about 400,000 farm households.

Different Egyptian public sector agencies have improved their management capacity, such as EPADP, which monitors and evaluates both the technical aspects of drainage (for example, measurement and analysis of hydraulic conductivity, salinity, and crop yields), and important social and institutional issues. Cost recovery for drainage investments and maintenance has improved, as is reflected in a 25-year time frame for full recovery of capital costs, shared between government (50-55 percent) and beneficiaries (40-45 percent).

Lessons Learned and Issues for Wider Applicability

- Flexibility in implementation is key to guaranteeing success in this type of project.
- Although EPADP has improved its institutional capacity, further institution building is needed, especially support to computerize various aspects of its daily activities.
- Compensation for crops damaged during subsurface drainage installation should be incorporated into the drainage installation contract, to be paid directly to farmers by contractors. This will circumvent the delays farmers experience in getting compensation when a government agency manages the compensation.

Drainage has often been a neglected component of irrigation system development, but it can have a substantial effect on crop yields and system sustainability. Institutional innovations, training, and capacity building may be needed to reorient irrigation agencies and farmers from new irrigation investments to equally important drainage issues and investments.

Country	Egypt
Project Name	National Drainage Project I and II (NDP I and II)
Project ID	NDP I: P005146, and NDP II: P0 45499
Project Costs	NDP I: US\$160 million, and NDP II (orig.): US\$278.4 million
Dates	NDP I: FY 1993 – FY 2001, and NDP II: FY 2001 – FY 2007
Contact Point	Tijan M. Sallah ((202) 473-2977;: Tsallah@Worldbank.org), and Adel F. Bichara ((202)

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India: Rationalized Public, Private, and Farmer Roles in Groundwater Management

Rajasthan, the largest state of India (supporting about 50 million people) is a desert state with 10 percent of the national area and only 1 percent of the country's water resources. The present major user of water is agriculture (83 percent of consumptive use), but projections to 2025 indicate a rapidly increasing demand for nonirrigation use. Water scarcity and deteriorating water quality restrict the availability of water for domestic uses and irrigation supply.

What's innovative? A participative approach to sustainable groundwater management and surface irrigation system/services management, with a rationalized and improved public sector, and increased role for farmers and the private sector.

The critical challenge is twofold: ensuring Rajasthan's long-term, sustainable use of increasingly scarce water resources and improving the water use efficiency for agriculture. Water resources management is affected by weak capacity and uncoordinated effort among current water sector departments, a weak regulatory framework, poor management practices and unsustainable use in some areas, and high recurrent cost of delivery. Problems are inherent in past approaches based entirely on public sector resource management, with a lack of beneficiary participation in scheme management and financing.

Project Objectives and Description

The Rajasthan Water Sector Restructuring Project (RWSRP) aims to improve the efficiency of agricultural water use by increasing the productivity of irrigated agriculture through improved performance of surface irrigation systems and strengthened agricultural support services. The project aims at increasing system efficiency through downsizing and improved coordination and rationalization of public sector agencies, increased involvement of users and the private sector in design and management of systems, and increased cost recovery from users. To achieve these objectives, the project finances:

- Water sector institutional restructuring and capacity building through (1) creation of a state water planning department, (2) modernization of the water sector department, and (3) piloting a community-driven institution for groundwater management.
- Improving irrigation system performance through (1) the formation and fostering of 620 WUAs, (2) rehabilitation of irrigation schemes, (3) strengthening of agricultural extension, and (4) enhancing safety of 16 dams supplying the project area.
- Capacity building for a project management unit to ensure the effective implementation and coordination of activities involving several government departments.

The WUAs, over time and in close coordination with the Irrigation Department, are expected to take over the operation and management (O&M) of surface irrigation systems up to the distribution level. The Government of Rajasthan has committed to moving toward full cost recovery of O&M costs. The rehabilitation of irrigation schemes (about 90 major, medium, and minor schemes) also involves participation of WUAs, which contribute 15 percent of the rehabilitation costs.

The project would support at least three pilot schemes for a community-driven approach to groundwater management. This would involve the establishment of groundwater conservation districts (GCDs) covering identified aquifer areas with water depletion and quality problems. The GCDs would include an elected body of stakeholder representatives (rural and urban communities, farmers, industry, state agencies, and local government) empowered to develop and implement groundwater management plans, involving both supply- and demand-side approaches for groundwater management. The plans would be prepared at the village level by the Groundwater Management Associations and integrated at the community level by the Gram Panchayat Level Committees, with assistance from NGOs and technical support groups.

The project includes a pilot scheme on “commercialization of irrigation services” in a distributory command, which would develop a farmer-owned and -managed utility for the management of a larger command area on a commercial basis. The core function of this entity is to provide water to farmers and other users, and to manage and maintain the water supply assets, including irrigation and drainage facilities. The farmer company would develop into an autonomous entity that would operate on commercial lines and have a bulk water entitlement from the Irrigation Department.

Benefits and Impacts

The project is in the early stages of implementation but is expected to benefit about 250,000 farm families. The annual value of additional agricultural production resulting from the improved delivery of irrigation water and agricultural support services under the project could reach Rs2.1 billion (US\$45 million) by the end of the project. The project would stimulate additional demand for labor, estimated at about 29,000 jobs per year, (mainly of hired labor) and provide employment opportunities for the landless. Construction of civil works would generate an additional temporary five-year increase in labor demand in the project area. Other benefits include reduced pollution, fewer water-related diseases, and improved public health.

Lessons Learned and Issues for Wider Applicability

- A strong government commitment to fiscal and institutional reform at the highest level, and a sound legal framework, is critical to the successful formation and operation of WUAs. WUAs can effectively and efficiently implement rehabilitation, if they are empowered early in the process.
- Agricultural demonstration programs for application technology should focus on a few high-quality demonstrations that can be replicated with good results.

- Minimizing the turnover of senior staff will improve the effectiveness and timeliness of the implementation of project activities.
- Funding from increased water charges can make funds available for O&M, improving the state's overall recurrent budget situation.
- Hybrid policy and multisectoral, statewide investment projects are complex. Investments are better concentrated on a few critical issues. This lesson is reflected in the design of this project, which has limited project period objectives but is set in a longer-term context.

Country	India
Project Name	Rajasthan Water Sector Restructuring Project
Project ID	P040610
Project Cost	US\$180.2 million
Dates	FY2002 – FY 2008
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Mali: Institutional Reform to Focus Public Role on Essential Public Goods

A 1998 survey estimated that 72 percent of Mali's people live below the poverty line, with poverty widespread in rural areas. Mali has areas with good agricultural potential. In the short and medium term, poverty reduction in Mali is dependent on accelerated growth in the agricultural sector.

What's innovative? Redefining responsibilities and core activities of a public sector organization to create a clear and viable focus on essential public goods.

Increased irrigation was expected to be one effective means to enhance productivity. However, without effective policy reform, major investments in the irrigation sector cannot be expected to result in significant benefits. Reform required (1) reorganizing the management of the Office du Niger (ON), the major public regional development agency specializing in irrigation, (2) establishing secure land tenure for farmers, and (3) liberalizing pricing and marketing policies for paddy and rice. ON's mandate included the construction, operation, and maintenance of irrigation facilities; extension and applied research; and commercial activities, such as procurement and distribution, agricultural credit provision, and paddy and rice marketing and processing. Redefinition of ON's activities was achieved over time and completed with this project.

Project Objectives and Description

ON's Consolidation Project sought to reduce poverty, increase agricultural production, and reduce government subsidies for agriculture by providing strong incentives to farmers to increase production, improve the efficiency of irrigation management, and create mechanisms for sustainable irrigation development. ON's mandate has been redefined and is now limited to activities directly related to the management of the land and water resources, with most commercial activities being progressively transferred to farmers or other economic agents.

The project financed the following:

- Sectoral policy reforms: (1) progressive divesting of ON's commercial activities, (2) liberalizing rice prices and marketing, and (3) establishing land tenure security for ON farmers.
- Institutional reforms: (1) streamlining ON's relationship with the government through performance contracts, (2) reorganizing and capacity building of ON, and (3) restructuring ON's finances to eliminate its chronic deficit.
- Irrigation infrastructure and agricultural services in five areas: (1) rehabilitation and modernization of the irrigation network and perimeters, (2) a pilot scheme to test farmers' capacity to participate in irrigation rehabilitation and development, (3) applied research on agricultural services, (4) improved resource management, and (5) agricultural training and extension to promote improved production practices and crop diversification.

Market activity of ON was progressively divested to market agents, and the credit function to the National Agricultural Credit Bank. Relations between ON and the government were streamlined to ensure the autonomy of ON and to establish a contractual agreement between the two. ON was internally reorganized, its financing restructured, and investment made in capacity building. Village Associations (active in other parts of Mali) were promoted to partner with ON and take on some of its agricultural support functions over the longer term.

Benefits and Impacts

Significant gains made in the productivity and output of Mali's agricultural sector included:

- Increases in agricultural output, including nearly tripling total rice production and substantially improving vegetable production, resulting in an annual increase in real per capita income of US\$70.
- Liberalization of the rice trade and reduction in government expenditures on subsidies to the rice sector.
- Successful restructuring of ON, including a shift of some of its functions to other agencies and restoration of its financial health.
- Rehabilitation and modernization of 57 kilometers of canals and main drains.
- Improved water fee collection rates from 60 to 97 percent, with fees now being retained in the areas where they are collected.
- Improved land tenure and thus an increased incentive for farmers to invest in productivity improvements.

Lessons Learned and Issues for Wider Applicability

- Sectoral reforms should be accompanied by adequate complementary sectoral investments to have a major impact.
- Difficult institutional reforms, particularly those that go beyond a single ministry, should be headed by an independent agency outside the concerned ministries/agencies.
- Greater farmer empowerment and involvement is one good way to ensure sustainability of irrigation investments.
- Greater transparency in land management increases farmers' land security even in the absence of official land titles. Land tenure security is one of the necessary conditions for private sector investment in irrigated farming.
- The mechanism for setting water fees should be an independent and transparent negotiated process based on clear needs, and free from government interference.

Under some conditions, reorienting institutional objectives for a specific administrative agency may be key to broad success. This is particularly true where the agency has a portfolio of responsibilities that are not closely related, and for which adequate staff expertise is not available and where public sector institutions undertake commercial activities.

Divesting authority within a state structure is never a simple or easy process. Sometimes, however, this is necessary to enable an agency to better serve its clients. As shown in Mali, the institutional realignment must also be accompanied by changes in attitude and behavior of employees.

Country	Mali
Project Name	Office du Niger Consolidation
Project ID	P001718
Project Cost	US\$83.6 million
Dates	FY1989 – FY 1999
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Niger: Tailoring Irrigation Technology to Users' Needs

Three-quarters of Niger's 1.3 million square kilometers is desert, leaving 3.8 million hectares cultivable, most of which is in the south. Even in cultivable areas, variable and declining rainfall and frequent drought cycles make rainfed agriculture a risky enterprise. Niger has the potential to irrigate 270,000 hectares, using ground and seasonal surface water sources, but only 22 percent of this potential area is actually irrigated.

What's innovative? Focus on privately owned, inexpensive, and simple pumping technologies, which are promoted through a nongovernmental project implementation unit.

Large-scale, publicly funded irrigation schemes have the potential for positive returns based on existing technical capacity. Such schemes, supported in the past, were extremely costly, plagued by weak institutional support, and lacked cost-recovery measures to finance operations and maintenance. The government also supported small-to medium-scale irrigation cooperatives on the perimeter of these large-scale projects. The National Office of Hydro-Agricultural Perimeters was to provide technical extension support to these schemes, but with no budget or incentives for efficient service provision, its technical support has been quite weak. State-controlled cooperatives have neither been able to fully control nor to profit from their enterprises in a sustainable manner, owing to state intervention and political interference in cooperative affairs.

Project Objectives and Description

The factors limiting farmers' use of irrigation technologies included lack of knowledge of technologies, lack of availability of tested technologies and maintenance services, and lack of finance. The Pilot Private Irrigation Project aimed to address these issues through assisting Niger in testing and evaluating the following: capacity building of the private sector, improved low-cost technologies for small-scale irrigation, improved grassroots saving, erosion control works, and monitoring of replenishable shallow aquifers. The project focused primarily on the poorest farmers and on selected private commercial irrigators. Farmers interested in adopting technologies were asked to form economic interest groups.

The private irrigation association, Nigerien Association for Promotion of Private Irrigation (Association Nigérienne de Promotion de l'Irrigation Privée, ANPIP), was the implementing agency for the project. One distinguishing features of the project is the private legal status of ANPIP, free from political and bureaucratic interference, with adequate legal and administrative flexibility. Promotion of small-scale irrigation technologies was undertaken through information and assistance to farmers to access the technical and financial resources required to adopt the technologies.

ANPIP (1) carried out promotional campaigns in support of the government's private irrigation development strategy; (2) facilitated small farmers' access to legal and administrative assistance for obtaining tenurial security; and (3) provided assistance,

upon demand, in preparation of irrigation projects and in establishing economic interest groups. Tasks contracted out to consulting firms included testing and evaluating technologies, promoting grassroots savings and credit schemes (by an NGO), and project related evaluation studies and periodic audits.

Benefits and Impacts

The project has strongly supported the national agricultural strategy to increase productivity. Significant gains made in Niger's irrigation sector included:

- ANPIP grew gradually from a small group of 10 people to 19 decentralized committees constituting 13,500 farmers.
- An information campaign about the new national irrigation policy (through printed booklets, a prospectus, and radio and TV commercials) reached 2,000 representatives of farmers, and administration and traditional authorities. Following this campaign, over 1,500 economic interest groups were established with membership of over 15,000 farmers.
- The training component included 382 training sessions covering 4,150 participants, and it was complemented by radio, television, newspaper, a printed handbook, and demonstrations in the local market.
- The project introduced the treadle pump and promoted the tubular borehole, submerged pumps, motor pumps, and irrigation via buried pipes as components of comprehensive on-farm water systems. Farmers pay the full cost of the technologies.
- Cultivated area increased by about 63 percent, and yields of major crops increased by 27 to 32 percent (onion and sweet pepper, respectively).

Lessons Learned and Issues for Wider Applicability

- The shift of project administration from government to a private agency (ANPIP) enabled a private sector management style, and the legal and administrative flexibility to execute the project.
- Promotion of private ownership of treadle pumps and improved irrigation technologies, with incentives for good operation and maintenance, was undertaken. In relying on genuine demand in deciding the location of local pump manufacture, the project increased the chances that the nascent treadle pump market would be sustained in the long run.
- Giving farmers a menu of technology options allowed them to choose the level of technology and investment appropriate to their farming conditions.
- Making available simple, locally made, and affordable technologies, and training local craftspeople to manufacture and repair treadle pumps, kept the supply chain between farmer and manufacturer as short as possible, ensuring that pump parts and repair expertise would be locally available. Adaptations to irrigation technologies reduced their prices.
- Linking these basic technical changes with other changes, such as a sound irrigation policy, available credit, land tenure security procedures, and effective monitoring of project success, facilitated adoption and contributed to the program's success.

Country	Niger
Project Name	Pilot Private Irrigation Project; Niger Private Irrigation Promotion Project
Project ID	Pilot Private Irrigation: P001994 Private Irrigation Promotion: P072996
Project Cost	Pilot Private Irrigation: US\$7.5 million Private Irrigation Promotion: US\$48.4 million
Dates	Pilot Private Irrigation: FY 1997 – FY 2002 Private Irrigation Promotion: FY 2002 – FY 2008
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