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CONJUNCTIVE USE OF GROUNDWATER AND SURFACE WATER

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Conjunctive water use refers to simultaneous use of surface water and groundwater to meet crop demand. Each day, hundreds of thousands of farmers in canal, tank, and other surface irrigation systems combine surface water with groundwater. They do so in an individual manner, uncontrolled by any scheme or basin-level entity. Conjunctive management, by contrast, refers to efforts planned at the scheme and basin levels to optimize productivity, equity, and environmental sustainability by simultaneously managing surface and groundwater resources. In many systems and basins, such planning is needed to raise crop water productivity.

Conjunctive management occurs when system administrators control ground and surface water simultaneously. It may be achieved by modifying the configuration of the surface system and its operating procedures (Box 1). It is less widespread than conjunctive use because it requires institutions and coordinating mechanisms that few client countries yet have. Conjunctive management is complex and can be controversial. Nevertheless, it can be paramount, particularly in water-scarce regions and in times of drought, because failure to integrate conjunctive water resources can result in groundwater overexploitation.

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Box 1: Benefits of Conjunctive Management in Madhya Ganga Canal Project, Uttar Pradesh, India

River diversion systems often use lined canals to remove excess floodwaters during monsoon. However, simple modifications in infrastructure and the operating system can transform this waste into wealth. Uttar Pradesh had a network of disused earthen surface drains constructed in the 1950s to control waterlogging and floods. After the 1950s, intensification of groundwater use created new opportunities for conjunctive management by building check structures at suitable intervals to promote groundwater recharge with monsoon floodwaters. In the course of a 10-year collaborative study, scientists from the International Water Management Institute (IWMI), Roorkee University, the Water and Land Management Institute, and the Uttar Pradesh Irrigation Department found that using these modified drains for monsoon flood irrigation produced the following benefits:

- **A 26 percent increase in net farmer income**
- **A decrease in average depth of groundwater from 12 meters in 1988 to 6.5 meters in 1998**
- **Annual energy savings of 75.6 million kilowatt hours and pumping cost savings of Rs. 180 million**
- **An increase in canal irrigation from 1,251 hectares in 1988 to 37,108 hectares in 1998**
- **A 15-fold increase in rice area**
- **A 50 percent reduction in conveyance losses in canals**

Source: IWMI 2002.

Users of surface irrigation systems install tubewells as part of a strategy to avoid yield loss caused by unreliable water delivery. Tubewell irrigation water is costlier but offers control and helps save input investments. Farmer

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tubewells raise the productivity of irrigation systems, extend the area served, and help prevent waterlogging. In some situations, they reduce public investment in drainage by providing vertical drainage. High-income countries have finely developed conjunctive management to even out spatial and temporal variations in regional water availability (Blomquist, Heikkila, and Schlager 2001).

Since surface irrigation practices directly influence groundwater recharge, improved main system management is key to conjunctive management of surface and groundwater resources. These improvements may require changes in the infrastructure but are more a question of building technical capacity, adapting the organizational and institutional framework for more efficiency, and improving information and communication systems.

Potential Areas of Investment

Five areas of investment opportunities appropriate for different conditions follow bellow:

RECONFIGURING SURFACE IRRIGATION PROJECTS. Many surface irrigation projects were designed under a slew of antiquated assumptions about cropping patterns and hydraulic infrastructure in the command. Reconfiguring the main system, rationalizing the operating rules and practices, and training system managers to operate the modernized system in a conjunctive management mode offer a major investment opportunity.

GROUNDWATER RECHARGE TO SUPPORT INTENSIVE GROUNDWATER IRRIGATION. A new development in densely populated areas of Asia is intensification of well irrigation in regions where rainfall precipitation is the only source of groundwater recharge. Western and southern India have experienced this phenomenon on a significant scale. In those two regions the number of groundwater wells has increased from fewer than 100,000 in 1960 to nearly 12 million today (Shah, Singh, and Mukherjee 2004). With falling aquifers and erratic rainfall, local communities and governments are turning to constructing local water harvesting and recharge structures on a massive scale with the primary objective of increasing groundwater availability for improved drinking-water security, drought proofing, and protecting rural livelihoods. Evidence suggests that these community-based investments significantly stabilize livelihoods in regions that may never benefit from large surface irrigation projects (Shah 2003), especially if accompanied by investments in demand-side irrigation management through real water resources savings (Foster et al. 2002).

CONJUNCTIVE USE WITH POOR-QUALITY WATER. Difficulties and costs involved in disposing of wastewater often present new opportunities for conjunctive use. Growing wastewater use in periurban agriculture in cities around the world are a case in point. Research by IWMI in several cities in India, Pakistan, and Mexico points to ingenious practices developed by periurban farmers to use urban wastewater and groundwater conjunctively for irrigation (Buechler and Devi 2003). However, in water-scarce situations, some industrial wastewater also offers opportunities for livelihood creation through irrigation (Box 2).

Box 2: Conjunctive Use with Poor-Quality Water: Irrigation with Mine Water in South Africa

Disposal of mine wastewater is a problem wherever there are coal and gold mines, as in South Africa. High concentrations of salt make the wastewater unsuitable for direct discharge into rivers except in periods of high rainfall. The potential for irrigating with mine water in suitable soils is increasingly viewed favorably as a way of solving the twin problems of wastewater disposal and shortage of irrigation water. How big the opportunity is depends on the availability of suitable soils nearby, the resultant soil water and salt balance for different cropping systems, the choice of irrigation management strategies, and the impact of the irrigation drainage on local and regional water resources. The approach is inherently conjunctive, because polluted mine water is used to complement inputs from rainfall and stream flows.

In a field trial in South Africa during 1997-2000, three center pivots were set up for irrigation with coal mine wastewater—one in virgin soil (unmined) and two in mine-rehabilitated land. Several crops were successfully irrigated with gypsiferous mine water on a commercial scale. Excellent yields were obtained for wheat on both virgin and rehabilitated land, and also short-season maize grown on virgin land. The yields of sugar beans were reasonable and higher than with dry land cropping. Problems that caused yield reductions were not related to irrigation with gypsiferous mine water and were recognized as surmountable with experience in the management of the system. Research is continuing, using catchment-scale computer modeling to assess the impact of scaling-up on the volume and quality of surface water and groundwater.

Source: Olufemi Idowu and Simon Lorentz, University of Kwa Zulu Natal, with inputs from IWMI, Africa.

CONJUNCTIVE MANAGEMENT OPPORTUNITIES IN TOWNS. Rapid urbanization in many parts of the world have created new threats for periurban agriculture. However, conjunctive management of rainfall, surface water, and groundwater creates new opportunities to meet these threats.

CONJUNCTIVE USE WITH SALINE GROUNDWATER. In regions with primary salinity, conjunctive use of surface and groundwater presents unique challenges and opportunities. In such places the objective of conjunctive management is to maintain both water and salt balances. In this situation, system managers require great control and precision in canal water deliveries to different parts of the command to maintain an optimal ratio of fresh and saline water for irrigation (Murray Rust and Vander Velde 1992). In many systems, it makes sense to divide the command areas into surface water irrigation zones and groundwater irrigation zones, depending on the aquifer characteristics and water quality parameters. In others, providing recharge structures within a surface system is often a useful component of a rehabilitation and modernization package. It is a risky business and requires a sound conceptual model of the fate of the salts mobilized, if it is not to cause more problems than it solves.

Potential Benefits of Reform

Conjunctive water management strategies help reduce evaporation losses from reservoirs, for their storage can be drawn down more quickly if groundwater can be relied on to meet water needs later in the year. Conjunctive management can also add to drought proofing. Surface water storage varies far more than groundwater storage in response to interyear variations in precipitation. As a result, groundwater can play a powerful drought-mitigating role when surface and groundwater are managed and used conjunctively. In the situations identified above, the key benefits of investing in conjunctive use are the following:

- Enhanced yield of past investments in surface water irrigation projects through increased irrigated area, improved water productivity, and expanded production, employment, and incomes
- Improved sustainability of groundwater irrigation in regions of intensive groundwater use with inadequate availability of runoff for recharge
- Use of poor-quality water to increase agricultural production, employment, and incomes
- Enhanced long-term environmental sustainability of irrigated agriculture in salinity dominated environments by improving salt balances and sustaining the productivity of irrigated agriculture

Policy and Institutional Issues

CONJUNCTIVE MANAGEMENT REQUIRES A BASIN PERSPECTIVE. Where practiced, conjunctive management is often confined to the irrigation-system level. Overall gains from conjunctive use can be enhanced by managing resources at the riverbasin level, but this cannot be done until the river basin becomes part of the water and land management unit.

REFORM OF WATER RESOURCES MANAGEMENT INSTITUTIONS. A major obstacle to conjunctive management is the fragmented structure of governmental institutions entrusted with various water management roles. Typically, the main system is managed by irrigation departments, groundwater by groundwater departments, and energy supply for groundwater pumping by an electricity utility. Seldom is there any coordination among these line departments. These roles must be coordinated if conjunctive water management is to succeed.

MONITORING AND INFORMATION SYSTEMS. Improving monitoring of groundwater behavior and use patterns in the conjunctive management domain is a priority. Most developing countries have poor monitoring infrastructure. This precludes spatially coordinated use of groundwater and surface water that is critical in a saline environment. Geographic databases with data on cropping patterns, evapotranspiration, groundwater levels, and canal alignments would be a valuable aid to understanding where canals contribute most seepage to groundwater, where water-intensive perennial crops are grown, where soil salinity is inherent or due to waterlogging, where soil salinity could be controlled by leaching with irrigation water, and where waterlogging is caused by improper surface drainage.

PUBLIC-PRIVATE PARTNERSHIP. In many surface irrigation systems, public tubewells are used to stop waterlogging and secondary salinization due to surface irrigation. Experiments with the Salinity Control and Reclamation project tubewells in Pakistan and the Satjej-Yamuna Canal in northwest India have shown, however, that private tubewells often do the same job as well or better. The problem is lack of coordination in private tubewell development. Since surface systems are managed by government departments and tubewells are operated by independent farmers, opportunities arise for mutually gainful public-private partnerships with better coordination and an appropriate policy framework.

REHABILITATION AND HARDWARE IMPROVEMENT. Reshaping the hydraulic infrastructure is critical where groundwater levels are shallow, soils are saline but still favorable, soils are coarse rather than fine, and canal seepage is abundant.

Remote sensing can be used to identify such areas. Hardware improvement should improve control of water levels in main and branch canals; automate flow measurement and control in distributaries, minors, and water courses; and upgrade the distribution network and field channels.

Lessons Learned

- Conjunctive use of groundwater and surface water often occurs by default. Big opportunities to enhance its gains lie in introducing planned conjunctive management through coordinated strategies at various levels from the river basin down.
- To achieve effective conjunctive management, planned investments are required in hardware (system modernization and improved infrastructure), software (improved database), planning and management capacities, and institutional reform.
- Improving main system management is central to better conjunctive management and water level control is critical for better main system management. New technologies offer big opportunities. For instance, expensive communication infrastructure can be replaced by low-cost cell phones.
- Conjunctive management in a poor water quality environment presents more difficult, and often unique, technical and management challenges requiring higher investment.

A key challenge is to create strong incentives for conjunctive management among different stakeholder groups. Typically, perverse incentives through faulty pricing of surface irrigation, electricity for pumping, and investment in groundwater structures undermine gains from conjunctive water management.

Recommendations

- Even where river basin institutions are absent or underdeveloped, planning of conjunctive management seems best done within a river basin framework.
- The biggest new opportunities for improving food security and livelihoods arise in densely populated agricultural regions that rely on intensive use of groundwater in agriculture. In such cases, conjunctive management requires a paradigm shift. The need and pressures are for augmenting and concentrating groundwater recharge—through recharge structures to increase percolation from rainfall and runoff, as well as from imported water-in pockets of groundwater-intensive use.
- Conjunctive management investments should strike a balance between improving infrastructure and building conjunctive management capacities—through improved monitoring systems, institutional reform, improved management practices, and greater incentive compatibility.

Conclusion

To optimize conjunctive use of water, the best way forward is to concentrate on capacity building of irrigation system managers to improve system management and reshape hydraulic infrastructure of large and small-surface systems. To sustain groundwater use in tubewell-irrigated areas, enhancing recharge from precipitation and surface water imports is necessary. None of these improvements can be made without the proper institutional and organizational development, including investment in the capacities of local governments to lead on participatory groundwater management and integrated water resources management.

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