



Shaping the Future of Water for Agriculture

A Sourcebook for Investment in Agricultural Water Management



THE WORLD BANK



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in Agricultural Water Management



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1818 H Street NW
Washington, DC 20433
Telephone: 202-473-1000
Internet: www.worldbank.org
E-mail: feedback@worldbank.org

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CONTENTS

Foreword	vii
Acknowledgments	ix
Acronyms and Abbreviations	xiii
Overview	
Sourcebook Objectives	1
Background of the Three World Bank Corporate Strategies	2
The Agricultural Water Management Sourcebook	4
Challenges Facing Agricultural Water Management	4
Cross-Cutting Themes of the <i>Sourcebook</i>	7
Lessons and Next Steps	12
Chapter 1: Building Policies and Incentives	
Overview	21
Investment Note 1.1: Preparing a National Agricultural Water Strategy	24
Investment Note 1.2: Development Policy Lending to Support Irrigation and Drainage Sector Reforms	31
Investment Note 1.3: Agricultural Trade, Water, and Food Security	38
Investment Note 1.4: Pricing, Charging, and Recovering for Irrigation Services	45
Investment Note 1.5: Economic Incentives in Agricultural Water Use	53
Innovation Profile 1.1: Agricultural Water in the New Country Water Resources Assistance Strategies	59
Innovation Profile 1.2: Enabling Smallholder Prosperity: Irrigation Investments for Ready Markets	63
Chapter 2: Designing Institutional Reforms	
Overview	67
Investment Note 2.1: Investing in Participatory Irrigation Management	70
Investment Note 2.2: Investing in Water Rights, Water Markets, and Water Trade	78
Investment Note 2.3: Investing in Building Capacity in Agricultural Water Management	87
Innovation Profile 2.1: Drivers of Public Irrigation Reform in Australia	93
Innovation Profile 2.2: Investing in Farmer Networks for Inclusive Irrigation Policy Processes in South India	96
Chapter 3: Investing in the Improvement and Modernization of Irrigation Systems	
Overview	101
Investment Note 3.1: Lending for On-Farm Water-Saving Technologies	105
Investment Note 3.2: Investing in Irrigation for Crop Diversification	110
Investment Note 3.3: Investing in Smallholder Irrigation	114
Investment Note 3.4: Selecting Technologies for the Operation and Maintenance of Irrigation Systems	119
Investment Note 3.5: Cost-Effective Operation and Maintenance of Irrigation and Drainage Projects	123
Investment Note 3.6: Using Satellites to Assess and Monitor Irrigation and Drainage Investments	127

Investment Note 3.7:	Prioritizing Lending for Public Irrigation Schemes with the Rapid Appraisal Method	134
Innovation Profile 3.1:	Investing in Automation and Centrally Operated Irrigation Systems	139
Chapter 4: Investing in Groundwater Irrigation		
	Overview	143
Investment Note 4.1:	Investing in Shallow Tubewells for Small-Scale Irrigation	145
Investment Note 4.2:	Deep Tubewell Irrigation	150
Investment Note 4.3:	Conjunctive Use of Groundwater and Surface Water	156
Investment Note 4.4:	Groundwater Governance and Management	162
Innovation Profile 4.1:	The Republic of Yemen's Sana'a Basin Water Management Project	169
Chapter 5: Investing in Drainage and Water Quality Management		
	Overview	173
Investment Note 5.1:	Investing in Land Drainage	176
Investment Note 5.2:	Investing in the Reuse of Agricultural Drainage Water	181
Investment Note 5.3:	Investing in the Reuse of Treated Wastewater	185
Innovation Profile 5.1:	Drainage Investments in the Context of Integrated Water Resources Management	190
Innovation Profile 5.2:	Investing in Controlled Drainage	193
Innovation Profile 5.3:	Investing in Evaporation Ponds	196
Innovation Profile 5.4:	Investing in Biodrainage	198
Innovation Profile 5.5:	Investing in User Operation and Maintenance of Drainage	201
Chapter 6: Investing in Water Management in Rainfed Agriculture		
	Overview	205
Investment Note 6.1:	Investing in Supplemental Irrigation	208
Investment Note 6.2:	Investing in Watershed Management	214
Investment Note 6.3:	Investing in Water and Soil Fertility Management	219
Innovation Profile 6.1:	Investing in Community-Based Soil Conservation and Watershed Management Projects	225
Innovation Profile 6.2:	Investing in Watershed Management in China's Loess Plateau	229
Innovation Profile 6.3:	Integrated Water Management to Enhance Watershed Functions and to Capture Payments for Environmental Services	232
Chapter 7: Investing in Agricultural Water Management in Multipurpose Operations		
	Overview	237
Investment Note 7.1:	Investing in Agricultural Water through Community-Driven and Social Fund Approaches	239
Investment Note 7.2:	Investing in Aquaculture Activities	244
Innovation Profile 7.1:	Rural Water Supply and Irrigation	251
Chapter 8: Coping with Extreme Climatic Conditions		
	Overview	255
Investment Note 8.1:	Investing in Drought Preparedness	258
Investment Note 8.2:	Investing in Flood Control and Management	264

Innovation Profile 8.1: Planning Scarce Water Resources Using Evapotranspiration Quotas: The Hai Basin Integrated Water and Environment Project in China	270
Innovation Profile 8.2: Fighting the Adverse Impacts of Climate Change on Agriculture	272
Innovation Profile 8.3: Investing in Participatory Approaches for the Cultivation of New Varieties and Soil and Water Conservation in India	275
Chapter 9: Assessing the Social, Economic, and Environmental Impacts of Agricultural Water Investments	
Overview	279
Investment Note 9.1: Monitoring and Evaluating the Poverty Impacts of Agricultural Water Projects	281
Innovation Profile 9.1: Assessing the Economic Benefits of Land Drainage	286
Innovation Profile 9.2: Guiding Environmental and Social Safeguard Assessment in Agricultural Water Projects	290
Innovation Profile 9.3: Estimating the Multiplier Effects of Dams	294
Innovation Profile 9.4: Benchmarking for Improved Performance in Irrigation and Drainage	299
Innovation Profile 9.5: Applying Environmental and Social Safeguard Policies to Agricultural Water Operations and Monitoring Them during the Project Cycle	304
Index	315

FOREWORD

Agricultural water management is vital to food security, poverty reduction, and environmental protection. As demand for increased rural incomes and agricultural productivity grows, human systems increasingly put pressure on water supplies, and this is especially true for agricultural water. After decades of successfully expanding irrigation and improving productivity, farmers face emerging crises in the form of poorly performing irrigation schemes, slow modernization, declining investment, constrained water availability, and environmental degradation. Taken together, these crises profoundly compromise rural livelihoods.

Three World Bank sectoral strategies—rural development, water resources management, and environment—all call for using water more productively, managing water and land resources in a more sustainable manner, and reducing poverty.

To respond to this challenge, and to the challenge of the Millennium Development Goal of halving poverty and hunger by 2015, the World Bank, working with many partner agencies, has compiled a selection of good practices that can guide practitioners in the design of high-quality investments in agricultural water.

This *Sourcebook's* messages center around the key challenges to agricultural water management, specifically the following:

- Building policies and incentives
- Designing institutional reforms
- Investing in irrigation system improvement and modernization
- Investing in groundwater irrigation
- Investing in drainage and water quality management
- Investing in water management in rainfed agriculture
- Investing in agricultural water management in multipurpose operations
- Coping with extreme climatic conditions
- Assessing the social, economic, and environmental impacts of agricultural water investments

As is the case with its companion, *Agriculture Investment Sourcebook*, which focuses on investments in the agricultural sector more generally, our hope is that, by sharing acknowledged good practice widely among practitioners, further excellence in practice may be identified and brought to bear in what are intended to be living documents.

Kevin Cleaver
Director
Agriculture and Rural Development

Sushma Ganguly
Sector Manager
Agriculture and Rural Development

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ACRONYMS AND ABBREVIATIONS

ACIAR	Australian Centre for International Agricultural Research
AIS	<i>Agriculture Investment Sourcebook</i>
ANAE	National Association for Environmental Action <i>(Association Nationale d'Actions Environnementales)</i>
ANCID	Australian National Committee of the International Commission on Irrigation and Drainage
ARD	Agriculture and Rural Development Department, World Bank
APL	Adaptable Program Loan
APP	Agricultural Perspective Plan
ASAL	Agricultural Sector Adjustment Loan
ASCE	American Society of Civil Engineering

AWS	Agricultural water strategy
B/C	Benefit-cost (ratio)
BCM	Billion cubic meter(s)
BNWPP	Bank-Netherlands Water Partnership Program
BP	Bank Procedure
CAS	Country Assistance Strategy
CDD	Community-driven development
CDHI	Centre for Development of Human Initiatives
CGE	Computable general equilibrium
CIDA	Canadian International Development Agency
CGIAR	Consultative Group on International Agricultural Research
CGISP	Community Groundwater Irrigation Sector Project, Nepal
COAG	Council of Australian Governments
COTAS	User-oriented technical commission(s) of water (<i>Comité Técnico de Aguas Subterráneas, Mexico</i>)
CRS	Colorado Revised Statutes
CWRAS	Country Water Resources Assistance Strategy
DECRG	Development Economics Research Group
DFID	Department for International Development, U.K.
DPL	Development Policy Lending / Development Policy Loan
DRAINFRAME	Drainage Integrated Analytical Framework
DRI	Drainage Research Institute
DWR	Department of Water Resources
EA	Environmental assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
EPADP	Public Authority for Drainage Projects, Egypt
ERL	Emergency Recovery Loan
ERR	Economic rate of return
ESCAP	Economic and Social Commission for Asia and the Pacific (UN)
ESSD	Environmentally and Socially Sustainable Development
ET	Evapotranspiration
FAO	Food and Agriculture Organization
FI	Financial Intermediaries
FMIS	Farmers-Managed Irrigation Systems
GEF	Global Environment Facility

GIS	Geographic information system(s)
GW	Gigawatt
GW-MATE	Groundwater Management Advisory Team
HACCP	Hazard analysis and critical control point
HPIL	Hybrid Policy and Investment Loan
I&D	Irrigation and drainage
IBRD	International Bank for Reconstruction and Development
ICARDA	International Center for Agricultural Research in the Dry Areas
ICID	International Commission on Irrigation and Drainage
ICLARM	International Center for Living Aquatic Resources Management
IDA	International Development Association
IDE	International Development Enterprises
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
IIVAV	International Information Centre and Archives for the Women's Movement
IIED	International Institute for Environment and Development
IIMI	International Irrigation Management Institute
IIIMP	Integrated Irrigation Improvement and Management Project
ILRI	International Institute for Land Reclamation and Improvement
IMF	International Monetary Fund
IN	Investment Note
INCID	Indian National Committee on Irrigation and Drainage
I/O	Input/output
IP	Innovation Profile
IPDP	Indigenous Peoples' Development Plan
IPM	Integrated pest management
IPTRID	International Programme for Technology and Research in Irrigation and Drainage, UN
ISC	Irrigation service charge
ITRC	Irrigation Training and Research Center
IUCN	World Conservation Union
IWASRI	International Waterlogging and Salinity Research Institute, Pakistan
IWSFM	Integrated water and soil fertility management
IWDP	Integrated Wasteland Development Program
IWMI	International Water Management Institute

IWRM	Integrated Water Resources Management
KfW	Kreditanstalt für Wiederaufbau
kWh	Kilowatt-hour
LBOD	Left Bank Outfall Drain, Pakistan
LIL	Learning and Innovation Loan
LoDP	Letter of Development Policy
LSI	Large-scale irrigation
M&E	Monitoring and evaluating
MCM	Million cubic meter(s)
MDG	Millennium Development Goal
MODIS	Moderate Resolution Imaging Spectroradiometer
MOM	Management of Operation and Maintenance
MRRP	Mahaweli Restructuring and Rehabilitation project
MW	Megawatt
MWRI	Ministry of Water Resources and Irrigation, Egypt
MWRRRA	Maharashtra Water Resources Regulatory Authority
NACA	Network of Aquaculture Centers in Asia-Pacific
NATP	National Agricultural Technology Project
NGO	Nongovernmental organization
NPK	Nitrate, phosphorous, and potassium
O&M	Operation and maintenance
OLIBS	On-Line Irrigation Benchmarking Service
OD	Operational Directive
OED	Operations Evaluation Department
OP	Operational Policy
PAD	Project Appraisal Document
PAVCOPA	Agricultural Trading and Processing Promotion Pilot project (<i>Projet d'Appui à la Valorisation et Commercialisation des Produits Agricoles</i>), Mali
PCB	Polychlorinated biphenyl
PDPL	Programmatic Development Policy Lending
PESW	Programmatic economic and sector work
PIM	Participatory irrigation management
PLC	Programmable logic controller
PMP	Pest management plan
PROMMA	<i>Programa de Modernización del Manejo de Agua</i> (Water Resource Management Modernization Program, Mexico)
PRI	Institutional Revolutionary Party, Mexico

PRSP	Poverty Reduction Strategy Paper
PSAC	Programmatic Structural Adjustment Credit
PSAL	Programmatic Structural Adjustment Loan
PVC	Polyvinyl chloride
QAG	Quality Assurance Group
QACU	Quality Assurance and Compliance Unit
RAP	Rapid Appraisal Procedure
R&D	Research and development
RDS	Rural Development Strategy, World Bank
RIL	Rehabilitation Investment Loan
RP	Resettlement Plan
RPF	Resettlement Policy Framework
RWSS	Rural water supply and sanitation
S-I/O	Semi-input/output
SA	Social assessment
SAM	Social accounting matrix
SEA	Sectoral Environmental Assessment Strategic Environmental Assessment
SEBAL	Surface energy balance
SECAC	Sector Adjustment Credit
SECAL	Sector Adjustment Loan
SEO	State Engineer's Office
SF	Social fund
SI	Supplemental irrigation
SIL	Specific Investment Loan
SIWI	Stockholm International Water Institute
SIP	Subsectoral Irrigation project, Peru
SPS	Sanitary-phytosanitary standard(s)
SRH	Secretariat of Water Resources, Brazil
STREAM	Support for Regional Aquatic Resources Management
SWIM	Systemwide Initiative on Water Management
TG	Thematic group
TORs	Terms of Reference
TTL	Task Team Leader
ULA	Upper level association
UN	United Nations
UNDP	United Nations Development Programme

UNIFEM	United Nations Development Fund for Women
UP	Uttar Pradesh
USBR	United States Bureau of Reclamation
VDC	Village development committee
WRAP	Water Resources Action Program, Zambia
WATSAL	Water Resources Sector Adjustment Loan
WBI	World Bank Institute
WHO	World Health Organization
WIN	Women Irrigation Network, Zambia
WP	Water productivity
WRAP	Water Rights Adjustment Program, Mexico (PADUA in Spanish)
WRMG	Water Resources Management Group
WRS	Water Resources Strategy
WRSS	Water Resources Sector Strategy, World Bank
WUA	Water user association
WUAF	Water user association federation
WUE	Water use efficiency
WWF	World Wildlife Fund
ZATAC	Zambia Agribusiness Technical Assistance Center

OVERVIEW

SOURCEBOOK OBJECTIVES

PROBLEMS FACING AGRICULTURAL WATER MANAGEMENT

There are heavy demands on agricultural water to provide more food to consumers and inputs to industry, create incomes and wealth in rural areas, reduce poverty among rural people, and contribute to the sustainability of natural resources and the environment. As urban demand grows, agriculture is also increasingly viewed as a reservoir of water for transfer to towns, sometimes in exchange for recycled wastewater from cities.

After a century of expansion of large-scale surface irrigation and decades of rapid groundwater development, opportunities to harness new resources are fewer and more expensive. Improving the productivity of existing water use and reusing secondhand water are therefore becoming common investment objectives. However, returns on public investment have been generally disappointing.

New solutions have emerged, based on widely available technology and new management options. The role of government is changing, responsibility is being decentralized, farmers are playing an increasingly important role in decisions and investment, and markets are driving growth.

How to grow more food, increase incomes, reduce poverty, and protect the environment—all from an increasingly constrained resource base—are the challenges facing agricultural water management discussed and addressed in this *Sourcebook*.

BACKGROUND OF THE THREE WORLD BANK CORPORATE STRATEGIES

The World Bank's approach to the agricultural water management challenges summarized above is guided by the recent corporate strategies for Rural Development, Water Resources, and the Environment. These three corporate strategies all assign a vital role to agriculture and water management in promoting rural growth, sustaining the environment, and reducing poverty.

The Bank's *Reaching the Rural Poor: A Renewed Strategy for Rural Development (RDS)* (World Bank 2003) highlighted the pivotal importance of the rural sector as the home of the vast majority of the world's poor and underlined the centrality of rural development to the Bank's poverty reduction mission. *RDS* demonstrates that agricultural development is the primary instrument for poverty reduction in most developing countries and urges, against a sharp decline in agricultural lending in recent years, the return of agriculture to the forefront of the Bank's agenda.

RDS also argues forcefully for a strengthened role for the Bank as an advocate for rural poverty reduction and as a leader in investment and policy dialogue.

Agricultural water management is critical to achieving key *RDS* objectives: durable rural growth, enhanced productivity and competitiveness, and sustainability of natural resource management. Underlining the growing shortage of water and competition from other users, *RDS* outlines the agenda for improved *water resources management*: to ensure that agricultural water is managed within an integrated basin approach, to allocate water to environmental uses, to prepare for the likely increase in recycled water use in irrigation, and to devise long-term approaches to issues of waterlogging and salinization. *RDS* also focuses on improving the *productivity* of existing water management systems, especially on small-scale projects characterized by demand-driven on-farm improvements, rehabilitation, and participatory approaches. On the *economic* side, *RDS* emphasizes the key role of incentives and the need to increase the role of private investment and management as well as the efficiency of public investment. Finally, *RDS* outlines an agenda for reform of fragmented *institutions* and unaccountable and inefficient public bureaucracies.

The Bank's *Water Resources Sector Strategy: Strategic Directions for World Bank Engagement (WRSS)* (World Bank 2004b) also gives prominence to irrigation as the key producer of food and source of livelihood for the world's poor, and as the largest user of water. *WRSS* underlines that water management and development are essential for growth and poverty reduction and argues that both broad and poverty-targeted interventions further those results. *WRSS* emphasizes two imperatives: to expand investment in irrigation and to change the way irrigation is managed. Calling for "principled and pragmatic reforms," the strategy stresses the need to return to basic economic principles that incentives should reflect both the financial cost of supplying services and the opportunity cost of water. *WRSS* also argues that, although the Bank portfolio in irrigation has been shrinking, there are compelling reasons to

What Is Agricultural Water Management?

Agricultural water management includes irrigation on large and small schemes and farms, drainage of irrigated and rainfed areas, watershed restoration, recycled water use, rainwater harvesting, and all in-field water management practices.

“get back in.” As for *RDS*, *WRSS* envisages a broader and more active role for the Bank in the irrigation sector, arguing that dealing with complexity and risk is a strength of the Bank, which should embrace “affirmative engagement with risk,” through a business model that puts development impact first.

WRSS proposes an agenda for agricultural water management directed toward improving the *efficiency of water service delivery and use* at the farm, scheme, and sector levels, underlining that water efficiency is pro-poor. The strategy emphasizes the role of *demand management* (cost recovery and water pricing, water rights, and the links between energy subsidy and groundwater depletion), the need to improve *governance* (user associations, gender participation, modernizing formal irrigation institutions, addressing the political economy of reform), and *integrated approaches and multi-functional technologies* (basin management, packages for drought, saline soils and floods, and drainage).

The Bank’s *Making Sustainable Commitments: An Environment Strategy for the World Bank* (World Bank 2001) recognizes irrigation’s vital contribution to rural economies and welcomes the increased attention to mitigating adverse environmental impacts. The strategy supports *participatory approaches* to address problems of *groundwater depletion and drainage*.

Although each corporate strategy has a different thematic emphasis, their combined messages for agricultural water management are clear:

- **Productivity.** The age of expansion is drawing to a close. In the future, governance, management, and technology must combine to improve the productivity of existing assets and available resources.
- **Incomes.** The bottom line is sustainable increases in farmer incomes, with a focus on the poor.
- **Institutions.** Improved governance is basic to increasing efficiency of resource use, and the energies of water users need

to be harnessed through expanded private and user participation at every level, and through inclusion, notably of women.

- **Integration and sustainability.** Water has to be used sustainably within an integrated approach. Resource constraints and environmental risks impose integrated water management approaches. Productivity at every level hinges on integrated management of land and water and on integration of policies and programs among water management, agriculture, and the environment.

OPERATIONALIZING THE CORPORATE STRATEGIES

The priority assigned to the agricultural sector in these three corporate strategies, along with their arguments that the Bank can and should play a central role in the development of the sector in the coming years, impelled the Bank’s decision to prepare a set of documents putting into operational terms the messages in the strategies. For the agriculture sector as a whole, the *Agriculture Investment Sourcebook* (World Bank 2004a) sets out specific examples and guidance on project design and investments that World Bank task team leaders can consider when preparing their projects to promote sustainable development and poverty reduction in the sector. The *Agriculture Investment Sourcebook* is complemented by a Directions in Development Report, *Agricultural Growth and the Poor: An Agenda for Development* (World Bank 2005a), which sets out guidance on policy interventions and reform initiatives that can underpin pro-poor investment and sustainable growth.

In conjunction with these documents, the present *Sourcebook* and its companion Directions in Development Report, *Agriculture Water Management: An Agenda for Sustainable Development* (World Bank 2005b) have been compiled. The preparation of two documents specifically devoted to agricultural water management demonstrates that agricultural water management is vital to meeting the objectives of the corporate strategies and underlines the intersectoral nature of water use in agriculture, reflected in its central place in all three corporate strategies.

Taken together, the above publications are among the World Bank's handbooks for its reengagement with the agricultural sector. They give policy, investment, and implementation guidance for the operationalization of the Bank's corporate strategies on rural growth and poverty reduction through agricultural development and sustainable natural resources management.

THE AGRICULTURAL WATER MANAGEMENT SOURCEBOOK

With the background of the corporate strategies and alongside its companion publications, the *Shaping the Future of Water for Agriculture: A Sourcebook for Investment in Agricultural Water Management* is designed to show how—in conjunction with macroeconomic and broader sectoral policies and investments—policy and investment in agricultural water management can contribute to sustainable rural growth and poverty reduction. Although the *Sourcebook* covers a whole range of issues, the focus is operational, concentrating on the following:

- The policy and institutional reforms needed to *make improved water productivity profitable for the farmer and for the nation* through governance, management, markets, and trade policy
- The investment, technology, and management means available to *increase water productivity*

The *Sourcebook* guides Bank staff in the design of agricultural water management investments:

- It documents a range of solutions and good practices from Bank and worldwide experience that can be mainstreamed into the Bank's portfolio, including policy and institutional reforms, investments in hardware and software, and recent innovations and successes for scaling up.
- It highlights means of improving performance and increasing production, incomes, and social returns.

- It suggests ways of increasing investment and improving its quality and sustainability.

WHAT IS NOT COVERED

The *Sourcebook's* coverage is not always comprehensive and it is expected that there will be periodic updates as fresh topics arise and material becomes available. The *Sourcebook* is essentially a guide to designing investment programs. Policy issues are discussed where they are relevant to investment. However, enabling policy issues are treated more broadly in the companion Directions in Development paper (World Bank 2005b), where they are presented within the wider strategic framework.

This section of the overview has briefly outlined the overall problem of investing in agricultural water and has described the purpose of the *Sourcebook*. The next section will look in more detail at the challenges facing investment in agricultural water.

CHALLENGES FACING AGRICULTURAL WATER MANAGEMENT

Challenges facing agricultural water management include (1) the policy and institutional challenge, (2) the economic and financial challenge, (3) the problem of declining investment, (4) the challenge of technology and water resources to supply growing demand, (5) the poverty and rural incomes challenge, and (6) environmental dimensions and the sustainability imperative.

THE POLICY AND INSTITUTIONAL CHALLENGE

Governments readily shouldered the development mission in the 1970s and 1980s, with the state as principal investor and service provider. In irrigation, government planning and top-down solutions often led to poor choices, high costs, poor service, low cost recovery, and a culture of dependency on the state. In many countries, the poor track record of the state has prompted a shift toward a new public-private

paradigm for irrigation, in which government progressively becomes more of a facilitator, and regulator and users and markets play a growing role in management and finance. Reconciliation of agricultural policy with macroeconomic policies is often challenging: governments that aim for low-cost, domestically produced food encounter problems in providing adequate incentives—and incomes—to farmers, and governments have to adjust to the best tradeoff between support to agriculture and an economically efficient food security policy. Within agriculture, too, there is a need to integrate agricultural water management issues into broader agricultural policy. Both irrigated and rainfed agriculture use and invest in water resources and management as one of the many inputs to the agricultural production process and in response to market opportunities and incentives that are determined in the broader agricultural and macro economies. Thus, investment and incentive policies for agricultural water management have to be developed in an integrated way within a broader agricultural policy. At the same time, agricultural water allocations and management priorities have to be integrated with overall water management priorities at the basin and national levels. These and other policy and governance adjustments drive sector reforms in many countries. An understanding of the political economy of these reforms, and of how reform processes work, is needed. New water management skills and institutional capacity building are also needed.

THE ECONOMIC AND FINANCIAL CHALLENGE

Compared to other water-using sectors, agriculture in most locations generates the lowest value added per unit of water, and so will progressively give up water to domestic, municipal, and industrial uses as water scarcity increases and competition mounts. Yet within agricultural use there is considerable scope for improving returns on water. Low returns mean low incomes; higher returns will boost incomes for farmers, including the poor. The key economic challenge is to get an incentive framework in place that encourages efficient water use and profitable high-value

agriculture. There is evidence that, for the service provider and the farmer, a well-balanced incentive framework improves efficiency and accountability, raises productivity, and promotes sustainable and environmentally responsible resource use. The parallel financial challenge on irrigation schemes is to generate cost recovery adequate to finance an excellent service to farmers. A broader financial challenge is to set up an enabling and incentive framework that will encourage both large- and small-scale private investment. These challenges are considerable. At the international level, markets are widely protected and commodity prices generally low. Domestically, many agricultural economies are characterized by inadequate or noncompetitive markets, pervasive subsidies, and food self-sufficiency goals that are inconsistent with comparative advantage. Cost recovery remains a contentious issue in many countries and private investment is often crowded out by public subsidy or deterred by uncertain investment environments and distorted incentive frameworks.

THE PROBLEM OF DECLINING INVESTMENT

Governments are investing less public money in agriculture worldwide; public investment in agriculture has dropped, and investment in irrigation, drainage, and other agricultural water management projects has also been declining worldwide. World Bank lending for new irrigation and drainage projects dropped to a record low of \$220 million in fiscal 2003, a dramatic plunge from the levels of the 1980s and early 1990s, when it averaged between \$1.0 billion and \$1.2 billion annually. There are several reasons specific to agricultural water management for this decline. First, investment costs have risen because irrigation has moved into more marginal areas. With the average cost of developing new irrigated land now above \$6,000 per hectare, rates of return on new schemes are generally in single digits. Second, the performance of large surface schemes has been disappointing. Third, much of the effort on large schemes now goes into rehabilitation and management changes to improve water delivery service. These investments are inherently lower cost than developing new schemes.

In groundwater irrigation, investment has been predominantly private. In most countries, groundwater is now fully exploited, often over-exploited, and investment has to switch to improving on-farm efficiency. Improving water use efficiency pays high economic returns, but often the incentive framework is distorted so that farmers do not invest because it is not financially profitable. Another area in which investments are needed but neglected is drainage, where the multifunctional aspects and multiple impacts and externalities are not usually taken into account in project design and socioeconomic justification. Cost-benefit analysis typically understates benefits, and cost recovery is difficult. A final reason sometimes adduced for decline in investment is that the safeguard policies of the World Bank are seen as adding to the transaction cost of preparing projects.

THE CHALLENGE OF TECHNOLOGY AND WATER RESOURCES TO SUPPLY GROWING DEMAND

The threat of global food shortages that appeared in the 1960s has diminished through innovations and investments in the Green Revolution and water control technologies. Increases in irrigated areas and improved yields have helped to increase food production per capita, despite significant population increases. For all developing countries, average daily caloric intake per person has risen from 2,360 in the mid-1960s to 2,800 during 1997–9. Output per unit of water worldwide rose 100 percent during 1961–2001—for wheat, the increase was 160 percent. As a result, the water needed to feed a person for a year has been halved in the last 40 years, from 6 m³ to 3 m³ a year. In addition, investments in irrigation, drainage, and general water management have driven the growth of rural economies and of lasting employment in many parts of the world. Today, irrigated agriculture supplies about 40 percent of the world's food, though occupying only 17 percent of the cultivated land. However, for the future, the Food and Agriculture Organization (FAO) estimates that by 2030, food production needs to grow at 1.4 percent a year, and about half of this growth would have to be generated from irrigated agriculture. The ability of the world's

farmers to meet this increase in demand is constrained. Indeed, the pace of technological change has slowed down—the water resource base is in most places fully developed, and now more than half the world's population lives in water scarcity. Intersectoral competition for water is growing, with water supply to cities taking priority and demand for water for nonirrigation purposes projected to increase 62 percent between 1995 and 2025 (Rosegrant, Cai, and Cline 2002). Efficiency of agricultural water supply and use remains well below technical potential. Groundwater overdraft and pollution are further reducing available resources, especially for poor and small farmers, and climate change is also expected to increase farmer vulnerability and reduce water availability in water-scarce regions, especially through increased risk of drought. Domestic, industrial, and, increasingly, environmental and resource protection needs will take a growing share of the world's water. The share of agriculture, which already uses about 70 percent of total water abstractions worldwide, can only shrink. The International Food Policy Research Institute (IFPRI) calculates that, on current trends, global annual cereals production will be 300 million tons¹ less in 2025 than would be the case if an adequate supply of water were available, a difference nearly as large as the entire U.S. cereals crop in 2000 (Rosegrant, Cai, and Cline 2002).

The water resources challenge thus requires better resource allocation—systems of integrated management and incentives that allow water to flow to the highest social and economic priorities. But it also requires a reinforcement of the intensification process: most of the extra production needed in the future will have to come from intensification of land and water use and only a minor share from newly harnessed land and water resources. Globally, cereals yields will have to increase from the current average of about 3 tons per hectare to 4 tons per hectare by 2030. Agricultural water management will thus have to provide more efficient and equitable solutions for intensification at the basin level to increase water and land productivity at the field level. Farmers everywhere will seek to improve their incomes from an increasingly constrained water resource,

and this too will provide a powerful impetus to increasing water use productivity.

THE POVERTY AND RURAL INCOMES CHALLENGE

Agricultural growth is central to poverty reduction. Seventy percent of the world's poor live in rural areas, and most of them are dependent on agriculture. Typically, the rural poor live on marginal lands or on drylands, with little or no access to controlled water sources. Their technological options for improved water management are limited, and they face high risks from rainfall variations. The poor are also exceptionally vulnerable to drought, floods, effluent discharge, aquifer depletion, waterlogging, salinization, and water quality deterioration. Thus the key agricultural water challenges for the poor are food security, risk mitigation, and income growth. Millennium Development Goal (MDG) 1—*Eradicate extreme poverty and hunger*—can be achieved only if agriculture grows and can provide access to food for the poorest and most vulnerable. Improved management of available water thus has a critical role to play in poverty reduction and food security. Other MDGs such as gender equality,² child nutrition, and market access also depend directly or indirectly on pro-poor agricultural growth and related management of scarce water.

ENVIRONMENTAL DIMENSIONS AND THE SUSTAINABILITY IMPERATIVE

Rural people are the trustees of much of the world's land and water resources, and therefore are central to achieving MDG 6—*Ensure environmental sustainability*. However, this trusteeship is increasingly hard to respect. Many countries are at the limit of water resources development, and pressure on land and water is intense. The tension between production and protection of natural resources has grown. In some basins, water no longer reaches the sea, and environmental flows have virtually ceased. In many basins, where competition is allowed, overabstraction of groundwater is leading to irreversible decline in water tables. Salinization and waterlogging have affected 30 million

hectares worldwide, and a further half million hectares go out of production each year—as much farm land as new irrigation creates. Disposal of agricultural drainage water and reuse and recycling of water are causing environmental and health problems. The “multifunctional” dimension of much agricultural water use and the prevalence of environmental externalities create a complex challenge, which integrated water resources management is only beginning to take up. At the same time, 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 use.

Improvements in agricultural water management have much to contribute to the goals of improving productivity and sustainability, and thereby to increasing incomes and reducing poverty. However, not all goals can be achieved together in all circumstances; tradeoffs will be needed, for example, where environmental concerns and poverty reduction goals cannot both be met. Informed policy decisions have a key role to play in selecting alternatives in these circumstances. The Directions in Development Report *Agricultural Water Management: An Agenda for Sustainable Development* (World Bank 2005b) that accompanies this *Sourcebook* will give guidance on the management of these tradeoffs.

The next section summarizes the cross-cutting themes that emerge from the *Sourcebook*.

CROSS-CUTTING THEMES OF THE SOURCEBOOK

Shifts have occurred in the way countries approach development policy for agricultural water management in recent years, including the following:

- A stronger focus on poverty reduction;
- An awareness of the need to “manage scarcity”—of water, capital, and institutions;
- Growing emphasis on sustainability and environmental externalities;

- More consideration of the value of markets and economic incentives; and
- Political economy processes of democratization, decentralization, and participation.

These shifts have brought about significant changes in agricultural water management. Almost every country is moving along the continuum shown schematically in table 1.

These shifts in emphasis are captured in the cross-cutting themes of the *Sourcebook*, which are presented briefly below. The references are to the relevant chapter of the *Sourcebook*.

FACILITATING POLICY REFORM

In most countries, agriculture uses more than 80 percent of water resources and produces most

national food requirements, generating income and supporting most of the poor. Therefore, policy for agricultural water management is vital: it must deal with managing scarcity, with water allocation, with food security, with poverty reduction, and with environmental risks. These issues are central to the Bank's mandate and are at the heart of poverty reduction strategies in most countries. *The Bank should invest in agricultural water policy (chapter 1).*

Reconciling best-practice water management principles (integrated approach, basin management, participation and decentralization, water as an economic good) with local physical, economic, and sociopolitical realities is unlikely to be easy, and *the policy reform agenda for agricultural water management is a difficult one*: setting the legislative and regu-

Table 1 Agricultural Water Management: Changing Emphasis

From:	To:
Area expansion	System improvement and increased water use efficiency, intensification, and reuse
Major physical investments to harness water resources, large-scale irrigation schemes	Targeted investment in irrigation improvement, drainage, and agricultural intensification
Resource development	Development of institutions and the incentive structure
Food self-sufficiency, increasing output	Resources management and environmental protection
Centralized planning approaches	Food security, increasing incomes, diversification, intensification, high-value crops, poverty reduction
State focus	Demand-driven approaches, participatory planning, dialogue, and political economy analysis
Government as service provider	Focus on the private sector, market, and community ownership
Subsidies and nonmarket interventions	Government as catalyst, facilitator, and regulator
Government-run and -subsidized irrigation schemes	Market-led growth
Studies	Participatory irrigation management, cost sharing, and irrigation management transfer
Project focus, investment lending	Dialogue, pragmatic political economy analysis
Sectoral approach	Long-term focus, program approaches, lending for selected investments and for policy reform
	Integrated resource management approach

Source: Author.

latory framework; establishing an incentive regime consistent with poverty reduction, rural development, and agricultural goals and with trade and macroeconomic policies; matching investment and incentive policies in agricultural water management with broader agricultural policies on both the input and the output sides; ensuring that agricultural water fits within an integrated, intersectoral water management framework; designing institutional models to separate bulk water delivery from distribution and to provide efficient least-cost water service; redefining the role of public and private sectors and of markets; and ensuring an enabling environment for private investment. Although policies cannot be uniform, *successful reforms* generally limit the role of government, decentralize responsibility to local authorities and agencies, and to water users, promote market-based solutions and private investment, and emphasize market-led growth policies with domestic and global trade reform. Tradeoffs between food self-sufficiency goals and efficiency goals will be increasingly on the policy agenda, as water-scarce nations faced with high opportunity costs of domestic food production turn increasingly to virtual water imports, which result in water savings for importing countries but also real global water savings because of the differential in water productivity between exporting and importing countries (**chapter 1**).

Many water management reforms have high political transaction costs. These can be absorbed at least in part by investing in *participatory processes of ownership building*. Adjustment lending may also help. Typically, reform is likely to take a long time, requiring stamina and consistency both from the nation and from external partners such as the Bank. *Understanding the political economy of reform is essential* (**chapter 2**).

BUILDING GOVERNANCE AND CAPACITY

The character of governance for agricultural water is changing everywhere. Many countries are pursuing *decentralization, participation, and demand management* policies in irrigation. In

more than 50 countries, this movement has taken the form of participatory irrigation management, with user associations emerging as decentralized and democratic user groups and taking responsibility for some management tasks. In the long run, the transfer of irrigation management, or even of full ownership, may be the target. The counterpart is the *modernization of formal irrigation institutions*, tightening accountability, and improving performance. These changes, together with the development of an increasingly knowledge- and skills-based agricultural and irrigation economy, create a need for *significant investment in institutional development and capacity building* (**chapter 2**).

SETTING AN INCENTIVE FRAMEWORK

Investment and management in agricultural water are driven by incentives, and *distorted incentive structures have been at the root of poor water management*. Service providers often have little incentive or accountability to deliver good service. Farmers have been faced with an array of prices and markets distorted by subsidies and administrative decisions and by trade, energy, and macroeconomic policies. The results have been risk aversion and reduced private investment, slow adoption of new technology and diversification, low cost recovery, and groundwater depletion and other environmental degradation. Good outcomes from investment in agricultural water require an *incentive framework that encourages both service providers and farmers to invest and to manage water efficiently and sustainably* (**chapter 1**).

Subsidies have been used to make irrigation accessible to farmers, to promote technological innovation, to compensate for externalities, or to target the poor through watershed management, flood-risk management, or drought preparedness. In general, the use of subsidies should be limited, as good investment packages have built-in incentives, and cost sharing creates ownership and improves investment quality and sustainability. *If subsidies are used, they need to be carefully designed to achieve their policy objective* (**chapter 1**).

Reticence on subsidies reflects the market-driven approaches to improving agricultural water management developed in the *Sourcebook*. Technological solutions are generally available, and ways to improve water management and farm management are known and can be adapted. Successful investment is ultimately a matter of incentives—a matter of addressing the question, “What is the bottom line for the farmer?” The answer lies in *private markets, not public subsidies*. New instruments being developed can offer a market-based approach to paying upstream farmers for good natural resource management in the common interest (**chapters 2 and 3**).

Water charges are often contentious, but *adequate cost recovery to pay for good service for farmers is a key element in improving investment outcomes*. This can be best achieved where the institutional framework makes service providers accountable and efficient and where user associations have a positive effect on recovery (**chapter 1**).

Often, lack of clear water rights, particularly for groundwater, drives excessive consumption and overirrigation. Definition of water rights is, in principle, a strong incentive to efficient use. If water rights are tradable, water markets can develop, helping intersectoral transfer and optimizing economic incentives by raising the market price to match opportunity cost. However, there is often disagreement on the subject of water rights, particularly where there is cultural reticence and weak governance. *In most countries water rights are a long-term solution* (**chapter 2**).

Increasing Investment Returns

Many approaches in the *Sourcebook* promise more income from better use of water; some promise more income for less water. Some complementary investments such as conjunctive use pay particularly high returns. *Increasing net returns to farmers is the main incentive to investment*. Ultimately it is this potential to generate “more income for less water” that justifies investment. Already, many farmers finance all their own on-farm investments in, for example, micro-

irrigation. As diversification continues, driven by market forces, farmer investment will grow. *Thus, the policy and incentive environment for private investment is key* (**chapters 1 and 3**).

Investment in large-scale irrigation should have high returns because of economies of scale, especially where investment is in improvement of existing systems. However, despite the availability of cost-effective technology for modernization, results of improvement projects have not always been satisfactory. Successful investment in irrigation modernization requires a systematic benchmarking approach to rank investments according to their contribution to the *service delivery goal of cost-effective and timely water delivery*. In the case of investments such as watershed management or dams, benefits are too often understated, and investment preparation needs to ensure that all benefits are taken into account (**chapter 3**).

The quality of Bank lending for agricultural water can be improved not only by the application of good practices, but also by the appropriate choice of lending instrument from the wide range available (see the section on Lessons and Next Steps below). Quality should be improved, too, by the application of Bank safeguard policies, which were designed not as a constraint but as an aid to investment, to integrate environmental and social issues into projects, and to support participatory approaches and transparency—all requirements for quality investment (**chapter 9**).

PUTTING TECHNOLOGY TO WORK

With irrigation efficiencies worldwide well below technical maxima, pressurized systems and protected agriculture still occupying only a small area, low-value staples predominating in cropping patterns, and agricultural yields and farmer incomes well short of potential, *the scope for investing in efficiency gains is enormous* (**chapters 3 and 4**).³

There is “more technology available than we know what to do with” (box 1). Technology to improve water service on major schemes is well

known and available; on-farm technologies such as piped distribution, drip, and bubbler are widely available and becoming more affordable; many water management and crop husbandry improvements are known; drainage, drought management, and flood control technologies are all well developed; and technology exists for watershed management and for even the most unpromising of marginal rainfed systems. Much technology already exists and only needs to be put to work. Adoption of water-saving technologies has been slow and performance below potential. Adoption requires knowledge, reliable water service, and an economic environment that provides undistorted incentives, manageable risk, and access to product and credit markets. Ultimately, farmers will adopt new technology when it is shown to increase incomes and reduce risk, and when there is market access. However, the intensification needed to feed the world and to raise rural incomes in coming decades cannot rely only on existing technologies; the size of the increase needed creates a future research agenda on water and land productivity, both for irrigated and rainfed production (*chapters 1, 3, 6, and 8*).

OPERATIONALIZING INTEGRATED APPROACHES TO AGRICULTURAL WATER MANAGEMENT

Successful investment in agricultural water requires an integrated approach to the different inputs to the production system—soil, water, agronomy. Many examples are discussed in the *Sourcebook*—integrated water-saving approaches to on-farm management; supplementary irrigation and conjunctive use; combined water and soil fertility management; and integrated approaches to combating drought, salinity, and floods. At policy level, agricultural water management investments and incentives have to be integrated within overall agricultural policy, both on the input side (with policies for research, extension, fertilizer, investment, and input support) and on the output side (with policies for transport, market development and trade, agricultural prices, and protection). Integration is also imperative at the level of water resources management, where bulk water, irrigation, drainage, wastewater, and floods all have to be managed within basin plans that

Box 1. Some Technologies and Management Practices Discussed in the Sourcebook

- Large scheme irrigation improvement (chapter 3)
- On-farm improvement (chapter 3)
- Conjunctive use (chapter 4)
- Drainage technology (chapter 5)
- Reuse of treated waste and drainage water (chapter 5)
- Supplemental irrigation (chapter 6)
- Groundwater recharge (chapter 8)

ensure intersectoral coordination, allocative efficiency, and social and environmental protection (*chapters 1, 3, and 6*).

MAKING PARTICIPATORY MECHANISMS MORE EFFECTIVE

Farmers in rainfed cropping, traditional irrigation, or watershed management traditionally worked together, and farmer organization is recognized as a powerful force for improving management. The Bank's effectiveness in implementing participatory irrigation management and helping user associations to develop has been rated highly by its Operations Evaluation Department (OED) (World Bank 2002). *Participation is a key element in successful investment for poverty reduction through agricultural water management.* The *Sourcebook* gives many examples of how farmer involvement (including women's involvement) can also improve investment outcomes in other areas, including policy making, technology development, intersectoral transfer through water rights and water markets, community-driven development (CDD) approaches to small-scale irrigation and watershed management, private irrigation (supplementary irrigation, groundwater management, conjunctive use), and drought management (*chapters 2 and 7*).

TARGETING POVERTY REDUCTION IMPACTS

The Bank's OED has found irrigation projects to be effective in reaching the poor, provided that macroeconomic policies are conducive (World Bank 1994). However, as intensification proceeds, it is the better-off farmers who benefit most, because they can finance on-farm investments,

assume risk, and access knowledge and information services. *Care is needed to ensure a pro-poor element in investment programs, because a purely market-driven approach will favor the better off.* To offset this, irrigation investments can be targeted at the poor. For example, priority can be given to small-scale irrigation and water conservation investments, which are more pro-poor and characterized by high flexibility and rapid implementation (**chapter 3**).

Some investments (for example in supplementary irrigation, infrastructure, and market development) described in the *Sourcebook* also help *reduce risk for rainfed farmers*. Other investments to help the poor include improving market access and better management of environmental risk, including watershed management approaches and drought and flood management (**chapter 6**).

MANAGING WATER FOR SUSTAINABILITY

The *Sourcebook* covers a range of *environmental investments in agricultural water management*. Recovering control over groundwater requires user and government commitment, an incentive structure that favors conservation and efficiency, and a governance system that allocates and regulates rights. There are few successful examples of groundwater overdraft being brought under control, but as resource-mining problems grow worse, this could be a significant investment area. In drainage, the economic logic is clear—the cost of “saving” an irrigated hectare through drainage is less than \$1,000, compared with more than \$6,000 to create a new irrigated hectare. Few countries are yet awake to this compelling case for investment in drainage, but those that are—the Arab Republic of Egypt and its participatory drainage program, for example—are benefiting. In watershed management investments, integrated and participatory approaches with a focus on poverty reduction are working (**chapters 4 and 5**).

LESSONS AND NEXT STEPS

This section of the overview summarizes some of the lessons learned from the *Sourcebook* and

gives guidance on how to put the knowledge to work in policy analysis, technical assistance, and—above all—lending.

SOURCEBOOK LESSONS

Two principal areas of investigation are addressed in the *Sourcebook*: policy and institutional reforms, and investment, technology, and management practices. Much of the material is familiar, and the value added lies in bringing it all together in a systematic way within a single publication. Among the well-known elements on the *policy and institutional reforms* front treated in the *Sourcebook* are solutions to problems of sector governance: decentralization, participation, and the emphasis on private sector involvement and the role of markets. The need for an integrated approach in agricultural water investment is another familiar element, and the *Sourcebook* emphasizes integration not only within the context of the whole rural market economy, but also as part of the hydrological and overall ecosystem, and as a component of the macroeconomy. One aspect of this need for an integrated approach is the insistence throughout the *Sourcebook* on the enabling environment, particularly input and output markets and prices, financial markets, and risk reduction for the poor: participation, land tenure, water control, disaster management.

Regarding *investment, technology, and management practices*, the *Sourcebook* confirms that there is a broad array of technology available. For large-scale irrigation, combinations of management and investment can greatly improve the cost-effectiveness of water service. For small farmers, low-cost technology is widely available, and there are technical solutions for even the most marginal land and water situations.

Some of the main lessons for investment emerging from the *Sourcebook* are briefly summarized in the following paragraphs.

TRADE AND MARKETS PLAY A KEY ROLE IN IMPROVING AGRICULTURAL WATER INVESTMENT. The *Sourcebook* underlines the role of trade and markets in driving technology adoption, investment, and growth, even for smallholders. The *lesson* is that

A SOURCEBOOK FOR INVESTMENT IN AGRICULTURAL WATER MANAGEMENT

policy for agricultural water has to be analyzed within an integrated framework that includes trade and market development policy, and that investments may be needed to promote market development.

ADEQUATE COST RECOVERY AND GOVERNANCE IMPROVEMENTS ARE CRITICAL FOR SUSTAINABLE IRRIGATION MODERNIZATION. The *Sourcebook* shows how adequate cost recovery is key to ensuring efficient water service, and how this has to be matched with accountability and cost-effective water supply on the part of the service provider. The *lesson* is that investments in irrigation modernization need to be accompanied by both a credible cost-recovery strategy and by governance improvements that ensure accountability, and by least-cost and efficient service delivery by the service provider.

THERE ARE NEW TOOLS TO HELP IMPROVE INVESTMENT QUALITY. Investment quality is a widespread concern, and the *Sourcebook* provides some tools and orientations to help improve outcomes and impacts. These include a rapid appraisal benchmarking tool to help focus irrigation modernization investment on cost-effective service delivery and a tool to plan for drainage investments integrated within a basin approach. The *lesson* is that tools are available—or can be developed—for an output-based approach to investment design.

INVESTMENT IN TECHNOLOGY NEEDS TO BE BACKED BY A CONDUCIVE INCENTIVE FRAMEWORK. There is disappointment with modernization programs in large-scale irrigation, and more generally a vast gap between potential and actual performance in irrigated agriculture. The finding is that there is a great deal of technology that can be applied but is underused at present, both on large schemes and on-farm, where supplementary use, conjunctive use, protected agriculture, agronomic improvements, and drainage have great potential for improving water use efficiency and farmer incomes. The *Sourcebook* finds the causes less in knowledge and technology transfer capability than in distorted incentive frameworks and markets, which reduce farmer motivation and increase risk. The *lesson* is that investment in crop intensification and

diversification has to look not only at technical solutions, but also at the incentive structure and market environment.

INTEGRATION IS A KEY THEME ACROSS THE WHOLE RANGE OF WATER INVESTMENTS. The role of water as just one input in complex production processes is reflected in the *Sourcebook's* insistence on integration of irrigation system modernization and farming intensification, on the need to integrate technical packages (soil, water, crop management), and on integration of technical and market aspects. The *Sourcebook's* underlining of the need for integration in multi-purpose investments such as dams and drainage reflects a more complex aspect of water: its multisectoral and multi-institutional character and the widespread externalities associated with its use. The *lesson* is that all agricultural water management investments have to consider integration aspects within the production system and within the agricultural sector, but also integration of agricultural water use with other uses and users and their representative stakeholders and institutions, together with environmental and social externalities.

PARTICIPATION IMPROVES THE QUALITY OF INVESTMENTS. Many contributions to the *Sourcebook* underline the value of participation in improving investment quality, developing technology, influencing policy, and improving ownership across the board. One insight is that the social and environmental safeguards, with their transparency requirement, can be a mechanism to improve participation and ownership of investments. The *lesson* is that participation, properly adapted and managed, improves quality and ownership across the whole range of investments, innovations, and institutional development.

AGRICULTURAL WATER MANAGEMENT IS A VITAL COMPONENT OF POVERTY REDUCTION STRATEGIES. The *Sourcebook* documents the wide availability of technologies that can help poverty reduction in both irrigated and rainfed situations and the scope for making this technology available and affordable for the poor. The *Sourcebook* also highlights the vulnerability of the poor to negative environmental and water-related impacts (drought, flood, watershed

degradation, groundwater depletion, surface water contamination) and the consequent high poverty reduction impact of investing in control and mitigation. The *Sourcebook* also underlines the potential of market liberalization to drive pro-poor growth and the parallel need to target interventions, because the better-off typically gain more from free market approaches. One *lesson* is that all agricultural water investments can be designed with a pro-poor approach but that targeted interventions may be needed. A second *lesson* is that certain types of agricultural water investment such as watershed management will have particularly high poverty reduction impacts.

NONCONVENTIONAL WATER IS AN AREA FOR FUTURE INVESTMENT. The *Sourcebook* reviews the possibilities of harnessing nonconventional water sources such as drainage water, wastewater, and flood water. The *lesson* is that “unwanted water” is not necessarily a problem; it can be turned to good account as a resource, and investment is likely to increase.

Following this summary of some of the key lessons for investment emerging from the *Sourcebook*, the next section examines ways in which the World Bank could put the *Sourcebook* knowledge to work.

PUTTING THE SOURCEBOOK INTO PRACTICE

GETTING THE POLICY, STRATEGIES, AND PROGRAMS RIGHT. The *Sourcebook* describes the vital role of policy and strategy processes and of governance and incentives. It also describes how reforms take place, including the reforms’ political economy aspects. Clearly, it is important for the Bank to accompany its partner countries along the sequence from policy determination to choice of governance and incentive structures to sector strategy, and thus to choice of investments. One key instrument for following this sequence and for adding value through policy dialogue is the new *Country Water Resources Assistance Strategy* (CWRAS) introduced by the WRSS (see chapter 1). CWRAS links the Bank’s program to national strategies, helps mobilize the linkages between sectors, and ensures that an integrated approach to water is incorporated into the

Country Assistance Strategy (CAS) investment and sector work program. The agreed CWRAS becomes an agenda for a Bank-government partnership in the water sector.

USING WORLD BANK INSTRUMENTS SELECTIVELY. For sector work, the range of Bank products has widened. A CWRAS would normally propose a balance among policy dialogue, capacity building, technical assistance, and investment lending. Of particular value for long-term development processes such as water sector reform is “programmatically economic and sector work” (PESW), which allows the Bank and the member government to agree on a multiannual structured program of study and technical assistance, supporting reform but not necessarily tied to subsequent lending.

For lending, a broad range of instruments is available (table 2). As the table shows, a Development Policy Lending instrument may be appropriate for supporting policy reform. When a reform can be better implemented gradually through stepwise revised regulations, a Programmatic Development Policy Lending instrument could be appropriate. For long-term investment programs, the Adaptable Program Loan is indicated, or a Specific Investment Loan for a free-standing investment project. If policy and investment components interact strongly, a Hybrid Policy and Investment Loan, or two independent but highly correlated loans (such as a Development Policy Loan and a Specific Investment Loan) can be used. A Learning and Innovation Loan may support pilot projects, and an Emergency Recovery Loan can be used in the wake of disaster.

TARGETING SECTOR WORK, TECHNICAL ASSISTANCE, AND STUDIES TO STRATEGIC PRIORITIES

The program of sector work, technical assistance, and studies agreed by the Bank and government as part of a partnership approach will be determined by the country situation. Best-practice approaches will likely be characterized by a longer-term commitment on both sides and by a structured approach to

Table 2 World Bank Lending Instruments for the Water Sector

Nature of investment	Instrument	What does it do?
Major multi-institutional policy and institutional reforms (such as changes in governance or incentive structures for agricultural water) that can be done in a short time frame of one to two years.	Development Policy Lending (DPL) “quick-disbursing” tranching balance of payments support	It supports institutionally difficult policy reforms, agreed with the government in a Letter of Development Policy.
Longer-term water sector reform that can be divided into phases with benchmarking. May be used where issues are sensitive or political support for reform may shift.	Programmatic Development Policy Lending (PDPL)	As for DPL but supports a long-term reform program through a series of DPLs over three to five years.
Investment program accompanied by reforms needed to ensure outcomes but which are not major and can be implemented during the investment period (for example, restructuring an irrigation agency).	Hybrid Policy and Investment Loan (HPIL)	Supports sector investments and institutional development linked to relevant policy reforms.
Restoration of assets and production levels in the wake of disaster. Could also be used to establish a more provident disaster management capability.	Emergency Recovery Loan (ERL)	Rapid appraisal and fast disbursing investment loan.
Long-term, phased water investment programs. Performance criteria can be set to allow break points and correction.	Adaptable Program Loan (APL)	Supports investment program in two to three projects over 10 to 15 years, subject to performance criteria at completion of each project.
Investment program in agricultural water with monitorable outputs and outcomes. Reforms may be promoted but are not critical to outcomes.	Specific Investment Loan (SIL)	Finances specific investments. Can set reform conditions to accompany the program.
Testing high-potential innovations for subsequent scaling up.	Learning and Innovation Loan (LIL)	Short-term pilot projects to test ideas for subsequent large-scale investment. Typically rapid preparation, lighter procedures, two-year implementation period.

Source: Author.

issues, by a focus on governance and institutions, and by integration of water sector issues with other sectors (rural development, agriculture, social, and environment). These characteristics of a Bank-government relationship would be mirrored within the Bank by a similar long-term commitment to a reform program and by internal integration of the Bank’s work on water.

The Bank and its government partners would also seek and sustain partnerships with other international institutions in the field of agricultural water management, including FAO, IFPRI, IWMI, ICID, and the International Fund for Agricultural Development (IFAD). Also important will be financing from the Global Environment Facility (GEF) and partnerships with international institutions in the environmental

field, including World Conservation Union (IUCN) and World Wildlife Fund (WWF).

REVIVING AND REORIENTING THE LENDING PROGRAM

The range of possible investments discussed in the *Sourcebook* is vast (table 3). Each country situation will be different, but several common approaches can be proposed. A first investment approach is *piloting* for innovative solutions or for adapting practice from elsewhere. For this type of operation, the Bank has the advantage of international expertise and cross-country experience and a facility for learning and disseminating lessons. The Bank is also a development risk taker, with an appropriate lending vehicle (the LIL). Areas suitable for piloting include *institutional innovations* such as water user associations or basin committees, water rights, and water markets. Piloting may also be appropriate for *technically innovative solutions* such as pressurized systems, integrated soil and water management for smallholders, water management by evapotranspiration quotas, and risk management instruments such as crop insurance or commodity risk management.

A second investment area that follows logically from a piloting approach is *scaling up* good practices and successful experiences. Here the Bank's comparative advantage is in its financing strength and its ability to commit to longer-term programs. Examples include work on institutional change, watershed restoration, integrated water management, and new hardware and software mixes.

A third area of business is in *multifunctional operations* such as drainage and wastewater treatment and reuse, where the Bank has not only the financial resources needed but a comparative advantage in technical know-how and in integrating and convening power for the multiple institutions involved.

A fourth priority area for the Bank would be operations that directly *reduce poverty*. The Bank has the advantage of an integrated poverty reduction approach (in the poorer

countries through a Poverty Reduction Strategy Paper [PRSP], and in all countries through its operations in most sectors of the economy). Examples of poverty-reducing investments include flood and drought preparedness programs, integrated programs that include supplementary irrigation, conjunctive-use or low-cost pressurized systems, programs that integrate smallholders into the supply chain, and watershed management programs.

A final area where the Bank can have a comparative advantage is investment in *technical assistance* at the cutting edge, for example programs to evaluate water resources, groundwater management programs, studies on multifunctional approaches to drainage, and benchmarking to improve irrigation service delivery.

MOTIVATING AND ENABLING BANK STAFF TO PROMOTE GOOD AGRICULTURAL WATER MANAGEMENT AND TO INVEST IN IT

Bank staff from all disciplines working on agricultural water management would benefit from focused training based on this *Sourcebook*. Training—and staffing—needs to be balanced between engineering and nonengineering considerations. Engineers are essential to trace out the critical path to efficient irrigation service delivery, to manage the benchmarking process, to bring in technical innovations, to factor in environmental risks and management requirements, and to set agricultural water management in its integrated context. Nonengineering profiles and skills requisites include governance, institutional development, economics, environment, political economy, and social and community-driven development expertise. Most important, all staff should have the ability and motivation to see agricultural water management in its bigger context of poverty reduction, growth of livelihoods, and wealth creation.

ADAPTING THE MESSAGES TO THE SPECIFIC NEEDS OF EACH REGION

Analysis of the main issues in the six regions of the World Bank reveals that each may have a unique situation requiring a different focus and

Table 3. Some Investment Opportunities Described in the Investment Notes and Innovation Profiles

Some typical operations mentioned in the <i>Sourcebook</i> Notes	Investment type
<p>Integration of smallholders into supply chains Controlled drainage Institutional innovations such as water user associations or basin committees, water rights, and water markets Technically innovative solutions such as pressurized systems or integrated soil and water management Development of financing and risk management instruments such as crop insurance or commodity risk management Weather-based insurance</p>	Pilots
<p>Modernization of irrigation schemes Water resources development for supplementary irrigation Water retention, flood mitigation, and flood protection Drought and salinity investments Watershed management Integrated water management Multifunctional operations such as drainage, wastewater treatment, storage, and reuse Water trade facilitation</p>	Specific investment projects
<p>Supplementary irrigation Pressurized irrigation with protected agriculture` Smallholder irrigation under social fund and community-driven development approaches Integrated land and water management</p>	Alternative technologies within integrated programs
<p>Policy analysis and related capacity building Water resources assessment Benchmarking to improve irrigation service delivery Capacity building of farmer and extension Drainage Integrated Analytical Framework (DRAINFRAME) multifunctional approach to drainage Participatory irrigation management, water user associations, and irrigation management transfer Water markets development Groundwater management programs Water rights governance systems Drought and flood preparedness programs Irrigation and drainage research Rapid appraisals for irrigation modernization Water swap programs Monitoring and evaluation systems Impact evaluation</p>	Technical assistance

Source: Author.

perhaps a different set of approaches. Table 4, based on consultations with the regions, gives an indicative picture of the messages that are priorities in each region. The issues mentioned have been raised by staff in the regions. They are, of course, not mutually exclusive, and will evolve over time and be adapted to specific country situations.

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ENDNOTES

1. All references to "ton" in this *Sourcebook* denote a metric ton.
2. Women form 70 percent of the rural poor and produce between 60 and 80 percent of the food in most developing countries (WHO 2000).
3. There are a number of water use efficiency definitions and measures. These are best discussed and summarized in Jensen (1973) and Burt et al. (1997).

Table 4. Some Indicative Agricultural Water Management Issues in Each Region

Type of issue	Sub-Saharan Africa	Middle East and North Africa	Latin America and the Caribbean	South Asia	East Asia and Pacific	Europe and Central Asia
<i>Policy, institutions, and governance</i>						
Policy and strategy issues	*	*	*	*	*	*
Demand management		*		*	*	
Public-private role		*	*	*		
Participatory irrigation management/ water user associations/irrigation management transfer	*	*	*	*		*
Cost recovery	*	*	*	*	*	*
<i>Water resources management</i>						
Integration, IWRM issues	*	*	*	*	*	
Managing scarcity	*	*			*	
Watershed management	*		*	*	*	
Surface water management	*	*		*	*	
Groundwater management		*	*	*	*	
Environmental issues, water quality		*		*	*	*
Technology					*	
Focus on productivity rather than area expansion	*	*	*		*	
Enabling environment						
Land tenure	*		*			*
Input markets and credit	*		*			
Output markets and prices	*		*			
<i>Large-scale irrigation development</i>						
New schemes			*			
Rehabilitation	*	*		*	*	*
Management	*	*	*	*	*	*
<i>Smallholder programs, poverty focus</i>						
Poverty focus	*			*	*	
Rainfed issues (drought, floods)	*	*			*	
<i>Nonconventional water</i>						
Drainage, waterlogging, salinity, soil depletion	*	*	*		*	*

Source: Author.

IWRM: Integrated Water Resources Management.



BUILDING POLICIES AND INCENTIVES

- Investment Note 1.1 Preparing a National Agricultural Water Strategy
- Investment Note 1.2 Development Policy Lending to Support Irrigation and Drainage Sector Reforms
- Investment Note 1.3 Agricultural Trade, Water, and Food Security
- Investment Note 1.4 Pricing, Charging, and Recovering for Irrigation Services
- Investment Note 1.5 Economic Incentives in Agricultural Water Use
- Innovation Profile 1.1 Agricultural Water in the New Country Water Resources Assistance Strategies
- Innovation Profile 1.2 Enabling Smallholder Prosperity: Irrigation Investments for Ready Markets

OVERVIEW

This chapter presents a snapshot of different approaches to the many reform challenges in agricultural water management. There are key themes on process, particularly the need to be clear about goals and to orient policies, strategies, and investments toward those goals; on the importance of political economy, identifying champions and winners and losers; on the central value of participation and inclusion in all processes; and on the need to pilot in areas where solutions are not yet proven.

The chapter also shows how reforms are driven and facilitated, and how they can be supported by dialogue, analysis, and lending. The role of incentives in change is examined at two levels. In reform, the incentives have to be sufficiently attractive to persuade all parties to make policy adjustments that are sometimes difficult. In agricultural water management, incentives are the key to the adoption of new practices and open the door to higher productivity and incomes.

GETTING THE POLICY FRAMEWORK RIGHT IS ESSENTIAL

Governments are inevitably major players in the water sector because water resources are in part a public good, because water is closely linked to major public policy goals such as poverty reduction, and because water use creates widespread “externalities” (what one person does with water affects other people and the environment). Because agriculture is the major water user (80 percent worldwide and more than 90 percent in developing countries), government policy is critical to successful investment in agricultural water management. (See IN 1.1 on formulating policy and strategy, and IN 1.2 on facilitating reforms with lending. See also “Preparing a National Agricultural Development Strategy,” Module 1 in the *Agriculture Investment Sourcebook* (AIS).)

POLICIES ON TRADE AND MARKETS DRIVE GROWTH ...

Open trade in agricultural products can contribute to growth in agricultural investment and incomes and promote more efficient and less water-intensive crop management practices and cropping patterns—fruit, vegetables, flowers. There are well-known constraints to freeing trade internationally, particularly with the most lucrative markets. Often, governments will create internal restraints to market development, too. Trade-driven growth needs to be accompanied by knowledge-intensive agriculture. Care is needed on the environment—market prices do not reflect the social cost of soil and water depletion or pollution, so some regulatory measures may be needed.

Overall, evidence shows that properly managed liberalization drives growth and can benefit the poor. Trade reform enhances both domestic food security and national growth, and poorer countries benefit the most. Overall, investment outcomes are likely to improve where trade and markets are liberalized. At the household level, trade-driven modernization can be the engine of growth and poverty reduction by reducing food costs and supply uncertainties, generating growth through diversification and productivity

gains, increasing and diversifying incomes, and providing employment. A case study from Zambia illustrates these effects. (See IN 1.1 on overall growth policy, IN 1.3 on agricultural trade, and IP 1.2 on growth from smallholder irrigation in Zambia. See also “Reform of Agriculture Subsidy and Protection Policy,” and “Facilitating Efficient Adjustment to Liberalized Trade” in AIS, Module 1.)

...AND THE INCENTIVE FRAMEWORK HAS TO MOTIVATE FARMERS

Incentives for agricultural water use are often identified with water charges. But economic incentives understood, in a broader sense, as “all signals that affect farmer decisions” provide the essential framework for quality investment in agricultural water. The incentive framework can encourage water use efficiency, promote environmentally friendly practices, reduce costs to government, and increase farmer income. The incentive framework should encourage farmers to invest and manage their farms and water resources efficiently and profitably. “Negative” incentives, which increase the costs of current behavior and provide a push for change, need to be matched with “positive” incentives, which facilitate change toward a more efficient, sustainable use of water. (See IN 1.5 on economic incentives in agricultural water use. See also IN 3.1 on incentives for on-farm water saving.)

COST RECOVERY CONTRIBUTES TO GOOD INVESTMENT

Properly managed, irrigation service charges are a key element in ensuring good investment outcomes. Full recovery of operation and maintenance (O&M) costs ensures good water service and scheme sustainability and reduces reliance on government for subsidies or rehabilitation. However, the service provider must be held accountable within a well-designed governance framework. Irrigation service charges have proven less effective for encouraging water use efficiency. Volumetric pricing can affect use patterns, but it is hard to administer. (See IN 1.4 on cost recovery for irrigation.)

STRATEGY IS KEY TO A GOOD INVESTMENT PROGRAM

Agricultural water strategy translates pro-poor economic growth policies and improved efficiency and governance into action. Best practice on strategy will bring all partners into a coherent framework for action. Strategy should show how macro and sector policies are aligned; integrate land, water, and environmental strategies; and define institutional relations and development paths. It should set the legal agenda and make the case for changes in the incentive framework. Strategy should be linked to an investment program, which can be a means of attracting donor and private investment. The World Bank frequently takes part in participatory water strategy processes and has devised a new instrument—the Country Water Resources Assistance Strategy (CWRAS)—to link national strategies and Bank programs. The CWRAS should set an agreed long-term strategic context, identify quality investments, and set out a policy and institutional agenda that will ensure sound investment outcomes. (See IN 1.1 on strategy and IP 1.1 on the CWRAS.)

INTEGRATION AND COORDINATION ARE VITAL

Water is a multisectoral and multi-institutional business, and integration of resource management and interinstitutional coordination are vital. For example, in China 12 separate departments are responsible for some aspects of water management at different levels. Coordination is vital within the Bank also, where interaction among the various sector departments, the

country departments, and the anchor departments of the Environmentally and Socially Sustainable Development Network requires constant attention. The new CWRAS is proving useful in this kind of coordination. (See IN 1.1. For CWRAS, see IP 1.1.)

SOME TYPICAL INVESTMENTS

Investments in technical assistance could include the following:

- Policy analysis
- Water resources assessment
- Capacity building
- Strategy formulation (including CWRAS)

Pilots may include the following:

- Weather-based insurance contracts
- Integration of smallholders into commercial supply chains
- Development of financing and risk management instruments

These pilots could be undertaken in collaboration with the International Finance Corporation (IFC).

Project investments may include trade facilitation, and research and development (R&D). And finally, policy-based investments may include major policy reform.

PREPARING A NATIONAL AGRICULTURAL WATER STRATEGY

An agricultural water strategy (AWS) is a set of programs that brings all partners into a coherent framework for action. It defines institutional relations and development paths, sets the legal agenda, mobilizes support for changes in the incentive framework, sets the investment program, attracts investment, and creates a public-private dynamic. Participation brings ownership and strengthens prospects for implementation. The strategy is a process, a product, and an action plan. Lessons learned point to a need to balance management improvements with investment in infrastructure, to work across sectors, and to sustain dialogue over the long term.

As a multisector input with pervasive externalities, water requires rules and organization—legal framework, planning and allocation systems, and economic instruments. The Dublin Principles treat water as a social, environmental, and economic resource within an integrated strategic approach built through participatory means. Water overall is thus an area for public policy and strategy.

Agriculture is the major water user and therefore a major component of water strategies at national and basin levels. An AWS is a set of medium- to long-term action programs to support the achievement of development goals of equitable and sustainable wealth creation and poverty reduction (see box 1.1 for an example of poverty reduction as a key determinant of irrigation strategy in Tanzania). AWS also serves as a roadmap to assist government, civil society, and donors in translating agricultural water policies into action.

INVESTMENT AREA

Agricultural water policies normally set sectoral objectives in terms of macroeconomic

contribution, income and employment generation, water use efficiency, and so on; define the role of the private sector (in investment and market development); define the public sector's role (in planning, investment, management, and research); set incentive frameworks, including cost-recovery practices; show how water use efficiency will improve,¹ and guide investment, including the public investment program.

An AWS usually covers the following elements:

- *National objectives and policies* for agricultural water
- *Resource assessment*—agricultural water use in the national water resources strategy, links to basin management, watershed management, rural-urban competition, groundwater overdraft, water quality
- *Information systems*—data quality and availability, monitoring and evaluation systems
- *Technical aspects*—improving water use efficiency and, where relevant, increasing supply
- *Economic aspects*—returns on capital, scope for efficiency gains and efficiency incentives, supply- and demand-management instruments (such as water permits, volumetric water charges, and water markets)
- *Human aspects*, including incomes and poverty aspects
- *Institutional and governance issues*—relation to governance systems for water resources management, mechanisms for conflict resolution and intersectoral allocation, water rights, public-private areas of responsibility, water user associations (WUAs), irrigation management transfer, local informal management groups and rules, and participation issues
- *Financial aspects*—investment framework, investment needs and financing, public and private investment, and subsidy and cost recovery

- *Investment and implementation issues* and key constraints to future sector development
- *Public health* considerations, including water-related diseases
- *Environmental aspects*—covering surface water (stream flow variability, environmental flow requirements, upstream and downstream issues, sedimentation, groundwater recharge, runoff, and water quality issues such as drainage discharge and irrigation-related salinity); groundwater (including depletion, land subsidence, saltwater intrusion, waterlogging, and groundwater quality); and watershed management and rainfed farming issues
- *Riparian and international* issues

A successful AWS process starts with an *assessment phase*, which reviews policy goals, prepares an inventory of information and experience on the elements discussed above, and then selects, analyzes, and ranks issues (box 1.2). It is typically followed by a *review phase*, in which stakeholder reaction and expert advice is brought to bear on the assessment results. The *strategy phase* develops and evaluates options and proposes a strategy, action plan, and investment program. Each phase could take six months, and getting all partners to adopt a strategy may take a year. An AWS should have a long-term vision (up to 25 years), a medium-term strategic framework (3 to 10 years), and a short-term action plan (2 to 5 years).

Good water strategy focuses on institutional issues (including the legal framework), agricultural and irrigation sector organization, and pricing and markets but does not neglect the need for infrastructural investment, particularly where water resources are undeveloped. A good AWS balances supply and demand issues, is founded on sound economics, and incorporates social and environmental aspects. It explicitly reconciles the country situation with the Dublin Principles in a “principled-but-pragmatic approach,” and adopts participatory approaches for both preparation and action, thus strengthening ownership.

Box 1.1 Tanzania’s National Water Policy and Irrigation Strategy

In Tanzania, water is vital to poverty reduction, food security, and growth. In the early 1990s, the country was approaching crisis in agricultural water use. The World Bank and the government agreed on the “TZ-River Basin Management and Small Holder Irrigation Improvements Project,” which linked investment in irrigation and basin management with participatory work on national water policy.

With project support, Tanzania developed a policy that treats water as a *social resource* (participatory basin management), an *environmental resource* (environmental flow requirements), and an *economic resource* (water permits, volumetric water charges, water markets). It separated development from regulatory functions. Project investments in irrigation increased water availability, mobilizing support for water resources management, and improving farmer incomes and cost recovery. Implementation and participatory development of an irrigation strategy are next.

Lessons from the project are summarized below:

- Linking irrigation investment to strategy development creates synergies.
- Project support to strategy development provides necessary time and resources but requires follow-up after the project.
- A sequence starting with water policy and followed by irrigation strategy is workable.
- An irrigation strategy can be prepared after an investment period provides lessons.

Source: De Jong 2003.

Box 1.2 The Strategic Planning Cycle

The strategic planning cycle can be seen as the answer to a series of questions:

- Where do we want to be? Setting development objectives and key water policies
- Where are we now? Assessment and analysis of issues
- How can we get where we want to be? Options and choices
- Which way is best? Strategy
- How will resources be allocated? Investment plan
- How do we ensure arrival at goals? Implementation and control
- How did we do? Monitoring and evaluation

Source: Adapted from LeMoigne et al. 1994.

Country situations indicate different paths to the best strategy and strongest ownership. In the Republic of Yemen, where there is a low level of governance, full participation was essential. In Brazil's stronger institutional environment, the Bank opted for sector work in partnership with government (box 1.3). In Tanzania, with uncertain prospects for dialogue, strategy work was anchored within an investment project. All three approaches produced viable, well-owned strategies.

BENEFITS

An AWS brings all partners—national and external—into a framework for action. It defines institutional relations and development paths, sets the legal agenda, mobilizes support for changes in the incentive framework, sets the investment program, attracts investment, and creates a public-

private dynamic. Participation brings ownership and support for implementation.

Bank involvement brings cross-country experience and networks, capacity building (including the World Bank Institute [WBI]), additional finance (including the Global Environment Facility [GEF] and IFC), partnerships, and macro- and microeconomic links. The focus of AWSs on the Bank's main missions—poverty alleviation, food security, governance, and public finance—leads directly into Country Assistance Strategies (CASs), Country Water Resource Assistance Strategies (CWRASSs), and Poverty Reduction Strategy Papers (PRSPs).

POLICY AND IMPLEMENTATION

ADAPTING THE SCOPE TO THE KEY CHALLENGES. Scope has to be decided in the country context. In Brazil and Tanzania, the focus was on irrigation. In the Republic of Yemen (box 1.4), the strategy covered groundwater management, rural-urban transfer, and water resources management and sector governance.

METHODS OF STAKEHOLDER INVOLVEMENT. Participatory approaches cannot be uniform. Strategy work starts by analyzing stakeholders and ways to involve them. There are risks: when political or populist voices or weak national institutions are given a forum, quality may be sacrificed to ownership. Table 1.1 shows a framework for stakeholder participation.

INTELLIGENT TIMING. Timing is also crucial. In the Republic of Yemen (box 1.4), the key step of raising diesel prices was made in a ratchet fashion when the economy was prospering. In Jordan, irrigation sector adjustment was helped by improvements in the regional political situation.

MULTIPLE MINISTRIES AND "SECTORS." The Dublin Principle—that the basin must be the unit of analysis and that land and water must be managed together—proves hard to put into practice. Interests stemming from separate institutions and strategies for water resources management, watershed protection, rangeland and forest management, and irrigation and

Box 1.3 Brazil's Regional Agricultural Water Strategy

To prepare the next phase of irrigation investments in Brazil's semi-arid region, government, the private sector, and the World Bank revisited the agricultural water strategy in the light of empirical observation and economic analysis. The Bank contributed a study measuring returns from irrigation in terms of poverty, equity, growth, and employment. The study showed the following:

- Irrigation took 10–15 years to reach full development.
- The secondary employment and wealth impacts were considerable.
- Success depended on private management and innovation.
- Irrigation-related jobs demanded less investment than did manufacturing jobs.
- Irrigation investment reduced poverty and migration.
- Land markets and administrative rules hindered private development.
- Research and technology transfers were inadequate to support new crops.

From this analysis, an irrigation strategy was developed aimed at poverty, efficiency, and growth. The process set priorities to optimize existing infrastructure, improve the institutional framework, and promote private irrigation. It also helped develop sequencing—intensification before expansion—and action plans.

Source: Simas 2003.

Table 1.1 Managing Participation

Level of participation	Role	Stakeholder profile	Typical forum
HIGH	Forming/agreeing to decisions	Decision makers/originators	Formal negotiations, mediation
to	Having an influence on decisions	Advisers	Workshops
LOW	Being heard before decision	Reviewers	Task forces
	Knowledge about decisions	Observers, listeners	Public hearing, seminars

Source: Adapted from LeMoigne et al. 1994.

agriculture may thwart application of the principle. Analysis of what is feasible for agricultural water must match broad water resources management imperatives. In Tanzania, working down from global and basin plans has succeeded (box 1.1). In Brazil, working up from regional irrigation strategies has worked

(box 1.3). Managing the risk requires astute identification of issues and good dialogue throughout the strategy process.

IMPLEMENTATION. Implementation has worked well where government is committed, an oversight body coordinates and ultimately validates, a

Box 1.4 The Republic of Yemen: Strategy for Water and Agriculture

In 1996, the Republic of Yemen requested World Bank help in developing a water strategy. Given limited national capacity and the crisis in the sector, it was agreed to *focus* on just three problems: groundwater mining by irrigators, lack of water for cities, and low potable supply coverage. Because agriculture uses 90 percent of the available water, irrigation was the central element of the strategy.

The intervention was *timely*. Government was creating a water resources authority. Economic conditions were right—diesel prices, the main motor of groundwater overdraft, were rising, and a fiscal crisis was forcing a rethinking of public assistance to irrigation. Donors were promoting the Dublin Principles.

A participatory sequence began with working groups, dialogue, and analysis. Then a Bank paper was debated with support from WBI. Preparation of a national strategy and an irrigation strategy culminated in a water law. Dialogue continued for five years. Projects supporting the strategy were implemented in groundwater and spate irrigation, urban and rural water supply and sanitation, and basin management.

The design of the *participatory approach* included officials, “wise men and women” from civil society and the religious establishment, technical working groups, and a multidonor group for the Republic of Yemen’s water. Gender issues were carefully examined: women were consulted through the field review of rural water supply and sanitation that was carried out within one of the supporting projects. Women’s representatives and women’s nongovernmental organizations also attended the main workshop at which strategy recommendations were discussed. The role of women features prominently in the strategy that emerged from the process.

Opposition to change moderated as open debate made the risks and costs clear and allowed a say in solutions. Weak governance and implementation capacity restricted options. The long-term commitments required stretched government and Bank stamina.

The lessons

- *Strengths*. Increased awareness through national debate, grounding in sociopolitical realities, dialogue supported by WBI, links to the CAS, prompt action by projects’ “locking” agreed strategies into projects.
- *Weaknesses*. Slow progress on local management, water rights, and regulation, and hence on groundwater overdraft.

Source: Ward and MacPhail 1997.

broad range of stakeholders participates, and an expert team (including nationals) offers inputs.

RISK OF WORDS, NOT DEEDS. Strategy is the point in policy making where nations allocate resources. A good AWS shapes institutional behavior and investment patterns. Throughout the process, care is needed to prioritize issues, keep solutions practical, ensure stakeholder ownership, produce a viable action plan and investment program, and, above all, avoid vagueness.

RISK OF EXCLUSION. Even with good “participation planning,” key stakeholders may be left out. In the Republic of Yemen (box 1.4), decisions on groundwater are made by 100,000 well owners. No groundwater management effort will work if the users’ points of view are not understood. It is a mistake to imagine that a public agency effectively voices their views. Special approaches may be needed. In the Republic of Yemen, as a follow-up to a policy study, a field pilot tested approaches to groundwater management.

RISK OF NEGLECTING SOCIAL AND ENVIRONMENTAL ISSUES. In an AWS, analysis of the role of women and the poor tends to be neglected. Environmental aspects are often discarded as too complex and troublesome. Inclusion of these key aspects requires special effort.

LESSONS LEARNED ON SUBSTANCE

BALANCE HARDWARE AND SOFTWARE. Infrastructure and management have to be balanced in an AWS. This balance differs for each country. The Bank’s Water Resources Sector Strategy notes that many countries lack hydraulic infrastructure and could invest in harnessing more available water, especially in Africa (World Bank 2004). This is a risky area, but an AWS should help countries choose and develop their hydraulic infrastructure, putting development impact first.

ESPOUSE PRINCIPLED PRAGMATISM. Ten years of experience with the Dublin Principles shows that it is hard to apply them to irrigation. Good prac-

tice points to the need for prioritized pragmatism that aims to achieve efficiency, equity, and sustainability but which recognizes political process, vested interests, and implementation prospects.

KEEP AWSs LINKED TO WATER RESOURCES MANAGEMENT STRATEGY. Because agriculture is the major water user, AWSs and water resources management strategies are interconnected and should be developed together. This applies particularly to arid countries such as the Republic of Yemen (box 1.4), where water demand from thirsty cities and industry is growing. Mechanisms for intersectoral transfer will gain importance and must be developed in a framework of Integrated Water Resources Management (IWRM). Watershed management should not be neglected.

DEMAND MANAGEMENT IS MORE THAN WATER CHARGES. Water charges have sometimes dominated AWSs. In Jordan in the mid-1990s, they nearly undermined overall strategy. Balancing this element with “positive” incentives, such as transferring ownership or management to users, should be considered.

LESSONS LEARNED ON PROCESS

AN APPROACH ACROSS SECTORS IS HARD TO PULL OFF. Both in the Bank and in countries, generating a multisectoral and integrated approach is hard. On the other hand, integrated teams do create synergies that help implementation.

PARTICIPATION DOES STRENGTHEN OWNERSHIP. Experience with the Bank’s 1993 water strategy shows that participation does strengthen ownership. In Brazil (box 1.3), the demand-driven study helped gain ownership of the AWS. In the Republic of Yemen (box 1.4), the participatory process and the WBI-supported dissemination program helped create broad support.

STAY IN FOR THE LONG HAUL. In natural resources management, decades can pass from problem identification to final resolution. AWS development and implementation require years of stamina and consistency within the country and the Bank. Governments think short term, and

even Bank commitments are short term. Teams change—a CAS covers only three years. The Comprehensive Development Framework and PRSP have not resolved this problem, although CWRAS should help. The challenge is developing context-specific, prioritized, sequenced, realistic, and patient approaches (World Bank 2002). Sustained dialogue is essential. Consensus, once reached, must be locked in by an action plan and investment program.

SEQUENCE PLANNING. The AWS process has to be adapted to country situations. An AWS can be prepared once a national water resource strategy is in place and after an investment period provides lessons (as in Tanzania, box 1.1). In other countries, an AWS is a precondition for government and donors to invest in irrigation.

RECOMMENDATIONS FOR PRACTITIONERS

- *General recommendations on process.* A decade of experience in AWSs suggests the need to adapt processes to circumstances; prepare a plan to get stakeholder participation; be issues oriented; prioritize; set practicable action plans and investment programs; start with success; adapt AWSs to broader economic programs (macro reforms, adjustment); and back champions.
- *Manage the integration process within the Bank, too.* In preparing an AWS, it is vital to keep the other water-using sectors involved, to ensure ownership by country department management, and to plan for an integrated and long-term approach within the Bank. This could include setting up and motivating an intersectoral team, persuading and updating management, and interacting with broader Bank processes such as CASs or PRSPs.
- *Plan for social and environmental analysis as a central part of the process.* Poverty, watershed management, and environmental implications should not just be add-ons.
- *Plan for dissemination.* A strategy is only a first step in a long process toward impact.

The Bank should design dissemination plans with performance measures, budget, and a role for WBI.

- *Managing subsidiarity and integration.* Subsidiarity must be reconciled with the need for an integrated approach. In an AWS, the watchwords are “think integrated” and “act pragmatically.”

INVESTMENT OPPORTUNITIES

The Bank requires that an AWS effect clarity on development goals, policy, and strategy; reconcile agricultural water use with overall water resources management (and the Dublin Principles); bring all partners into a long-term framework for action and investment; and be developed through an ownership-building process.

In that vein, investments may include facilitation and dissemination, technical assistance for specific studies, and implementation through projects.

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ENDNOTE

1. Agricultural water efficiency is defined as meaning “more crop per drop” and includes improved conveyance efficiency (less loss between source and field), improved in-field efficiency (more water reaches the plant roots), and economic efficiency (higher returns per unit of evapotranspiration).

This Note was written by Chris Ward and reviewed by Sarah Cline, Timothy Sulser, and Mark Rosegrant of the International Food Policy Research Institute (IFPRI).

INVESTMENT NOTE 1.2

DEVELOPMENT POLICY LENDING TO SUPPORT IRRIGATION AND DRAINAGE SECTOR REFORMS

Development Policy Lending (DPL) gives national governments an incentive to undertake the comprehensive multiagency policy and institutional reforms necessary to improve water resources and irrigation sector performance despite their high political and economic transaction costs. Reforms of this nature might not be effectively addressed by sector investment projects alone, especially when the sector agency itself needs reform. In some cases, when there are strong cross-conditions between policy and investment component disbursements, a Hybrid Policy and Investment Loan, or two independent loans (a DPL that is independent but highly coordinated to a Specific Investment Loan) can be used. Moreover, if many revised regulations are required to achieve the reform outcomes desired, a Programmatic Development Policy Lending instrument could be appropriate.

Water resources sector investment and management is undertaken in most developing countries by large, “top-down,” “supply-driven” bureaucracies, using “command and control” organizational systems. The irrigation and drainage (I&D) sector usually uses 60–80 percent of available water resources. Water is delivered by costly assets under a low (or no) service cost-recovery policy, which strains government fiscal capacity. The ensuing shortage of funding for O&M results in deferred maintenance and premature deterioration and rehabilitation. This situation is often exacerbated by low personnel remuneration and chronic overstaffing, political interference, rent-seeking focus on investment projects, and declining agency governance, accountability, and management efficacy. Addressing such problems requires a combination of reforms in the policy, legislative, and regulatory framework; in sector institutions and stakeholder participation; in agency structure and organization; and in economic instruments. Such comprehensive reforms are also often

needed to enable adoption of IWRM policies, strategies, and interventions. Macroeconomic policy and other reforms may also be required in other sectors for the reforms needed in the water sector to be fully effective (for instance, for I&D affected by agricultural policies). Whenever “champion” leadership and political will for policy reforms affecting one or more sectors is strong, the development policy lending instrument can be effective.

A WORLD BANK INSTRUMENT: DEVELOPMENT POLICY LENDING

DPL CHARACTERISTICS. Development Policy Lending is a World Bank lending instrument that focuses on policy and institutional reforms (World Bank 2004). It is regulated by Operational Policy/Bank Procedure (OP/BP) 8.60, which replaced Operational Directive (OD) 8.60 in August 2004 (World Bank 2004).¹ It provides “fast-disbursing” deposits in tranches to a special account in the national treasury as an incentive to undertake institutionally difficult policy reforms. The government commits itself to the agreed reform program through a Letter of Development Policy (LoDP), signed by a senior minister. The program design includes measurable indicators for monitoring progress during implementation and evaluating outcomes upon completion (for example, issuing of regulations and establishment of participatory institutions and new agencies). DPLs do not support sector investments or agency expenditures but may support either balance of payments or specific sector-related imports such as food or agricultural or irrigation equipment (see Jordan in “World Bank Projects Discussed” at the end of this Investment Note). Consequently, DPL tranche disbursement is always conditional on the government’s maintaining satisfactory macroeconomic policies and performance. “Satisfactory” macroeconomic performance is a judgment made by the International Monetary Fund (IMF) and/or a Bank Country Economist. Because of the complexity involved, no indicators are given in the Loan Agreement.

However, if a water law amendment or many revised regulations are required to achieve the

reform outcomes desired, a Programmatic Development Policy Lending instrument, focused on a sector instead of the macroeconomy, could be appropriate. A Programmatic Development Policy Lending is an adaptable, medium-term approach. It involves an integrated medium-term framework of reforms, with notional amounts and dates linked to a country's policy and budget cycle. Within this framework is a planned series of operations, phased to support the country in achieving its reform program, with monitorable indicators of progress and triggers for moving from one operation to the next.

REFORM PROGRAM CONTENT. An agreed reform program outlined in a LoDP is derived from prior Bank economic and sector analysis, prior sector project lending experience, and intensive dialogue with the government, donors, and non-governmental stakeholders. A reform program

could include reforms such as national sector policy revision; legislative and regulatory changes; governance improvements (including provisions for stakeholder and gender participation); institutional and organizational reform to address market failures; change in financial incentive regimes; improvement of monitoring and safeguard arrangements; and encouragement of private sector participation (box 1.5). Thus, preparation and execution of the reform program usually involves many other ministries and agencies in important sector roles.

LENDING INSTRUMENT ALTERNATIVES. The selective policy and institutional interventions included in Specific Investment Loans (SILs) are limited and not always effective because sector agencies cannot reform themselves and usually focus on infrastructure investment components to the neglect of "difficult" policy and institutional reforms. This often occurs when the loan

Box 1.5 Indonesia Water Resources Sector Adjustment Loan*

Approved in 1999, the Water Resources Sector Adjustment Loan (WATSAL) is a US\$300 million SECAL, for balance of payments support, disbursed in three tranches over a period of 3.5 years. The government was committed to four IWRM reforms as follows:

- *Policy, institutional, regulatory, and management information system frameworks.* Revision of legislation and organization to include a National Water Council with stakeholder members; a National Water Resources Policy (a water rights and water use licensing framework); representation of nongovernmental stakeholders on provincial and river basin water resources councils and establishment of such councils in eight provinces and their river basins; a national hydrology management framework; a national water quality monitoring network; and an integrated sector management decision-support framework.
- *Improved river basin management institutions.* Includes improved basin management regulations; formation of provincial basin management units in key basins in eight provinces; and establishment of river basin management corporations in four economically strategic basins.
- *Improved water quality management institutions.* Includes improved framework for water quality management and pollution control; tax incentives for corporate investment in wastewater treatment facilities; payment of effluent discharge fees by polluters; and undertaking of effluent monitoring and an effluent discharge fee program in six river basins.
- *Improved irrigation management institutions and arrangements.* Reforms include issue of a policy and national framework for the establishment of empowered self-financing WUAs and WUA federations (WUAFs) and their establishment in at least eight provinces; revision of the roles and responsibilities of provincial and district irrigation agencies to provide support services to WUAs and WUAFs; sustainable mechanisms for financing of irrigation O&M by government, WUAs, and WUAFs; and a "demand-based" WUA Irrigation Improvement Fund for financing of rehabilitation of networks under WUA/WUAF management control.

*The box is titled according to the old nomenclature (that is, Sector Adjustment Lending/Loans instead of Development Policy Lending), because the project was approved before August 2004.

Source: See Indonesia entries in "World Bank Projects Discussed" at the end of this Investment Note.

is the borrower's main concern, while the Bank requires governance and economic reforms to ensure that investments remain sustainable. A Hybrid Policy and Investment Loan (HPIL) could be used instead of a DPL if the reforms are not too comprehensive (for example, involving new regulatory concepts and paradigms). An HPIL supports sustainable sector investment programs and improvements in institutional capabilities that are closely linked to policy reforms (for example, major sector issues and policy related to investment productivity). An HPIL can be appropriate if the reforms are a precursor to an investment program to ensure their efficacy and sustainability; and/or if policy reform and the investment can unfold together, without allowing the investment infrastructure to take precedence over and compromise the reform process. HPIL policy reforms (such as decrees to raise water charges or reorganize an agency), if they must precede asset investments, should not take a long time. Strong cross-conditions between policy and investment component disbursements are needed for HPIL success. However, HPILs are generally "discouraged" by Operation Policies and Country Services, since their hybrid nature makes them too complex and may slow down the whole process. Hence, two independent but highly coordinated loans, namely, a DPL and a SIL, may be better suited in these cases.

The effectiveness of a DPL, contrary to the Bank's sector investment instruments, resides in the fact that it allows amendment of national sector laws and regulations during project implementation. This "power" does not have to be interpreted as a means of imposing reforms by the donor. On the contrary, the new OP insists on "country ownership" of the reform proposal and implementation process. This is why a DPL involves the highest levels of government, whose collective will can foster inter-sector coordination. The process of intergovernmental dialogue while preparing the reform program and reaching consensus on its content creates mutual understanding and strengthens intergovernmental "ownership" of

the outcomes. It also facilitates coordination of subsequent sector lending by all donors.

POTENTIAL BENEFITS AND IMPACTS

The outcomes of a DPL in the agricultural water sector are mainly of an institutional nature, residing in the formal and informal rules and practices affecting economic, developmental, and regulatory activities that govern, constrain, or change the behavior and actions of individuals and organizations. Its beneficiaries are the national or regional economies that benefit from improved sector performance; the sector agencies whose operational environment and incentives are more conducive to better management and quality assurance; and the various beneficiaries of sector investment and water services, as well as other stakeholders affected by more socially and environmentally sustainable sector management. In cases such as a WATSAL, where reforms introduce legislation and institutions for water use rights together with stakeholder participation and empowerment, social capital is created, benefiting society as a whole.

If some of the policy and institutional root causes of poor sector performance are not also addressed (for instance, poor governance of sector agencies), sustainable benefits may be unlikely. Policy reforms can adversely affect stakeholder groups nationwide: for example, elimination of agricultural subsidies and import protection, together with water price increases can reduce farmer income benefits as in the Jordan Agricultural Sector Adjustment Loan (ASAL) (see Jordan in "World Bank Projects Discussed" at the end of this Investment Note). Thus, reforms may have to include mitigation policies (for example, establishing a subsidized demand-based fund to assist WUAs to which management of unrehabilitated irrigation networks have been transferred) or alternative instruments to achieve the reform.² Where some reforms are implemented gradually (for instance, incremental water charge increases), a parallel project may be used to monitor reform

impacts and make corrections (see Jordan in “World Bank Projects Discussed”).

POLICY AND IMPLEMENTATION

LOAN PERIOD. The loan period is the maximum time needed to deliver all outcomes listed in the program design. For reforms that are primarily government administrative decisions (examples include formulation of a policy, agency reorganization, and increased water prices), a shorter period of one to two years may be adequate. For reforms requiring clearance of new regulations, an intergovernmental and/or parliamentary process, up to three to five years, is advisable.

LOAN AMOUNT. The loan amount depends on the amount of specific budget support needed. For balance of payments support, the loan amount may be determined by the funding needed to supplement other adjustment operations in the Bank’s CAS undertaken in collaboration with the IMF and a country donor aid group, and by the nature of the reforms in terms of implementation difficulty and political transaction costs. For import support, the loan amount and tranching would be related to the expected foreign exchange cost of the sector’s import package needs over the loan period. For multitranche DPLs, the individual tranche amounts are related to the above considerations; however, it is prudent to reduce the Bank’s risks by end-loading, making the last tranche amount the largest one.

ENVIRONMENTAL AND NATURAL RESOURCES ASPECTS. According to the new OP/BP 8.60, the Bank determines whether specific country policies supported by the operation are likely to significantly affect the country’s environment, forests, and other natural resources. For country policies with likely significant impacts, the Bank assesses in the Program Document the borrower’s systems for reducing adverse effects and enhancing positive effects, drawing on relevant country-level or sectoral environmental analysis (undertaken by the country, the Bank, and third parties). If there are significant gaps in the analysis or shortcomings in the borrower’s systems, the Bank describes in the Program Document

how such gaps or shortcomings would be addressed before or during program implementation, as appropriate.

Upstream analytic work on the environment and natural resources can be useful to support the preparation of development policy loans. Strategic Environmental Assessment (SEA), in particular, concentrates on policies and institutions within a specific sector. SEA considers the linkages between a given sector (agriculture, for example) and the environment and natural resources, reviews the policy and institutional framework for dealing with environmental issues within the sector, assesses institutional capacity, and may make recommendations for reforms of policies or institutions.

This assessment should be based on a credible national public consultation process involving all stakeholders. The WATSAL SEA is a “good Bank practice” example of this process and methodology (see Indonesia in “World Bank Projects Discussed”).

GOVERNMENT COMMITMENT AND SUSTAINABILITY. To ensure government commitment, it is good practice to ensure that some reform actions are undertaken prior to loan negotiations—for example, the promulgation of an irrigation management reform policy or the establishment of an interministerial coordination team. Reform sustainability risks are also mitigated if the reform program includes establishment of organizational units or other concrete results (such as water price increases) during the loan period (box 1.5).

IMPLEMENTATION ARRANGEMENTS. Policies and regulations should be prepared by a government-appointed multidisciplinary intergovernmental task force (see Indonesia in “World Bank Projects Discussed”).

As part of its country dialogue, the Bank advises borrowing countries to consult with and engage the participation of key stakeholders (including senior agency professionals, some representatives of nongovernmental organizations [NGOs], and civil society) in the country formulating the country’s development strategies.

The task force would be chaired by a “neutral” entity (such as the National Planning Board) reporting to a steering committee of heads of the ministries involved, who may refer to the inter-ministerial coordination body to resolve major policy issues. Such an arrangement improves the transparency of the reform process and protects the interests of weaker agencies.

LESSONS LEARNED

The principal lessons learned from SECALs, such as Indonesia’s WATSAL (box 1.5), that can be applied to new DPL instruments are as follows.

- Reforms cannot be imposed; those that are may create roadblocks. The Bank’s credibility is harmed when it supports unrealistic targets linked to the wrong instruments. The Bank has to be sensitive to the reform’s political economy, acceptability, and timing. When the conditions are right for a particular issue, reform can go quickly. If, by contrast, a reform is unacceptable (owing to, for instance, cost recovery, water rate increases, or volumetric pricing), other ways should be sought to achieve the reform objective. If this cannot be done, the DPL operation should not be pursued and the Bank should cease sector investment support until conditions are conducive to reform and investment support.
- Not everything can be done at once—it is better to have a sequence of more narrowly focused goals ranked according to the extent of borrower ownership. Sector operations should be as simple as possible, while consistent with achieving their goals. This problem occurs when both agricultural and I&D reforms are pursued simultaneously, and the linkages cause adverse impacts, as occurred with the ASAL in Jordan. Large reform agendas also take a long time, and a balance must be struck between the need for sector reform and the government’s desire for macroeconomic support.
- Revision of a law should be avoided, if possible, unless it can be scheduled through

the use of a Programmatic Development Policy Lending (PDPL). Details in a water law should be amended, instead of drafting an entirely new law addressing all issues and introducing new principles to enable IWRM. Presentation of a new law to parliament invites extensive debate, and its uncertain outcome may conflict with the government’s prior LoDP commitments. If government desires a new law instead of amending the existing one (as was the case with WATSAL in Indonesia), a PDPL framework should be sought for the introduction of those reforms. The regulations needed for the new law may be issued during a second PDPL.

- A PDPL instrument should be used if political conditions are likely to change and undermine basic assumptions underlying the reform program. If major government system changes are likely (such as the introduction of administrative and fiscal decentralization in Indonesia during the WATSAL), use of a PDPL approach reduces the Bank’s operational risks.
- Successful piloting of controversial aspects of a reform program prior to, or during the loan period creates confidence and generates political support. The chances of reform success are enhanced if untried concepts (such as irrigation management transfer and empowered federations of WUAs) are first piloted under a parallel project or a Learning and Innovation Loan.

RECOMMENDATIONS FOR PRACTITIONERS

These lessons have implications for practitioners—they illustrate the flow of policy from the task force to the agencies charged with putting policy into practice.

- *Implementation organization.* The government’s task force should have a small secretariat for organization, reporting to the steering committee and assisting line agencies in processing outcomes of reform. The task force should also manage the public

consultation process, prepare the SEA, and hire NGOs to conduct SEA consultations.

- *Reform outcome processing.* According to national law and public administration regulations, the responsible line agencies will implement the outcomes within their mandate (for example, issue of regulations and reorganization). In preparing their legal instruments, the line agencies would use the draft documents prepared by the task force and cleared by the steering and inter-ministerial committees and submit them to any formal interagency review process required by law.
- *Funding implementation.* For a major reform program, funding is needed for task force expenses (examples include in-country travel, lodging for working meetings, and conduct of public consultations). This budget may be derived from ongoing sector projects, donor contributions, or a parallel Technical Assistance Loan that complements adjustment operations by supporting specific tasks related to their preparation or implementation.
- *Consultants.* Since reform “ownership” is crucial, preparation of reform deliverables (such as draft laws and regulations) by expatriate consultants should be avoided because it does not build domestic policy analysis capacity. Expatriate resource persons should be used sparingly to advise on subjects for which little country experience exists (for example, a tradable water rights framework). Outcomes that are “owned,” that can be implemented, and that will achieve their purpose are preferable to “cutting edge” perfection in international theories or practice that will be shelved or disregarded.
- *Bank supervision.* A local expert Bank task team would be desirable, composed of staff and consultants fluent in the local language. This team would serve as resource persons and advisers on questions about the task force’s ideas and proposals. However, final decisions regarding Bank inputs rest with

the task force and government provided that they are consistent with the LoDP. The Bank’s task team (and the task force) should be vigilant against unilateral last-minute “changes” to accommodate specific agency views without steering committee approval, which could jeopardize tranche completion.

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ENDNOTES

1. The new OP/BP 8.60 uniformly applies to DPL as a single lending instrument: the Bank has discontinued the use of special names and acronyms for Sector Adjustment Loans/Credits (SECALs/SECACs), Rehabilitation Investment Loans (RILs), and Program-

matic Structural Adjustment Loans/Credits (PSALs/PSACs).

2. In a water-scarce economy such as Jordan's, the linkage of adjustments in agricultural policy to adjustments in water sector policy is an essential one. This linkage has, however, not only positive aspects (for example, market liberalization permitting and encouraging water conservation measures) but also less positive ones (for example, where market outlets fail to develop, it may be difficult to pursue demand management for water conservation through increases in water charges). Where demand management through water tariff increases is problematic, alternative measures that contribute to the same objective can be used, such as handing over management responsibilities and costs to farmers (see Jordan in "World Bank Projects Discussed").

This Note was prepared by Theodore Herman with inputs from Richard Reiding and reviewed by Sarah Cline, Timothy Sulser and Mark Rosegrant of IFPRI; and by Hagie Scherchand of Development Alternatives, Inc. Following the World Bank new OP/BP 8.60 (Development Policy Lending) the Note has been modified with inputs from Erick C. M. Fernandes, Jan Bojo, and Nalin Kishor.

INVESTMENT NOTE 1.3

AGRICULTURAL TRADE, WATER, AND FOOD SECURITY

In coming decades, water-scarce countries will need to increase the value added of produce grown with irrigation water and achieve food security through exports. This switch implies replacing irrigated cereals production with irrigated horticultural products. But client countries see the multilateral and bilateral trade agendas in agriculture as self-serving. They point to the lack of market access for agricultural commodities in high-income countries and the agricultural subsidies in developed countries that depress world market prices and provide a powerful rationale for maintaining support for protected water-intensive activities. (Such activities include irrigated cereals production, livestock, sugar, and dairy.) Investment openings that may exist despite these conditions are discussed in this Investment Note.

Within two decades, one-third of the world population will live in countries afflicted by water scarcity. In some areas, part of the increased demand may be met through investments in irrigation and water supply systems and in nontraditional sources of supply. In other areas such as the arid Middle East and North Africa region, the economic and environmental costs of developing water resources constrain expansion of supply. There, development of water supplies will not meet growing demands. There will be a push for investments in water policy and water man-

agement reforms that increase the water use efficiency of existing systems. However, even with substantial increases in the efficiency and productivity of water use, many countries will not have enough water to satisfy minimum water requirements for domestic uses and at the same time meet industrial, environmental, and agricultural demands for water. Since agriculture consumes by far the largest percentage of water, most countries will take water from agriculture, allocate it to other sectors, and rely on increased food imports to meet their domestic needs.

Hence, agricultural trade is linked to food security and to water management. Declining water availability in some regions may be offset by openness of agricultural markets. Indeed, global trade liberalization by developed and developing countries would encourage water-scarce countries to expand imports of agricultural water-intensive products (such as cereals), consequently ensuring them food security, and to pay for these imports with exports of less water-intensive, higher value-added cultivations (such as horticultural products). By the same token, water-rich regions could grow water-intensive products (such as rice and cereals) and sell them to water-scarce countries. This would lead to an increased economic efficiency in the agricultural sector worldwide. This is often referred to as “trade in virtual water” (box 1.6).

The benefits of agricultural trade liberalization in developing and developed countries have been widely documented in the literature. More open trade in agriculture smoothes out the bumps in the market, rather than aggravating them, as many believe. More open trade allows food to move from places where it is in surplus to deficit areas and enhances the capacity of deficit regions to feed themselves. In an analysis of the impacts of a “pro-poor agreement”¹ in trade implemented progressively through 2010, the World Bank’s *Global Economic Prospects 2004* report indicates that by 2015 likely gains will be on the order of US\$350 billion for developing countries and US\$170 billion for rich countries (World Bank 2004).

Box 1.6 The Virtual Water Concept

Virtual water is the amount of water that is embedded in food or other products needed for its production. Trade in virtual water allows water-scarce countries to import high water-consuming products while exporting low water-consuming products and in this way making water available for other purposes.

Source: World Water Council. See http://www.worldwatercouncil.org/virtual_water.shtml.

INVESTMENT AREA

The linkages between agricultural trade, water, and food security have important implications for agricultural development and water resources management strategies. The issues are broad and complex and do not readily translate into investments. As water becomes increasingly scarce, ever more investment resources are allocated to augmenting supply. These investments (for instance in groundwater mining, desalinization, irrigation scheme expansion, and transport of water through long pipelines) are less productive than others, both at the national and at the household level; they also have negative environmental implications. Trade will reduce this rising tide of allocative inefficiency by switching incentives to less water-intensive crops in water-short countries and by directing increasingly costly investments to more cost-effective uses within the same sector. This reduction presupposes an environment that enables rising public and private investment to switch from older water-intensive technologies to new knowledge-intensive ones. Such a switch will be helped by building new R&D in skill-intensive responses in research and extension capacities, farming skills, infrastructure to develop alternative crops, water management techniques, marketing and supply enhancement, and agroprocessing. It entails shifting to a market-based agriculture that is more water- and resource-efficient and that can therefore grow and absorb labor.

Investment will ideally focus on enhancing agricultural productivity, improving water resources management, and facilitating trade. Because the range of investments in each area is enormous, the recommendations for investments in this Investment Note are selective rather than exhaustive or definitive.

AGRICULTURAL PRODUCTIVITY. Meeting national and global food security needs will require significant increases in water productivity. Key areas of investment will include the following:

- Agricultural R&D (crop breeding for drought and salinity resistance)

- Rainfed agriculture
- Crop diversification and creation of an enabling environment for high-value agriculture
- Agricultural risk management—for example rainfall-based contracts for cereals farmers currently being piloted by IFC in Morocco (box 1.7)

WATER RESOURCES MANAGEMENT. Enhancing water conservation in agriculture is already imperative in many countries to meet demands from increasing urbanization and other sectors. Water resources development will continue to be important in some regions (such as Africa) but in other regions, increasing water use efficiency at the field and basin levels will be critical to moving water to high-value uses. Key recommendations follow:

- Modernizing irrigation systems
- Inducing investment through public-private sharing (for example the Andhra Pradesh micro-irrigation project in India, which involves Netafim and the government in a

Box 1.7 Innovative Risk-Management Instruments: A Rainfall-Based Contract for Cereals Farmers in Morocco

With the advent of an international market for managing weather-related risk, the use of insurance products based on a weather index is becoming a reality. In Alberta and Ontario, Canada, insurance programs based on weather and vegetative indexes have become mainstream insurance products for farmers. In emerging markets, such as Mexico and South Africa, risk insurance contracts based on the weather are also beginning to be used. Following a feasibility study and technical assistance by the World Bank, a weather insurance project with the Moroccan insurance company MAMDA, sponsored by IFC, has developed weather insurance for cereals and sunflower production in Morocco that will be sold to farmers for the 2003–4 season. Likewise, a pilot project has been launched in collaboration with public and private partners in India, where small-scale farmers have purchased insurance contracts based on rainfall indexes.

Source: Skees, Varangis, and Siegel 2002.

public-private partnership to supply micro-irrigation equipment to at least 185,000 farmers working around 250,000 hectares)

- Institutional and policy reforms (such as successful regulatory reforms instituted by Jordan to curb groundwater overexploitation)
- Promoting IWRM

TRADE FACILITATION. Trade facilitation will be important for countries that need to increase their competitiveness, as well as for water-scarce regions that need to ensure food security. This “behind-the-border agenda” includes anything from institutional and regulatory reform to improving customs and port efficiency. It is intricate and costly to implement. The World Bank attaches great importance to trade facilitation—as reflected by its portfolio of 80 active projects totaling US\$4.6 billion. Box 1.8 offers a sample of Bank-financed projects for trade development in agriculture.

POTENTIAL BENEFITS

Improved water management practices and trade in “virtual water” can help alleviate water scarcity, release water for other uses, increase productivity, and ultimately reduce food prices for consumers. Investments in these areas can

therefore drive growth and poverty reduction, both directly and indirectly—because they may reduce food costs and supply uncertainties, improve the diets of the rural and urban poor, raise and diversify incomes, provide employment and entrepreneurial opportunities both inside and outside cities, and induce small-holder farmers’ productivity gains, which would increase their opportunities for wealth creation and better integrate them into local, national, and international markets.

POLICY AND IMPLEMENTATION

AGRICULTURAL PRODUCTIVITY. Some of the core areas to be addressed for increased water productivity are integrated farm resources management and agricultural research and extension.

Research on cereals and legumes shows that significant and sustainable improvements in water productivity are attainable only through integrated farm resources management. Water use-efficient on-farm techniques coupled with improved irrigation management options—such as supplemental irrigation, deficit irrigation, and water harvesting; better crop selection and appropriate cultural practices; improved genetic make-up; and timely socioeconomic interventions—can help achieve this objective.

Scientific research has allowed global food supplies to outpace increases in demand. Evidence from China and India shows that public expenditures on agricultural research and extension have the largest impact of all possible rural investments on growth in agricultural productivity and generate large benefits for the rural poor. However, investment in research usually pays dividends only years, if not decades, after the decision. Some important research areas include crop breeding to improve adaptation to moisture and temperature stress, and promotion of effective risk management. A necessary complement to scientific research for increased food production is the development of a market for the additional products and/or quantities, to ensure that increased productivity is translated into increased income for farmers. Hence, agricultural trade is fundamental in ensuring the

Box 1.8 Trade-Related Lending

The two largest categories of World Bank trade-related lending in 2002 were loans for (1) export development (such as the Foreign Investment and Export Facilitation Project in Armenia) and competitiveness, and (2) trade financing. In Mauritania, the Bank will provide support through livestock and agricultural competitiveness projects (that address standards issues) as well as port modernization and airfreight projects to expedite trade. In addition, the Bank is leading the Standards and Trade Development Facility, an interagency partnership with the World Trade Organization, Food and Agriculture Organization, and World Health Organization, which will deliver technical assistance for food safety and related standards.

Source: Tang 2003.

dividends of research. Moreover, enhanced investment in education, training, and rural infrastructure to improve the adaptive ability of farmers and the rural economy generally is of paramount importance in complementing agricultural research and extension.

WATER RESOURCES MANAGEMENT. In most regions, only new conservation efforts, and new policies promoting it, can send the signal that water is scarce. The appropriate combination of investments in hardware and in policy reforms varies. Water policy reforms should balance improved management at the river-basin level with decentralization to the private sector or community-based user groups at the subbasin level. The policies needed to improve water management include making resource allocation in agriculture more flexible by removing subsidies and taxes that distort incentives and encourage misuse of resources, as well as by establishing secure property rights in land and water. (See IN 1.5 for a detailed discussion of economic incentives in agricultural water use.)

TRADE FACILITATION. The greatest benefits from agricultural trade will come from a tandem of reduced policy distortions in domestic markets coupled with increased access to the developed countries' market, especially in the European Union, United States, and Japan. This will also necessitate reforms in marketing and market organization. Box 1.9 presents an example of how Mali has successfully exported mangoes to Europe, displacing traditional exporters such as India, Israel, and Brazil.

Trade facilitation may, on the other hand, pose new challenges. Meeting these challenges will involve, among other things, creating a framework that encourages the private sector to offer risk management tools such as microfinance and insurance. Modernization of agriculture may well require joint and collaborative efforts with IFC, specifically with regard to industry and sector competitiveness assessments; design and support of schemes that allow the integration of smallholder farmers into commercial supply chains; and the development of market-based financing and risk management instru-

ments in selected countries. The IFC-supported Morocco Rainfall Insurance project is a good example of collaboration between IFC and the International Bank for Reconstruction and Development (IBRD).

Trade liberalization is likely to have impacts on the environment and poverty intermediated through its effects on water demand. A World Wildlife Fund–World Bank program (World Wildlife Fund 2004) would contribute to the international development community's understanding of the economic, social, and environmental impacts of trade liberalization. Its case studies analyses will provide the basis to identify, with governments, policy and institutional reforms that strengthen trade's contribution to poverty alleviation and environmental sustainability. For instance, the Vietnam case study examines the expansion of shrimp aquaculture in Truong Son Mountains and its impacts on social communities as well as land, forest, and water resources. In South Africa, global trade liberalization will present an opportunity to expand

Box 1.9 Linking Farmers to Markets: Exporting Malian Mangoes to Europe

In Mali, a pilot project to export fresh mangoes to Europe put in place an efficient supply chain managed by a not-for-profit marketing agency and private business investors through the Agricultural Trading and Processing Promotion Pilot project (PAVCOPA—*Projet d'Appui à la Valorisation et Commercialisation des Produits Agricoles*—Cr. 2737 [US\$6 million]). Upstream, the pilot helped producers improve their production and their knowledge of the marketing channels. Downstream, it established a partnership with an export company and improved export logistics. One innovation was setting up a multimodal shipping system directly linking the Malian production center to the North European customer market; and coordinating efficiently the entire supply chain. The returns to the producers make this successful pilot a good example of how to connect farmers to ready markets, promote private investment in rural areas, and further promote multiple and cross-border partnerships, while supporting diversification and improving export logistics. Moreover, the pilot demonstrates that investments can be profitable, and that constraints to marketing and export of agricultural products can be overcome with creative, adaptive, and professional approaches.

Source: Danielou, Labaste, and Voisard 2003.

the (water-intensive) sugar industry, with possible negative impacts for water resources and for the poor, who do not have access to water services. Hence, investments in trade facilitation should attentively consider impacts on both the rural poor and the environment.

LESSONS LEARNED

The social and political implications of food security and trade cannot be overstressed. Visible and effective opposition to global trade and investment liberalization from civil society has mushroomed from Seattle (1999) to Prague (2000) and Genoa (2001). Perceptions of national interest in food self-sufficiency too often lead governments to hoard food stocks, artificially encourage production, and limit imports. Even where the international market offers an alternative source of food, the idea of dependence on external sources is anathema to many politicians and their constituents in the North and South. Food self-reliance and independence from foreign interference, even at demonstrably higher costs to the nations involved, are popular forms of nationalism (Runge et al. 2003). However, these attitudes are gradually giving way to the more enlightened view that food insecurity is a problem caused mainly by poverty and the consequent inability of the poor to buy food, not by insufficient national production. It follows that insecurity is increased by tariff and nontariff barriers to food imports and therefore cannot be resolved without an effective poverty reduction strategy.

The distributional consequences of global agricultural trade liberalization are complex and country specific. For example, if liberalization allows previously suppressed prices of agricultural goods to rise to world levels, it will benefit farmers who are net producers but will hurt consumers. If farmers are more likely to be poor, the liberalization will be, on average, pro-poor, but important distributional distortions may remain or be exacerbated. Agricultural trade liberalization will entail significant transition costs, and timing and sequence of reforms will be critical. In sum, managing the transition politically, economically, and socially is the main challenge.

RECOMMENDATIONS FOR PRACTITIONERS AND INVESTMENT OPPORTUNITIES

Recommendations on agricultural productivity

- Invest in agricultural competitiveness, diversification and technology, planning, and feasibility studies; support agricultural and agricultural water strategies such as China's Agricultural Technology Project and Mali's Agricultural Competitiveness and Diversification Project.
- Invest in improving market organization.
- Invest in agricultural reform through DPL and Sector-Wide Approaches.
- Invest in research for value-added, efficient agriculture (that is, SIL). Crop-breeding research on varieties that are drought and salinity resistant could have significant impacts on rainfed agricultural production.
- Invest in increasing rainfed production (which comprises 80 percent of agriculture worldwide) to compensate for lower irrigation investments through crop-breeding research (see above); encourage technologies that are inexpensive, gender sensitive, and pro-poor. These technologies, which include supplementary irrigation, small-scale micro-irrigation, household and in-field rainwater harvesting, can be coupled with management strategies to enhance soil infiltration and water-holding capacity. (SILs are recommended.)
- Invest in vertical integration of agriculture into processing and local industry. Because this can succeed only if adequate infrastructure (roads, energy, water, communication) is available, investment in rural infrastructure is key. (SILs are recommended.)
- Pilot weather-based insurance contracts in selected countries. (Learning and Innovation Loans [LILs] are recommended.)
- Improve collaboration with IFC on industry/subsector competitiveness assessments; design and support schemes that allow the

integration of smallholder farmers into commercial supply chains; support the development of market-based financing and risk management instruments in selected countries.

Recommendations on water resources management

- Prefer Adaptable Program Loans (APLs) over complex project loans in the irrigated agriculture sector. Plan Programmatic Lending to have a first phase on feasibility analysis; a second phase on construction, construction supervision, and start-up; and a third phase on agricultural development and technical assistance including agricultural credit programs. This will avoid the tendency of borrowers to emphasize the construction of infrastructure and to divert funding from later phases such as technical assistance and agricultural development to meet overruns in the cost of infrastructure.
- Promote a policy environment for adopting water conservation through pricing, modern technologies, and improvement of water quality (for example, DPL, APLs, Sector-Wide Approaches).
- Improve irrigation system efficiencies through selective rehabilitation (using SILs). This will increasingly be driven by the need to tamp down rehabilitation costs and develop asset management strategies to enhance the life of existing hydraulic infrastructure.
- Draw on Bank and non-Bank experiences on water trading and water rights (for instance, LILs, Chile, and Indonesia).

Finally, on *trade facilitation*, investments using, among others, tools, technical assistance, and other types of loans are recommended.

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ENDNOTE

1. Rich countries cut tariff peaks to 10 percent in agriculture and 5 percent in manufacturing, reciprocated by developing countries' cuts to 15 and 10 percent.

This Note was prepared by Shobha Shetty with inputs by John Nash, and reviewed by Sarah Cline, Timothy Sulser, and Mark Rosegrant of IFPRI.

INVESTMENT NOTE 1.4

PRICING, CHARGING, AND RECOVERING FOR IRRIGATION SERVICES

Many irrigation systems are deteriorating because of poor management and inadequate funding for operation, maintenance, and replacement of facilities. Consequent poor performance leads to low water productivity—waste, low crop yields, and misallocation—a common experience in World Bank–funded projects. Properly designed irrigation service charges directly address the funding issue and can contribute to demand management, but limiting demand to the available supply is commonly addressed through the careful specification of water rights. Stakeholders (users, operating agencies, planners, and politicians) have differing interests that must be considered in designing a successful charging system. Political commitment is of primary importance.

Irrigation development, combined with the green revolution and increased fertilizer use, has driven agricultural production and productivity for the past 50 years. Continued increases in production (with more than 80 percent of irrigation potential already developed) depend primarily on improving the operations of existing facilities to make more productive use of water resources that already have been developed.

Yet, as noted, many irrigation projects are in decline. Increasing funding for irrigation services is, however, extremely contentious. Governments are often unwilling to increase charges—for fear of political repercussions—or to supplement current charges to meet the full cost of service to a favored group. Farmers are unwilling to pay for poor service and often believe that irrigation bureaucracies are overpaid and inefficient. Bank-funded projects in the sector have frequently failed to reach financial self-sufficiency goals, and scarce irrigation water is often wasted (Bosworth et al. 2002).

INVESTMENT AREA

Performance in the irrigation sector can be improved through specific investments in rehabilitation and modernization of existing projects; institutional investments to improve organization, funding, and management of the sector; or sector loans addressing all these components. Such investments should always assess the potential role of irrigation service charges (ISCs) to contribute to project objectives.

Water resources managers face twin crises of sustainability:

- Scarcity of the water resource itself (manifested by falling water tables, ecological damage to estuaries and wetlands, and severe competition among users)
- Limited funds to manage, maintain, and develop the facilities required to utilize water (manifested by poor maintenance and operational performance and the repeated need for “rehabilitation”)

Appropriate ISCs have the potential to address both issues simultaneously: higher charges should *restrict demand*, especially in low-value uses, and *generate revenues* to fund the cost of providing irrigation services.

Where water is scarce, ISCs cannot be separated from the procedures for allocating water—water rights defined based on “seniority” or as a proportion of available supply; rationing and quotas; or tradable water rights. The various parameters (cost, charge, and price) need careful specification. The *cost* includes operation, maintenance, and replacement of facilities, plus capital costs in the form of amortization charges and the cost of collecting ISCs. The *charge* includes all fees payable by the irrigator. These may be based on crops irrigated or volume of water received—or they may be fixed charges. The *price* is the marginal price of water—how much extra the irrigator pays per additional unit of water received. Often, with crop-based or quota systems, the marginal price is zero (even though the charge may be high), and, after the farmer decides to

irrigate, there will be no marginal incentive to save water.

In formulating appropriate ISCs, the charging mechanism (the type of ISC proposed) must be matched to the objectives sought. Irrigators, operating agencies, and resource planners have legitimate but different objectives: irrigators want a reliable, affordable service; irrigation agencies want a stable source of income and ease of administration; and resource planners want to limit demand to the available supply and ensure that the resource is allocated to its most productive uses. Table 1.2 summarizes the most common means of charging for and allocating water and the potential of each to contribute to the most common objectives. The farmers' interests will generally be best served

by a system that is easily administered and encourages high productivity.

No single universal water-pricing mechanism is best for all systems. The pricing method selected will depend on specific government policies and institutions, local conditions, irrigation type, irrigation infrastructure, and project objectives. If O&M cost recovery is the overriding objective, a wide range of pricing methods is available, ranging from a charge per hectare cultivated to a charge per unit of water delivered to the field. However, the range narrows significantly when water is scarce and reducing water use per hectare is an important objective. Here the charge has to be related to something that encourages reduced water use such as a charge per cubic meter of water

Table 1.2 Common Water Charges and Allocation Methods

Type	Detail	Productivity impact	Demand impact	Stability of agency revenues	Ease of administration
Area based	A fixed rate per hectare of farm	None	None	Excellent	Excellent
	A tradable fixed charge per hectare irrigated	None	Small	Fair	Fair
Crop based	A variable rate per irrigated hectare of crop—in other words, different charges for different crops	Small	Small	Fair	Fair
Volumetric	A fixed rate per unit water received	Positive	Positive	Poor	Poor
	An increasing rate per unit of water received—also known as rising block tariff	Positive	Positive	Poor	Poor
Quotas or rationing	Entitlement to water defined in volume terms	Positive	Ensured	Not relevant	Variable
Tradable water rights	Entitlement to water tradable to other users seasonally or in perpetuity	High	Ensured	Not relevant	Poor
Two part	Fixed charge to balance budget, volumetric for demand management	High	Positive	Excellent	Fair

Source: Author.

delivered. The Armenia Irrigation Rehabilitation Project (box 1.10) provides a good example of how water measuring posts and meters improved water monitoring and charging, as well as users satisfaction. The assessment report by the World Bank's Operations Evaluation Department (OED) also provides more general lessons of outstanding importance in the design and appraisal of irrigation projects.

As second-best solutions, if implementation costs for volumetric water devices turn out to be too high, a proxy for water volume can be used as a basis for pricing. Or, a crop- and area-based pricing with a higher price for water-intensive cultivations can be considered.¹ For example, in the [Arab Republic of] Egypt Irrigation Improvement project, water user groups

were encouraged to base cost recovery on a proxy for water volume (for example pumping time) rather than on a per *feddan*² basis, since this would provide incentives to improve water use efficiency (Seckler 1996).

Nevertheless, analysis of the likely impact of proposed charges on demand for water—even volumetric charges, set at high enough rates to recover operation, maintenance, and replacement costs, will often not be high enough to bring demand and supply into balance. In such cases, additional quota constraints will be needed to achieve balance, and the analyst must then evaluate the potential additional benefits against the substantial extra administration and infrastructure costs of complex charging mechanisms (box 1.11).

Box 1.10 Volumetric Water Measuring Devices in the Armenia Irrigation Rehabilitation Project

The Armenia Irrigation Rehabilitation Project, approved in 1994, focused primarily on helping to maintain irrigated agricultural production at pre-independence (from the former Soviet Union) and pre-macroeconomic crisis (1991–4) levels.

The ability to monitor and bill water sales was improved after 1999 when project savings were used to purchase and install 2,145 water measuring posts and 1,545 water meters in open sections of canals and pipelines. Simultaneously, hydrometric communication system and water management were improved using specially designed software and computer equipment supplied under the World Bank's Structural Adjustment Technical Assistance II project. The project also introduced two-tariff electricity meters so that differential day and night tariffs could be introduced. In the four irrigation schemes inspected by the World Bank's OED assessment mission, water measuring devices were found to be in excellent working order, and all water users expressed their satisfaction with the metering and billing procedures that were now seen as objective and fair, with measurements at the point of sale to water user groups being jointly carried out and agreed by the water user group and agency in charge of O&M.

The OED project review in May 2004 highlighted the following main lessons:

- Rehabilitation is only a partial solution for most irrigation projects because it is generally a symptom of inadequate management and insufficient maintenance funding. This project clearly demonstrates that rehabilitation should be supplemented by measures to foster creation of efficient institutions with the ability to measure and manage water and accurately cost O&M.
- Some simple and effective investments can greatly improve irrigation project efficiency such as the installation of many water and electricity flow measuring devices; consultation with stakeholders about operating rules is also highly effective.
- Adequate attention must be given during appraisal to linking investments in agricultural technology with measures to improve output production and marketing. The absence of such complementary investment may jeopardize the project beneficiaries' chances of covering O&M costs, thus undermining sustainability.
- Social assessment and interventions are needed, especially in very poor rural areas. Such assessment will help to ensure that infrastructure investments give adequate attention to beneficiary ownership and their ability to contribute toward the new facilities' maintenance. In the project, such an approach could have created smallholders' cooperatives or micro-credit groups that could have moved landowners beyond subsistence agriculture.

Source: Project Performance Assessment Report, Armenia Irrigation Rehabilitation Project 2004; Burt 2002.

Often a combination of interventions is required to limit demand, encourage productive use, and recover costs. The most sophisticated intervention is tradable water rights (box 1.12). (See also IN 2.2.)

Both demand-management and cost-recovery objectives require that the nature of the service be specified: *who* is entitled to *how much* water, with what degree of *priority*, in conditions of normal, below-, and above-average water availability.

Box 1.11 Irrigation Charges in Morocco

Morocco has a clear policy for irrigation service charges in all major schemes, requiring full recovery of operation, maintenance, and replacement costs, plus a large part of capital costs. Charges, levied volumetrically—at US\$0.022/m³ or more (equal to \$100 to \$200/ha)—are high by international standards for surface irrigation. Even at this price, demand for water would exceed supply, because returns on water are about 10 times the volumetric price. Demand management is therefore achieved through quotas specified and measured at farm level. Cost recovery is high, and most systems cover at least O&M costs.

Source: Cornish and Perry 2003.

Box 1.12 Australia: Tradable Water Rights in the Murray Darling Basin

In the Murray Darling Basin, water use is constrained to equal the sustainable supply through a complex system of water rights, defined in terms of volumes and security of supply. Formally codifying these property rights—in systems that were already well managed and orderly—took decades. Once this process was complete, a system of trading was introduced, allowing managers the flexibility to better manage their enterprises (in some areas 80 percent of water delivered was traded). The water rights system also provides the basis for improved environmental management because water can be “purchased” by the state and assigned to environmentally desirable uses. The parallel system of charging for water services in the basin is separate from the sale and purchase of water rights and exists to ensure that the income of water supply agencies covers ongoing maintenance and projected major capital replacements.

Source: Don Blackmore, personal communication.

As for the objective of cost recovery, the most important issue to consider is that farmers’ willingness to pay depends on good and reliable service, as well as system transparency. Good and reliable service can be ensured by financial autonomy. Without autonomy, collecting sufficient funds from users does not guarantee improved O&M services because most of the revenues from water charges do not go back to the project itself but are commingled in the central treasury with revenue from other taxes. A prime example of this practice is India, where water charges and the quality of services are not directly related in many projects. Improved services will give farmers an incentive to pay their fees and increase their ability to pay because better services means higher farm incomes. Financial autonomy can be an important key to improved irrigation water management by providing a positive feedback system through a clear financial link between farmers and water suppliers.

System transparency means farmers can see how much water they receive, how their payments are used, and how water charges are determined. The integrated circuit machines case in Shandong, China (box 1.13), illustrates good system transparency in terms of water delivery and payments. Farmers interviewed said that they were satisfied because they receive a precise, electronically printed statement each time they use the card.

The case in Sindh, Pakistan, is a counter-example. Farmers there are not willing to pay because the financial system is not transparent, and owing to the corruption of irrigation officials, the farmers do not think that the charges paid are used in their system.

Moreover, for successful cost recovery, good practice requires clear objectives and political commitment:

- What costs are to be recovered from which beneficiaries? Domestic supplies drawn from irrigation system facilities may pay different rates; commercial farmers or orchard owners may get preferential services at higher rates.

- Who will recover ISCs?
- Who will administer ISC revenues?
- For what purposes can ISC revenues be used?
- What actions will be taken in case of default in provision of service or payment for service?

In case of default, some suppliers strictly enforce penalties. In Bayi Irrigation District, China, defaulters receive no more irrigation water until they pay their debts. In Shandong, China (box 1.13), the problem of defaults does not arise because users must pay as they go to obtain irrigation water.

POTENTIAL BENEFITS

Well-designed ISCs will accomplish the following:

- Ensure the sustainability of irrigation facilities through proper maintenance
- Reduce the pressure on governments for subsidies and repeated “rehabilitation” of infrastructure
- Provide incentives for improved management and increased productivity of water
- Transparently link the *payment for service* and its *cost*
- Encourage financial efficiency in operating agencies because operation costs will be transparent and comparable over time and between systems
- Discourage wasteful use of water

POLICY AND IMPLEMENTATION

For an effective cost recovery/pricing scheme, a combination of approaches could be recommended. As seen from many pricing reforms in the irrigation sector, farmers should have more authority and responsibility over water management, usually through WUAs. In a transparent consultation process, farmers should help to decide which costs should be recovered through

the water charges they will pay. Farmers should not only agree on the fees but also realize that the fees collected remain within the system for maintenance and improvements. Parallel to farmer empowerment, water suppliers should also be given incentives such as the possibility of becoming financially autonomous. This incentive works to encourage water providers to improve infrastructure, service, and collection rates. Implementation is relatively straightforward when a fee structure is simple to administer and easy for users to understand because it reflects local conditions and needs.

Box 1.13 An Automated Irrigation Charge Collection System in Shandong, China

Shandong is one of the biggest agricultural provinces in north China. Irrigation water accounts for 70–80 percent of the total water use, but water is scarce. Consequently, to improve water use an automated system was adopted, where irrigators buy prepaid integrated circuit cards. The card must be inserted into an automated server before water is released, and the flow stops when the card is removed. After each irrigation, the farmer receives a receipt, stating the amount of water used, the price paid per unit of water, and the total deducted from the card. All servers are connected via the Internet, so they are easy to control and monitor, and administrative costs are low. Each irrigation costs 1,000 yuan (US\$120), which is equal in value to the water saved annually under this new system. With more than 200,000 integrated circuit card servers across the province, Shandong saves about 5 billion m³ of water annually.

Highlights:

- This method enables a 100 percent collection rate. If the pricing structure is designed appropriately, full cost recovery will be achieved, assuming no stealing.
- Administrative costs (personnel costs) are greatly reduced. No one has to collect fees or open and close gates, and users are charged directly, thus reducing transactions among farmers and intermediate bureaucrats.
- The amount of water used is accurately recorded, and the charges are transparent, greatly reducing the chance of arguments over possible measurement errors.
- Farmers have full control over when, how, and how much water they use.

The water charge is on a volumetric basis, which encourages reduced water use.

Source: Easter and Liu (2005), citing Wang and Lu (1999).

LESSONS LEARNED

- Failure to negotiate ISC systems that are acceptable to governments, irrigation agencies, and farmers has led to a vicious circle of physical deterioration, declining performance, and unwillingness to pay in many irrigation projects.
- Irrigation service charges often have implications beyond the project level, requiring political endorsement and support for implementation. This, in the context of a typical Bank project, requires careful analysis beyond the framework of the investment package.
- Linking World Bank funding to the borrower's obligations to recover ISCs—and make good any shortfalls at the expense investment funds—is one approach to ensuring commitment to ISC objectives (box 1.14).
- In designing ISCs, the procedures for allocating water must be in place and operational. Defining water rights is contentious and difficult at the best of times. Where water is already overallocated (and “tail-enders” often get no water, or fresh aquifers are consistently overdrawn to meet current

demand), defining and enforcing sustainable water rights is an enormous political and social challenge that must precede the establishment of an ISC system.

- Water pricing in irrigation may equate supply and demand, but this is more difficult than addressing the financial sustainability of the irrigation system.
- The primary means of balancing supply and demand for water resources is administering water rights in a manner that is consistent with available supply.
- Tradable water rights offer the best opportunity to encourage productive use of water at sustainable levels, but the demanding legal, administrative, and managerial requirements make the approach a long-term possibility in the conditions prevailing in most developing countries.
- Simplistic interventions designed to serve a single objective rarely succeed and may introduce unexpected complications. Successful ISC reforms must be evaluated over the wide range of hydrological circumstances that inevitably occur (box 1.15).

Box 1.14 India: Haryana Water Resources Consolidation Project

This project, appraised in the mid-1990s, was Haryana state's third major irrigation project, the first two having failed to achieve objectives related to the reform of irrigation charges. During project formulation detailed discussions with the government identified and specified the total expenditures required for operation, maintenance, and replacement; the limited areas where subsidies would continue; the policy for differential charges between sectors; and the linkage between cost recovery and the investment components to be financed by the project. By project-end, water services in the state were fully self-funding.

This success hinged on clear definitions of service and priorities for water allocation (formulated as part of a State Water Plan under the project), a well-managed irrigation system, and an effective, legally enforced revenue collection system.

Source: India, “Haryana Water Resources Consolidation Project,” World Bank Project Appraisal Report 1994.

RECOMMENDATIONS FOR PRACTITIONERS

- *Assemble the basic information.* Is the specified irrigation service consistent with the sustainable use of surface and groundwater resources? What level of expenditure is needed to finance sustainable operation of the system in accordance with existing or proposed government policy?
- *Define and prioritize the objectives of the proposed ISC system.* Evaluate alternative charging mechanisms in terms of the objectives and the impact on various stakeholders; evaluate the proposed system under different scenarios (such as drought, unexpected failure of a major structure, and inflation).
- *Specify responsibilities in the implementation of the selected system,* including assessing and recovering costs, setting charges, accounting,

allocating funds, enforcing penalties in case of failure of an agency to supply or users to pay, and reassessing water availability and water rights.

INVESTMENT OPPORTUNITIES

- Support to hydrological services for long-term (planning) and short-term (operational) purposes
- Infrastructure to measure hydrological data
- Local and national institutional capacity to analyze hydrological data
- Facilities to disseminate information to planners, managers, and operators

Formalization of water rights

- Development of legal framework for surface and groundwater rights
- Institutional capacity to record rights
- Institutional capacity to administer and resolve disputes

Institutional capacity to provide specialist technical services

- Pollution management and control
- Advice on measurement of water diversion and consumption
- Training in new techniques, especially remote sensing to monitor water use
- Evaluation of options in water rights administration, such as water markets and water “banks”

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Box 1.15 Irrigation Management Reform in Mexico

In the 1990s, Mexico launched a radical program of irrigation reform—essentially transferring responsibility for system management to both local and federated farmer organizations. Some donors advocated pricing systems narrowly based on volumetric charges to encourage efficient use and limit demand. Some farmer groups based charges entirely on volumetric deliveries. When drought occurred, deliveries (and consequently revenues) fell dramatically, requiring layoffs of operators and putting severe financial stress on the farmer organization. Subsequently, more traditional bases for charging—combining an area-based charge to ensure income stability with a volume-based charge—were adopted.

Source: Kloezen 2002.

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ENDNOTES

1. An ample discussion of the performance of different water pricing methods is provided in Easter and Liu (2005).
2. The Egyptian area measurement unit, *feddan*, equals 0.42 hectare.

This Note was prepared by Chris Perry and reviewed by Sarah Cline, Timothy Sulser, and Mark Rosegrant of IFPRI.

INVESTMENT NOTE 1.5

ECONOMIC INCENTIVES IN AGRICULTURAL WATER USE

Economic incentives are one way to improve agricultural water use efficiency, increase cost recovery, and “internalize” costs imposed on third parties and the environment. A broad range of both positive and negative instruments is available. Best practice is to analyze country needs and to develop a balanced set of efficiency incentives, emphasizing decentralized and market-based mechanisms.

Agriculture consumes three-quarters of the world’s fresh water, yet less than half the water delivered is actually used (box 1.16). Now, as water is becoming scarce and its cost is rising, it is important to improve the efficiency (returns per unit of water) and sustainability of agricultural water use. Improving water use efficiency (WUE) is often the cheapest way to increase the availability of water for agriculture (box 1.17); it could meet half of the projected increase in water demand to 2025 (Dinar 2001).

Agricultural subsidies pose a second problem. Governments frequently shoulder the cost of developing and operating irrigation schemes. Without an exit strategy, the fiscal burden mounts. Many subsidies are not only inefficient but also inequitable. In Punjab, India, larger farmers (those with holdings greater than 6 hectares) capture 55 percent of the electricity and canal water subsidies (Singh 2003). Trade reforms, combined with reform of economic incentives in agricultural water use such as water-pricing reforms or promotion of water markets, improve welfare more than do subsidies (Diao and Roe 2000).

The third issue with agricultural water use is the *externalities* generated during the production process—costs or benefits that affect third parties, intentionally or not. For example, excess pumping lowers the water table, or abstraction from a river reduces water available to maintain ecosystems, or drainage contaminates downstream uses.

Improved WUE and “internalizing externalities” can be achieved via economic, institutional, agronomic, and engineering means. Economic incentives, which will be explored in this Investment Note, are increasingly used to promote WUE, improve allocation, promote environmentally friendly practices, and reduce costs to government. Implementation is relatively simple and cheap, and the impact is sustainable (Tiwari and Dinar 2000).

INVESTMENT AREA

Economic incentives are signals that affect decisions. They can motivate water suppliers and users to manage water in line with policy

Box 1.16 Irrigation Can Be a Wasteful Water User

In China, *in-field irrigation efficiency* (percentage of water reaching the field that is beneficially used by plant roots) is 30–40 percent, and *conveyance efficiency* (percentage of water from source reaching the field) is 40–50 percent. Thus, as little as 12–20 percent of water captured may reach plant roots. In India, seepage loss from irrigation canals is 45 percent and in Pakistan as much as 70 percent.

Sources: Qian and Xu 1994; Yoduleman 1989.

Box 1.17 What Do We Mean by Water Use Efficiency?

Economic incentives encourage delivery agencies and farmers to adopt water-conserving and efficient practices. The benefits of WUE can be analyzed in three stages. The first benefit is *end use efficiency*—meaning that the user will achieve “more crop per drop,” an increase in the economic return per unit of water. If mechanisms for transferring water between users exist, additional *allocative efficiency* may be achieved—water will be transferred to the user who can achieve the best returns. This could be, but rarely is, done outside the agricultural sector. Finally, if the environmental “externalities” can be “internalized” into the incentives structure, *environmental efficiency* can be achieved. Then water use will be consistent with overall “societal benefit”—farmers, for example, might cease mining groundwater or would pay to clean up pollution. The combination of these three efficiencies is the ultimate goal, *overall water use efficiency*.

Source: Author.

objectives. Experience has shown that the most important incentives are the following:

WATER PRICING. Water pricing is the most commonly promoted incentive in World Bank–financed projects (box 1.18). Water charges are justified on the “user pays” principle, which states that individuals who benefit from public investment and scarce resources should pay. The advantage is twofold, because water charges not only signal opportunity cost but bring in revenue. Various approaches are in use. Water pricing is a political issue, and getting the price right is hard—in Jordan the price has been the object of endless debate and study for decades. There is always the fear of a negative impact on poverty, although there is little empirical evidence in support of this possibility.

USER PARTICIPATION. Associating users in management and decisions in various forms (for instance, WUAs managing the retail delivery of water) is the second most commonly used incentive in Bank projects (box 1.18). It reduces public costs and gives incentives for responsible management and conservation. Where user participation works well, it has reduced politicization of

water issues. Evidence from Taiwan (China) (Wade 1995), India (Nagaraj 1999), and Nepal—where 75 percent of irrigation systems are managed by farmers (Tiwari 1987)—shows high efficiencies and cost effectiveness.

WATER RIGHTS. Assignment of water rights creates strong incentives to efficient use and can underpin water markets that increase agricultural efficiency and, in some cases, permit intersectoral exchanges of water. Water rights may be a share or a fixed quantum. Assignment of transparent and stable rights, together with a measure of accountability and transferability, requires a workable property regime, the right ecological characteristics, and clear definition of the resource, which is particularly hard with groundwater.

ASSET TRANSFER. Farmer ownership of assets increases incentives, reduces transaction costs, and increases farmers’ willingness to invest (FAO 1996). It requires a strong institutional base.

REGULATION. Regulatory instruments include bans, quotas, and permits. Regulation is typically used where market or monetary measures cannot take full account of social, environmental, and intergenerational costs of water use. For example, common property and intergenerational interests in groundwater can rarely be managed through market mechanisms.

SUBSIDIES. Capital and recurrent subsidies for irrigation have been almost universal, yet their efficiency is questionable (see above), they are hard to eliminate, and the fiscal cost is often exorbitant—the annual irrigation subsidy in Egypt is US\$5.0 billion (Rosengrant 1997). Input subsidies on agricultural water include subsidies on diesel fuel, electricity, or equipment. They are hard to target and usually do not promote water conservation. However, subsidies on efficiency-improving technology such as drip irrigation are increasingly being used. Though justified on grounds of encouraging innovation and compensating for externalities involved in water conservation, these bring their own distortions (such as capital bias, fiscal cost, crowding out, and locking in).

Box 1.18 Bank Projects Promote a Broad Range of Incentives, But There Is Room for Improvement

In a review of the World Bank irrigation and drainage portfolio covering 68 projects, all but 9 promoted at least one economic incentive measure. Twenty-six projects covered three or more instruments, usually associated with one another to increase impact.

Water pricing was most common (52 of the 68 projects), though usually aimed at cost recovery rather than changing behavior. Second was user participation, employed in half the sample (34 projects). Capacity building, water rights, and asset transfers to users were also common. Few projects included direct incentives such as new technology, or indirect economic incentives such as diesel price, water quotas, or water markets.

The review concluded that Bank projects miss a chance to harness well-designed packages of incentive measures to investment projects.

Source: Dinar 2001.

Best practice starts with a review of policy objectives and of the existing incentive structure, which is often complex and conveys countervailing “distortions.” The review goes well beyond irrigation water charges. It will cover *irrigation development policy*. Often objectives beyond optimizing economic returns are behind the existing incentive structure for irrigation—for example resettlement, poverty alleviation, and food security. The objectives and the related incentives have to be “unbundled” to understand what a country is trying to achieve, its relation to WUE, and the optimal mix of incentives to achieve those objectives. In addition, the review examines the *agricultural incentive and trade policy framework*, which sends water users strong messages that need to be analyzed (box 1.19). Irrigation incentive policy needs to be linked to national and international market conditions, taking account of rigidities encountered in market development. Finally, *fiscal policy* needs to be examined. Governments have specific revenue or spending goals or constraints such as cost recovery for O&M or for capital costs.

The review then examines the optimal match of possible instruments with policy objectives and with physical, social, economic, political, and institutional feasibility. This should result in an “integrated” set of measures. Some will increase costs of current behavior and provide a push for change. Others will facilitate that change toward a more efficient, sustainable use of water. For example, changes in water prices could be linked to the allocation of water rights. This could make the package easier to pass and implement.

For all “packages,” the practicalities, political economy, and likely timescale require careful study; pricing changes may encounter political opposition, and water rights changes may take time. Rigidities built up over years need to be overcome. Sequencing thus takes thought. Transfers of assets, management by users, and capacity building form another powerful package. Incentives to use more efficient technology are a useful complement to all approaches. Box 1.20 shows how Jordan used the tariff system

both to give incentives to water conservation and to achieve full and equitable cost recovery, while providing “positive” incentives through technology transfer and investment subsidies to irrigation efficiency.

POTENTIAL BENEFITS

Economic incentives should encourage delivery agencies and farmers to adopt resource-conserving and sustainable agricultural practices. Benefits to individuals and society are the increased efficiency of water use within agriculture, possibly increased allocative efficiency, and “environmental efficiency,” including third-party and intergenerational benefits (box 1.21).

Box 1.19 The Influence of the Overall Agricultural Incentive Framework on Agricultural Water Use

In Jordan, agricultural pricing policy in the 1990s made banana growing profitable, even though bananas used a stunning 20,000 m³ of water per hectare in a dry country. In the Republic of Yemen, diesel for pumping at prices a quarter of border parity and cheap credit on pumps and engines drive the groundwater overdraft. In Morocco, border protection of 100 percent on cereals helps explain why 40 percent of expensive modern irrigation schemes are planted to low-value wheat.

Source: Ward 1997.

Box 1.20 Every Situation Demands a Different Mix of Incentives—The Case of the Jordan Valley

Though aware that water use was inefficient, the Jordanian government was reluctant in the 1990s to increase prices for political reasons. An integrated approach was adopted whereby every farmer had a quota of water at a relatively low price, and a step-tariff system obliged bigger users to pay more. The tariff system was calibrated to cover the costs of operating and maintaining the system. A parallel program provided incentives for more efficient water use through technology transfer and lower-priced irrigation improvement equipment. Thus, local physical, economic, and political factors contributed to an integrated incentive package.

Source: Ward 1997.

POLICY AND IMPLEMENTATION ISSUES

WATER PRICE INCREASES MAY NEED TO BE PHASED IN SLOWLY. Governments often fear that with higher tariffs, agriculture will lose its competitiveness. Therefore, price increases may be phased in gradually while other incentives, improved services, and technology transfers allow farmers to regain competitiveness.

ECONOMIC INCENTIVES SHOULD BE SEPARATED FROM POLICIES TO REDISTRIBUTE TO THE POOR. Policy makers often resist changing incentives, believing that the poor will suffer. Most empirical evidence shows the opposite. In Morocco, better-off farmers gain most from low water charges and high border protection. Studies should be conducted to predict the impacts of economic incentives on the poor and ensure that their needs are considered without distorting pro-efficiency and pro-growth impacts. A study on who gained from water tariffs in Jordan led to the introduction of a progressive step tariff, with a low “lifeline” starting rate (box 1.20). While “economically suboptimal,” it accounted gracefully and practically for concerns about the poor.

Box 1.21 Evidence for the Benefits of an Efficiency—Promoting Incentive Structure

The use of pricing in Germany has been effective in raising revenue and reducing pollution, but charges remain too low to curtail demand. In Israel, where irrigation water is priced close to the marginal-value product and where extensive public support on technology and markets is provided, efficiency gains have been evident as agricultural water use fell by half in the 1980s, agriculture surrendered water to urban use, and product per unit of land doubled.

In China and Jordan, the use of irrigation improvement subsidies combined with technology transfer has been quite effective. In China, drip and sprinklers are now used on one-sixth of cultivated land. In Jordan, a combination of incentives to adopt improved technology and rising water prices have led to investment and innovation (for example, plasticulture, and fertigation).

Experience shows that a combination of instruments is more effective than a single instrument and that careful design and implementation are needed to achieve objectives.

Source: Saleth and Dinar 1999.

NOT ONLY FARMERS NEED TO IMPROVE EFFICIENCY. Losses of water through seepage from public canals undermine arguments for improving in-field efficiency. Changes in tariffs should be accompanied by improvements in service. Irrigation rehabilitation often has to precede the use of the price instrument to promote on-farm efficiency.

DEPOLITICIZING PRICES. Water charges are often “political.” There is an advantage in “privatizing” the debate by creating water rights and transferring ownership or management to user groups or other private entities.

INDIRECT MEASURES ARE EASIER TO AGREE AND IMPLEMENT. Water pricing is a contentious—often blunt—instrument. Countries may prefer indirect price incentives (such as deprotection, as is now the case in Mexico) together with “positive” incentives such as irrigation-management transfer.

TIMING AND POLITICS ARE IMPORTANT. Reforms have to come at the right moment, after an election, perhaps, or a drought. They can be locked in, or ratcheted up.

LESSONS LEARNED

RAISING WATER CHARGES SHOULD BE ONLY A PART OF THE INCENTIVES PACKAGE. Water charge increases help improve efficiency and cost recovery, but the political cost of water price changes can be high. Price changes should be part of a range of incentives that also improves farmer returns over time (box 1.22).

CHANGING INCENTIVE STRUCTURES HAS POLITICAL AND TRANSACTION COSTS AND MUST THEREFORE BE BASED ON PRIOR RATE ANALYSIS. Altering incentive structures carries political and transaction costs. Each situation needs evaluation to identify objectives and assess the feasibility and efficiency of each instrument. The analysis should evaluate the political and technical feasibility of each instrument relative to policy objectives; the relative impact to be expected from each instrument; and the transaction costs involved in implementing the reform.

PACKAGES SHOULD BE MUTUALLY REINFORCING AND INCLUDE “POSITIVE” INCENTIVES. Incentives should be grouped and complement one another. “Negative” incentives such as price increases should be supported by “positive” incentives such as the assignment of property rights or transfer of irrigation management.

PACKAGES SHOULD PROVIDE INCENTIVES TO ALL ACTORS. *Government* can be motivated by reduced fiscal charges and by the prospect of private sector–led growth and consequent poverty alleviation. *Water suppliers* can be motivated by the prospect of improving their performance and reducing friction with clients. *Users* can be motivated by ownership of assets, water, or institutions, and by having means of improving productivity and incomes. Incentive packages may be different at the local level (encouraging end-use efficiency) and at the regional or basin level (where they could also promote allocative efficiency).

RECOMMENDATIONS FOR PRACTITIONERS

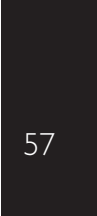
- Base project design on careful analysis of objectives, political and technical feasibility, likely impact of instruments, and the transaction costs of implementing the reform. Evaluate the best sequence of reforms, given their likely different time scale. Economic analysis should precede investment.
- Educate policy makers, managers, and users on the incentives available, how they work, and what methods can be used to implement them.
- Combine different “positive” and “negative” instruments to win the support of stakeholders. Adapt packages to the scheme, basin, and national levels.
- Increase the use of economic incentives associated with Bank projects and country programs. Experience shows that Bank projects and programs can be a powerful vector for change, underexploited in the past.
- Move toward decentralized, market-based mechanisms in order to depoliticize decision

making and increase the sustainability of WUE improvements.

- Factor product markets into thinking about economic incentives for agricultural water use, because they are often determinants of farmers’ capacity to respond.
- Pilot any untested incentive before going full scale.
- Monitor and evaluate outcomes and impacts throughout in order to show participants the results—and to allow for corrections.

INVESTMENT OPPORTUNITIES

- Technical assistance inputs to reviewing policy objectives, the existing incentive structure, irrigation and agricultural policy, and fiscal and trade policy
- Dialogue and iterative shared analysis to match possible instruments to policy objectives, assess feasibility, develop balanced and integrated packages combining positive and negative incentives, and win support from stakeholders
- Pilot investments to test incentive packages
- Full-scale investment projects in irrigation improvement or water resources management, linked to an improved economic incentive structure



Box 1.22 Requirements for a Good Incentives Package

Good incentives will have the following characteristics:

- Be focused on objectives of WUE, environmental sustainability, and fiscal affordability.
- Contain an integrated set of measures that both increase costs of inefficient behavior and facilitate change toward more efficient and sustainable water use.
- Take account of agricultural policy and markets.
- Reflect political economy and socioeconomic realities and be feasible and effective in the country situation.

Source: Author.

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AGRICULTURAL WATER IN THE NEW COUNTRY WATER RESOURCES ASSISTANCE STRATEGIES

What is new? This Innovation Profile summarizes a World Bank water assistance program matched with a CAS/PRSP, integrating all sectors, recognizing both principles and pragmatism, and agreed to by the government. Agricultural water strategies can be well articulated through this new instrument.

Water sector planning is difficult because sustainable resources management has to be reconciled with the interests of the water-using “sectors”—agriculture, urban and rural supply, and hydropower. As described in the World Bank’s *Water Resources Sector Strategy* (WRSS; World Bank 2004), the Dublin Principle of “subsidiarity”—devolving decisions to the lowest possible level—has to be reconciled with the principle of “integrated management” of the resource. Within the Bank, the overall water resources strategy has to be reconciled with the strategies and business plans of the water-using sectors. On the whole, the Bank has not handled this integration well. Sectoral strategies have not been coordinated or integrated, and at the country level, the CAS/PRSP process has dealt summarily with the complexities of integrated water resource issues and tended to focus on selected sectoral issues. Therefore the WRSS identified a need for a cross-sectoral CWRAS to integrate the range of Bank programs that have an impact on or are affected by water resources.

The problem of irrigation, drainage, and agricultural water management within the WRSS is an acute example of this problem of “matrix management.” In addition to the need to align agricultural water policy with overall resource management policy, agricultural water typically comes under several different institutions and can even be treated as several different “sectors”—such as basin planning, dams, irrigation, agriculture, and watershed management.

OBJECTIVES AND DESCRIPTION

The core objective of CWRAS is to produce an operational plan for Bank involvement in the water sector. Preparation involves analysis, dialogue, and decisions that pinpoint a country’s water challenges and opportunities; set those challenges and opportunities within a framework in which long-term objectives, together with political, social, and economic constraints; Dublin Principles; and CAS/PRSP are reconciled in a strategy; and set out the action plan agreed to by the government in question and the Bank. The resulting CWRAS is a *Bank strategy*, but set within the *national strategy*. CWRAS is a “water CAS, making the Bank/Government water contract explicit and tailored.”

Given the predominance of agricultural water use in overall water use and the role of irrigation in food production, income creation, and poverty eradication, agricultural water will be an important component of CWRAS.

The CWRAS Equation

National Policy + Bank Water Resources Strategy + CAS/PRSP + Sectoral Strategies = CWRAS

In January 2003, the Bank’s Water Resources Management Group (WRMG) developed some interim CWRAS guidelines for practitioners. The guidelines describe a CWRAS process in three parts: internal Bank consultation and review, engaging all Sector Directors and Country Directors working on water; a consultative process with country stakeholders, focusing on Bank role and choices; and agreement with government on the CWRAS as a framework for Bank water interventions.

Describing CWRAS as a “a rolling ten year plan for the Bank in water, linked to CAS goals,” the guidelines set out the recommended content of a CWRAS: analysis of critical water challenges, goals, policies, and strategy in the country; evaluation of the Bank’s comparative advantage as a development partner; assessment of the relevance to the country water situation of the Bank’s “overarching” contract through the CAS; assessment of the impact of Bank water interventions on growth and poverty reduction; a

reconciliation of the country situation with Bank global water principles; an assessment of the political economy of reform and a sequenced prioritized set of Bank activities supporting reform; and a program of Bank lending and nonlending activities.

The guidelines are well reflected in the 2002 Philippines CWRAS (box 1.23).

During fiscal 2004, financing of US\$200,000 per region was provided through the Bank-Netherlands Water Partnership Program to support the Philippines CWRAS.

ASSESSMENT

CWRAS imposes a more integrated approach on water programs. It links principles, opportunities, and action, and leads directly to investments. CWRAS also links parallel objectives to water, particularly poverty reduction, through its obligatory link to PRSP and the Millennium Development Goals. It works best

where there has been previous dialogue, as in China and the Philippines. In the Republic of Yemen, with a long and sustained dialogue, the CWRAS team has adopted a more ambitious approach (box 1.24).

Agricultural water use has figured prominently in CWRASs produced to date. In the China CWRAS, agriculture water issues include groundwater management, irrigated agriculture, basin management, watershed management, environmental flows, water pollution control, hydropower linkages, and flood control and protection. The Republic of Yemen’s CWRAS has a major focus on groundwater and surface irrigation, groundwater management, and water quality issues.

OUTPUT AND IMPACTS

The CWRAS output is a program of Bank lending and nonlending support for water schemes, agreed with the government, set within a strategic framework, and broken down by sector (box 1.25). It explicitly addresses the range and consistency of Bank activities as a mechanism of poverty reduction (table 1.3). It is an input to—or at least consistent with—the CAS and the PRSP.

The Philippines CWRAS (box 1.25) is expected to have impacts on Bank water work, including improved coherence between sectors (requiring close work across sector directors), better fit of water work with the CAS (requiring close work with the country director), and improved quality (for example, by bringing the Water Resources Management Group into country work).

Box 1.23 Objectives of the Philippines Country Water Resources Assistance Strategy

The objectives of the Philippines’ CWRAS were to define a framework and overall strategy for the World Bank’s water program, including a review, prioritization, and recommendations for changes in existing and planned water-related activities in light of the new Bank strategy, Bank corporate goals, and foreseen national challenges in water. The CWRAS was prepared by a Bank team, in consultation with the government.

Source: Philippines CWRAS.

Table 1.3 Country Water Resources Assistance Strategy: Analytic Framework for Poverty Impacts through Water Programs

Area of action	Broad social impacts	Poverty-targeted impacts
Resource management and development	Regionwide water resource interventions	Targeted water resource interventions
Service delivery	Broad water service delivery reforms	Targeted improved water services

Source: World Bank 2004.

LESSONS AND ISSUES FOR REPLICABILITY

The Bank teams have grasped the CWRAS instrument in some very different ways, ranging from a focused Bank-only strategy (Philippines), through a broader, issues-oriented approach (China), to what is essentially an update of the national water strategy (the Republic of Yemen). Although variety and flexibility are good, teams would welcome an evaluation and some clearer guidelines.

Early examples have been able to mobilize intersectorally within the Bank quite effectively, but the process is still led by one “sector” or another. In the Republic of Yemen, water resources and agriculture lead, and water supply and sanitation take a back seat. The “integration” between water resources management and the sectors is still imperfect, especially in very large countries such as China, where the CWRAS is essentially a list of issues rather than a comprehensive framework.

Most teams have stuck to the “Bank-only” approach, which is in line with the concept. Including more stakeholders and other donors becomes very ambitious and is probably realistic only in smaller countries with a history of good dialogue (for example Jordan or the Republic of Yemen).

In China, the approach has historically been fragmented (regionally, sectorally, and within the Bank, where seven different units handle water). The CWRAS has been seen as a chance to bring the strands together in an issues-oriented, problem-solving approach. Agricultural water issues figure prominently. For the first time, the China CWRAS covers water resources management as the “missing” theme that brings the analysis together. The lesson is that CWRAS is a good opportunity for agricultural water analysis and for integrating agricultural water into the big picture.

CWRAS requires a good partnership among Country Directors and Sector Directors, sustained dialogue with government, and a good appreciation of the political economy of reform. Other factors include a good intersectoral and

integrated approach and monitorable indicators of success, together with a related monitoring and feedback process. Best results will probably come where monitoring and dialogue are sustained by annual Bank budgets for follow-up (essentially a Programmatic Economic and Sector Work approach).

Finally, all the early efforts suggest the need for flexibility and country adaptation of the CWRAS approach within the common objective of a cooperation framework over a short- and medium-term horizon.

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Box 1.24 A Broader Approach: The 2004 Republic of Yemen Country Water Resources Assistance Strategy

The 2004 the Republic of Yemen CWRAS can be summarized as follows:

- It is a joint exercise among government, donors, and the World Bank.
- It updates a national strategy and investment plan.
- It adopts a fully participatory approach through stakeholder working groups and workshops.
- Its objectives include deepening relationships with local actors, and building local capacity.

Source: Author.

Box 1.25 The Chapters of the Philippines Country Water Resources Assistance Strategy

1. Water resources base, uses, and challenges
2. Government institutional, legal, and policy framework
3. Implications for the CAS, including review of Bank and other donor programs and lessons learned
4. Evaluation and priorities for the CWRAS—what the Bank should do more, less, or better

Source: Philippines CWRAS.

WORLD BANK PROJECTS DISCUSSED

Yemen, Republic of. "CWRAS." Author's personal communication. Scheduled for delivery and external dissemination in the third quarter 2005.

USEFUL LINKS

Country Water Resource Assistance Strategies
Web page: <http://lnweb18.worldbank.org/ESSD/ardext.nsf/18ByDocName/StrategyCountryWaterResourceAssistanceStrategies>.

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INNOVATION PROFILE 1.2

ENABLING SMALLHOLDER PROSPERITY: IRRIGATION INVESTMENTS FOR READY MARKETS

What is new? Now that irrigation technologies are affordable, individual, and modular, linking African smallholders to markets is the next challenge. How can the production of a dispersed population of small producers be channeled toward domestic and foreign markets? A successful case of bilateral donor support to agribusiness companies that link up with smallholders is discussed in this Innovation Profile.

Agriculture holds the greatest promise for Zambia's prosperity. The country's vast tracts of fertile soil, tropical climate tempered by altitude, good rainfall, and access to more than 45 percent of Southern Africa's water resources endow its farmers with considerable comparative advantages. Zambia's pursuit of economic liberalization and structural reform holds promise for transforming the country into a more open market economy.

In the absence of appropriate irrigation strategies, an overwhelming proportion of Zambian farmers still depend on rain for production, and produce one crop of maize a year. When rainwater is not sufficient, smallholder farmers in this water-rich nation irrigate their crops using small cans or buckets to fetch water from nearby streams or wells. It takes 6 to 8 hours to irrigate a quarter-hectare plot using this method. This technique is practiced by 85 percent of Zambia's farmers, of whom 600,000 are smallholders.

Acknowledgment that Zambia's great water endowment offers high potential for economic growth led to the formation of the Water Resources Action Program (WRAP). But what hinders the advancement of irrigated agriculture is primarily the lack of appropriate investments. Reluctance to address irrigation directly and

innovatively in a more commercially oriented environment has deprived smallholder farmers of improved livelihoods and saddled them with food and income insecurities. Not surprisingly, Zambians live on one of the lowest per capita incomes of the continent (US\$350).

OBJECTIVES AND DESCRIPTION

In August 1999, a bilateral donor created the Zambia Agribusiness Technical Assistance Center (ZATAC). Its aim is to help break the cycle of persistent rural poverty and food insecurity and increase smallholder household income by applying commercial approaches.

ZATAC focuses on wealth creation through commercialization of smallholder production. Its market-based and demand-driven approach to smallholder production, combined with economies of scale through outgrower schemes directly linked to ready markets, has increased household incomes for smallholders. ZATAC's strategy involves evaluating the commercial potential of smallholder production, then lifting constraints to commercialization by whatever means—for example, by helping smallholders shift from bucket-watering to pump irrigation or intercrop high-value crops to maximize returns on land and labor. ZATAC also aims at striking deals and establishing linkages between smallholder outgrower schemes and agribusinesses seeking to enhance their supply volume and competitiveness in domestic and export markets. This strategy gives small growers an opportunity to increase household cash flow quickly while becoming partners in the value chain. It offers agribusinesses a chance to increase their supply base and benefit from economies of scale without the associated capital investment.

Central to the strategy is the identification of affordable, appropriate, and efficient systems that add value so that smallholders can work themselves out of poverty. For example, in export vegetables, ZATAC helped override the water constraint by providing credit for irrigation equipment to make water work for smallholders. The access to credit for irrigation equipment that

ZATAC provided enabled smallholders to better utilize the resources they own: land and labor. As a result, smallholders are producing more cycles of crops, growing higher-value crops, and spending less time watering while expanding production. Some smallholders earn as much as US\$8,000 a year on a 2-hectare plot, producing export vegetables.

The simple provision of irrigation credit, tied with ready buyers, has unleashed the farmers' potential. This type of market linkage not only increases real income for smallholders but also provides an avenue for repayment of the credit. With ZATAC assistance, the equipment credit is channeled to smallholders through their producer groups, and further guaranteed by the ready markets or agribusinesses that ultimately purchase the product. As part of the relationship, the agribusinesses help remit repayments to ZATAC for producer groups and their member producers.

Under the ZATAC Integrated Coffee Program, smallholder farmers intercrop specialty coffee with vegetables for the local market and paprika for the export market. Paprika production is linked to a local processor and exporters, while coffee is exported through the local coffee growers association. ZATAC also provides irrigation credit to these smallholders through their cooperative enterprise for the purchase of treadle pumps, which has enabled smallholders to tap Zambia's water resource more effectively than they would have with the bucket technique. The switch to treadle pumps has meant that farmers now need an hour or less to water an area that used to take 6 to 8 hours. Treadle pumps cost less than US\$100 on average. ZATAC applies interest and a service fee on these kinds of credit but adjusts the terms to help smallholders manage their debt burden. As with export vegetables, ZATAC rallies agribusiness assistance in establishing a repayment system to reimburse ZATAC for credits disbursed.

In addition to credit, ZATAC provides technical assistance, business development services, and training in production and processing, both at

the farm and company levels. It does so directly and through alliances with other donors, research institutions, the ministries, as well as the agribusinesses themselves.

OUTPUT AND IMPACT

Participating smallholders now earn more and grow more cycles of crops and more varieties of products than ever before. Smallholder agricultural practices are changing, and in the process, farmers feel encouraged to upgrade themselves by using improved technologies, better-variety seeds, and labor-saving mechanization that all help them break free from their dependence on rain and from poverty.

For the first time in the history of Zambia, smallholders are growing fresh vegetables for European markets, thanks to the alliance between smallholder producers and agribusinesses. In 2003, 300 smallholder farm families exported close to 300 tons of fresh vegetables to the United Kingdom. This example shows how this type of linkage not only increases income for smallholders but also contributes to the nation's economic growth.

ISSUES FOR WIDER APPLICABILITY

Because of the success of the programs, the model has been replicated across other subsectors and provinces. ZATAC now operates in 5 out of 9 provinces and manages smallholder outgrower schemes in dairy, coffee, paprika, honey, cashew, and essential oils. To date, ZATAC has worked with 10,000 smallholders and rural entrepreneurs linked to more than 15 agribusinesses.

With less than 15 percent of Zambia's arable land under agricultural production and not more than 12 percent of the nation's irrigable area under irrigation, the potential is enormous to expand food production for domestic and foreign consumption. Constraining fuller utilization of this opportunity is access to credit, or lack thereof, particularly for smallholder farmers without the collateral to secure loans from

financial institutions. For irrigation credit to work, production activities must be tied to ready markets that ensure a reasonable return. The ZATAC approach provides that linkage.

USEFUL LINKS

The ZATAC Web site: <http://www.zatac.org/>

This Profile was prepared by Bagie Sherchand of Development Alternatives, Inc., and reviewed by Sarah Cline, Timothy Sulser, and Mark Rosegrant of IFPRI.

2

DESIGNING INSTITUTIONAL REFORMS

- Investment Note 2.1 Investing in Participatory Irrigation Management
- Investment Note 2.2 Investing in Water Rights, Water Markets, and Water Trade
- Investment Note 2.3 Investing in Building Capacity in Agricultural Water Management
- Innovation Profile 2.1 Drivers of Public Irrigation Reform in Australia
- Innovation Profile 2.2 Investing in Farmer Networks for Inclusive Irrigation Policy Processes in South India

OVERVIEW

Together with public policy (chapter 1), institutions create the enabling environment in which markets guide the allocation of resources for efficient outcomes. This chapter examines key institutional reforms that can improve the pro-poor enabling environment and increase the efficiency of water resource use.

WATER SECTOR REFORM SOMETIMES DEMANDS HIGH POLITICAL TRANSACTION COSTS OF MANAGEMENT. Water sector reform is a complex, multisectoral challenge, with many stakeholders and sometimes high associated political transaction costs. The process requires investment—of time, political capital, and financial resources (for studies, capacity building, and institutional development). Reform champions are needed, and experience shows that participatory approaches, though sometimes risky, strengthen ownership. Irrigation management transfer in Australia is an example of success achieved under conditions of well-developed governance, political commitment, skilled and devoted stakeholders, and extensive investment at every level in learning and participation.

Another example (from South India) shows how farmer irrigators were brought into the policy reform process and made it more farmer oriented. (See IN 1.4 on stakeholder interests, IN 1.1 and IN 1.2 on the political economy of reform, IP 2.1 on coalition building in Australia, and IP 2.2 for the South India case. See also “Strengthening Farmer Organizational Capacity to Influence Agriculture Policy,” in *Agriculture Investment Sourcebook* (AIS), Module 1.)

FOR DIFFICULT REFORMS, ADJUSTMENT LENDING MAY BE SUITABLE. Policy-based loans can provide an incentive for governments to undertake comprehensive, multisectoral policy and institutional reforms despite their high political transaction cost. Using a policy-based lending instrument focuses attention on a specific high-profile reform agenda and musters a constituency within government and civil society to implement it. It also has a democratic and “inclusive” nature, because program publicity stirs public debate throughout the nation. (See IN 1.2. See also “Adjustment Lending for Agriculture Policy Reform,” in AIS Module 1.)

IN AGRICULTURAL WATER INVESTMENT, DECENTRALIZATION, DEMAND DRIVE, AND PARTICIPATION ARE ROUTES TO IMPROVE EFFICIENCY. About half of the irrigated area in the world has been developed and managed by governments, but inherent structural problems have sent government-owned irrigation schemes into a spiral of degradation. On these schemes, irrigators do not generally have a sense of ownership and responsibility for the system or for efficient water use. Service is often poor, and the systems cannot mobilize adequate resources to finance costs. Governments have become increasingly reluctant to pay subsidies. As a result, the condition of infrastructure and the quality of water services have declined. This poor experience has led to a shift of emphasis away from government and toward a new public-private paradigm in recent years. The private sector—in the form of contractors, private investors, water user associations (WUAs), community organizations, nongovernmental organizations (NGOs)—is taking on more responsibility for irrigation management and financing. The key message is that

investments are more efficient when accompanied by decentralization, demand drive, and participation (see IN 2.1). Other chapters discuss the power of participation in private irrigation improvement (IN 3.3); multipurpose operations such as dams and groundwater management (IP 4.1); community-driven approaches to small-scale irrigation and watershed management (IN 7.1); and supplemental irrigation, watershed management, and drought and flood management (IN 6.1, IN 6.2, IN 8.1, IN 8.2).

WATER USER ASSOCIATIONS ARE AN IMPORTANT INVESTMENT AREA. WUAs in irrigation can play many roles along a sequence from the most basic cooperation at the turnout (tertiary, quaternary) right up to managing irrigation schemes. As the degree of transfer of responsibility grows along the sequence, investments will be needed to build institutions and capacity. The approach has proven successful and popular. WUAs can also help the inclusion of women and the poor in discussion and decision making, and even in leadership, on water rights and management. Participatory irrigation management (PIM) has been adopted in more than 50 countries since the 1980s. Investment in a well-designed PIM strategy can bring many benefits: reduced cost to government, increased cost recovery and farmer investment, improved maintenance, more equitable and efficient water distribution, improved water quality, fewer water conflicts, and improvement in government services. Participatory approaches and user associations are also now being introduced for drainage, for example in the Arab Republic of Egypt. But there are risks, too. The cost of water to farmers may increase; water productivity may not rise quickly; local elites may capture control; and government may reduce its support too quickly. The most common causes of failure are inadequate preparation of the enabling framework, weak political and civil society support, and a hasty transfer without capacity building. (See IN 2.1 for WUAs and participatory irrigation management. See IP 5.5 for participatory drainage in Egypt. See also “Investments to Empower Farmers to Manage Irrigation and Drainage Systems” in AIS, Module 8.)

AS AGRICULTURAL WATER MANAGEMENT MOVES FROM AN ENGINEERING PHASE TO A TECHNOLOGY- AND MANAGEMENT-INTENSIVE PHASE, INVESTMENT IN CAPACITY BUILDING BECOMES MORE AND MORE ESSENTIAL. As the technical challenges of scarcity and environmental degradation grow, and as stakeholder involvement becomes more important, skill needs change. Capacity building is needed at all levels—from farmers to government, covering the whole range from adaptive research to hands-on management coaching for WUAs. The cost of adequate capacity building worldwide has been estimated at US\$1 billion a year, but actual investment does not come close to that amount. (See IN 2.3.)

INVESTING IN A WATER RIGHTS SYSTEM CAN HELP IMPROVE WATER MANAGEMENT, BUT ESTABLISHING A RIGHTS-BASED SYSTEM IS FAR FROM EASY. Where water rights are not secure, management is inefficient. If water is treated as a public or common resource, incentives to efficient management and allocation are dulled. Management will also be inequitable, because use of water without a formal rights system results in exploitation by the most politically and economically powerful. Finally, water management without a clear rights system is unsustainable: absence of rights provokes irresponsible use through the law of

capture and abuse of a common pool resource. A system of rights has proven to be an efficient, equitable, and sustainable water management option, promoting efficient water use and increasing cost recovery. Water rights are also a prerequisite for the development of water markets, which can allow intrasectoral and intersectoral transfers. However, introducing rights-based systems can be politically contentious, particularly where there is cultural reticence and weak governance. A long-term participatory approach is essential. (See IN 2.2.)

SOME TYPICAL INVESTMENTS

Investments in technical assistance could include the following:

- Capacity building (for sector management, farmer associations, and the like)
- Institutional development (water rights, PIM, Irrigation Management Transfer, law, water markets, and so on)

Project investments could focus on irrigation and drainage research. And finally, pilot investments could include pilot projects for PIM and water markets.

INVESTMENT NOTE 2.1

INVESTING IN PARTICIPATORY IRRIGATION MANAGEMENT

Unable to finance and manage the large irrigation schemes they built and now own, governments are seeking to transfer management authority to users. Transfer shifts the government role mainly to regulating operation and maintenance (O&M) by building the capacities of WUAs, providing support services, and piloting the decentralization of management of river basins and aquifers. WUAs may, in turn, contract private sector entities to provide management services. Both levels of transfer require agreements, new incentives, and new methods to ensure inclusiveness and accountability among stakeholders. They require investments in building institutions and human capacity. Mature networks of WUAs could enhance the prospects for reforms such as volumetric allocation, water pricing, and conflict resolution.

Irrigation systems are a vital resource for food production, rural livelihoods and income, and increasingly, fisheries and rural industry. About half the world's irrigated area has been developed and managed by government. In such systems, water users generally do not have a sense of ownership and responsibility for the system or its water. Moreover, many irrigation systems cannot mobilize adequate resources to finance costs. As a result, the systems' infrastructure and the quality of water services rapidly decline. In addition, competition for water and pressure on the environment are growing.

Under these circumstances, the key challenge becomes *how to put the limited resources of farmers, governments, the private sector, and international development agencies to best use for optimal water productivity and sustainability of irrigation systems*. Empowerment of water users is essential to meet this challenge because strategies that promote active participation and farmer investments show potential for increasing the returns on public investment. Collectively these approaches are called Participatory Irriga-

tion Management (or PIM, as noted above), and they are generally implemented through WUAs. These associations can also be a fundamental means for empowering women, thus contributing to Millennium Development Goal 3 (promote gender equality and empower women). In varying degrees and ways, participatory irrigation management has been adopted in more than 50 countries since the 1980s, including multiple states or provinces in India and China.

INVESTMENT AREA

In the 1970s and 1980s, PIM was often viewed as farmer contributions to management rather than farmer empowerment and government reorientation. Recent reforms in Mexico, Andhra Pradesh (India), and Indonesia, have updated the concept to mean *the empowerment of WUAs to govern the management and financing of public irrigation systems*. The key challenge is increasingly recognized as accountability: building incentives (rewards), sanctions, and transparency into water service organizations to induce them to meet standards set by the governing body of users, the representative of the owner government, and other stakeholders.

The following are the main potential investment areas in PIM:

- Policy, legal, and institutional framework for WUAs
- Restructuring government and building its capacity in sector regulation, building WUAs, and providing support services
- Creating and building governance and managerial and financial capacity of WUAs
- Restructuring the water supply, irrigation, and agricultural agencies to improve the way irrigation management, rehabilitation, and upgrading are decided and financed, with greater cost sharing and incentives for farmers
- Empowering women and the rural poor, through membership rights and inclusion in

local water forums; introducing water rights at the farm level; and enhancing leadership capacity for poor women and men in WUAs.

- Enabling the private sector to provide support services to WUAs for both irrigation and agriculture

Future investments in PIM will need to be linked to broader irrigation sector reform and efforts to increase the productivity of irrigated agriculture, especially for the rural poor, through innovations in credit, technology, demand-driven extension, and group-based agribusiness and marketing.

POTENTIAL BENEFITS

A well-designed PIM strategy has proven potential to increase farmer investment in irrigation management, improve the productivity of water used for agriculture, improve the sustainability of irrigation systems, promote development of demand-driven support services, and improve the cost-effectiveness of government regulation and responsiveness of its services.

Evaluations show that PIM yields a mixture of positive and negative results. Box 2.1 summarizes the most commonly reported benefits—and risks, if PIM is not designed properly. Most project and research documents report reduced government expenditures for irrigation, as in Mexico and Andhra Pradesh, in keeping with the objective. Farmers' irrigation costs often rise, but this rise may eventually be offset by increases in water productivity through more responsive management, improved support services, and better market access. Adoption of PIM in Mexico, Andhra Pradesh, and Mali brought about an increase in investments, including farmer investments, in maintenance and rehabilitation.

PIM also generates other benefits. The formation of WUA federations in Indonesia and Mexico has enabled farmers to participate in river basin forums, which deal with water competition and environmental concerns. In Mexico, Colombia, and Nepal, WUA federations and national networks provide support for political

issues, extension, and conflict resolution. In Shaanxi province in China, the private sector has invested in irrigation rehabilitation. In some countries, PIM has expanded the area served. PIM implies the creation of WUA federations, as well as partnerships with the private sector, that offer farmers new options to organize group input provisioning, agribusiness, and marketing. Hence, as PIM evolves to include WUA federations and the private sector, it enables WUAs to interact more with the socioeconomic, environmental, and political forces around them.

Innovation and change to empower women is likely to have a strong impact on irrigation performance. In Africa alone, women provide daily labor for irrigated production—especially in woman-headed households, which account for between 25 and 35 percent of smallholder irrigators (Chancellor 1997). The experience reported in box 2.2 shows how female leadership can foster local economic development and improved living conditions.

POLICY AND IMPLEMENTATION

Key policy and institutional decisions to be made in PIM programs are as follows:

Box 2.1 Benefits and Risks of Participatory Irrigation Management

Benefits

- Reduced cost of irrigation to government
- Increased cost recovery
- Improved coverage and quality of maintenance
- Better water distribution equity and efficiency
- Fewer water conflicts

Risks

- Cost of water to farmers may increase
- Water productivity may not rise quickly
- Local elites may capture control
- Government may reduce support too much
- Rehabilitation financing remains unresolved

Source: Author.

- How should the roles, services, and authority for irrigation management be realigned between farmers, government, and the private sector?
- What organizational arrangements and modes of farmer participation are appropriate for irrigation system governance, management, financing, and sector regulation?
- What type of capacity building is needed for effective functioning of WUAs, especially their women members?
- What should farmers' responsibility be in financing different aspects of irrigation, including management, rehabilitation, modernization, and construction?
- What incentives and accountability mechanisms are needed to make stakeholders follow irrigation-related agreements and regulations?
- What legal, regulatory, and institutional changes are needed for PIM to work?

- How should such changes be phased in and implemented?

Such questions normally require strategic planning exercises that include key stakeholders; they may also require research and pilots. A comprehensive strategy should emerge that includes building and maintaining political support, incentives, and accountability mechanisms to maintain and increase stakeholder support. The strategy should also target sustained capacity building and financing.

In parallel with the legal and institutional arrangements for creating PIM, most irrigation and agricultural services providers need to undertake major institutional reforms to meet the new demands posed by these newly dynamic customer relationships. Without that, WUAs' expectations may be raised while the governmental agencies remain inadequate to respond at the basin, district, or branch canal level. The challenge lies in getting irrigation and agricultural institutions to work together with WUAs and the private sector, when in most cases there is no history of cooperation. On institutional reforms, a lesson that comes out of recent experience in Sri Lanka is that WUAs significantly change the dynamics among farmers, water supply services, and agricultural service providers (box 2.3). Farmers organized into groups offer many opportunities that did not exist before the formation of WUAs. One of the lessons from Sri Lanka is that, once this new dynamic is established, the private sector becomes interested in dealing with farmer groups.

Box 2.2 What Women Can Do: An Indian Experience

In 1995, in Gujarat, India, the Self-Employed Women's Association, a trade union of 215,000 poor, self-employed women, launched a 10-year water campaign in nine districts of Gujarat. Watershed committees were set up at meetings where every villager from user and self-help groups was present. Out of a total of 11 members, 7 were women.

Under the program, the committees constructed 15 farm ponds, recharging 120 tubewells. Through soil and moisture conservation work, the salinity of the land decreased. With more productive land, the women began earning higher and more sustainable incomes. About 3,662 hectares were thus treated. Now they grow cash crops using organic farming. On panchayat wasteland, community pasture land, and private land, about 5,000 trees have been grown and grass planted on 3,500 square meters of field bunding for better retention of water. This has created a green belt in the area and generated employment opportunities for about 240 women. About 2,500 hectares of land that once supported only rainfed agriculture have been irrigated, and the supply of drinking water is also ensured.

Source: Maharaj et al. 1999.

Approaches and division of responsibilities

Experience suggests that reform requires a comprehensive, strategic, and participatory process of stakeholder consultations, dialogue, participatory decision making, awareness campaigns, implementation, monitoring, and adjustment. In the past, investments have focused mainly on infrastructure and modestly on institutions, with inadequate attention to incentives and accountability arrangements that would ensure stakeholder support and compliance with new institutions and rules. In the future, more attention should be

given to incentives and accountability measures such as farmer empowerment, irrigation service plans and agreements, management audits, sector regulation, and linkage of support and assistance to audit results.

The debate between “big bang” versus incremental approaches should be recast in terms of concern about which changes need to be designed and adopted rapidly (such as strategy and legal framework) and which aspects need an incremental approach (such as developing optimal levels of management transfer and accountability mechanisms). Experiences in Mexico, Turkey, and Andhra Pradesh suggest that the big bang approach generated basic support for reform. But they also indicate that the initial reforms are incomplete and further changes are needed: service plans, audits, asset management, financing, and support services. Proponents of PIM should expect and encourage the original PIM policies and arrangements to evolve in a long-term process of monitoring and evaluation through stakeholder workshops.

Risks and implications

There are risks related to the way irrigation sector reform is designed and implemented. An example is rapid implementation of physical construction works without proper capacity building in institutional and managerial aspects. Vested interests may limit development of new accountability mechanisms and adequate financing between service provider, governing authority, and sector regulator. Resistant bureaucracies may slow down or sabotage transfer of responsibilities. They may refuse to downsize or relocate staff. If management transfer is too rapid, WUAs may not yet be capable of taking over management. Local elites may assume undue influence in new WUAs. As government increases its role in regulating WUAs and service providers, underpaid employees may become vulnerable to bribes.

A key challenge is to include incentives and accountability mechanisms that ensure WUA compliance with government regulations, service agreements between WUAs and service

providers, and WUAs’ own rules. PIM may involve an increase in investment or expenditures by water users. This is often offset eventually by increases in the profitability of irrigated agriculture caused by both improvements in the management of irrigation systems and innovations in cropping, marketing, and agribusiness (the lattermost may require parallel investments). It may be beneficial to design loan programs to include tranche-based benchmarking of essential but sensitive aspects of reform such as indicators of political support, management transfer, and empowerment of WUA federations and networks.

WHEN IS INVESTMENT APPROPRIATE?

Investment in PIM is appropriate when a country has both a policy *need* for such investment

Box 2.3 The Mahaweli Restructuring and Rehabilitation Project in Sri Lanka

WUAs were formed and fostered under the Mahaweli Restructuring and Rehabilitation project (MRRP) in Sri Lanka. Usually only 1.0 hectare of land is allocated to each farmer. Farmers in the project area, subject to the Mahaweli Authority of Sri Lanka, had little say in the decision. However, after 330 to 400 farmers formed a “community of common concern” with some management authority over irrigation water, they were able to concentrate on increasing agricultural productivity and diversification. As a group, they decided what and when to grow. Under this farmer management, water use decreased, and productivity in the cropped area increased. Private sector involvement unleashed a new dynamic and brought economies of scale. What happened next was remarkable. The WUAs organized bulk purchases of fertilizer, high-quality seed, and other inputs at competitive prices. On the output side, agro-industries dealing in soybean, chili, chicken meat, and fresh vegetables found that they could talk with groups of farmers controlling hundreds of hectares. In the soybean industry, for instance, the industry reached agreement with groups of farmers to grow soybeans under contract. The industry wanted quality and high volume; the farmers were interested in price and quantity. The industry supplied them with high-quality seed and the extension expertise to ensure quality and high volume, and farmers entered into forward contracts for their crop. The partnerships started modestly with about 70 farmers and 70 hectares but soon grew to thousands of hectares.

Source: Geoffrey Spencer (personal communication); MRRP Implementation Completion Report (n. 28927/LK).

and the political *capacity* to make such investments effectively. Key signs of need for PIM investments are governmental inability to either finance irrigation O&M or collect fees from farmers; poorly managed irrigation systems dominated by ineffective, inefficient, and/or unaccountable government bureaucracies; heavy dependence by rural society on revitalizing irrigated agriculture for livelihoods and poverty alleviation; and potential for significant improvements in agricultural water productivity and irrigation sustainability through increased participation and empowerment of water users.

A country and donors have the optimum capacity to effectively invest in PIM and irrigation sector reform when high-level political commitment to it makes them feasible, when farmers stand to benefit economically, and when key stakeholders are willing to work together in a process of strategic change. So far, such conditions have often been lacking in PIM-related investments. They may be facilitated through linking up with pro-reform constituency groups, conducting pilot experiments, holding public consultations, and combining investment and adjustment loans. Financial options are discussed in the Investment Note on Development Policy Lending to support Irrigation and Drainage Sector Reforms (IN 1.2).

LESSONS LEARNED

CAUSES OF FAILURE. The most common causes of failure in PIM programs are listed here roughly in order of frequency of occurrence across countries: inadequate policy, legal, and regulatory frameworks and political support; lack of a lasting coalition of pro-reform constituency groups capable of overcoming resistance to reform by some government agencies; insufficient attention to capacity building of WUAs and reorientation of government agencies; attempts to transfer responsibilities to WUAs without necessary legal power or financial resources, restricting the scope for reform so narrowly, such as only creating WUAs, that it fails to address significant incentive and accountability problems between WUAs, government, and other stakeholders; and finally, unprofitable agricultural conditions.

MEASURES FOR AVOIDING FAILURE. Failures of PIM programs can be avoided, minimized, or corrected if the World Bank and its partners pursue a process that involves all significant stakeholders, each at its own level, in strategic planning, consultations, and negotiation; tests arrangements and pays attention to incentives and accountability challenges; and monitors progress and allows course correction.

CONDITIONS FOR SUCCESSFUL INVESTMENTS. The most important conditions for successful PIM programs are listed here by priority: high-level political commitment backed up by a strategy to maintain a solid stakeholder coalition; farmer dissatisfaction with present management performance and a PIM strategy that enables WUAs to make desired adjustments; a comprehensive proposal from the Bank and its partners for reform that includes reforms in irrigation service planning, government agencies, and a private sector role in service provision and support services; building capacity and support services; and significant potential to increase the profitability of irrigated agriculture.

EFFECTIVE CHANGE PROCESSES. Experience with Bank-supported programs for PIM suggests that the most important elements of an effective change process (listed by priority) are comprehensive, strategic, and participatory planning, monitoring, and adjustment; facilitation of change through participatory dialogues about agricultural and irrigation improvement strategies; WUA involvement in making investments jointly with the government; parallel assistance to revitalize irrigated agriculture (through modernizing extension, marketing, and agribusiness); and, where needed, modernization of land and water rights (that is, water rights at the farm level, including rights for women and the rural poor) paralleling PIM reforms.

RECOMMENDATIONS FOR PRACTITIONERS

Seven elements should be in place for PIM to result in sustainable and productive irrigation:

- Functional infrastructure that is compatible with accepted water use rights and local

management capacity. Approaches to rehabilitation toward supply-driven design and operations (as in India) suggest that bringing system design, water use rights, and management capacity into harmony is essential for sustainable PIM reforms.

- Empowerment of farmers to share authority over system policies, rules, selection of leaders and staff, service plans, and fees. Such empowerment in PIM programs in the United States, Mexico, Andhra Pradesh, Madagascar, the Dominican Republic, and Indonesia have been a powerful incentive for farmers to support PIM and improve the performance of irrigated agriculture. Early efforts that did not include significant farmer empowerment, as in the Philippines, Sri Lanka, and Thailand, were not sustainable.
- Gender-sensitive irrigation design. It is crucial that irrigation development take into account the prominent part that women play in producing irrigated crops, appreciate their needs, and enable them to select appropriate technology to improve productivity. Additionally, it should be appreciated that returns on investment in women, in terms of social and economic objectives, are potentially enormous (Chancellor, Hasnip, and O'Neill 1999).
- Institutional mechanisms to ensure accountability to regulations and agreements among farmers, WUA leaders, water supply and agricultural services agencies, and government officials. Institutional tools such as performance contracts among government, agency, and users should be used to create effective individual and group accountability and incentives for meeting agreed objectives. Though central to institutional design, such tools have often been overlooked.
- Capacity to mobilize sufficient resources to cover management and capital replacement costs. Reform programs should provide the basis for ensuring the physical integrity of irrigation systems. This can be achieved only if reform design addresses the means of financing every aspect of irri-

gation system construction, management, rehabilitation, and modernization. These will usually include farmer financing of routine management and other cost sharing by users. (See IN 1.4 on Pricing, Charging, and Recovering for Irrigation Services.) Public financial assistance should be designed to support adequate investment in irrigation.

- Responsive governmental and private sector support services for WUAs. As WUAs take over responsibility for irrigation management and financing, they need institutional, managerial, and financial capacity building for both irrigation system management and agricultural development. Setting up a support system for locally managed irrigation is essential to make PIM viable and sustainable.
- Parallel efforts to make agriculture more profitable and environmentally sustainable for farmers. Without economically and environmentally viable crop production, PIM will not be sustainable. Efforts to make agriculture more profitable for farmers—and to protect watersheds—will be essential to make PIM work.

INVESTMENT OPPORTUNITIES

PIM reforms offer opportunities to invest in the following:

- Capacity building for board members, WUAs, WUA personnel, and agency staff members
- Testing formulas for management and governance improvement
- Strong economic and agronomic programs to raise water productivity
- Building high-level political commitment
- Preparing the agency for new roles in user capacity building, support services, and regulation
- Developing new cost-sharing arrangements for O&M, rehabilitation, and modernization

- Hardware improvement following adoption of new policies for farmer co-investment
- Defining a clear and strong legal status for WUAs
- Codification of water rights for WUAs and individual users

These elements should be designed in participatory forums to fit local conditions and be incorporated into policies, legislation, regulations, WUA constitutions and by-laws, criteria for cost sharing and assistance, and irrigation service plans and agreements.

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USEFUL LINKS

International Network on Participatory Irrigation Management: <http://www.inpim.org/>

International Water Management Institute (IWMI): <http://www.iwmi.cgiar.org/>

Training Kit on Gender and Irrigation: http://web.idrc.ca/en/ev-5427-201-1-DO_TOPIC.html

World Bank Electronic Learning Guidebook on Participatory Irrigation Management: <http://www.worldbank.org/wbi/pime/g/>

This Note was prepared by Doug Vermillion and Joop Stoutjesdijk, with inputs from Arunima Dahr, Eija Pehu, and Wendy E. Wakeman of the Gender and Rural Development Thematic Group, David Groenfeldt of the Indigenous Water Initiative, and Geoffrey Spencer. It was reviewed by Maria Saleth of IWMI.

INVESTMENT NOTE 2.2

INVESTING IN WATER RIGHTS, WATER MARKETS, AND WATER TRADE

This Investment Note discusses investment in the development of a legal framework for water entitlements, in the issuance of such entitlements, and in the use of market-based mechanisms that permit voluntary adjustment by owners and users to meet temporary or permanent changes in demand. Cultural and political attitudes toward water, and the role of the government in its allocation and management, must be taken into account when considering such investments. By itself, such a system of entitlements and market-based transfer does not guarantee good water resources management, but it is an important component of improved water system management.

Use of water without a formal framework for entitlements may result in the exploitation of this resource by the most politically and economically powerful users. A legally recognized and regulated entitlements system has proven an equitable and sustainable water management option.

After the initial issuance, entitlements need to be able to be adjusted to deal with changing demand, particularly where water supplies are limited or subject to droughts. Such adjustments may be for the short or the long term. Historically, readjustment was frequently based on government fiat, prompted by political pressures or as an improvised response to a crisis. The cost of such readjustments usually fell on poor small farmers. Experience in both donor and client countries shows that market-based, voluntary temporary, or long-term adjustments yield more equitable outcomes, because they compensate those giving up water supplies or entitlements.

INVESTMENT AREA

Investments in new or existing hydraulic infrastructure and irrigation projects provide a chance to introduce the basic concepts needed

for the issuance of water entitlements. Often, issuance requires changes in the legal and institutional framework, the cultural and political attitudes toward water, and the role of the government in its allocation and management.

Inclusion of water entitlements and a well-designed legal and institutional framework in lending for water sector infrastructure are necessary to make the investment sustainable and to target the poor inhabitants of the borrower country. Implementation requires strong long-term commitment from both lender and borrower. A system of entitlements and market-based transfer does not, by itself, guarantee good water resource management. It is only one component in an entire program. It presupposes an already sound water allocation and water entitlements system. Without solid legal protection, lack of confidence will prevent a market in those entitlements from developing.

POTENTIAL BENEFITS

A system of water entitlements, defined volumetrically, enforced through measurement and monitoring, and coupled with market-based mechanisms for transfer or trade may produce the following benefits:

- Equitable distribution of water resources among users and among sectors of use
- An equitable base for the collection of water use charges that reflect actual O&M costs
- A base for measuring use efficiency and for creating incentives to install new technologies that maximize the use of the resource
- An equitable method of adjusting entitlements to meet changing demand and shortages in a voluntary manner that compensates those giving up water supplies and shifts the opportunity cost of additional water to those acquiring it
- Elimination of ad hoc water allocation decisions by government in reaction to political or emotional pressures or short-term economic expediency

- Registration of the allocation and use of water supplies that provides a foundation for water sector planning and conservation on a river basin or regional level

POLICY AND IMPLEMENTATION

Many countries regard water as a free good to which all citizens are entitled and one that should be allocated and managed by the government. This view and the government authority that it implies are jealously guarded by the management agency. Its personnel tend to believe that users are not competent to participate in water allocation or management. This view has produced inefficient management and uncompensated expropriation of low-priority users during drought or periods of changed demands. It has also resulted in poor planning, unrestricted use, and infrastructure deterioration.

Assigning water rights can effectively address these problems. They can be used either as nontradable or as tradable entitlements to water abstraction and use. If tradable water rights can achieve higher levels of economic efficiency on one hand, their application implies major social and institutional changes on the other. Hence,

where the institutional environment is not considered mature enough to implement a water market, nontradable water rights can be an effective first step in that direction. The legal provision and application of water rights do not guarantee success in solving problems of over-exploitation, inefficient water use, or water conflicts. The design of the water rights framework has to be based on sound hydrological, economic, and social impact analyses. The lack of sound background studies can cause the system to fail, as was the case in Mexico until 2003 when the Water Rights Adjustment Program (WRAP) was initiated, with the Bank's assistance (box 2.4).

Water markets have many advantages for water reallocation with respect to nontradable permits, but the property rights structure has to be designed specifically for water transactions. Otherwise these markets are unlikely to work efficiently (Matthews 2004). Water markets can better address the issue of water resources sustainability when the traded rights are volumetric entitlements. Volumetric entitlements encourage users to manage the resource and to maintain the infrastructure in a sustainable manner. In combination with access to market-based, voluntary exchange

Box 2.4 The Role of the Water Rights Adjustment Program in Water Sustainability in Mexico

In Mexico's arid and semi-arid zones, a large part of the Irrigation Districts and Irrigation Units for Rural Development, supplied both by surface and groundwater, face serious problems. In many cases, irrigation areas, in general designed originally to meet the needs of their era and with the hydrological information then available, are now redesigned. The problem is worse in the case of groundwater because over the years the storage of many aquifers has been compromised. Excessive concession of water use rights, owing to a malfunctioning concession system, has compounded this problem.

In 1992, the National Water Law was approved to formalize water rights entitlements and record them in the Water Rights Public Registry. The application of the law caused the issuance of concession entitlements that far exceeded national water availability. The reason was that concessions were granted for 10 years, for the volumes that users said they were using, without any calculations made on the basis of water availability. Indeed, the objective of the norm was not to give concessions that would be sustainable but to enforce the registration of all water users in order to collect information for future planning and water allocation.

The Water Rights Adjustment Program (WRAP, or PADUA as it is known in Spanish) was launched in August 2003 to recover excessive concessions of water by means of economic incentives—and to contribute to refining water rights and turning them into a true instrument for integrated, sustainable management of water resources. The program has been initially applied in Sonora state. Useful lessons learned have been identified in a World Bank-funded study. The main recommendation of the study is to integrate the WRAP with other (already existing) regulatory measures, as well as social participation and economic incentives, so that it will be able to reconcile water user rights in Mexico with the actual availability of water resources.

Source: Author.

of water entitlements, volumetric entitlements give users economic incentives to use their entitlements and supplies efficiently. On the other hand, volumetric entitlements imply the setup of costly equipment (that is, measurement devices for pumped groundwater or abstracted surface water) for water measurement at each user abstraction node. When this is not possible (for technical or economic reasons), a proxy of the volume of groundwater used can be calculated by applying *formulas* based on the energy consumed (as in Mexico) or on pumping time. A different approach that does not need volumetric measurements at each consumption node is based on a priori allocation of water rights to water user groups. In Chile, an annual distribution of water is made to WUAs based on historical criteria. Most WUAs maintain their own registries in order to distribute water to rights owners effectively, even if these rights do not imply legal title, and hence do not permit water trade by an individual user (Hearne and Donoso 2005).

During shortages and periods of changing demand, high-priority users can compete in the water market, and those who voluntarily give up their entitlements are compensated at a rate determined by the market value of those supplies. This process automatically factors in the costs of modifying delivery and distribution systems and the higher value of the resource to the buyers. Two case studies in South Africa (Nieuwoudt and Armitage 2004) show that water markets are effective in transferring water from farmers with lower return per unit of water to farmers with higher return—for instance, large-scale table grape growers. Where crop profitability in the area is similar for potential buyers and sellers, water trade is unlikely to take place, because there are no willing sellers of water rights.

Water markets can be an effective way for allocating water not only within the agricultural sector, but also among different sectors, namely from the agricultural sector to the urban, industrial, and even environmental sectors. Applications of intersectoral water trade are still rare, even in developed countries. Recent experiences are those of South Africa and Australia. An important aspect to be considered in intersectoral water allocations through water trading is how to ensure that environmental requirements are met, guaranteeing, for example, a minimum flow to preserve endangered species or protect wetlands. A pioneering attempt can be found in the Council of Australian Governments (COAG) Water Reform Framework. This framework dictates that not all water is available for transfer, since enough water for environmental needs has to be preserved, according to the principles listed in box 2.5.

Market-based opportunities to improve environmental flows are also being considered in some developed countries but they are still at the level of feasibility studies (Siebert, Young, and Young 2000; Burke, Adams, and Wallender 2004).

The existence of water markets does not necessarily mean that equity and social impacts have been adequately addressed. The privatization of water resources, without management and

Box 2.5 Australia COAG Water Reform: Key Elements Concerning Environmental Allocations

- States, in formally allocating entitlements to water, have to include allocations for the environment as a legitimate user of water.
- Environmental requirements are to be determined using the best scientific information available and with regard to intertemporal and interspatial water needs.
- In the case of overallocated or stressed rivers, substantial progress has to be made in achieving a better balance in resource use and allocating water to the environment in order to restore the health of the river system.
- Jurisdictions would consider establishing environmental contingency allocations that provide for a review of the allocations five years after their determination.
- Where significant future irrigation activity or dam construction is contemplated, environmental requirements have to be adequately met before any harvesting of the water resource occurs.
- Give high priority to research necessary to advance the implementation of the strategic framework, including consistent methodologies for determining environmental flow requirements.

Source: High Level Steering Group on Water, Australia 1999.

monitoring by appropriate institutions, can turn out to empower a few rich groundwater owners at the expense of poor farmers. Evidence from Pakistan's Punjab state indicates that monopoly power in the groundwater market resulted in a substantial misallocation of resources (Jacoby, Rehman, and Murgai 2001). However, poor farmers would rather pay a higher price for a secure groundwater supply, even if it is monopolized by rich landlords, than pay minimal fees for an unreliable supply of canal water regulated by government agencies (Saleth 1998 and Meinzen-Dick 1998).

Moreover, market-based transfer mechanisms do not necessarily consider the impact of transfers on third parties, including the local economy. As an example, losses incurred by the providers of agricultural inputs and products may not be considered when water is transferred from agricultural use to a different use. In addition, one area's tax base may grow at the expense of that of another area that loses the water. In the U.S. state of California, community resistance in the selling regions has soured a number of water-trading deals over the late 1990s and early 2000s and has likely prevented others from being proposed. In addition, many of California's rural counties have introduced ordinances that directly restrict groundwater exports and indirectly restrict the sale of surface water (Hanak 2003). Hence, any system of market-based permanent transfers needs a regulatory authority that ensures that third-party impacts are considered and that the purchaser of the water entitlement bears at least a portion of the third-party impacts or losses. In addition, institutional mechanisms for preventing and resolving social conflicts need to be put in place.

Flexibility must be built into the law to allow adjustments and provide for a system of market-based transfers and trades. Borrowers are usually more comfortable with the concepts of annual temporary transfers and rental of entitlements than with provisions permitting permanent transfers. Confidence can grow only as the system develops. It would be rare to be able to implement every desired aspect of a water entitlement legal framework at the outset. The primary goal

should be the implementation of a legal framework that provides for issuance of volumetric entitlements to the users as usufructuary rights. The legislation should specify the role of government in issuing, enforcing, and protecting the use rights represented by the entitlements, adjustment that may be instituted during periods of scarcity, use priorities, and compensation for loss of supplies during water shortages.

Any system of permanent market-based water transfer mechanisms should be designed to minimize or mitigate third-party impacts. Each country requires a custom-tailored approach, because cultural, political, and social situations differ. Reforming the water sector involves political tradeoffs, institutional tradeoffs, and accommodations to historic precedents and philosophical rigidity. Development of a strong governmental policy requires a long-term program of education, marketing of ideas, and a strong champion within the governmental structure.

Boxes 2.6, 2.7, and 2.8 illustrate the diversity in the implementation of water sector reform.

LESSONS LEARNED

The major lessons learned from Bank and non-Bank projects are as follows:

- A legally and operationally solid water entitlement program is the foundation for sound water management and for water charges to support sustainable management and maintenance of water resources.
- Such an entitlement program is a precursor for a system of voluntary transfer of water entitlements to meet temporary and permanent changes in demand.
- Water rights and markets by themselves are not sufficient to guarantee beneficial effects on water allocation, economic efficiency, and poverty reduction. Only well-conceived institutional mechanisms can avoid unintended negative distributional and social effects from the application of sound economic principles.

Box 2.6 India: Maharashtra Restructuring and Policy Reform

Maharashtra state in India took bold and innovative action in 2002 and 2003. The World Bank was a knowledge partner when the Maharashtra government initiated a program to restructure water resources management functions. The program included the development and adoption of a State Water Policy; introduction of an act for the establishment of the Maharashtra Water Resources Regulatory Authority (MWRRA); introduction of an act (Farmers-Managed Irrigation Systems—FMIS) empowering the formation of WUAs and upper level associations (ULAs); and the drafting of an amendment act transforming the irrigation development corporations into river basin agencies. The FMIS Act mandated the transfer of O&M of minor canals and facilities to users, the transfer of upper level canals and reservoirs to the ULAs where rational, and the issuance of bulk water entitlements to the WUAs.

The MWRRA Act provides for the establishment of a system of water entitlements for every use sector, the regulation and administration of those entitlements, dispute resolution, and the future adaptation of market-based transfers of water entitlements, both on a temporary annual basis and on a permanent basis. This draft act is far reaching in that this new authority will have regulatory jurisdiction over entitlements for both surface and groundwater and will be responsible for promulgating criteria for sustainable water tariffs, water quality criteria and standards, and wastewater discharge permits.

This advance in water resources management policy was possible because of the strong support by the chief minister, the minister of irrigation, and the secretary of irrigation. With inputs from the Bank and its consultants, Maharashtra state crafted an act that satisfied the most important principles of water entitlements, market-based transfers, water tariffs, and water quality criteria. This act provides the basis for the evolution of a water entitlement program and the adoption of market-based transfers. A draft act is also being considered to transform five irrigation development corporations into river basin management agencies responsible for water resources management, issuance of entitlements, enforcement of water charges, and operation of key river basin management infrastructure.

Salient points in this important development are summarized below:

- A strong need to modify the water sector, created in part by the sector's financial crisis
- Recognition by state government leaders that changes were needed in the entrenched status quo in water resources management
- Early identification of key legislative action needed to facilitate the implementation of modern water resources management principles
- The World Bank's ability to provide technical assistance and guidance in these processes
- A task team leader who commanded respect and was dedicated to helping government reformulate its water policy and to restructuring the water resources sector along internationally recognized frameworks and principles
- Funding of technical assistance, iterative drafting process, and water sector education
- Open discussions with all related agencies and users regarding the potential benefits and impacts of the policy and institutional changes
- The tenacity of key government leaders in advocating these changes, while remaining receptive to major policy changes suggested by the Bank team
- Stability in the government and in the key state personnel during the lengthy period required to develop, refine, and introduce the key legislative actions

Source: Author.

- Initial issuance of entitlements should be based on rational beneficial need and historic use or carefully identified near-term development. Initial issuance should not permit monopolies on future entitlements or entitlements for largely speculative purposes.¹ It should also guarantee a minimum flow for environmental purposes.

- Adoption of a legal framework and implementation of a system of water entitlements can threaten entrenched interests and evoke

strong political opposition. If intense social or political conflicts occur, specific measures are needed to build confidence among stakeholders. Because it cannot be assumed that such legislation will pass, lending requiring such legislation should not be appraised until the laws have tacit governmental approval, and passage is imminent.²

- Implementation of water entitlements, particularly if coupled with the introduction of market-based transfer mechanisms, is an

Box 2.7 Chile: Market-Based Transfer System for Water Rights

To contribute to the knowledge of water markets in developing countries, the Limari Basin in Chile's Fourth Region was studied by the World Bank in 2000. This basin has two closely related markets for irrigation water: a spot market for volumetric water transactions and a permanent transactions market for buying and selling water rights. In the spot market, volumes of water are traded. In the permanent market, the purchases and sales of water rights take place over time. In the spot market during the 1999–2000 season, about 14 percent of the allocated water was reallocated through trades. In the dry 1995–6 season, that figure reached 21 percent. In the permanent market, from 1981 through 2000, more than 27 percent of water rights were exchanged independently of land transfers.

These figures support the hypothesis that, when efficient legislation allows private decision making, a water market can be an active mechanism for water reallocation. These facts should provide policy makers with strong incentives for considering the adoption of market mechanisms as effective tools for reallocating entitlements. In Chile, a water code that allows transfers of water rights, independent of land titles, has contributed to the development of an active market for water entitlements. The Limari Basin in areas downstream of storage facilities has an active water market in which the annual spot market and a permanent transaction market coexist. Key considerations are as follows:

- An annual distribution of water is made to WUAs based on historical criteria.
- Differences in the marginal return of water exist among farmers.
- Many farmers with nonperennial crops can, with relative ease, modify their water consumption by changing their planted area or crops. If the price of the spot market is greater than their anticipated net income from their own production, they are willing to sell their annual allocation on that market.
- Sufficient in-system storage capacity, the use of flexible floodgates, and the proper functioning of WUAs allow the exchanges to be accomplished administratively and physically.

Spot market

Because the distribution of water among WUAs does not coincide with the water demands of each WUA, large volumes of water are transferred among associations. This generates a significant flow of internal water transfers from farmers with lower marginal water returns to those with higher marginal returns. Between 1995 and 2000, 24 percent and 13 percent, respectively, of the total amount of water assigned to each of the two associations was transferred.

The area studied also has a fairly well-developed permanent market of water entitlements initially assigned by the state. Subsequently, these entitlements have been reallocated through the market. The percentage of reallocated water rights, independent from land transactions, during 1980–2000 fluctuated between almost 20 percent and almost 50 percent per WUA. Transactions began slowly and accelerated in 2000 toward the end of the study period. This reflects the maturation period required by a permanent transactions market, in this case almost 10 years. In the spot market, what is exchanged is a known volume of water during a specific season. A permanent market transaction transfers an asset that delivers variable volumes of water over time.

Conclusion

Both the spot market for temporary transfer or rental of water allocations and the permanent market for the transfer of water entitlements evolved after the enabling legislation was adopted. These still-evolving markets have become key tools in adjusting water allocations to changing demands and changing climatic conditions.

Source: Azevedo et al. 2000.

evolutionary process that may take many years. Long-term follow-through should be anticipated, with strong technical assistance and capacity building to continue after the loan ends.

RECOMMENDATIONS FOR PRACTITIONERS

- Explore the historic system and identify key areas that may be retained or modified to

further the acceptability of entitlements and market-based transfer mechanisms.

- Analyze the existing legal framework to ascertain the least change needed to accommodate the desired sector restructuring.
- Discuss the concept of water entitlements with leaders in the public and private sectors to gauge acceptability and to identify

Box 2.8 Brazil: Ceará Water Entitlements Program

In the early 1990s, Ceará state in Brazil embarked on a program to transform its system of water resources management into a rational and modern program. This still-evolving program has become one of the more successful experiences.

Water resources were primarily seasonally oriented, with water in the rivers only during the rainy season. Prior to 1992, anarchy reigned. Users upstream and close to storage structures received most, if not all, of the water. River water was available on a first-come, first-served basis with no limit on the volume or timing of use. In the late 1980s and early 1990s, the state began a reform to eliminate corruption and to rationalize water resources management. It established a legal basis for reforming the water sector for which an integrated Water Resource Management Plan laid the foundation. This innovative plan and accompanying legislation were the work of experts in water resources management and water law from the state, the federal university, and outside consultants.

Evolution

The plan was developed under pressure from growing industrial and tourism sectors demanding a stable and reliable water supply. First, state water resources had to be stabilized. Ceará began by educating the political leaders and the stakeholders, then followed up with legislative changes. The state was experiencing a severe drought, and the water supplies for the Fortaleza Metropolitan Region, the state's economic center, were insufficient. Major reservoirs were nearly depleted, and the entire economic and political system was focused on resolving this problem. A Secretariat of Water Resources (SRH) was formed, and negotiations with the World Bank were started to finance a water resources sector reform. The state's political and water resources management leadership had participated in an intensive Bank-funded study tour of water resources systems in the United States in 1993. The tour instilled an appreciation of the potential outcomes of reform. The reform process was fortunate to have political stability under two governors who were staunch reform advocates and together served for about 16 years. Kept informed of aims and implementation progress, these governors were strong driving forces for the reforms.

Legal and water rights framework

SRH was also charged with the establishment of a system of water entitlements. This system was key to the development of a rational program of allocation of the available water resources. SRH developed rules and regulations for the issuance of water rights and criteria for the incorporation of traditional and grandfathered rights. The initial water law was amended several times to reflect a growing knowledge and confidence within the political leadership and legislative body of the water rights process—and the development of awareness, along with the users and stakeholders, of the value of the concept. The state is now considering a pilot program for the use of market-based water entitlement transfers as a tool to allow water allocations to be adjusted to meet changing demands.

Source: Simpson 2003.

stakeholders, potential opponents, and potential advocates.

- Identify ways to win over opponents (for example, confidence building programs) and enroll advocates to improve chances for acceptance of changes in the legal and institutional framework.
- Begin a long-term program of education, negotiation, diplomacy, and public relations to sell these concepts to the key players in the public and private sectors.
- Support the drafting of key legislation and regulatory provisions with inputs by experienced and knowledgeable consultants over

a time frame that allows numerous iterations and discussions.

INVESTMENT OPPORTUNITIES

Any investment in the supply side of water resources offers an opportunity to invest in the development of the legal and institutional aspects of the management of the supply-side development and for the evolution of sound demand management. These include a strong system of water entitlements, the administration and enforcement of those entitlements, and a mechanism to allow that system of entitlements to adjust to meet changing demand patterns.

Any supply-side investment also offers a chance to develop entitlements and market-based mechanisms as a part of that investment.

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ENDNOTES

1. In Chile, water entitlements were initially issued based on beneficial need and historic use. Subsequently, an auction was held for the future use of surplus water resources. The main winners of this auction were the wealthy mining and energy sectors, which now hold a virtual monopoly in some basins on the future water supplies that can be developed.
2. See the Implementation Completion Report for the “Sri Lanka Mahaweli Authority Restructuring and Rehabilitation Project” (World Bank 2003).

This Note was prepared by Larry Simpson and reviewed by Maria Saleth of IWMI.

INVESTMENT NOTE 2.3

INVESTING IN BUILDING CAPACITY IN AGRICULTURAL WATER MANAGEMENT

Many borrowing countries are located in arid and semi-arid areas where the productivity of the agricultural sector is highly dependent on the provision of water for irrigation. A key investment target for developing this sector is therefore building capacity in agricultural water management.

With agriculture using more than 80 percent of the world's available water, improvement in the efficiency of water use is urgently needed. Growing populations around the world in the next 20 years will greatly increase demand on water for crops (SIWI/IWMI 2004). A great deal of water is being misused or mismanaged owing to weak institutions and poor water policies. The solution entails taking human and institutional processes and capacities more into account in the design and operation of hydraulic devices and infrastructure.

INVESTMENT AREA

The solution involves providing the right know-how to the stakeholders and improving institutions (IPTRID 2003). It requires capacity building at every level—from farmers to government. An integrated approach is needed that goes beyond training and brings wider issues into the picture: applied research and demonstration, technology transfer, community participation, effective governance, technical assistance, and institutional development. Capacity-building programs to assist developing countries in formulating sustainable agricultural water management strategies are a most important strategic investment need for international funding agencies because they act as seed funding for stable and sustainable economic growth.

Current thinking in most international financing agencies is that investment in a programmatic approach will lead to strong domestic drivers for investment. In line with this reasoning, this

Investment Note argues in favor of investment in the development of agricultural water management capacity. Capacity building should be part of an overall reform program with full policy support. Only a strong commitment by policy makers can create the conditions for trainees to use their new knowledge once they return to work.

POTENTIAL BENEFITS

The benefits of capacity-building programs in agricultural water management are outlined below:

- Higher irrigation efficiency and productivity for irrigated agricultural production (“more crop per drop”)
- Enhanced sustainable livelihoods for people involved in irrigated agriculture
- Protection for soils and reduction of waterlogging and salinization
- Protection for people and land against water damage through flood mitigation
- Collection of runoff through water harvesting
- Better water resources management to conserve water supplies and quality

POLICY AND IMPLEMENTATION ISSUES

Building capacity should always start by identifying needs and gaps in current capacity so that the best responses for specific needs can be selected. A brief description of possible responses for effective capacity building follows. The strategy will be most effective if it combines the right mix of interventions at different levels, according to the identified needs.

Training

Building capacity involves “in-depth” investment in graduate and postgraduate education in water resources management, focused on technical aspects (box 2.9) as well as on institutional issues (box 2.10).

Box 2.9 EIER-ETSHER Schools in West and Central Africa

The EIER-ETSHER Group (schools for agricultural engineering and water) was established in Ougadougou, Burkina Faso, to support development in 14 countries in West and Central Africa. Nearly 2,500 technicians and graduates have passed through their training courses, and the group is a successful example of integrated cooperation between countries to support capacity building. A principal local constraint is insufficient capacity building, which limits the development and management of irrigation systems. Thus the development of human resources, as provided by this group, is a key component in projects to improve food production and to reduce poverty. This initiative is a good response to the problems in training and education such as limited curricula, high operation costs, restrictions on the needs addressed (especially for nonscientific courses), and shortage of jobs suitable for new graduates.

Source: Compaore 2003.

Box 2.10 Indonesia: Water Sector Management

Some of Indonesia's capacity-building activities have focused on the development of capable institutions for sustainable water resources and irrigation management. This is a consequence of present government policy to transfer water management to farmers. The initiative has focused on the following:

- *Socializing the consequences* of decentralization policies, of introducing water resources management at the level of new river basin organizations, and of transferring management to WUAs
- *Defining new roles* for government organizations to be more service oriented, and for better coordination of stakeholders through improved management mechanisms
- *Strengthening the new organizations* to be more effective in their new roles (provision of accountability mechanisms and management transfer tools).

Source: Hofwegen 2003; Dedja 2003.

Knowledge transfer for water management

Multilateral and bilateral projects may create national capacity-building networks between donor and client countries. These networks can help match growing demand for capability with initiatives to build capacity, to develop educational services, and to promote knowledge about reforms needed in the water sector.

Research

Better linkages are needed between research and development (R&D) organizations and farmer groups. An example is the "Water Saving in Irrigation" research program implemented in Tunisia to respond to the challenges of overexploitation of shallow groundwater and irrigation with marginal quality water (box 2.11). The program has achieved research results but, more important, has built capacity in the broad sense and forged partnerships among Tunisian institutions. This has resulted in training for program staff and improved linkages between research and extension.

Box 2.11 Tunisia: The "Water Saving in Irrigation" Research Program

Research initially financed as a World Bank investment project (using an Agricultural Sector Investment Loan during 1992–7) was supplemented by a Water Sector Investment Loan (PISEAU). Seventeen R&D projects were selected and ranked by priority during a joint mission to Tunisia by the World Bank and the International Programme for Technology and Research in Irrigation and Drainage (IPTRID). The research results were to be integrated with the national research program, linked with international research, and integrated with the main government agency. To facilitate uptake, an integrated management system was created and multidisciplinary teams formed.

Source: Bahri 2003.

Institutional strengthening

Transferring irrigation management responsibility from government to WUAs demands the provision of sufficient support, and a comprehensively prepared capacity-building program (box 2.12).

Gender mainstreaming

Giving women a voice in the management of irrigation systems leads to more sustainable

livelihoods in irrigated agricultural regions. By integrating irrigation, gender, and nutrition as issues, improvements can be made in household food security, vulnerability of poor families can be reduced, and capacity can be built up in rural areas (box 2.13).

LESSONS LEARNED

Capacity development means much more than “training.” Unless farmers are given enough back-up, handing irrigation systems over to them will not work. When looking for the best opportunities in this sector, investors must take this and other key considerations into account.

Capacity-building strategy

Capacity building must address the needs of, and be “owned” by, the beneficiaries. It is strongly influenced by the policy environment and should always be in the center of development strategies. Identifying needs and gaps in capacity is difficult, especially if there is a local shortage of experts. Hence, this is a job for interdisciplinary experts who can work at a high level and with the full participation of stakeholders. The first step should be targeting priorities, based on analysis of the needs of the beneficiary government, authority, or community. To facilitate such analysis and priority setting, IPTRID and the Food and Agriculture Organization (FAO) are developing a generic methodology applicable to the agricultural water management sector.

Donor-recipient partnership

The role of donors in capacity building is to broaden thinking and to stimulate positive impact over the long term. Capacity building within existing institutions calls for improvements in local managerial capability and skills. Managerial capacity building should be a long-term activity with gradual, sustained change, especially in governmental settings. Making institutional changes is difficult because of low salaries, inappropriate recruitment policies, and slow organizational culture. For project success, international consultants sent to work on institutional modernization projects should have sufficient ability to implement

Box 2.12 Peru: Subsectoral Irrigation Project

Insufficient provision for the transfer of irrigation administration from the Ministry of Agriculture to user organizations in Peru resulted in inadequate organization of user groups, lack of knowledge about water use regulations, demise of systematic irrigation planning, and failure to collect fees. The immediate result was deterioration of schemes for lack of money to pay for maintenance. The Subsectoral Irrigation project (SIP) was launched in 1997 to solve these problems. It involved improving the irrigation infrastructure, strengthening WUAs, improving fee collection, assisting with modernization, and ensuring safety at four upstream dams. The SIP was funded by loan agreements with the World Bank and Japanese Bank for International Cooperation. The investment area of the SIP covered 10 provinces, 45 valleys, 64 user boards, 622 WUAs, more than 300,000 water users, and an irrigation area of about 900,000 hectares in Peru's coastal provinces. Successful training exercises for user boards, WUAs, and users resulted in the start of effective irrigation management and the collection of fees that now enable the system to be self-financing. The training programs were carried out by SIP Coordination Centers in conjunction with the users.

Source: Ledesma 2003.

Box 2.13 Zambia: Women Irrigation Network

The Women Irrigation Network (WIN) project used problem identification through participatory constraints analysis, community action planning, district stakeholders workshops, multisectoral WIN teams, participatory training and extension, and district-based monitoring frameworks. Outcomes were as follows:

- Increased capacity in government and community
- Synergy from partnering with NGOs
- Strengthening of local community groups
- Rural women's participation in water resources management
- Preparedness for drought, flood, and critical food insecurity.

Source: Phiri 2003.

management change over a long-term, difficult process. People working on these projects need, in addition to their own specific expertise, a participatory-minded outlook. The local organization acts as the point of contact for the donor and avoids the creation of new institutions (Walbeek and Vlotman 2003).

Education

Education is essential to develop the skills of the professionals who will become the future

managers, leaders, and capacity builders. This process should start with universities and higher education establishments.

Research

Research to solve the problems of irrigation and drainage can be most successful when linked to investment projects and can show its value directly. A good example of this has been the research project in Pakistan between the International Waterlogging and Salinity Research Institute (IWASRI) and the International Institute for Land Reclamation and Improvement (ILRI) (IPTRID 1997), addressing the functioning of farmer organizations and of horizontal and vertical land drainage. This research was shown to have saved millions of dollars in investment through improved advice on the technologies to be adopted.

Enabling environment

Farmer management of large-scale irrigation systems is unrealistic. Water management has to be structured so that governments are responsible for the main infrastructure, and farmers are responsible to local bodies such as WUAs and distributary boards. In this perspective, training farmers for water management is essential (box 2.14).

Box 2.14 Participatory Training and Extension Program

The participatory training and extension approach is based on analysis by the farmers themselves of their constraints and opportunities. The approach involves group-based extension, training to enhance farmers' skills and capacities, and capacity building of extension staff. It is a tool to improve farmer water management that involves and supports farmers. To achieve this, farmers need training and support in introducing improvements and new technologies.

The approach was developed within FAO's Food Security Special Program and was tested in Zambia, Nepal, Cambodia, and Bangladesh. The tools used include farmer field schools, staff-training methodologies (such as the Farmer Water Training Program in Indonesia), and farmer water management at the farm level (such as organizing water control).

Source: van Keulen, Smith, and Renault 2003.

RECOMMENDATIONS FOR PRACTITIONERS

Table 2.1 summarizes the activities that can be tailored into capacity-development projects.

INVESTMENT OPPORTUNITIES

Investment in capacity development

Investment in capacity development has to build on water management strategies that go beyond training and construction. Such strategies will help governments tackle poverty in rural areas by strengthening technology transfer and help build capacity to increase the technical and managerial know-how of farmers, farmer associations, and service providers. Identifying capacity constraints and helping governments and the private sector lift them is one effective way development institutions can help. Capacity has to be developed to measure, research, and understand; educate and create awareness; legislate and regulate; and provide appropriate infrastructure, services, and products.

Investment in responsible water management

Providing the knowledge and skills to use and manage water responsibly and efficiently to farmers, farmer associations, service providers, and government bodies, is essential to reduce wastage and increase water productivity. The problems in meeting growing water needs stem not only from water scarcity, but also from thin water management capacity.

Public aid investment in capacity building

Large areas in developing countries still suffer severely from poor water management; inefficient irrigation and drainage practices and technologies; lack of knowledge and know-how on the part of farmers, farmer associations, and service providers; and institutional weaknesses. As a response, integrated capacity-building projects are needed, instigated either by communities through self-generated realization and desire for betterment or by outside actors. Both are valid, and both feed into local government decision making. However, neither will succeed if the government departments from which support is needed do not have sufficient capability.

Table 2.1 Capacity-Development Project Activities

Activity	Local groups	Trainers and academia	Government and policy makers
Training sessions and workshops	✓	✓	✓
Enhancement of research capacities		✓	
Implementation of demonstration sites	✓		
Production of field guides and training material		✓	
Development of monitoring systems		✓	✓
Development of data processing and data management systems		✓	✓
Development of models and decision support systems		✓	✓
Development of planning capacities and management tools			✓
Assistance for institutional development	✓	✓	✓
Organization of national and regional networks	✓	✓	✓

Source: IPTRID 2003.

A good example is the water management transfer in Peru.

The types of project urgently required include the establishment of more training centers, experimental fields, demonstration sites, field guides, monitoring systems, water management units, and planning units, as well as the enhancing of local research, producing of training material, development of systems for monitoring and decision support, and strengthening of capacities for water management and planning. Without any exaggeration, capacity building in agricultural water management will require more than an estimated US\$1 billion a year in investments.

Investment in capacity building of local institutions

As public development assistance moves toward a program approach and budget aid, bottlenecks will arise owing to gaps in local institutional capacity. These institutions are key players and need support in needs assessment, research, strategic planning, project identification, project design, project management, and evaluation. Without such support, they face considerable

difficulty in achieving the high standards in project proposal preparation demanded by investment institutions—particularly to ensure that projects are technically feasible, economically and financially viable, designed and planned according to professional standards, and intended to produce visible and sustainable outputs. They should fit into coordinated programs, follow a sector strategy, and contribute to poverty reduction and environmental conservation.

Developing countries need support in preparing national agricultural water management strategies, but they also need assistance in project planning and fundraising negotiations.

Development institutions also need local advice on needs assessment for capacity building and on appropriate investment strategies in the sector.

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This Note was prepared by Geoff Pearce, with inputs by Adel Bichara, and reviewed by Maria Saleth of IWMI.

INNOVATION PROFILE 2.1

DRIVERS OF PUBLIC IRRIGATION REFORM IN AUSTRALIA

What is new? The policy rationale for reform of the public irrigation sector is rarely sufficient to implement it. Rather, implementation usually needs impetus from powerful domestic stakeholder groups in society at large that pursue goals requiring reform of the governance and management of government-owned schemes.

Before its reforms, the government of New South Wales, like other Australian state governments, built schemes, allotted landholdings and water rights, set water prices, and managed water distribution. In earlier times, the government even told farmers what and how much to plant. The two main social goals that drove scheme building were to increase inland settlement and reintegrate soldiers decommissioned after major wars. Most farms were sized to maintain a family but only with intensive irrigation. This type of scheme takes in around 30 percent of all irrigation water in Australia. The departments responsible for the schemes had a monopoly on service provision and little compulsion to put their customers first. The department in New South Wales serviced more than 400,000 hectares through works that today would cost more than US\$1 billion to build.

The government and the irrigation-scheme communities were uncomfortably settled in an antagonistic relationship. Officials perceived the irrigators as recipients of government largesse in the form of sizable but hidden subsidies for O&M. The irrigation communities perceived the government as using yesterday's costly methods and resented the paternalism of agency officials. There was little meaningful communication: the irrigators opposed price increases because they believed efficiencies could be found—and fearing a price war, the agency did not introduce new technologies.

OBJECTIVES AND DESCRIPTION

About 1980, three challenges arose. Massive expenses loomed for the renewal of the aging infrastructure. The quality of land and water was deteriorating because of rising water tables and salinity, and aquatic environments lacked sufficient water inflow owing to intake by irrigation.

At that time, too, Australia traded its economic policy of protectionism and subsidization for a policy of openness and economic rationalism. To compete on global markets, the business community needed a reduction in the government's share in the economy, and consequently a reduction of the sizable hidden subsidies that went to public irrigation schemes.

As evidence emerged that irrigation land use practices were ecologically unsustainable, an environmental lobby arose that promoted awareness of the deteriorating water situation among state and local governments, irrigators, and voters. The lobby advocated changes to make more water available for environmental uses by restricting water for irrigation.

Irrigators and industrial and environmental users were finding that the reliability of the water supply, critical for the profitability of livestock and production, decreased as irrigation development increased.

The combined impact of the business community, environmental groups, and expansion forced government and irrigators to seek a new institutional paradigm. The nonirrigation stakeholders shaped the new institutional framework, which revolved about irrigation corporations with licenses defining environment targets.

OUTPUTS AND IMPACTS

Water management in New South Wales changed in response to these drivers. In the early 1980s, the government introduced temporary and permanent trading in water allocations. In the late 1980s, it established irrigator-driven management boards for the irrigation schemes. In the early 1990s, it corporatized its metropolitan water utilities.

A suite of agreements entered into by COAG reflects the direction of reform in Australia. The 1995 agreement included the following commitments:

- Full cost recovery for water services
- Water allocations and property rights
- Promotion of water trading
- Introduction of environmental water allocations and assurance that all new projects would be environmentally sustainable
- Institutional reform promoting integrated natural resources management, separation of services from water resources management, and promotion of local management responsibility

The Commonwealth government offered substantial tranche payments to each state that demonstrated sufficient and timely reforms in terms of the agreements. These agreements enshrined the initial concerns of the business community and the environmental groups and are powerful drivers for change. Similar institutionalization of new stakeholder positions can be observed in Mali and Mexico (boxes 2.15 and 2.16).

ISSUES FOR WIDER APPLICABILITY

By dealing with each irrigation scheme as the bulk entity, the New South Wales government could keep the regulatory regime simple, giving each irrigation corporation flexibility on how to achieve its supply, drainage, and environmental targets. Communities have greater trust in companies they own and managements they elect than in government agencies. Irrigators are more accepting of the rules set in an environment they can influence than in rules set where their views count for little.

As a result, policies supporting sustainability are much tougher than government regulation would achieve. Examples are the ceiling on average water application of 4,000 cubic meters per hectare per year, and compulsory testing of soil suitability for rice growing. Before the reforms, an “us and them” attitude meant that irrigators made a sport of breaching government rules. Now irrigators see abusers as “ripping us off.” Peer pressure among farmers, help with emergencies, and companionship obtain compliance more easily than government enforcement but are available only to governments that form healthy coalitions with local communities.

Several factors contributed to these negotiated outcomes. The process was not rushed, and

Box 2.15 Mali: Coalition Building for Reform

In 1978, the government of Mali requested the World Bank to expand its 45,000-hectare rice scheme. The Bank and bilateral donors responded that reform should precede expansion. The agency lacked financial transparency and accountability to the users, and the users lacked incentives to produce, because they were forced to sell their paddy to the agency. The government opposed reform. The donors built support by trading funding for canal rehabilitation against small reform steps such as the creation of canal and credit associations. One donor also entered into a temporary alliance with the single political party to introduce movable threshers, which made the farmers independent of the agency’s industrial threshers, and movable dehullers, which reduced the workload of women and further increased farmer autonomy.

These steps helped liberalize the rice market and raise producer prices, which encouraged farmers to raise production by leveling their fields and buying inputs. Another donor negotiated joint farmer-agency committees to manage O&M spending. These and other actions made the scheme financially sustainable and transformed the farming population, from the resource-poor group it was in 1978, and lacking professional organizations, into an assertive and informed stakeholder. In 1992, the group helped a new government decide to consolidate these reforms into law. Now farmers have performance contracts, and donors fund expansion.

Source: Aw and Diemer 2005.

Box 2.16 Mexico: Drivers Shaping Irrigation Reforms

Mexico's irrigation transfer program has attracted much attention, but the forces shaping it have stayed in the background.

In 1976, the Secretariat for Hydraulic Resources, which ran the government's 3.6 million hectares of irrigation systems, was merged with the Ministry of Agriculture. The bureaucracy lost its financial and administrative autonomy, and the service fees were incorporated into rural development district programs. Farmers realized that they no longer had an incentive to pay, and the systems deteriorated.

The dilapidation of the infrastructure helped the agency argue for the restoration of its authority with the president-elect, who sought to transform the long-ruling Institutional Revolutionary Party's (PRI) economically inefficient patronage structures by encouraging private investment and economic liberalization. In 1989, the agency convinced the president-to-be to direct the water bureaucracy to create and run an innovative fiscal system for integrated water resources management to respond to Mexico's water woes. The agency also sought authority to operate and maintain the irrigation systems again but, in line with his objectives, the president limited the agency's role to oversight and opted to transfer irrigation management authority to user associations. All in all, the water bureaucracy's new mandate restored its final authority over the irrigation systems.

Main drivers of the reform thus were the domestic nonirrigation interests that pushed the president to pursue economic liberalization and political modernization and the agency's quest for renewal of its mandate.

Sources: Manuel Contijoch, personal communication, Washington, DC, 2004; Rap, Wester, and Perez-Prado 2004.

public participation in planning for change was well managed. Despite initial antagonisms, the dialogue among key players was meaningful and led to commitments for change. Government efforts to build trust at every level fostered cooperation over time because trust and cooperation were reciprocated and not misused or exploited.

A general message that can be derived from the Australia, Mali, and Mexico cases concerns the importance of building coalitions among stakeholders to drive policy reforms in the irrigation sector. Donors can have a major role in the coalition-formation process by facilitating dialogue and participation of stakeholders in the negotiation phase. These coalitions can take various forms and involve parties with different objectives but common means. For example:

- Coalitions of different nonirrigator stakeholders (such as industrial and environmental lobbies), using their political pressure to induce the government to implement reforms
- Coalitions of donor(s) and political parties or other lobbies for the introduction of step-by-step reforms

- Joint committees made up of farmers and agency representatives to manage O&M of irrigation systems
- Coalitions of water agencies with ranking political leaders in an effort to reach broad economic and political objectives through improved water management

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This Profile was prepared by Tony McGlynn, with input from Philip Keefer.

INVESTING IN FARMER NETWORKS FOR INCLUSIVE IRRIGATION POLICY PROCESSES IN SOUTH INDIA

What is new? By forming state-level networks registered as societies or NGOs, representatives of WUAs attempt to play a larger, structural role in irrigation policy formulation and implementation. By getting themselves included in these policy processes from which they are normally excluded, farmer-irrigators hope to accelerate reform, make it more pro-farmer, and increase the accountability of government.

Irrigation reform and larger participation of farmers in irrigation management has been on the Indian policy agenda since the 1970s, but progress has been slow, and reform design confined to a narrow circle of senior bureaucrats and some water academics and professionals. The lack of a broad-based consultation of all relevant stakeholders has made the reform process vulnerable to personnel changes. Also, the content of the reforms scarcely questions the exclusive government control over allocation and distribution of water and other resources—a questioning that is necessary for management practices to improve. The strategic analysis of the actors in this innovation profile was that, unless farmer-irrigators actively *demand*ed and shaped the reform, progress would be slow and haphazard.

OBJECTIVES AND DESCRIPTION

In 1997, some water professionals set up an organization called *Sahayoga* [work together]. They planned to act as brokers between farmer-irrigators and government using their wide experience and varied networks. The group held meetings with farmer-irrigators in the large irrigation systems of the South Indian state of Karnataka, where they presented Sahayoga's analysis. Asked whether they

would be interested in taking action, the farmer-irrigators responded affirmatively—and enthusiastically. Quickly, system-level federations of WUAs were formed in eight major irrigation systems.¹ Interactions with government and ministers started around specific issues such as whether to register WUAs as societies or cooperatives subject to some government control and the implementation of maintenance contracts.

Sahayoga succeeded in placing a farmer who was well versed in tank systems on the technical committee of the Society for Water Resource Development, Karnataka's implementing agency of a World Bank-supported project for community-based tank restoration.

The idea of an “intermediary organization of water professionals,” which also had farmer members, worked for several years, but the organization ran into disagreements among the water professionals. The farmer members decided that they wanted their own organization to allow them to interact directly with the government. In 2002, they formed *Pragathi* [Farmers' Society for Rural Studies and Development], which continued the activities, with one nonfarmer executive director based in the state capital acting as facilitator. *Pragathi* publishes a newsletter in English and Kannada that reports on its activities and in which members report their experiences.

Karnataka's ministers for water resources and agriculture acknowledge and appreciate the active involvement of *Pragathi* members in policy matters. The chairperson and secretary of *Pragathi* are nominated members of the Karnataka State Agriculturalist Society. Negotiations are also on to include farmer-irrigators as resource persons to train farmers at the Water and Land Management Institute. As a regular course of action, *Pragathi* attempts to ensure farmer participation in workshops and conferences at all levels in water- and agriculture-related issues.

Karnataka adopted a dual approach in implementing the community-based tank restoration

program—the state department implements it in a different way from the World Bank–supported project. Pragathi is mobilizing district-level tank federations to address issues such as structure, functions, and sustainability of tank user societies, which the irrigation law does not define well (table 2.2).

In 2003, farmers from Andhra Pradesh and Tamil Nadu discussed the possibility of forming similar networks in their states, each with its own obstacles in the irrigation and water resources reform process. Farmer-irrigators presented papers on the status of irrigation

reform in their state; new issues in water management such as environment and gender; and the possible role of farmers in interstate water dispute resolution. Again, the response was enthusiastic. Formation of farmer networks in Andhra Pradesh and Tamil Nadu is ongoing, and a South Indian federation called *Jala Spandana* [South India Farmers Organisation for Water Management] has been formed and registered. The International Network on Participatory Irrigation Management supports strengthening (as of 2004). The objective is to formulate state-level farmer water policies by the end of the project.

Table 2.2 Projects Implemented by Pragathi

Year(s)	Project title and activities	Budget(s)^a (Indian Rs.)
1997–2002	<i>Sahayoga</i> (NGO-initiated activities; <i>Pragathi</i> formed in 2003; <i>Sahayoga</i> continues independently) Supported under Collaborative Work Programme between Irrigation and Water Engineering group, Wageningen University, the Netherlands, and Water Cluster at the Agricultural Research Department, World Bank (funded from Dutch trust funds)	315,000
2002–	<i>Pragathi</i> members contributed cash and organized meetings at own expense (ongoing)	125,000
2002–3	<i>Farmers, Water and Political Process of Policy Reforms—Role of Farmers' NGO in Water Resource Development in Karnataka</i> Supported by Technology, Labor Organization and Development, The Netherlands (completed)	192,937
2003–	<i>Information Framework for Water Management</i> Supported by Management Studies Department, Indian Institute of Science, Bangalore (ongoing)	79,500
2004–	<i>Compendium of Water Disputes in South</i> In collaboration with World Wildlife Fund and International Center for Research in the Semi-Arid Tropics, Hyderabad (ongoing)	182,200
2004–	<i>Farmers Network for Water Sector Reform in South India</i> ^b Supported by the International Network for Participatory Irrigation Management, Washington, DC (ongoing)	1,677,000 ^c

a. Early 2004 US\$1 = Rs. 45.
b. Project formally comes to Jala Spandana (South India Farmers Organisation for Water Management) and Jala Spandana allocates equally to three state organizations in Andhra Pradesh, Karnataka, and Tamil Nadu.
c. Budget for 12 months, January 2004 to December 2004, for activities in three states.
Source: Authors.

APPROACH

- The networks are farmer organizations, with only farmer-irrigators as members. The members decide the agenda, priorities, and the pace of activities.
- Facilitation is provided by individuals with substantive field research experience in irrigation and water management, as well as in social mobilization and advocacy.
- The organizational infrastructure of the networks is light, and partly uses existing farmer and water user organizations.
- The perspective is long term, even when concrete activities center on immediate issues.
- The networks started with large irrigation systems, then moved to cover tanks, lift irrigation, and watershed and farmer-managed systems, with the scope broadened to include land and water management issues. The social constituency of the networks will also be broadened. Everybody knows that reforming the governance and management of water resources will be a long, perhaps never-ending, process.
- The idea is that taking NGO-style initiatives for improved local water management is not enough. Local issues have to be raised to the policy level to accomplish the changes in policy that will allow local initiatives to work and last.

OUTPUT AND IMPACT

The main focus has been to get government to acknowledge the need for and feasibility of a larger role for farmer-irrigators in policy formulation and implementation. This effort has centered around issues such as the legal status of WUAs in government policy (societies with full farmer control versus cooperatives with more possibilities to influence government) and who should implement local maintenance contracts (contractors identified by the government agency or WUAs). Extensive direct interaction has been triggered between farmer-irrigators and water resource ministers.

An open question still is the institutionalization of such interaction. In Karnataka, WUA federations at system and state levels are now part of the new policy, which may be the beginning of more inclusive policy processes. However, a change from a fully government-controlled policy system to a multistakeholder situation is a conceptual, institutional, and political leap that will take years to consolidate.

The network and federations are now players to be reckoned with in the state of Karnataka, but this achievement requires continuous reproduction and harbors several contradictions. The formulation of water policies will be an interesting test of the ability of the system to work with policy processes that include the irrigator-farmers.

WIDER APPLICABILITY

If it is true that irrigation and water sector reforms are hampered by the exclusion of direct stakeholders from policy formulation, there is wide scope for farmer organizations to participate in policy reform. So far, programs for participatory irrigation management have been largely government focused and have viewed water users and irrigators as recipients of policy, not as agents in the policy process. If political will for reform has to be generated, direct stakeholders would logically have to be a primary constituency, generating, in coalition with others, momentum for change. (See also box 2.15 in IP 2.1 on reform drivers.)

An important device for network building is the establishment of a communication device for the members—a newsletter, in this case.

Farmer networks for water sector reform have to be rooted in the farmer-irrigator community, not externally imposed. This requires small-scale, strategic, and patient support of emerging initiatives, rather than time-bound, project-wise, external approaches dominated by “experts.”

Intensive field research leading to detailed knowledge of field situations is an essential element in the preparation of initiatives and support and in building credibility in the farmer-irrigator community. A logical step in

the empowerment of the networks would be to create a facility for research defined by farmer water users (a water users' research facility) to generate the knowledge base for engagement in the policy process.

ENDNOTE

1. The systems are Krishnaraja Sagar, Harangi, Hemavathy (Cauvery Basin), Upper Krishna Project, Tungabhadra, Bhadra, Malaprabha, and Ghataprabha (Krishna Basin).

This Profile was prepared by R. Doraiswamy and Peter Mollinga, and reviewed by Maria Saleth of IWMI.

3

INVESTING IN THE IMPROVEMENT AND MODERNIZATION OF IRRIGATION SYSTEMS

- Investment Note 3.1 Lending for On-Farm Water-Saving Technologies
- Investment Note 3.2 Investing in Irrigation for Crop Diversification
- Investment Note 3.3 Investing in Smallholder Irrigation
- Investment Note 3.4 Selecting Technologies for the Operation and Maintenance of Irrigation Systems
- Investment Note 3.5 Cost-Effective Operation and Maintenance of Irrigation and Drainage Projects
- Investment Note 3.6 Using Satellites to Assess and Monitor Irrigation and Drainage Investments
- Investment Note 3.7 Prioritizing Lending for Public Irrigation Schemes with the Rapid Appraisal Method
- Innovation Profile 3.1 Investing in Automation and Centrally Operated Irrigation Systems

OVERVIEW

In this chapter, the focus is on investing in irrigation management and service delivery, illustrating improvements that give farmers reliable service and thus enable them to increase their incomes. The chapter also covers technologies and management systems available to encourage water saving, ranging from micro-irrigation installations on farms to an innovative system of regulation through the assignment of “evapotranspiration (ET) quotas.”

IRRIGATION MODERNIZATION HAS SO FAR PRODUCED DISAPPOINTING RESULTS. With most of the world’s irrigation already developed, and with very high costs for new development, the challenge is to get more out of existing systems. The scope is enormous for efficiency gains in large-scale irrigation. Irrigation efficiencies worldwide are well below technical maxima, water-efficient technology is used on only a small area, and intensification and diversification are happening but slowly. Yet “irrigation modernization” has been disappointing: a recent study could not find a single example

of a successful modernization package in a World Bank–financed irrigation project (Burt and Styles 1999). Successful modernization investment requires attention to economic, technical, managerial, and market considerations—within an integrated approach. Only after a clear vision has been established for developing an area’s agricultural potential can investment objectives be set. The diagnostic phase using the Rapid Appraisal Procedure (RAP) can then be approached with the real future objectives of irrigation systems in mind. (See IN 3.2, IN 3.5, and IN 3.7. Other chapters cover the incentive framework [IN 1.5, IN 1.4] and the market environment [IN 1.3]. For on-farm improvements, see IN 3.1 and IN 3.3. For irrigation modernization technology, see IP 3.1.)

THE GOAL IS TO IMPROVE WATER USE AND FARMER INCOMES, THUS CREATING A “VIRTUOUS CIRCLE.” Investment in irrigation improvement is justified—and risks for farmers reduced—only if the system delivers the high and reliable level of service that allows users to optimize water use and diversify into higher-value production. Farmers well-served by irrigation systems can improve efficiency and incomes and can afford water charges. This is the “virtuous circle,” the opposite of the old downward spiral of poor service, low cost recovery, system degradation, low-risk and low-value cropping, and ultimate need for rehabilitation. (See IN 3.2 and IN 3.7. See also “Investments in Irrigation for Crop Diversification,” in *Agriculture Investment Sourcebook* [AIS], Module 8.)

IRRIGATION MODERNIZATION HAS TO FOCUS ON DELIVERING COST-EFFECTIVE SERVICE TO FARMERS. The recent focus in large-scale irrigation investment has been (correctly) on improved governance and on system upgrading to improve water control. Yet these investments have focused on major capital projects such as canal lining and on computer modeling, rather than stepping back and looking at the problem to be solved—poor service to farmers and its economic and environmental consequences. A new benchmarking tool using RAP has been developed to help select investments. RAP first analyzes internal processes such as operating

rules, budgetary processes, and hydraulic structures. It then benchmarks those internal processes along external indicators such as irrigation efficiency, crop yield, and the environment. The last step is to prioritize the internal processes that must be improved through investment to affect the external indicators. (See IN 3.7 and IP 9.4.)

INTEGRATED INVESTMENTS STAND THE BEST CHANCE OF SUCCESS. Many factors affect water use productivity. These include soil characteristics (soil fertility, fertilization, drainage, soil salinity and sodicity, breeding); agronomic factors (plant variety, cropping patterns); crop management practices (tillage, weed control, soil moisture management); irrigation practices (irrigation scheduling, deficit irrigation, irrigation technology and technique); and inputs, credit, markets, and prices. Investment packages should integrate “hardware” improvements with improved irrigation management, better crop selection and management, and access to profitable market outlets. (See IN 3.1, IN 3.3, and IN 3.6.)

PHYSICAL SYSTEMS MAY NEED TO BE ADAPTED. As farmers diversify, they are confronted with the technical challenge of adapting a rigid and uniform irrigation system to a more varied cropping pattern. Higher-value crops need guaranteed, controlled-flow water delivery directly to the plot, together with good drainage. Soil management and land consolidation may be necessary, too. Physical systems may have to be adapted, for example from open channel to pressurized pipes. Investments need to incorporate an integrated approach. (See IN 3.7 for diagnosing the problem, IN 3.2 and IN 3.4 for technical solutions, and IN 3.5 for management approaches.)

USERS HAVE TO BE PARTNERS IN MODERNIZATION PROGRAMS. The cooperation of users is critical to successful outcomes from modernization investments. There should be a clear up-front agreement on service levels, technology, and roles and responsibilities. For example, where farmers install field irrigation system improvements such as micro-irrigation, they have to work with scheme management to agree on technology

and on subsequent management of the inlet structures. Already farmers on many schemes finance all their own on-farm investments in micro-irrigation and the like. As diversification continues, driven by market forces, farmer investment will grow. And as farmers share more of the costs and take on more of the responsibility, their share in driving change will grow. This participation underlines the value of the water user associations (WUAs) discussed in chapter 2. (See IN 3.4. On participatory irrigation management and user associations, see IN 2.1.)

MANY INVESTMENTS CAN CONTRIBUTE TO ON-FARM WATER SAVING—BUT IN THE END IT WILL ONLY HAPPEN IF THE FARMERS THEMSELVES ARE BOTH MOTIVATED AND ENABLED. On-farm technologies such as piped distribution, drip, and bubbler are widely available, and can cost as little as US\$250–\$500/hectare. Treadle pumps that can irrigate up to 0.5 hectare using family labor cost only \$50–\$100. A wide range of water management and crop management improvements is known. Yet adoption of water-saving technologies has been slow and performance below potential. Investment in water saving will be optimal in the private and public interest only where both available technology and favorable incentive and institutional structures are present. In the end, the incentive structure is the key: if water is too cheap, markets are dysfunctional, or water rights are insecure, and farmers will not save water. In the end, only the prospect of higher farmer net income and lower risk will drive investment and water saving. (See IN 3.1 and IN 3.3. On the role of markets and incentives in general, see IN 1.5.)

COMPLEMENTARY INVESTMENT IN MARKET DEVELOPMENT MAY BE NEEDED. The objective is a sustainable increase in farmer incomes. Thus, the availability of profitable crops and markets is an important element in the success of modernization. Some complementary investments may be needed to develop product markets, financial markets, and market information and to build infrastructure (for example postharvest investments, or rural and farm access roads). (See IN 3.2. See IP 1.2 on linking smallholders to international markets. See also “Market-Driven

Diversification,” in AIS, Module 4, and “Supporting Market and Supply Chain Development,” in AIS, Module 6.)

IRRIGATION INVESTMENT, COMBINED WITH OTHER FACTORS, SHOULD BRING MORE INCOME FOR LESS WATER. Better control of irrigation water, combined with the other factors listed above, should result in higher cropping intensities, higher-value crops, and higher farmer incomes. One project described in this *Sourcebook* specifically targets more income for less water as its objective (the Hai Basin project), using ET quotas to assign rights and working with farmers not only on irrigation, but also on a broad range of improvements in agronomy, crop husbandry, and general management practices. The project uses satellite imagery to determine quotas and to monitor use. Output in the area is likely to be maintained, and expanded after completion. This is an optimal investment outcome of more income for less water—and it is sustainable. (See IN 3.1 on the benefits of water control, and IN 3.6 and IP 8.1 on ET quotas and the use of satellite imagery, including the Hai Basin project.)

CARE IS NEEDED TO ENSURE A PRO-POOR ELEMENT IN MODERNIZATION INVESTMENTS, BECAUSE A PURELY MARKET-DRIVEN APPROACH WILL FAVOR THE BETTER-OFF. An element of inequity pervades all irrigation, because the very poor do not control water resources. Diversification does create employment, but the better-off farmers benefit most, because they can finance on-farm investments, assume risk, and access knowledge and information services. To offset this, investments can be targeted toward the poor. For example, priority can be given to small-scale irrigation and water conservation investments, which are pro-poor, highly flexible, and rapidly implemented. Conversion of public surface irrigation schemes may also be a pro-poor investment. For the very poor, investment in treadle pumps has allowed farmers in Africa and Asia to more than double their income. (See IN 3.1 and IN 3.3. Other chapters cover inequitable resource distribution [IN 7.1] and innovative ways to bring irrigation to the poor [IP 1.2]. See also “Targeting Agricultural Investments to Maximize Poverty Impacts,” in AIS, Module 11.)

SOME TYPICAL INVESTMENTS

Investments in technical assistance projects include the following:

- Performance-oriented rapid appraisals for public irrigation
- Technical benchmarking
- Customer satisfaction surveys
- Development of operation and maintenance (O&M) plans
- Data collection and ET measurement

Individual investment projects include the following:

- Modernization of water distribution systems
- Water measuring devices
- Advanced technologies for water control
- Desilting works

- Canal lining
- On-farm development
- Micro-irrigation, greenhouses, tunnels, and mulching
- Pressurized irrigation and protected agriculture: sprinklers, localized and piped, and drip

Finally, possible pilot investments include pro-poor smallholder irrigation programs, and other related investments include extension, and financial and credit service development.

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INVESTMENT NOTE 3.1

LENDING FOR ON-FARM WATER-SAVING TECHNOLOGIES

Water saving on farms located on public irrigation schemes has lagged behind saving on private farms with their own source of water. The few programs introducing field-level modern water-saving irrigation technology and management practices on public irrigation systems have had limited success. Experience in Tunisia, the Republic of Yemen, and elsewhere demonstrates that a mix of farmer investment with government subsidies has the greatest impact on both water saving and incomes through switches to more rewarding crops and reduced pumping costs (FAO 2003).

Government-owned irrigation systems perform poorly in terms of water productivity. This is due to poor irrigation water management on both the scheme and the farm (FAO 2001a). Inefficient surface irrigation methods still prevail (box 3.1). Overall irrigation efficiency in 93 developing countries was estimated at 45 percent in the late 1990s, which means a loss of more than half the water mobilized for irrigation. Part of this loss returns to the system; the rest is captured uselessly. The best opportunities for producing more with less water require shifting to demand-driven water management and using improved on-farm water management hardware and software.

INVESTMENT AREA

The amount of water that could be saved by 2025 by achieving 70 percent irrigation efficiency on the world's gross irrigated area could meet about half the demand for additional water supplies (FAO 2001b). Such savings are the main option for addressing water shortage challenges in many developing countries.

Irrigation technologies and management tools that permit high water use efficiency open avenues for water saving. On-farm irrigation infrastructure and equipment include improved

surface irrigation methods and sprinkler and localized piped systems that come in a multitude of versions. The management tools comprise all the ingredients necessary to ensure that the systems are adequately operated and maintained.

The adoption of such water-saving technologies and practices has been slow. The initial capital investments for these systems vary according to the method of irrigation and type of installation, in addition to regional variations. The average costs of piped irrigation systems range from less than US\$500 to more than US\$6,000 per hectare. These costs are lower for piped surface methods, followed by conventional hand sprinklers, and higher for micro-irrigation fixed installations. Capital costs are generally recovered from the benefits within two to seven years.

Affordable micro-irrigation technologies have also proven cost effective and competitive. They are adapted to smallholdings, raise incomes, and stimulate the development of local markets, particularly in Sub-Saharan Africa and mountainous regions in Asia and Latin America. In semi-arid regions, the coupling of low-cost irrigation technologies with water conservation and harvesting technologies allows better control of limited water resources and results in much higher returns to farmers. Small-scale, low-cost irrigation is simple and can be supported and easily managed by farmers in an efficient and sustainable manner. Investment costs in small-scale, low-cost irrigation range between US\$200 and US\$500 per hectare. The rates of return can be substantial (see IN 3.3).

Box 3.1 Old-Style Water Investments

Public investment in irrigation used to mean building water conveyance and distribution networks to deliver water to the farmgate, not promoting on-farm water-saving technology. Moreover, investment focused only on infrastructure and equipment at the expense of farm-level management. These investments now constitute sunk funds that can generate profits by upgrading the technology, improving management, and involving the private sector.

Source: Author.

POTENTIAL BENEFITS

The main expectations from investment in improved on-farm irrigation techniques are the benefits derived from saving large amounts of water, lower operational costs, higher crop yields, and better produce quality. The benefits often also include substantial savings in irrigation labor, better weed control, reduced risk of waterlogging and salinization, less drainage effluent, less mobilization of contaminating salts and nutrients, and longer life expectancy for pumping equipment. Moreover, better control of irrigation water usually results in higher cropping intensities and more rewarding cropping patterns. If farmers are well connected to markets, these benefits translate into economic returns to farmers, and benefits for regional and national economies. When irrigation projects for improved on-farm irrigation technologies are well designed, properly implemented, and adequately managed, the investment returns are comparable to investments in sectors such as industry (FAO 2004). These benefits stem from the many advantages that improved irrigation techniques offer over traditional irrigation methods (box 3.2).

POLICY AND IMPLEMENTATION

Important policy and implementation measures include technical support services for farmers

and institutional reforms that encourage private sector involvement and prompt farmers to invest in improved technologies and better agriculture water management practices.

Investments in irrigation have a better chance of success if they are integrated with a wide array of elements such as sound agricultural practices, crop and food diversification, human resource development, infrastructure improvements, and marketing. On-farm irrigation technology investments should be integrated with these elements, and not just focused on water management inputs.

Projects to improve on-farm water management should be demand driven, based on the needs of beneficiaries who should be committed to operating efficient production systems. Participants should be trained in the O&M of their irrigation systems and be willing to help pay the related costs. To this end, institutional arrangements, including the establishment of WUAs on public schemes, should be an integral part of the investment. The public sector has proven unable to sustain the O&M of the installed on-farm irrigation systems or provide the necessary support services. Strengthening the capacity of the private sector to provide services such as spare parts and skilled maintenance and advisory services is necessary to lift this limitation (box 3.3).

Incentives including subsidies (box 3.4) to promote on-farm water conservation technology have been effective in enhancing the adoption of this technology. However, several measures are needed to ensure the achievement of water conservation and sustainability goals. A demand-driven approach is necessary with active farmer participation in O&M and in capital-cost financing. Introducing the economic cost of water in any form encourages water saving and increases demand on water-saving equipment.

The capacity of existing institutions to provide adequate services for project implementation, management, and O&M should be assessed during the project appraisal and study phases. If possible, a monitoring mechanism with quantifiable indicators should be set up.

Box 3.2 Main Advantages of On-Farm Modern Irrigation Technology

- Control of the amount of applied water and irrigation timing. Piped systems allow the application of small amounts of water in a timely manner to fit crop needs. This facility in system manipulation allows a potential crop yield increase of 10–45 percent and improved produce quality.
- Operation and maintenance. Improved systems need only a tenth to a quarter as much labor as used for open canals. The complete system requires annual maintenance that costs only about 5 percent of the initial investment.
- Cost. The use of thermoplastic pipes and fittings, made from unplasticized polyvinyl chloride (better known as rigid PVC), low-density polyethylene, high-density polyethylene, and polypropylene, which are manufactured in most countries, has drastically cut the cost of piped irrigation installations, while open canal networks are becoming increasingly expensive to maintain.

Source: Phocaidis 2001.

An important benefit of improved on-farm technologies is their ability to reduce on-farm water losses and thus reduce the salinization that inevitably accompanies waterlogging in semi-arid and arid regions. But adequate drainage, natural or human-made, remains a key to sustainable irrigation.

Controlled drainage also saves water and reduces leaching of nutrients from the soil (see IP 5.2).

LESSONS LEARNED

Evaluation of projects intended to save water by introducing irrigation technology reveals multiple causes of failure. Often the failures stem from the way these projects were designed and managed. Fortunately, most if not all of these causes can be avoided.

Project success also hinges on the extent to which irrigation professionals, equipment dealers, and public and private extension agents have sufficient incentives to work closely with farmers to ensure proper O&M. It is important for irrigation projects to have quantifiable objectives that facilitate evaluation of their success or failure by measuring results against pre- or no-project situations. Switching to performance-oriented scheme management and modernization generates more gains than do new schemes, if the lessons learned from the degradation of the schemes are taken fully into account in the process (see also IP 9.4).

Hardware improvement on government-owned irrigation schemes should reward farmers for the use of water-saving irrigation technology. But the billing rules may have to be changed. In Morocco, for instance, the replacement of collective water-measuring devices by individual water meters for each farm induced greater water conservation under the same water tariffs (box 3.5).

RECOMMENDATIONS FOR PRACTITIONERS

Investments in on-farm water-saving technologies can be highly productive owing to the multiple economic, social, and environmental benefits that

Box 3.3 Irrigation Advisory Services

Irrigation advisory services relate to all information and support provided by governmental, nongovernmental, and commercial services to introduce techniques and technologies and improve capacity, leading to more efficient and better-performing irrigated crop production.

Traditionally, governments have supported farmers through agricultural extension services, but they have concentrated on crops, fertilizer, and pesticides rather than water. Where governments have focused on water management, they have looked at the engineering and management of the main distribution systems, not at what happens on the farm. Where an attempt has been made to provide water management services, resources have often been inadequate to do the job properly. Water management services are usually underfunded and staffed with inexperienced people and do not have the resources to reach farmers. Any successes have usually been supported by external aid, and their sustainability, once the support ends, is not certain.

Source: FAO 2002.

Box 3.4 Subsidies to Promote On-Farm Modern Irrigation

To overcome the drawbacks of past policies, many countries subsidize part of the cost of water-saving irrigation technology to promote use on their irrigated lands. This is the case, for instance, in the following countries:

- Tunisia—between 30 and 40 percent of modern irrigation systems' capital cost
- Morocco—between 40 and 60 percent of modern irrigation systems' capital cost
- Syrian Arab Republic—free studies and interest-free soft loans for 1 hectare per farmer
- Republic of Yemen—free studies for between 30 and 40 percent of piped conveyance network, 70 percent of booster pumps and modern irrigation systems, for selected projects

Source: Author.

can accrue from more efficient use of water in crop production (box 3.6). Such investments should therefore be promoted. Where the potential exists, investment programs should give priority to small-scale irrigation and water conservation, because these increase flexibility and can be rapidly implemented.

Box 3.5 Water-Saving Technologies in a Group Context

When a group of farmers using sprinklers on a scheme in Morocco were billed as a group, they responded to a 21 percent hike in water rates by using more water—perhaps to get their “money’s worth.” The same 21 percent rise triggered a water-saving by farmers who were billed individually.

Billing method	Water rate increase	Absolute water demand	Crop intensification	Water demand relative to aggregate crop demand
Group billing	+21%	+ 6%	+ 15%	-7.8%
Individual billing	+21%	- 5%	+ 38%	- 32%

In another large scheme, a 5 percent price increase resulted in a 10 percent reduction in water demand where water was billed individually. Here again, where water was allocated and billed to a group, demand increased in response to the price increase.

Source: Bazza and Ahmad 2002.

Box 3.6 Water Conservation and Income Generation in the Republic of Yemen

In the mid 1990s, the government of the Republic of Yemen launched a program to raise the productivity of irrigation from groundwater. The most important part of the program was the Land and Water Conservation project financed by the International Development Association and the World Bank. The irrigation component of this project was based on the promotion of irrigation technologies consisting of PVC and galvanized-iron pipes for transport and distribution, and drip, sprinkler, and bubbler systems in pilot farms, for demonstration purposes. A participatory, cost-sharing approach was followed.

Farm-level water-saving measurements varied between 10 percent and more than 50 percent, depending on, for example, the accuracy of the system design and installation, the capacity of farmers to operate and maintain their systems, the soil type, and the crop. At the regional level, the average water savings represented no less than 20 percent and nearly 35 percent in the northwest of the country where most farms were equipped with bubbler irrigation systems. Farmers recovered their 50 percent investment share within two to four years from water savings alone, in part because diesel was subsidized. But the benefits went beyond water savings, because the technologies improved produce yield and quality and allowed farmers to switch to more rewarding crops or increase their irrigated area.

At project completion, the savings resulting from all participating farms, covering 10,670 hectares, represented around 38 million cubic meters a year. Farmers used 15–20 percent of this volume to expand their irrigated area, and the rest remained in the aquifer. The total volume of water savings corresponded to that of 475 dams each with an 80,000 cubic meter capacity, the same capacity as the average small dam in the Republic of Yemen, if filled to capacity. The annual water savings from farms participating in the project were equivalent to more than US\$1.8 million.

Source: Bazza 2001.

RECOMMENDATIONS FOR PRACTITIONERS

In formulating new projects, the following actions are recommended:

- Assess the enabling environment for the successful introduction of on-farm irrigation technologies, particularly country policies on agricultural water use, existing regulations and institutional capacities, and the potential benefits from the technologies.
- Assist in reviewing policy and regulatory frameworks and reforming institutions to enable private investment and capacity to introduce and manage adapted on-farm irrigation systems. Promote hardware improvement on government-owned surface schemes so as to enable and facilitate their conversion to modern water-saving irrigation methods.
- Where groundwater is used for irrigation, develop mechanisms for the sustainable management of aquifers to encourage the use of modern technologies to manage demand.

- Build capacity in government and private agencies to provide technical support and advisory services to farmers on irrigation technology.
- Develop public sector capacity to establish national standards and control mechanisms of irrigation equipment and water allocation.
- Build capacity in the private sector to manufacture, import, and market irrigation equipment and to provide reliable services for users.
- Support farmer investments in water-saving technologies through the careful use of subsidies and soft loans.

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This Note was prepared by M. Bazza of FAO, and reviewed by Jack Keller of International Development Enterprises (IDE).

INVESTMENT NOTE 3.2

INVESTING IN IRRIGATION FOR CROP DIVERSIFICATION

Farmers' efforts to grow crops other than cereals are frequently hampered by their surface irrigation system. Diversification in irrigated agriculture often requires new or improved technologies for surface water delivery and drainage that allow flexible water application and drainage.

The green revolution and the rapid expansion of irrigated areas between 1960 and 1980 created grain surpluses that depressed prices in domestic and world markets. Market-oriented farmers responded by seeking alternatives to the cultivation of cereals. They were encouraged by the availability of advanced irrigation technology; the development of improved high-value crops; the increased domestic and regional demand for fruits, vegetables, and livestock products; the growth of private agribusiness in processing and marketing; and the removal of distorting policies.

However, many farmers in rice-based systems were constrained by the irrigation infrastructure, management practices at the farm level, an adverse policy environment, and a lack of support services. Because of the importance of rice, many issues in this Investment Note deal with the diversification of rice-based cropping systems but apply also to the increasing productivity of other irrigated agricultural systems.

INVESTMENT AREA

WATER DELIVERY. Paddy and nonpaddy crops require different irrigation management. Both excess water and deficits curtail nonpaddy crop yields, whereas rice does well with continuous irrigation and/or field-to-field irrigation, the dominant method of irrigation in most of South and Southeast Asia. Basin irrigation, the method used for irrigated rice, is also used for crops such as groundnuts, maize, and soybeans, but it is not suited to crops sensitive to wet soil conditions 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 because they were supposed to be used for field-to-field irrigation. Nonpaddy crops, in contrast, require direct plot access to irrigation and drainage that provide intermittent water supply and prevent soil saturation from inhibiting crop production.

DRAINAGE. Improved drainage reduces waterlogging and salinization, allowing a wider choice of crops and encouraging crop diversification. Complementary on-farm drainage facilities for removing excess water fast and lowering 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, though effective, take up considerable productive land area.

SOIL MANAGEMENT. Often, land can be converted from rice to nonpaddy cultivation only at great cost because the high clay content of heavy soils that are excellent for rice cultivation result in low infiltration rates and poor suitability for other crops and hence impose large power requirements for land preparation. Diversification from rice to other crops therefore has greatest potential on lighter soils.

LAND CONSOLIDATION. Construction of the dense surface irrigation and drainage system needed for crop diversification cannot reasonably be implemented where randomly shaped farm plots 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 Japan, the Republic of Korea, China, and Taiwan (China), economies where diversification is common, irrigation systems were systematically developed 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.

POTENTIAL BENEFITS

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

Two World Bank-supported projects—a success story in Brazil (box 3.7) and an unsatisfactory result in Thailand (box 3.8)—illustrate the importance of irrigation system design, access to markets, and farmer training in enhancing crop diversification.

POLICY AND IMPLEMENTATION

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 3.9). 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 the sustainability of groundwater supplies and the profitability of new cropping systems.

COMPLEMENTARY INVESTMENTS. Agricultural diversification is an evolving process that requires appropriate policies, technologies, road and

Box 3.7 A Successful Project in Brazil

In Brazil, the Upper and Middle São Francisco Irrigation Project, appraised in 1985, consisted of the rehabilitation of seven public schemes and construction of a new scheme, “Formosa.” Irrigation systems were designed to provide high-quality service to each user, with the possibility of adopting sophisticated, pressurized on-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 Brasília greatly enhanced prospects for output growth in Formosa, and the project has generated considerable off-farm employment.

Source: Brazil, “Upper and Middle São Francisco Irrigation Project,” 1986.

Box 3.8 An Unsuccessful Project in Thailand

In Thailand in 1977 at project appraisal, 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. More than 20 years later, cropping intensity during the dry season averages about 32 percent. Dry season vegetables are grown mostly near the larger canals. Expansion of diversified irrigated agriculture is constrained by the lack of tertiary canal service to individual fields and the unreliability of canal water, in addition to seasonal migration of rural labor to urban centers and poorly organized markets in the area.

Source: Burt and Styles 1999.

Box 3.9 Groundwater and Crop Diversification: “Farmers Vote by Drilling”

During the last 20 years, with low development costs, the use of groundwater resources for irrigation has increased dramatically. Canal water distribution is often erratic or rigidly scheduled, and large variations between planned and actual allocation of water hamper the 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, access to groundwater gives farmers freedom over crop calendars and choice of crops because they choose the best time to plant for their own situations and markets and can give their crops and soil all the water they need.

Source: Mainuddin, Loof, and Abernethy 2000.

transport infrastructure, and services (Barghouti, Garbus, and Umali 1992).

LESSONS LEARNED

The pace of crop diversification in irrigated rice systems is determined by markets and policies. Private investment usually 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 and alluvial areas, where explosive development has occurred in groundwater resources. In other surface irrigation systems, diversification will remain constrained if investments support only urgently needed rehabilitation without upgrading irrigation infrastructure to meet the requirements of diversified agriculture.

RECOMMENDATIONS FOR PRACTITIONERS

Diversification in irrigated areas may require the 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 land consolidation and improvements in 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 investments for modernizing marketing facilities as well as for improving roads, communication systems, and storage. Extension programs with information on irrigation, agronomic practices, and economics help farmers decide which crops to grow. A guaranteed 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 3.10).

Before initiating a crop diversification program, detailed studies should be done to determine the quality of irrigation service and its suitability for diversified crops and to assess the potential markets and the available level of services and technology. The in-depth diagnosis of the irrigation systems should go beyond an evaluation of the indicators of hydraulic, financial, agricultural, and environmental performance; it should evaluate the potential for participation by women and poor people in their efforts to diversify, especially their access to credit and markets.

INVESTMENT OPPORTUNITIES

- 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
- Micro-irrigation
- Greenhouses, tunnels, and mulching
- Marketing and food processing facilities
- Extension and financial services

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Box 3.10 Diversification in the Middle East and North Africa

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

Source: Author.

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This Note was prepared by Hervé Plusquellec with inputs from Walter Ochs, and other irrigation and drainage specialists in the Irrigation and Drainage Network of the World Bank. It was reviewed by Jan Bron of Royal Haskoning.

INVESTMENT NOTE 3.3

INVESTING IN SMALLHOLDER IRRIGATION

Smallholder irrigated horticulture has proven a viable and attractive option for poor farmers in developing countries. Returns from intensive irrigated horticulture, even on tiny plots, can greatly exceed returns from rainfed cereals production. Private ownership of simple pumping technologies has avoided collective action problems related to larger public or communal schemes. To promote expansion of smallholder irrigation, poor farmers must have access to cost-effective technologies that provide a rapid return on investment, a reliable and quality supply of water and other inputs, land for expansion, and markets to absorb increased production.

In many developing countries, irrigation is counted on to increase production, reduce reliance on unpredictable rainfall, and provide food security, income, and employment to poor farmers. Large schemes, which the World Bank financed for decades, have often lacked sustainability; frequently used to produce uncompetitive cereals for import substitution, such large schemes typically suffer from the inability of government or parastatals to maintain the infrastructure. Smaller, communal schemes work well in many countries but can be plagued by collective action problems, although the basic rules for success are well documented (Ostrom 1992). Elsewhere, there is considerable scope for the expansion of small, privately owned pumping technologies that benefit small farmers, particularly for production of high-value crops such as horticulture.

INVESTMENT AREA: FOCUSING ON THE PRIVATE SMALLHOLDER

Throughout the developing world, many smallholders produce vegetables on irrigated plots during the dry season as a hedge against a rainy season crop failure and as a source of cash income and food. These plots may be very small:

surveys have shown that garden size rarely exceeds 0.1 hectares and is often less than 0.05 hectares (500 square meters). With nonmechanized systems using ropes, buckets, and watering cans, irrigation of even such small areas can be extremely labor intensive. The labor constraint often limits increased production simply because the farm family lacks the time and energy to provide sufficient water for the crops. Moreover, the distance to water points has been shown to decrease the likelihood of girls' attending school because they are often responsible for collecting water (WHO 2003).

The first hurdle to expanded smallholder irrigation, therefore, is to demonstrate and provide access to labor-saving technologies for pumping and distributing water. Mechanized technologies such as small gasoline or diesel pumpsets often exceed the means of poor farmers—both in terms of investment cost (\$300 to \$500) and of operating costs of fuel, oil, and spare parts. Moreover, the small size of many gardens may preclude economical use of a motorized pump. The treadle pump, on the other hand, has been shown to provide an economically viable solution for water lifting that is within the financial means of smallholders in Africa and Asia and may allow a farmer to irrigate 0.5 hectares using only family labor and investing US\$50–\$100. Scaling up from traditional systems to treadle pumps and further to motorized irrigation systems requires careful thought and an incremental approach (box 3.11).

BENEFITS

Smallholder irrigated horticulture can provide significant returns to farmers and increase local manufacturing capacity while creating employment. Surveys have shown that many farmers increase their land under cultivation by three times within two years after the purchase of a treadle pump, more than doubling their annual incomes (boxes 3.12 and 3.13).

Benefits do not stop at the farmgate. When locally made treadle pumps are used, the artisan sector may be stimulated. Small metal shops

Box 3.11 Scaling Up with Improved Technology Takes Time

Economic analysis in Niger has found that for plot sizes less than 0.69 hectares, treadle pumps are more profitable than small-motorized pumps, but for larger plot sizes the motorized option becomes economically superior (World Bank 2001). To make best use of a motorized pump, an average farmer would need immediately to increase the size of his or her garden by 14 times (for example, from 0.05 hectares to 0.7 hectares) to ensure viability. This transition may easily surpass the technical and management capacity of the farmer, who will require more labor, inputs, and markets for the produce, which helps explain why many credit-based motorized pump-promotion projects for smallholders fail. Instead, by starting small and increasing incrementally, some treadle pump adopters have managed to graduate to mechanized technologies. The following scenario for scaling up has proven successful, minimizing risk for smallholders:

- *Year 0:* A farmer has a hand-dug well with a rudimentary rope-and-bucket gravity irrigation distribution system. This may be marginally profitable but is highly labor intensive.
- *Year 1:* The farmer buys a treadle pump but keeps the hand-dug well. The gardener realizes productivity gains but may observe that the water-lifting capacity now exceeds the well capacity and decides to improve the well.
- *Year 2:* The drilled tubewell, treadle pump, and rudimentary gravity irrigation distribution system permit a large expansion in the size of the garden, because neither the amount of water nor the time to lift it is a constraint.
- *Year 3:* As garden size expands and the length of the distribution canals increase, the gardener improves the distribution system with buried PVC pipes.
- *Years 4–6:* Extension of the PVC system again allows an increase in garden size. With a second well and pump, the distribution system is again expanded.
- *Year 7:* A motorized pump is added to the system, and manual pumps provide reliable back-up during fuel shortages or breakdowns. The farmer may later want to explore the micro-irrigation systems discussed in IN 3.1, the Investment Note on on-farm water saving.

Source: Author.

Box 3.12 The Benefits of Smallholder Irrigation in West Africa

In West Africa, projects implemented by Enterprise-Works Worldwide in Senegal, Mali, Niger, Benin, Burkina Faso, Côte d'Ivoire, and Ghana have promoted private sector sales of more than 8,000 treadle pumps and more than 1,000 low-cost tubewells. More important, these technologies have resulted in higher incomes for more than 80 small fabrication workshops and thousands of small-scale gardeners. The annual increase in income for gardeners varies widely between countries and within countries, but it ranges from \$290 in Niger to \$584 in Senegal.

Source: Author.

Box 3.13 Experience with Pro-Poor Irrigation in Asia

Treadle pump technology can be a powerful tool for poverty reduction in Asia. It self-selects the poor, puts to productive use the region's vast surplus family labor, and is claimed to raise the annual net household income by US\$100 on average. For a marginal farmer with \$12 to \$15 to spare in this region, there could hardly be a better investment than a treadle pump, which has a benefit-cost ratio of 5, internal rate of return of 100 percent, and payback period of a year. It thus ideally fills the needs of marginal farmers. The challenge lies in its marketing; exceptional ingenuity seems to be required to put the treadle pump in the hands of millions of rural poor.

Source: Shah et al. 2000.

learn new skills and develop their ability to solve local problems. Local products may be preferred to externally produced pumps, as the artisans are closer and more accountable for quality and repair.

The quality and quantity of food for local and household consumption is also important, and irrigated horticulture addresses household

food security concerns. Many of these benefits are perceived by women farmers, who are able to augment garden production. Household drip irrigation systems, supplied from periodically filled buckets or drums, often with a treadle pump, to water household gardens or small plots of vegetables or fruit trees are particularly important for women as well as men.

POLICY AND IMPLEMENTATION

Several policy and resources conditions must be met for successful implementation of smallholder irrigated horticulture.

Access to adequate irrigable land

Improved water-lifting technologies have a higher discharge than traditional methods, and time saved in irrigating may be used to expand surface area if suitable land is available. Land tenure systems are a potential impediment to the expansion of irrigated horticulture because, if farmers do not own the land, they will be reluctant to invest in permanent improvements such as tubewells. Conflicting land use can also be a problem, especially when dry season irrigation encroaches on land traditionally used by herders.

Existence of sufficient water of suitable quality

Expanded irrigated horticulture requires adequate supplies of ground- or surface water to meet the requirements of the crops being grown because the most productive smallholder irrigation is performed during the dry season (when insects and plant diseases are scarce and when rainfed cereals production does not compete for labor). Irrigation water is most economical if subsurface water supplies are within 7 meters of the surface or if surface water supplies are within 50 meters of the plants. Water quality is also important because salinity can become a major problem, especially in arid climates, even when concentrations of salts in irrigation water are relatively low. Technical advisory services would then be needed to advise on selecting salt-tolerant crop varieties and saline irrigation practices. (For groundwater governance issues, see IN 4.4.)

Availability of ample labor supply

Although rural household labor is frequently in short supply during the rainy season, when farmers focus on staple crops, it is usually relatively abundant during the dry season when irrigated horticultural activities are performed. Labor productivity can be increased significantly through higher yields and expanded irrigated surface areas through the use of

mechanized water lifting, piped distribution systems, and improved surface irrigation or drip irrigation systems.

Availability of nonirrigation inputs

Fertilizer, seed, and pesticides need to be adequately supplied by the commercial sector on the basis of market prices. If not, farmers produce their own seed, leading to reduction in yields as seed quality deteriorates. Vegetable seeds adapted to the prevailing environmental conditions are an important input that is frequently lacking. Subsidized inputs, typically fertilizer, have been shown to make these items *less* accessible to smallholders, because these benefits tend to be captured by larger farmers, creating scarcity.

Market conditions

Market outlets for irrigated production are imperative for a successful smallholder irrigation subsector. Proximity to markets or reliable transportation linkages must be present, particularly since horticultural products are perishable. Price cycles often accompany horticultural production, which may require additional investment in value-added production (such as drying) or better storage to smooth out supply. Of course, access to market information is also important.

LESSONS LEARNED

Two important lessons are reviewed here: development of supply chains for sustainable impact and the importance of a market-led approach for financing technology acquisition.

Supply chain development

Low-cost productive technologies must be available to smallholders in terms of both location and price and must correspond to their needs. A variety of ways of providing smallholders with access to these technologies have been used, ranging from importing treadle pumps to manufacturing items locally (box 3.14). For market-driven sustainable development to occur, all parties in the supply chain must make a profit. In the case of treadle

pumps, tubewells, and improved piped water distribution systems, the manufacturers, installers, and the gardeners all benefit. Treadle pump manufacturers earn \$15 to \$25 profit per pump, tubewell installers earn \$12 to \$18 per well, and the plumbers installing buried PVC pipe distribution systems earn roughly \$0.20 per meter of pipe installed.

Financing technology for a market-led approach

In many countries, the uptake of technologies by subsistence gardeners is hindered by the lack of institutions that provide rural finance. Although the development of low-cost technologies has reduced up-front costs, farmers typically require financial assistance, ideally through a pump supplier credit or other commercially viable credit mechanisms. Subsidized programs are risky because of market distortions, and should be investigated only if there are no rural finance institutions or it is felt that cost reduction is required for a “demonstration effect” where pumps are unknown. Therefore, coordination among donors in the irrigation sector is essential for mutual understanding of the long-term benefits of encouraging farmers to invest in a technology that will pay for itself in its first season of use. Poorly managed credit programs hurt the very people they are designed to help in the long term. Instead of developing sustainable local capacity, these programs leave smallholders dependent on foreign aid and waiting for a gift rather than investing in their own future. However, the smallholder market approach only works well when the technology being promoted has a short payback period (one or two seasons), and the initial cash payment is within the smallholders’ reach.

RECOMMENDATIONS FOR PRACTITIONERS

- Use privately owned technologies to avoid collective action problems and reliance on government assistance. This increases the likelihood that irrigation assets will be maintained.
- Consider simple technologies such as treadle pumps and drip irrigation kits. These self-select for poor households.

- Ensure that a minimum set of resource and market conditions are satisfied before promoting irrigation.
- Develop supply chains that are dominated by private entrepreneurs such as pump manufacturers and repair shops.
- Rethink the definition of smallholder-irrigated agriculture in view of market gardening. Many farmers, particularly the poorest, irrigate plots smaller than one-tenth of a hectare.
- Recognize that rapid introduction of mechanized technologies can easily overwhelm a poor smallholder in terms of capacity. Scaling up to mechanized pumps has been demonstrated successfully but may take time.
- Make sure there are markets for the outputs, or help create them, to ensure that increased production is profitable.

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Box 3.14 Developing a Supply Chain for Pumps

Certain principles are generally accepted as key to establishing a viable supply chain, including the following:

- Private sector actors, motivated by profit, are more successful than public sector entities.
- Extremely judicious use of subsidies can promote initial introduction.
- All actors in the chain need to make a profit.
- The development agent must play a facilitator’s role in developing a viable supply chain but must not compromise future sustainability by performing functions that the main actors in the chain cannot assume.

There are two schools of thought for the best design of a supply chain: decentralized manufacture (small workshops close to the markets) and centralized mass manufacture (several large manufacturers with a distribution network). Both methods have advantages and disadvantages. The choice will depend both on the project planners’ goals and on the available infrastructure.

Source: World Bank 2003.

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This Note was prepared by Jon Naugle of Enterprise Works and Daniel Sellen, and reviewed by Jack Keller of International Development Enterprises.

INVESTMENT NOTE 3.4

SELECTING TECHNOLOGIES FOR THE OPERATION AND MAINTENANCE OF IRRIGATION SYSTEMS

Appropriate technologies for the O&M of irrigation systems are essential for the service delivery expected of them. Technologies for operation (which are related to the structures in a system) have to be distinguished from technologies for maintenance (which are related to all components of a system, that is, all the structures, canals, and fields). Some key issues in the selection of the right technologies for the job are reviewed in this Investment Note.

System modernization will be a focal point of irrigation debate in coming years, especially in developing countries. The construction of new irrigation systems may also be expected in some of the least developed and emerging economies and in quite a few areas with rain-fed cultivation. As an integral part of the investigation and design processes, appropriate technologies for O&M will have to be selected to be able to use these systems properly. It takes several years after installation of an irrigation system for the benefits to show up: improved yields, crop diversification, and higher farmer income. At that point, good O&M becomes crucial, if improvements are to be retained.

Three main considerations should govern the selection of O&M technologies. First of all, they must fit the type of service that irrigation users expect. Second, the technologies have to be in balance over the system components: inlet, main and distributary system, and field system. For balanced performance, appropriate O&M technologies must be selected for each component. Third, the most cost-effective solution should be selected (see IN 3.5).

INVESTMENT AREA

Responsibilities and funding sources must be identified for each of three actors involved in irrigation O&M:

- *Government.* Government's responsibilities are defined by policy and legislation. They usually encompass oversight and maintenance of nationally important water bodies and major structures such as dams. Expenditures are covered from the national budget.
- *Agencies.* Public, semi-public, and private agencies (and sometimes WUAs) are usually responsible for the main and distributary systems. Expenditures are funded through fees charged to farmers and paid from their own resources. Subsidies paid from the government's recurrent budget may supplement this funding.
- *Water user associations and farmers.* WUAs and individual farmers are usually responsible for field systems. Operation and maintenance is funded by farmers with their own money or labor (see IN 1.4 and IN 2.1) and may be financed through loans from private banks.

For system operation, all kinds of technologies are on the market. They run the gamut from simple tools for manual operation to fully automated systems. Availability of technology is generally not the problem, but rather the selection of the most appropriate technology for the job. The selection of the control system (upstream or downstream) and the definition of operating rules are crucial. This is true at every level of the irrigation system, from the inlet to the main and distributary system, and to the field. The choice of appropriate technologies at each level should be made by whichever actor is in charge of O&M at point of service. Overall agreement is important, however, because there is strong interaction among the levels of the system. Such an agreement should be reached during the design phase for new installations or the preparatory phase for system modernizations.

Canal maintenance activities focus on shape, dimensions, and flow resistance. In most cases, aquatic vegetation is the predominant maintenance factor. For lined irrigation canals, the lining has to be kept up. An unlined irrigation canal is, by definition, in a very young phase in the vegetation succession and has to stay free of vegetation to retain its hydraulic function. The best time for canal maintenance is usually just before the start or during the irrigation season. Irrigation water is supplied in more or less known volumes, so maintenance can be planned around releases. Irrigation frequencies also have an impact on maintenance, of which there are four types:

- *Routine maintenance*—vegetation control (once or a few times per year)
- *Periodic maintenance*—cross-sectional control and maintenance of structures (once every 5 to 25 years)
- *Emergency maintenance*
- *Modernization*

The first two are the focus of this Investment Note. The third, effective emergency maintenance, depends on a clear decision-making procedure and the financial wherewithal to allow more than one choice of technology. The solution chosen depends on the nature of the emergency. Modernization is outside the scope of this note.

O&M of the inlets has always received close attention, and a body of experience has accumulated from around the world. After the hydraulic properties of the inlet structure, the sediment control function is crucial to prevent sediment from choking off the irrigation canals. Regarding the main and distributary systems, some less successful developments need to be mentioned. All the necessary tools are available to design, construct, operate, and maintain such systems and can very well result in sound canal networks. However, the word “sound” should be interpreted carefully. It refers to the level of *service* that can be realized within a system, not just to the *technical* soundness of

its design. Only when an irrigation system is operated and maintained properly does it benefit farmers by enabling them to get a good yield from their crops.

When groundwater is the source, the irrigation system is generally smaller. It consists of a well that abstracts groundwater from the aquifer and pumps it into open irrigation canals or a piped system. In a tubewell, the well itself, the filter, and the pump need maintenance. After maintenance, the operation of the pump has to be carefully planned and monitored. Farmers often do this themselves.

In traditional irrigation systems, water rights became established over years in certain areas, so that each user had some idea of how much water to expect. The operation of modern surface irrigation systems, however, is more complex. Their size and layout preclude the application of traditional water rights. The resultant tensions often culminate in bunds and dike cutting and other activities that impair system functioning.

Groundwater irrigation poses lesser management problems, because farmers can clearly see the relation between the system and the benefit, although this perception does not always prevent groundwater mining or excess energy consumption. The introduction of volumetric water measurement devices, when economically and technically feasible, can be an appropriate response to this problem (see IN 1.4). The joint benchmarking initiative by the World Bank, the International Water Management Institute (IWMI), the IPTRID, the International Commission on Irrigation and Drainage (ICID), and the FAO can help identify adequate indicators of system performance, which may help in choosing the best improvement options and technologies for O&M.

Most lined canals need inspection and minor routine maintenance work (local cleaning) annually. Aquatic vegetation in unlined canals can be controlled mechanically, chemically, and biologically. Mechanical control can be manual

or mechanized. Manual reshaping of canals means heavy work and a low output per worker. Mechanized control may be done by cutting or dredging. Cutting leaves stubble and weed regrowth, but the stubble protects the bottom or bank of the canal from erosion. Dredging removes a portion of the plants, buried in mud at the bottom. When there is a risk of erosion, aquatic plants should be mown or cut. A further distinction can be made between harvesting and nonharvesting mechanical control, using different kinds of equipment for different purposes. Much of the equipment can be tractor mounted. For other types of specialized equipment, mowing and sweeping boats have been developed, but they cannot be used in narrow or shallow canals and have to pass obstructions (bridges, culverts, weirs) in larger canals. Much of the equipment developed for vegetation control can also be used for desilting and reshaping activities. Special equipment is available for maintenance dredging of silt and vegetation.

For biological control, selective agents or polyphagous organisms can be used. Selective agents attack one or only a few weed species. Their effects are similar to those of selectively applied herbicides: one weed species decreases and other plant species take its place. Polyphagous organisms reduce the growth of nearly every species present to acceptable levels. Examples of biological control include Chinese grass carp, which consume all species of aquatic plant, although they prefer submerged plants; goats and sheep, which keep down the weed growth if they are allowed to graze on the banks and maintenance paths; and shade, which can be provided by allowing broad-leaved plants to grow in the water and by planting suitable trees along canals.

To reduce the deposit of silt, the canal can be fitted with sediment traps.

Chemical control implies the use of herbicides, some more selective in killing vegetation than others. The application of herbicides should be limited, however, because they can have serious negative effects on the environment;

because they can easily damage the vegetation growing along canals just above the water level; and because they do not kill weeds immediately, which means that half-dead vegetation may clutter the canal after application.

As long as desirable and unwanted effects are kept in balance, chemical control of aquatic weeds can be applied on a limited scale.

Aside from the widely used traditional field irrigation methods, such as basin and furrow irrigation, there have been some important innovations in field irrigation systems. All kinds of micro-irrigation systems have been developed. Farmers are usually completely responsible for the O&M of field irrigation systems. This implies that O&M technologies selected for use in the inlet structure and the main system have to be attuned to the technology that farmers select for their field system.

POTENTIAL BENEFITS

A wise choice of O&M technologies should result in a well-operated and well-maintained irrigation system. The services delivered by the system should enable farmers to improve their crop yields or obtain other benefits.

POLICY AND IMPLEMENTATION

The key policy decisions are the following:

- Selecting the type of control approach (downstream, upstream)
- Determining the level of service to be expected from the irrigation system
- Determining the O&M activities required to keep the system in the envisaged condition and allocating responsibility for those activities
- Selecting O&M technologies that are appropriate for the O&M activities
- Monitoring implementation
- Devising a mechanism for corrective action if a party reneges on its responsibilities

O&M technologies should be selected during the preparatory or the design phase. At the same time, the willingness of all parties to do their share in O&M must be established.

Before an irrigation project starts, all parties must understand the following:

- What is to be operated and maintained, how this has to be done, and when
- Who is to operate and maintain which part of the system (in other words, the division of O&M responsibilities between farmers and the agency should be clear)
- How, in case of a transfer, financial responsibility will be shifted from the government to the agency or the farmers

Reaching such an understanding requires delineation of the parts for which government will be responsible, clear guidelines for the agency or WUAs and individual farmers on standards to be maintained, and adequate legislation specifying executable control and sanctions.

LESSONS LEARNED

Parties at every level must make a commitment to fulfill their O&M responsibilities. When such a commitment is present, irrigation systems will be operated and maintained adequately. Routine O&M inspection practices may prove cost effective in identifying early deterioration.

Transparency in decision making is important to achieve overall agreement on O&M technologies, which should be proposed at each level by whichever actor is in charge of O&M at a specified point of service. Only technologies that can be operated and maintained under local conditions should be selected.

RECOMMENDATIONS FOR PRACTITIONERS

The following recommendations for a successful selection of technologies for the O&M of irrigation systems may be useful:

- Select technologies that fit the type of service that irrigation users expect. Make sure that these technologies are in balance over the system components (main, distributary system, and field system) and are the most cost-effective solutions.
- Make sure that all parties agree on who is in charge of the O&M technologies selected for each part of the system.
- Make sure that the farmers will be willing to pay their share of O&M costs to maintain the envisaged level of service.
- Have ready for use a mechanism to resolve disputes concerning responsibilities and payments.

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INVESTMENT NOTE 3.5

COST-EFFECTIVE OPERATION AND MAINTENANCE OF IRRIGATION AND DRAINAGE PROJECTS

High-quality design, planning, and construction minimize O&M costs. Rehabilitation projects designed to “fix the bad spots” without addressing the causes of poor performance may not have long-term effects. Rehabilitation and modernization—based on performance monitoring and in-depth diagnosis of operational and management practices—have high potential to improve the cost effectiveness of O&M.

O&M is a postconstruction activity—but should not be an afterthought. It is at the core of planning and design, particularly in hardware upgrades intended to lower management cost and improve irrigation services. Such projects should be based on in-depth analysis of actual operation practices, comprising both hardware features and staff incentives. They must incorporate the goals and requirements of desired future O&M, and the appropriate technologies should be selected based on considerations of system balance and expectations of irrigation users (see IN 3.4). Design understood only as structural design fails to address essential operational questions.

INVESTMENT AREA

Ideally, the preparation of a rehabilitation or modernization project is based on a multiyear assessment of the hydraulic, agronomic, financial, and environmental performance. In-depth diagnosis of infrastructure and operational and administrative procedures helps to identify the physical and administrative changes that must be included in the project. A methodology for rapid appraisal has been developed (Burt and Styles 1999; see also IN 3.7) and has been used to plan a World Bank irrigation project in Vietnam.

Irrigation projects require planning, implementation, and monitoring of O&M. Therefore, managers should propose a rolling O&M plan.

OPERATION. Seasonal or short-term planning of the operation of large irrigation systems to match expected supply with demand can be a complex and laborious process, requiring the collection and tabulation of climatic and crop data. Different methods can be used for the actual distribution of water: proportional, rotation, arranged demand, canal rotation and free demand (as in the Arab Republic of Egypt), and centralized scheduling. A water delivery method does not necessarily imply a specific design and technology. But technologies such as nonadjustable structures (flow dividers) limit the flexibility of water distribution. Some other technologies require frequent adjustments of control structures, up to two or three times daily, to meet the stated objectives of reliability and flexibility of delivery. Additional evaluations are needed on the possible impacts of operation on related factors such as potential salinity, waterlogging, and environmental and social conditions.

A wide range of technologies is available to improve the quality of service to users (flexibility, reliability, equity) and to reduce the cost of operation. Some technologies use simple principles of hydraulics (long-crest weirs) or hydraulically operated automatic equipment. Progress in communications and electronics has made possible the development of modern equipment for the operation of canal irrigation systems. New technology includes local automated controllers, supervisory control mechanisms combining local automation under master supervisory control, remote control systems, and, ultimately, central automated control systems for large and complex water projects.

These modern systems allow reductions in the frequency of field visits for visual observations and eventual adjustments. Some of them (downstream control, dynamic, central control) eliminate the need for a complex planning process.

MAINTENANCE. There are many examples of traditional irrigation systems, built and managed

by users, that have been operating for centuries. These systems illustrate the point that, if properly maintained, irrigation schemes can benefit many generations. A maintenance service needs good planning of the different types of maintenance:

- *Routine and preventive maintenance*, normally done annually, includes all the work required to keep the irrigation and drainage system in satisfactory condition.
- *Renewal work* includes the replacement of infrastructure that has reached the end of its expected life span.
- *Special maintenance* includes the repair of damage caused by major disasters such as floods, typhoons, and earthquakes, which are unforeseeable.

The O&M plan should be based on an inventory of all the infrastructure work and include an asset management plan defining the frequency of routine maintenance and life of the work. This plan should be the base for assessing the annual maintenance budget.

Silt deposition, weed infestation, and malfunctioning structures make it practically impossible to operate irrigation systems to deliver water equitably and reliably. These same factors affect the drainage system and can result in additional salinity, waterlogging, and other environmental problems.

Four main problems are associated with unlined canals: weed infestation, silting, slope erosion, and water leakage. These problems are indicative of poor design, inefficient maintenance, or improper operation. Corrective measures may be costly and sometimes severely disrupt irrigation service. Engineering solutions exist to alleviate or solve these problems:

- *Eliminating silting*: Special canal intakes to skim the upper, less loaded waters from rivers (Coello, Colombia); silt and sand extruders (Nara Canal in Sindh, Pakistan); desilting basins (Saldana in Colombia; Guilán in the Islamic Republic of Iran)

- *Battling weed infestation*: Chemical and biological methods (used in developed countries and tested in Egypt and Sudan)
- *Canal cleaning*: Mechanical methods using specialized equipment—not construction equipment left over after completion of construction (Mexico irrigation districts)

Reduction of maintenance cost is one of the reasons for lining earth canals.

Lined canals should need little maintenance, if they have been properly constructed and adequate solutions have been provided for any potential problems studied (gypsum, swelling soils, subpressure, permafrost). However, the costs of repairing poorly constructed concrete panels that crack a few years after construction are beyond the financial capacity of many agencies. The effectiveness of canal lining to control seepage losses depends on the lining technology used and the age of the lining. There is now strong evidence that hard surface linings can deteriorate in a few years to the point where there is as much seepage as from an unlined canal.

The geosynthetics industry (geomembranes, geotextiles, geocells, geomats) offers many opportunities to improve the effectiveness of canal lining by using geomembranes to control the erosion of canal slopes. New materials have potential for savings in installation costs and time, an important consideration for canals under operation. Irrigation districts in the United States claim that the cost of a recently developed technology, installation of field-fabricated material, can be as little as one-third that of concrete lining.

POLICY AND IMPLEMENTATION

Borrowing countries frequently limit maintenance activities to essential works to keep government-managed systems operating and perform rehabilitation works only every 15–20 years, mostly through external financing. This practice should be strongly discouraged, because it requires massive injections of money, several

times more than what is needed with well-designed asset management plans.

Adoption of high or advanced technology would reduce the labor requirements for the O&M of irrigation schemes. However, high technology requires higher labor skills. Cost-effective O&M through rehabilitation and modernization may require the retrenchment of unskilled staff, intensive training, or both (box 3.15).

Modern water control technologies can be introduced in steps starting with simple modifications of cross-regulators, adoption of local controllers on a pilot basis, and simple information technology. Once users are comfortable with the new systems, they can scale up to more sophisticated control systems, including remote control. Most irrigation districts in the U.S. state of California are engaged in a long-term process of modernization using their own financial resources

POTENTIAL BENEFITS

The benefits expected from the above actions for effective O&M include the following:

- Better irrigation service to users, which encourages crop diversification; cultivation of high-value, water-sensitive crops; and higher use of nonwater inputs
- Substantial water savings, and positive impacts on the environment and on saline and waterlogged land
- Increased life of irrigation infrastructure and postponement of the need for major project overhaul
- Higher motivation of the management entities' personnel
- Less conflict between users and the management entities

RECOMMENDATIONS FOR PRACTITIONERS

Irrigation agencies often strictly adhere to their old design standards and are reluctant to adopt

Box 3.15 Australia: New Technology Improves Financial Performance

Major reforms in the agricultural and water sector were carried out to improve the sustainability and profitability of irrigation in the state of Victoria, Australia. The renewal of the irrigation infrastructure, dating to the 1930s, provided the opportunity to redesign the irrigation systems by introducing new technologies.

The shortfall of revenues was reduced from US\$66 million to \$13 million over a period of 10 years (1984–94). Some 62 percent of the improvement in financial performance came from efficiency gains in O&M and 22 percent from price increases from the irrigators. The number of staff was substantially reduced and staff productivity increased by replacing unskilled personnel with young graduates familiar with new technologies.

Source: Langford, Forster, and Malcolm 1999.

techniques that they consider too costly and too sophisticated. They are unaware that their current standards are deficient and that some advanced technologies could be appropriate for their irrigation projects. Changing practices is a long-term process. Operational staff should encourage potential borrowers for irrigation to organize eye-opening training and to carry out some time-consuming surveys of canal conditions long before starting project preparation (box 3.16).

Most borrowers propose that earth irrigation canals be lined under development assistance projects. Lining costs may account for more than 50 percent of the total investment. Given budget limitations, borrowers should be encouraged to limit lining to sections where necessary and to further invest in modernization work that could improve the effectiveness of O&M activities. This work accounts for a small percentage of total costs.

High quality standards are required at every phase of project implementation: planning, design, and construction. Project consultants should have in-depth experience in advanced techniques to improve O&M. Budget and human resources for supervision by the Bank should be adjusted to the complexity of such projects.

Box 3.16 Checklist for Irrigation Project Planners

Before starting project preparation

- Make an in-depth diagnosis of the performance of each subproject, using RAP.
- Conduct short training seminars on RAP and irrigation modernization concepts for key personnel in the agencies involved.
- Measure seepage rates from lined and unlined canals.

Potential investments

- Adopt, selectively, advanced technologies for water control.
- Construct works (basins, extruders) to reduce the cost of desilting canals.
- Develop a conservation program to reduce erosion and sediment transport.
- Consider using advanced techniques to reduce installation costs and disruptions of irrigation, and adopt long-life solutions employing geosynthetics, if canals have to be relined or renovated.
- Purchase specialized maintenance equipment.
- Buy modern office and communication equipment.
- Build all-weather roads.
- Seek technical assistance to upgrade the skills of local consultants, construction industry, and O&M personnel at the irrigation entities.
- Seek technical assistance for the preparation of O&M plans for each subproject; an action plan for retrenchment and staff training; an action plan and schedule for gradual increases in irrigation service fees, collections, and coverage; and reforms in the allocation of collected water fees.

Source: Author.

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INVESTMENT NOTE 3.6

USING SATELLITES TO ASSESS AND MONITOR IRRIGATION AND DRAINAGE INVESTMENTS

Recent research breakthroughs in remote sensing enable the quantification of water consumption and crop production without agrohydrological ground data. These measurements provide a vehicle for assessing farm management in terms of land productivity, water productivity, irrigation efficiency, environmental degradation, and farmer income. Nonmanipulated information from satellites has the power to reveal the real need for World Bank loans, monitor the progress of project execution using the “eye in the sky,” and evaluate quantitatively the impact of previous or current water management improvement projects.

Appraisal of investment in public irrigation systems has faced at least four key challenges:

1. Indisputable data are often lacking to assess the validity and reliability of hydraulic performance data presented to justify rehabilitation funding or to assess the sustainability of the performance improvement resulting from earlier rehabilitation investment on other parts of the system.
2. Numerical data are lacking to assess the scope for raising the productivity of a water scheme.
3. Numerical data are lacking to assess the scope for raising basinwide beneficial transpiration in order to release water for underallocated uses.
4. Data may be lacking to calculate the size of salinized areas that could be reclaimed and the total area that may subsequently be irrigated if farmers change cropping patterns.

World Bank projects in the Indus, Ganges, Tarim, Hai, Nile, and Amu Darya Basins recently utilized remote-sensing data to enrich the customarily

available data. Satellites measure spectral radiances that can be converted into processes in the soil-water-vegetation-atmosphere continuum. A 2001 Wageningen expert consultation concluded that remote-sensing technologies have progressed far enough to offer products that can be implemented. The IWMI recognized that “remotely sensed data remain underutilized by practicing water resource managers” (Bastiaanssen, Molden, and Makin 2000, 1).

INVESTMENT AREA

Satellites measure hydrological systems in detail (spatial resolution of 1 to 30 meters) across vast areas (millions of hectares) at regular intervals (half daily to monthly repeat cycles). An analyst may survey the spatial variation of the parameters (box 3.17) across secondary and tertiary irrigation and drainage systems using just one satellite image. Satellites provide consistent, unbiased, and politically neutral information that is accessible to all through the public domain satellite data archives. Users can be ensured that data are not manipulated and reflect real land surface processes (Bos et al. 2001).

Irrigation and drainage performance indicators can be computed by combining remote-sensing parameters with field measurements such as flow-through irrigation and drainage canals (Bastiaanssen and Bos 1999; Menenti 2000). Groundwater extraction and recharge can be similarly determined by combining ground and

Box 3.17 Basic Remote-Sensing Technology Outcomes Useful for Irrigation and Drainage Projects

Remote sensing application applied to	Remote sensing technology outcome
Irrigated area	Soil moisture
Crop types	Soil salinity
Land use	Crop water needs
Waterlogging	Crop water use
Crop growth	Crop yield

Source: Author.

satellite data, thus avoiding labor-intensive field surveys of tubewell operations (Ahmad 2003).

POTENTIAL BENEFITS

Remote-sensing yields data that complement field interviews and conventional hydrometeorological point measurements. These data allow retrospective studies, because satellite data are archived from the early 1980s on. For instance, the impact of management transfer and institutional reforms over a 10-year timeline could be studied. The other examples, in table 3.1, were selected from recent Bank and non-Bank remote-sensing projects in agricultural water management. They show how satellites help obtain strategic data on changes and trends that may help confirm or contest certain views.

POLICY AND IMPLEMENTATION

CROP WATER PRODUCTIVITY. The advantage of expressing productivity per unit of water consumed is that it comprises all water resources, thus including water originating from precipitation, irrigation, groundwater, and soil moisture-storage changes. Moreover, evaporated water cannot be recycled for downstream users, so the depletion should be associated with productive use. Satellite images have been used to compute crop water productivity in World Bank projects in India, Pakistan, China, and Egypt on a scale that is not feasible with traditional field surveys and field campaigns (box 3.18).

INTEGRATED WATER AND ENVIRONMENTAL MANAGEMENT PLANS. These plans strive toward a desirable water balance that meets the environmental flow requirements. Such an ideal water balance can be achieved if the comprehensive ET from catchments and basins (including ET depletion from irrigated crops, soils, forests, and cities) is less than the rainfall, leaving the rainfall surplus available to feed natural streams. Irrigation fields may have to go out of production through an early land retirement program or undergo a “real water saving” program that reduces ET.

A satellite study determined comprehensive ET in the North China Plain in 2002. It was the only way to quantify the amount of water resources depleted because all earlier water balance studies had a field scale. It allowed policy makers to identify all counties with severe overexploitation of groundwater (box 3.19) and single them out for maximum attention to reduce water depletion during the Hai Basin Integrated Water and Environment Management project. An example is presented in figure 3.1. Outcomes of remote-sensing technologies allow the identification of huge water consumers and discussion of options with water user groups to temper groundwater pumping.

LAND RECLAMATION AND CROPPING PATTERN ADJUSTMENTS. Granting user groups water rights and water quotas is a way to deal with water scarcity in agriculture. Fixed river diversions provide a guarantee for user groups to plan their longer-term allocations and shares. The Tarim Basin

Box 3.18 India and Pakistan: Using Satellites to Assess Crop Water Productivity

The Indo-Gangetic plain may be considered a single agro-ecological zone. The surface energy balance remote-sensing algorithm was used to assess the full spectrum of wheat yield-ET combinations and to quantify the variations in crop water productivity (yield/ET) on a pixel-by-pixel basis. The average difference in productivity between India (Punjab and Haryana) and Pakistan (Punjab and Sindh) for an 18-year period is 65 percent, in favor of India. The data show that sound agricultural policy positively affects water productivity and that water productivity can be raised through manageable factors such as seed quality, pesticides, and fertilizers. The conclusion is that Pakistan may save huge amounts of water by increasing crop water productivity.

Water productivity of wheat (kg/m³) in India (Punjab and Haryana) and Pakistan (Punjab and Sindh)

Period	Pakistan	India	Difference
1984–5	0.76	1.15	51 percent
1994–5	0.64	—	n.a.
1995–6	0.57	1.23	116 percent
2001–2	1.00	1.28	28 percent

Source: WaterWatch 2002.

—, Not available.

n.a. Not applicable.

Table 3.1 Some Remote-Sensing Applications

Land use	In India's Indus Basin, 6 percent more land is under irrigation and 27 percent less land is irrigated during kharif season than suggested by 1994 census data for Pakistan. Owing to shift from rotational to continuous flow (4 percent in unimproved areas), 15 percent more rice is being grown in Egypt's northwestern Nile Delta.
Waterlogging	Waterlogging in the Chasma Right Bank Canal (Pakistan) varies from 1.1 percent to 6.1 percent of the total irrigable area, depending on the year selected. In Awati County (Tarim Basin), 3.2 percent of the land surface is waterlogged.
Water use	Owing to reuse of drainage water, no significant difference in ET between head and tail end of irrigation systems in the northwestern Nile Delta could be detected (in either 1995 or 2002). Volumetric water depletion varies little by irrigated and rainfed agriculture (7 percent and 8 percent, respectively) in Sri Lanka, and is significantly less than the depletion caused by natural heritages (23 percent), homesteads (7 percent), and rangelands (21 percent). Water consumption of cotton in the Harran Plain, Turkey, is 650 millimeters per season. This can be used to assess Euphrates diversions.
Irrigation efficiency	Classical irrigation efficiency (consumptive use/supply) is 40 percent in the 70,000-hectare Awati County (Tarim Basin). Classical irrigation efficiency in the Indus Basin (16 million hectares) is 95 percent; hence, recycling is a key phenomenon in large-scale irrigation systems.
Crop yield	Rice and cotton yield are hardly affected by rotational versus continuous flow in the northwestern Nile Delta. Significant differences in cotton and rice yield are found in Kazakhstan's Aral Sea Basin owing to salinity and irrigation water availability.
Water productivity	Wheat productivity in the Punjab/Haryana states of India is 65 percent more than in the Punjab/Sindh provinces of Pakistan. Water productivity of rice in the Yellow River Basin (2001) in China can be as high as 1.51 kilograms per cubic meter (std 0.16 kg/m ³); the Nile Delta shows 0.95 kg/m ³ (1995) to 1.45 kg/m ³ (2002) for rice; and the figure for Pakistan is 0.49 kg/m ³ (1984) and 0.42 kg/m ³ (2001).
Soil salinity	In Awati County (Tarim Basin), 12 percent of the soil is saline. Total salts in the Russian Federation's Karakalpakstan (Amu Darya Delta) increase little but head-tail effects are pronounced during dry years.

Source: Authors.

project of the World Bank East Asia and Pacific Program involves managers and water user groups in adapting land use and cropping patterns to maximize profit from their water quotas. The project encourages land reclamation by leaching saline land. Key questions were what areas could be reclaimed and what impact cropping pattern adjustments would have on water resources management (box 3.20). These could be answered only with remote-sensing data.

AID TO APPRAISAL AND EVALUATION STUDIES. Rehabilitation projects for irrigation and drainage are often appraised with limited field data or data selected by the recipient country to support the request. Not infrequently, these data are biased and stem from an unrepresentative sample designed to curry favor with Bank decision makers. A more comprehensive and truthful impression can be obtained from satellite data during the preappraisal and appraisal phases,

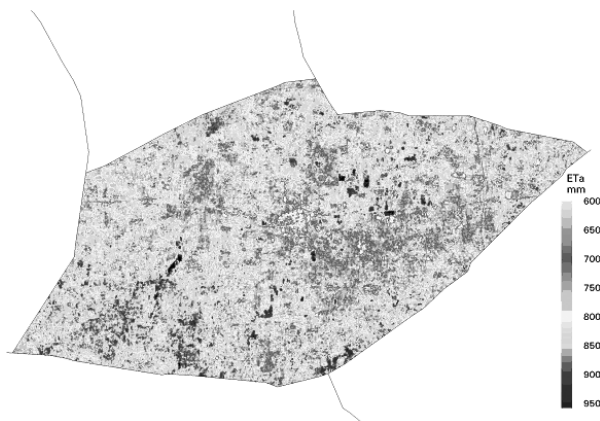
Box 3.19 Counties in the Hai Basin with Significant Overexploitation of Groundwater Resources, 2002

Beijing Province	Shenzhoushi County
Hebei Province	Jingxian County
Hebei Province	Hengshuishi County
Hebei Province	Jizhoushi County

Source: WaterWatch 2003a.

Note: Overuse is defined as greater than 450 mm/year.

FIGURE 3.1 ANNUAL EVAPOTRANSPIRATION FOR FEIXIANG DISTRICT, HEBEI PROVINCE, NORTH CHINA PLAIN



Source: WaterWatch 2003a.

Note: The map, with a 30-meter spatial resolution, is based on 24 Moderate Resolution Imaging Spectroradiometer (MODIS) images and 3 Landsat images captured during 2002. Groundwater overexploitation is a serious concern in this area. Areas shown by pixels corresponding to overexploitation exceeding 700 millimeters will be selected for a water-saving program.

often without extensive field surveys. A description of a mid-term evaluation study in the Middle East and North Africa region is presented in box 3.21.

LESSONS LEARNED

Water professionals who favor technological advances may accept remote sensing faster than engineers who demand convincing evidence. Going through a trust-building phase at the very beginning of any new agricultural water management project is recommended. Experience

has shown that local validation (“check first in your own backyard”) is essential for acceptance of the technology. This phase must be executed with local agricultural research institutes and universities that have expertise and their own field data on agricultural water management. These local institutes should lead the confidence-building phase and therefore be equipped with appropriate field devices.

Timely involvement of local stakeholders is essential to guide solutions to the irrigation and drainage problems, in other words, a bottom-up approach. Satellite data can help local management authorities explain to WUAs and agencies responsible for water distribution why certain features identified on the images occur and how shortcomings can be improved. Project benefits rely on stakeholder awareness, commitment, and timely action to remedy problems.

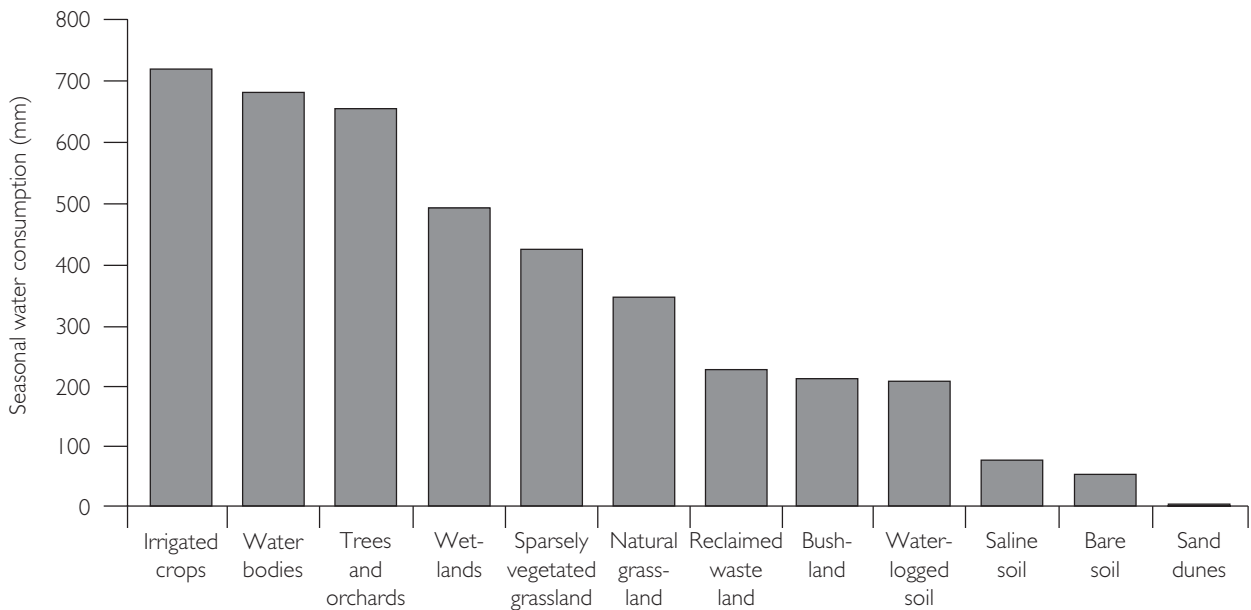
Task managers should invest a little extra in the appraisal studies on data collection through remote-sensing technologies (approximately US\$20,000 to \$100,000, depending on the detail required and the scope of the investigation) before a loan is approved. A similar satellite-based assessment can be made during the mid-term or evaluation phase of agricultural water management projects. These costs are only a small fraction of the total loan and can significantly facilitate the identification of the problem and the solutions chosen to mitigate adverse field conditions.

RECOMMENDATIONS FOR PRACTITIONERS

- Verify the conditions in the project area and appraise the hypotheses and needs of a new Bank irrigation and drainage project through remote-sensing techniques.
- Define the type of outcome of using remote-sensing technologies such as real water savings, uniformity in crop water consumption, water productivity, irrigation performance, groundwater extraction, or environmental degradation.
- Agree with the recipient organization on the required time (daily, monthly, seasonally,

Box 3.20 Impact of Land Reclamation and Crop Selection on Depletion of Aerial Water Quota

The Aksu River is the main contributor of water to the Tarim Basin in the Xinjiang Uygur autonomous region of northwestern China. To ensure delivery of adequate amounts of water to the middle and lower reaches of the Tarim River, a green corridor in the Taklamakan Desert, a maximum river diversion entitlement was negotiated. A remote-sensing study was conducted to estimate the ET of all land use and crop classes for the summer season. The study was based on high-resolution Landsat data, combined with low-resolution data from a satellite operated by the National Oceanic and Atmospheric Administration. The conversion from saline soil (ET=76 mm) via reclaimed wasteland (ET=226 mm) to irrigated cotton (ET=721 mm) requires an additional 645 mm (6,450 m³/ha) of water. The reclaimed area could be 9.2 percent larger if trees and orchards were planted instead of cotton, since cotton's ET is 9.2 percent higher than that of perennial trees.



Source: WaterWatch 2002.

annually) and spatial scales (1 m, 5 m, 30 m, 250 m, 1,000 m) of the remote-sensing data outcomes.

- Design the link between remote-sensing data outcomes and auxiliary data sources such as land use maps, geographic information system (GIS) databases on applied water, soil maps, and slope maps.
- Define the level of capacity building required to interpret and process satellite images.
- Include a local university or agricultural research institution in the process for independent validation of the remote-sensing results.

- Devise early on an appropriate strategy to disseminate the results to targeted users.

INVESTMENT OPPORTUNITIES

- Acquire additional information on current irrigation and drainage practices from satellites through the execution of quick scan studies.
- Discuss with local agencies the need for irrigation and drainage projects using unbiased satellite data.
- Launch capacity-building programs to endow recipient countries with geographical data and information systems that enhance the local knowledge base.

Box 3.21 Egypt: Project Impact Evaluation

The World Bank and the Kreditanstalt für Wiederaufbau (KfW) have jointly funded a multimillion dollar irrigation improvement project in the Nile Delta, Egypt, to transfer the on-demand irrigation systems into continuous flow at the tertiary level. This is part of the country's modernization of water management and is meant to reduce water use, enhance equity, and increase crop (kg/ha) and water productivity (kg/m³)—all of which indirectly affect farmer income. The first phase of the project started in 1995, and the execution is ongoing. A midway project evaluation was made on the basis of satellite data in 2002. A diagnosis has been carried out using Landsat images in areas for which at least 25 percent of the project interventions are operational. Though it is too early for a full midterm evaluation, some interesting trends are evident, as shown in the table.

Project dates	Improved area	Unimproved area
Start, 1995	49.8 percent rice	42.7 percent rice
	30.1 percent cotton	31.7 percent cotton
	5,454 kg/ha rice yield	5,642 kg/ha rice yield
	1,993 kg/ha cotton yield	2,017 kg/ha cotton yield
	582 mm rice ET	587 mm rice ET
	777 mm cotton ET	771 mm cotton ET
Midterm, 2002	57.3 percent rice	44.7 percent rice
	28.5 percent cotton	29.1 percent cotton
	8,516 kg/ha rice yield	8,563 kg/ha rice yield
	2,920 kg/ha cotton yield	2,921 kg/ha cotton yield
	586 mm rice ET	583 mm rice ET
	873 mm cotton ET	866 mm cotton ET

Source: WaterWatch 2003b.

- Use satellite data by involving local institutes in monitoring the progress and impact of the water management interventions.
- Identify subregions with good and bad agricultural water management practices and initiate farmers-train-farmers programs.¹

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ENDNOTE

1. This information comes from WaterWatch (2003a, 2003b).

This Note was prepared by Wim Bastiaanssen and Edwin Noordman of WaterWatch. Input was received from Shawki Barghouti. The note was reviewed by Aly M. Shady of the Canadian International Development Agency.

INVESTMENT NOTE 3.7

PRIORITIZING LENDING FOR PUBLIC IRRIGATION SCHEMES WITH THE RAPID APPRAISAL METHOD

A rapid, performance-focused appraisal of irrigation systems can give a pragmatic description of the status of both the internal process and the external input/output indicators of a system or sector. It allows identification of investments that can quickly improve water delivery service and financial stability, and mitigate environmental impacts. It presupposes an environment that rewards improvement.

Most public irrigation investments are directed toward improving existing schemes rather than building new ones. Such investments are difficult to prioritize, and their results have historically fallen well short of the impact predicted by feasibility studies. During the 1990s, most World Bank projects looked to governance reform to achieve fiscal sustainability and administrative autonomy (for example irrigation management transfer to WUAs, cost recovery). They were generally accompanied by hardware investments assumed to improve the controllability of water. The irrigation agency or ministry of irrigation generally gave priority to hardware investments, and they had the most clout in the

irrigation arena: they controlled the budget and had the best access to the government. Their favorite choices were canal lining and rehabilitation to put structures back to design shape.

Once a government-owned irrigation system achieves, or begins to achieve, sustainability and autonomy, the basic question becomes how to select investments that improve the controllability of water and give users the best value for their money. This Note discusses the usefulness in client countries of a procedure that evolved on 60 public irrigation schemes in the western United States where users self-finance O&M. This procedure has been adapted to client-country conditions and incorporated in the holistic benchmarking toolkit developed by IWMI. It has been applied in Mexico, Nepal, the Philippines, Thailand, Vietnam, and elsewhere.

INVESTMENT AREA

The procedure is known as rapid appraisal (RAP, as noted above). Consisting of office and field work and taking several weeks, RAP has three components:

- Several hundred questions, framed in a standardized Excel format, address topics such as water supply, personnel management, canal structures, and level of water delivery service throughout the system. Evaluators must personally travel from the dam to the ends of main, secondary, and tertiary canals, until they reach the farmer turnouts.
- The values of a large set of external and internal indicators are computed (box 3.22).
- Objectives are defined, and results of the procedure are used to target investments to accomplish those objectives (boxes 3.23 and 3.24).

One goal of investment is to break, or stay out of, the rehabilitation-deterioration cycle. Investing only in rehabilitation is therefore illogical. Instead, a modern approach to investment is needed. Or rather, what is needed is a total revolution in irrigation agriculture with much more focus on improving the *performance* of existing

Box 3.22 Indicators Used in a Rapid Appraisal Procedure

External indicators express forms of efficiency. They may relate to budgets, water, or crop yields. They require only knowledge of project inputs and outputs—but by themselves provide no insight into what to do to improve performance. They have often provided the basis for conventional public irrigation investment decisions. Internal indicators examine the hardware and processes that move, sell, and schedule water throughout the system hourly, daily, and seasonally.

Source: Burt and Styles 1999.

Box 3.23 Morocco: The Rapid Appraisal Procedure Can Prevent Waste of Investment Money

Plans had been made to conserve water within the Beni Amir project, Morocco, to expand the irrigated area. A simple water balance conducted as part of RAP showed that all inefficiencies were being recycled in the form of groundwater pumping for irrigation, either within the project or outside the project boundaries. Therefore, there was little or no water to “conserve.” It was determined that improving first-time usage of irrigation water in this case could offer benefits in terms of reduced groundwater pumping bills, higher crop yields (owing to better flexibility), and improved fertilizer usage, but investment would not result in an increased supply for expanding irrigated acreage. Proper application of RAP in this case avoided a waste of investment money.

Source: Burt and Styles 1999.

irrigation facilities and providing client-focused irrigation service (World Bank 1998).

This view emphasizes that investment is about technical, managerial, and organizational upgrading—not merely physical rehabilitation—of irrigation schemes, to improve resource utilization (labor, water, economics, environmental) and water delivery service to farms (Wolter and Burt 1997). Such modernization investment focuses on the details of the inner workings of an irrigation project—in contrast to traditional, simple, and broad-brush investments in canal lining or rehabilitation. Modernization is a process that sets specific objectives and selects specific actions and tools to achieve them. Planners and engineers for irrigation projects frequently equate modernization with practices such as canal lining and computerization. If improved performance is the objective, such investments should often be assigned the lowest priority.

Modernization pivots around service to the farm. Irrigation systems must serve the farmers well enough so that they attain high on-farm production and irrigation efficiencies and can afford to pay the water service fee. An irrigation system is typically a series of layers through

Box 3.24 Vietnam: Impact of Performance-Oriented Rapid Appraisal Procedure on an Investment Program

The Cau Son–Cam Son irrigation scheme in Vietnam underwent an RAP in March 2002, conducted by the Food and Agriculture Organization (FAO), the Irrigation and Training Research Center (ITRC), and local irrigation specialists. Initially, the local participants believed that canal lining was the best investment of World Bank funds. After the procedure they drafted detailed—and quite different—investment recommendations (\$1 US = 15,500 VN dong), and also distinguished between immediate and long-term investments.

Short term (US\$2.6 million)

- Repair and rehabilitate turnout gates (10 billion dong)
- Rehabilitate destroyed secondary canal, including regulators (5.5 billion dong)
- Establish WUAs (1 billion dong)
- Improve communication (initially, telephones) (1 billion dong)
- Improve control of secondary and cross-regulator-operated canals and change main cross-regulators to composites (15 billion dong)
- Treat canal sections for seepage (8 billion dong)

Long term (US\$7.1 million)

- Complete planning for entire system (2 billion dong)
- Upgrade reinforcement of two weirs: Cau Son and Quang Hien (8 billion dong)
- Upgrade secondary and tertiary canals with better cross-regulators (70 billion dong)
- Redevelop system operating procedures (0.5 billion dong)
- Upgrade pump stations for irrigation and drainage, dredge drains (20 billion dong)
- Construct small and medium-size regulating reservoirs (10 billion dong)

Source: ITRC 2002.

which water passes. Each layer has an obligation and needs incentives to provide good service to the layer immediately below (Burt and Styles 1999).

POTENTIAL BENEFITS

Public irrigation systems account for about half of the world’s irrigation. Adopting a radically different approach to irrigation investment will help secure the world’s food supply and promote social stability as well as help mitigate the systems’ impact on the environment.

A successful modernization approach consolidates WUAs by reducing risk factors such as inequitable and unreliable water deliveries. It also creates the conditions for higher water productivity. Water saving becomes possible only when farmers feel secure about water delivery. As long as they do not, they will store water in the soil as back-up and allow it to percolate or evaporate when their crops do not need it.

POLICY AND IMPLEMENTATION

One of the bigger challenges to implementation is the scarcity of specialists who understand the service concept and the hydraulic principles involved in managing unsteady water flow.

A second major challenge resides in the nature of loans and grants, as outlined below.

- Technical details are often dismissed as “matters to deal with later” and considered unimportant compared to the broad goals. Yet we now know that the lack of attention to internal details is a major cause of poor performance. Many internal details must be defined early in a project—which requires a shift in the way loans and grants are administered.
- A large human element is involved in changing internal processes. Local irrigation engineers and managers will not immediately understand how to design and manage new processes and structures. Farmers may object to higher fees and delivery practices they may experience as less reliable. Loan and grant programs have short lives, which leaves staff and farmers little or no time to field-test new ideas.
- Modernization costs more than most people think. As an example, the 200,000 hectare Imperial Irrigation District in California, United States, recently spent more than US\$100 million on modernization. It already had excellent communications, roads, canals, training, attitude, and irrigation scheduling. Yet the total investment in modernization will probably approach US\$500 million. This demonstrates that lenders and

borrowers should not entertain high expectations from investment if it is minimal and therefore quickly implemented.

LESSONS LEARNED

The greatest impediment to successful application of RAP is the lack of qualified irrigation specialists to conduct the procedure. Few irrigation experts adequately understand the concepts of water balance, efficiency, and water control to both conduct RAP and develop realistic recommendations. Intensive training and follow-up by experienced professionals are mandatory. The limited training that has occurred has not been followed up. Local participants must thoroughly understand the concepts and buy into the investment program if it is to be sustainable.

An RAP was done on the Yaqui Irrigation project in Obregon, Mexico, in November 2002 as a prelude to a large investment (table 3.2). The project depends on both surface water and wellwater. During 2002–3, no surface water was delivered—creating an emergency but also opening a window for construction.

The initial choice of project personnel was to spend about 80 percent of the budget on canal lining. The water-balance analysis done in the course of the procedure showed that net canal seepage losses were relatively small. Local participants in the two-week RAP training program, run by ITRC and the World Bank, developed the following set of investment priorities within budget.

RECOMMENDATIONS FOR PRACTITIONERS

- Become acquainted with RAP concepts.
- Contact the few individuals at the World Bank and FAO who have been personally trained and involved in RAPs.
- Assign a significant training budget for local individuals to study and learn to conduct and follow up RAP. This will take time, but it will improve the investments’ probability of success.

Table 3.2 Outcomes of a Rapid Appraisal Procedure in Mexico

Priority	Project	Units	US\$	US\$	US\$
			Cost/unit	Cost	Cumulative cost
1	Deep wells and pumps	140	178,000	24,920,000	24,920,000
2	Flow measurement flumes at canal entrances	35	44,500	1,557,500	26,477,500
3	Modernization of the upper canal beyond Km 105				26,477,500
	Regulating reservoir	1	1,800,000	1,800,000	28,277,500
	Long crested weirs	8	67,000	536,000	28,813,500
	Pumps for outlets above the command area	29	39,000	1,131,000	29,944,500
	Elimination of a flow restriction	1	450,000	450,000	30,394,500
4	Modernization of the lower canal				30,394,500
	Improved structures	7	390,000	2,730,000	33,124,500
	Regulating reservoir	1	200,000	200,000	33,324,500
	Pumps for outlets above the command area	20	39,000	780,000	34,104,500
5	Modernization of structures in the upper canal downstream of the reservoir—two or three ITRC flap gates per structure and one sluice gate per structure	8	22,000	176,000	34,280,500
6	Modernization of lateral canals				34,280,500
	Long crested weirs	250	13,000	3,250,000	37,530,500
	Flap gates	250	13,000	3,250,000	40,780,500
	Inter-ties of the tail ends to the lower canal, or terminal regulating reservoirs	50	56,000	2,800,000	43,580,500
	Small regulating reservoirs	10	56,000	560,000	44,140,500
7	Lining of lateral canals (km)	100	24,000	2,400,000	46,540,500
8	Modernization of canals 4 and 4P				46,540,500
	Structures	8	200,000	1,600,000	48,140,500
	Regulating reservoir	1	100,000	100,000	48,240,500
	Pumps for outlets above the command area	6	39,000	234,000	48,474,500
9	Improvement of farm turnouts	2,000	2,000	4,000,000	52,474,500
10	Miscellaneous actions				52,474,500
	Gated pipe systems (ha)	24,265	64	1,552,960	54,027,460
	Handheld data recorder system	20	3,300	66,000	54,093,460
	SCADA (remote monitoring system)—office and 12 field sites	1	2,000,000	2,000,000	56,093,460
*	Engineering, office, and contingencies	1	3,200,000	3,200,000	59,293,460

Source: ITRC 2002.

- The project definition must incorporate recommendations from RAP—rather than assuming that the procedure should be conducted after initial designs have been made.
- Local experts trained in RAP must be given authority to conduct a stringent review of designs provided by consultants—at several stages throughout the design process. This will add time to the design process, and a change in consultants may be required if satisfactory plans cannot be developed.
- All hardware designs must be accompanied by a description of the overall water management and operation strategy for the complete system, not just for specific structures. Specific descriptions must be provided for managing structures as part of the overall strategy, for correcting problems, and for modifying designs if problems are encountered.
- Implementation should be staged over five to six years after completion of designs. The project must have sufficient flexibility to shift designs, locations, and tasks to make course adjustments.

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This Note was prepared by Charles M. Burt of California Polytechnic State University and reviewed by Jan Bron of Royal Haskoning.

INNOVATION PROFILE 3.1

INVESTING IN AUTOMATION AND CENTRALLY OPERATED IRRIGATION SYSTEMS

What is new? Appropriate automation helps project managers provide water to users flexibly, reliably, and equitably. If appropriate structures and remote monitoring are used, project efficiency and water delivery service can improve simultaneously. Canal breaks, lining damage, and spills can be reduced, and better service enhances social harmony.

Modernization of centralized irrigation systems is a process of technical and management improvements in measurable goals related to project efficiency, crop yields, water delivery service to farmers, economics, and the environment. A key tool is automation. Automation implies that, once set, structures maintain desired flow rates or water levels in canals without manual intervention.

Burt and Styles (1999) found that the quality of water delivery service in irrigation projects is inversely proportional to the number of field employees per delivery point. Regardless of what performance might be theoretically attainable with a large staff and minimal hardware, the evidence shows that properly designed, located, and installed structures greatly enhance staff performance with fewer personnel. This is especially important during the night and where communications are poor.

OBJECTIVES AND DESCRIPTION

Irrigation projects (described simply) have five levels of automation, which should function continuously.

LEVEL 1—APPROPRIATE combinations/designs of structures that do not move automatically, but that control water levels or flows well despite constantly changing flows. The most common successful example is a combination of long-crested weir (which controls canal water level)

and a manual undershot (orifice) gate on the side to provide a constant flow rate to users.

In successful modernization of dozens of western U.S. irrigation districts by ITRC and the U.S. Bureau of Reclamation, canals of 10 cubic meters per second are almost “automated” with this simple and appropriate hydraulic combination that requires no electricity or computers.

An example of an *inappropriate* Level 1 structure widely used in international projects is the “distributor” or “flow rate module” that was successfully used on the elevated canal systems in North Africa in the 1950s. After examining scores of projects that have used distributor modules for automated flow control on canal turnouts (off-takes), the author has concluded that virtually none of them functions satisfactorily—even though these are a cornerstone of many automation projects. They worked well historically on elevated aqueducts, but they are inappropriate for typical canal systems because of installation problems, high expense, susceptibility to submergence on the downstream side, and improper control of canal water levels (Burt and Styles 1999).

LEVEL 2—HYDRAULIC GATES. These are gates placed in the canal to maintain a desired water level—thereby protecting the canal banks and providing steady flow rates to off-takes. The Neyrtec float gates are the classic design used throughout the world. For smaller canals with sufficient drops in the western United States, the inexpensive, locally fabricated ITRC Flap Gate has been installed in several hundred structures.

LEVEL 3—REMOTE MONITORING. This involves monitoring water levels or flow rates at key points throughout a project, and archiving and displaying that information at a central office. The information should be designed to improve management decisions on a real-time basis. Typical monitoring points are at the heads of key canals for flow rates and tail ends for water levels as well as flows. Flow rate monitoring requires excellent flow meters. Remote monitoring is a precursor to successful Level 4 computerized

automation. It involves electronic sensors, communications (usually radio), and office hardware and software.

LEVEL 4—COMPUTERIZED GATE MOVEMENT. This type of automation can be effective on large structures to maintain a water level in a canal or a desired flow rate into a canal. It is generally accompanied by both Level 1 and Level 3 investment.

Hundreds of electromechanical (precomputerized) automatic gates installed in the western United States before 1995 are being converted to PLC (programmable logic controller) automation, which uses electronics rather than electric/mechanical mechanisms. However, the failure rate of PLC-controlled canal systems has been extremely high in the United States and internationally. A checklist of prerequisites for Level 4 automation is presented in box 3.25.

If *all* of the prerequisites in box 3.25 cannot be met, PLCs should not be used. One of the biggest mistakes for PLC-based automation is to

underestimate the requirements for success and the long learning curve it takes. Numerous irrigation projects in Mexico, including the World Bank-funded Cupatitzio (Apatzingan) district were intended to demonstrate PLC-based control. Irrigation experts in Mexico now recognize that almost all PLC-based automation in Mexico has failed.

LEVEL 5—CENTRALIZED AUTOMATION. This comes in various forms, but all of them depend on a central computer to calculate required gate movements and automatically send those values to the field. While the literature has ample discussion of such control logics, there are only a few successful, sustained projects of this type in the world. In the western United States, there are no successful examples of this type of automation in irrigation projects, although research is in progress in a few irrigation districts.

ISSUES FOR WIDER APPLICABILITY

Irrigation projects are plagued by a recurring cycle of investment and deterioration. In addition to the repeated need for rehabilitation, other impacts include lower-than-expected crop yields jeopardizing investment yield and user ability to pay fees, haphazard collection of user fees, and degraded river water quality and volume. Typical “modernization” projects often focus only on institutional issues or canal lining. Those are important, but in the end, the water in a project must be physically manageable—simply and easily.

Appropriate automation to make water more manageable can be simple (as described above)—and it is essential. Appropriate automation removes the “art” and uncertainty from canal operation and allows the institutions to respond to conditions that change hourly. Today’s irrigation projects do not have that capability.

The question, then, is not “Why automate?” but “Which types of automation are appropriate for this project?” The cost of improved water control is not small, but it is typically a small fraction (10 percent or so) of the total project cost.

Box 3.25 Prerequisites for Level 4 Automation

- Excellent electricity availability
- Protection from vandalism
- Availability of high-quality electrical sensors, actuators, PLCs (developing “local” electronics is a common mistake that almost always guarantees failure)
- Existence of a permanent, well-trained staff that can troubleshoot and repair all components
- Availability of an experienced integrator company with a track record of installing such systems in irrigation projects
- Dedicated well-trained local staff with excellent mobility in all weather, night and day
- An adequate, guaranteed long-term maintenance budget for labor and parts

If numerous structures are to work automatically in series (that is, a whole canal), proper simultaneous modeling of the canal pools and gates with the appropriate algorithms must be done by experienced persons who can give the correct and complete information to integrators for the PLC programming.

Source: Author.

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This Profile was prepared by Charles M. Burt of California Polytechnic State University, with input by Shawki Barghouti. The Profile was reviewed by Aly M. Shady of the Canadian International Development Agency.

4

INVESTING IN GROUNDWATER IRRIGATION

- Investment Note 4.1 Investing in Shallow Tubewells for Small-Scale Irrigation
- Investment Note 4.2 Deep Tubewell Irrigation
- Investment Note 4.3 Conjunctive Use of Groundwater and Surface Water
- Investment Note 4.4 Groundwater Governance and Management
- Innovation Profile 4.1 The Republic of Yemen’s Sana’a Basin Water Management Project

OVERVIEW

The advantages of groundwater investment for irrigation, both as a main source of water and as a supplement, are examined in this chapter. Driven by technological advances, groundwater use has spread rapidly, bringing more reliable water supply, encouraging crop diversification, and improving incomes, including for the poor. The biggest problems are overabstraction and water-quality deterioration.

GROUNDWATER INVESTMENT BRINGS MANY ADVANTAGES. With improved pump technologies, groundwater has become a key resource for farmers, used either as a sole source or as a complementary source to surface water or rainfall. Groundwater irrigation can be developed through shallow wells (drilled or hand-dug wells less than 30–50 meters deep) or with deeper tubewells. Groundwater irrigation is attractive to farmers because they can control it to irrigate virtually “on demand.” Water is often of good quality and is available close to the point of use. Groundwater offers natural storage

capacity, reduced evaporation losses, improved drainage, and secure supply, even during droughts. Economically, groundwater irrigation is generally more productive than surface water irrigation, with crop yield per cubic meter up to three times as high. Even the higher cost brings an advantage in incentives to efficient use. Groundwater investment, particularly in lower-cost shallow wells, can have poverty reduction impacts, providing improved water supply for domestic use as well as for gardens and crops. (See IN 4.1, IN 4.2, and IN 4.4. On poverty reduction benefits, see also IN 3.1 and IN 3.3. See also “Investments in Shallow Tubewells for Small-Scale Irrigation,” in *Agriculture Investment Sourcebook* (AIS), Module 8.)

CONJUNCTIVE USE INVESTMENTS PAY HIGH RETURNS. Conjunctive use is the simultaneous use of surface water and groundwater. For example, farmers with access to canal water may also use groundwater. Investment in conjunctive use raises the overall productivity of irrigation systems, extends the area effectively commanded, helps prevent waterlogging, and can reduce drainage needs. Conjunctive use is growing as water becomes scarcer. Ideally, this type of use is a component of an overall basin-level integrated water resource investment and management plan. It is institutionally challenging because it requires coordination among various public institutions, and usually a “public-private partnership” because tubewells are usually private. Retrofitting planned conjunctive management on existing schemes entails changing the hydraulic structures and operating systems to fit new water use patterns. Other forms of conjunctive use investment include conjunctive use with saline groundwater to maintain water and salt balances, conjunctive use with poor quality water such as urban wastewater, and groundwater recharge from surface water for later abstraction. (See IN 4.3.)

THE CHIEF PROBLEMS OF GROUNDWATER ARE OVERABSTRACTION AND DECLINE IN QUALITY. Despite the advantages of groundwater investment, the biggest problems are overabstraction and the

related water quality problems. The poor are particularly vulnerable, because the richer farmers can pump out deeper and faster. Experience shows that the only workable groundwater management systems are those with intensive user involvement and user-government partnerships. A governance system is needed that establishes clear and monitorable entitlements and allows self-management by user groups supported by government in resources assessment, regulation, and dispute resolution. Energy prices have to be set at unsubsidized levels, or they will encourage depletion. Groundwater management is likely to be a significant investment area as resource mining problems grow worse. (See IN 4.4. On the incentive structure, see IN 1.5.)

SOME TYPICAL INVESTMENTS

Typical investments in technical assistance include the following:

- Building capacity of irrigation system managers for improving main system management for better conjunctive use
- Evaluating groundwater and monitoring systems
- Developing groundwater governance structures and user associations

Project investments include the following:

- Improving hydraulic infrastructure for optimal conjunctive use
- Enhancing recharge from precipitation and surface water imports to sustain groundwater use
- Investing in wells and efficient conveyance and on-farm irrigation systems for smaller farmers
- Investing in extension and training

Other related investments include the developing of credit systems.

INVESTMENT NOTE 4.1

INVESTING IN SHALLOW TUBEWELLS FOR SMALL-SCALE IRRIGATION

Small tubewells, also called shallow tubewells or shallow wells, pumping shallow groundwater, satisfy both domestic and irrigation needs. Their small engines also power boats, hand tractors, and other farm machinery. Shallow wells offer new choices in cropping and improve economic and social conditions. They cause conflict if owners overexploit the supply or contribute to salinization of groundwater. Investments in the assessment of the supply and quality of groundwater, in the regulation of well building, and in technical support to farmers are therefore vital to allow shallow wells to go on reducing poverty.

Tubewells are a cost-effective source of irrigation water for many small farmers where groundwater is available at less than 20 meters below the surface. They 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 where groundwater levels are close to the surface and soils are productive. Shallow tubewells are already common in Asia, Africa, and many other parts of the world.

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 crop water from shallow tubewells. Conjunctive use of mostly shallow tubewell water to supplement supplies of surface water to optimize crop production is also common in Pakistan, India, and many other countries (box 4.1).

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.” Tubewells are an 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-mounted pumps with 5–10 horsepower diesel engines.

In the semi-arid Sahelian Zone of southern Niger, groundwater depth is 6 to 8 meters. Annual rainfall of 400–800 millimeters provides groundwater replenishment of 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 3–5 horsepower portable gasoline-powered pumps, hand-operated pumps, or bucket and rope bailer systems (see also IN 3.3). The area irrigated by these tubewells is 0.3–0.5 hectares, depending on the lift needed and the water losses during transport to the field.

BENEFITS

Shallow tubewells provide substantial poverty reduction benefits owing to improved water supply 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. Because these are also used to power boats, hand tractors, and

Box 4.1 India: Groundwater Wells

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

Source: Singh and Singh 2002.

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 4.2).

Box 4.2 Nigeria: National Fadama Development Project

Nigeria's Fadama project was centered on developing small-scale irrigation through extraction of shallow groundwater with low-cost gasoline-driven pumps for tubewells. About 30,000 hectares were irrigated using the complete tubewell-pump package, and 30,500 pumps were distributed to farmers. This resulted in a boost to farmer income and significant poverty reduction. The economic rate of return was estimated at 40 percent. Additional benefits were the development of a simplified well-drilling technology, training of farmers to help other farmers construct wells, infrastructure for transportation and storage of products, establishment of the Fadama User Association, and development of an extensive monitoring and evaluation system. Today's improved welfare of Fadama farmers can be traced directly to this project.

Source: World Bank 2002.

Box 4.3 China: Water Overexploitation in Ningjin County

Groundwater has become the major source of irrigation in Ningjin county, China, since the reduction in the volume of Yellow River water. A rapid increase in irrigated areas has resulted in overexploitation of the groundwater resource, causing serious environmental problems. Tubewell density 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 a tenth of the wells go dry in summer. Farmers have reduced on-farm losses by using plastic tube 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 all production costs.

Overexploitation of groundwater has resulted in a progressive decline in profitability owing to an increase in suction lift; it has also led to less, and poorer quality, water. Salt in groundwater is raising soil salinity. Wheat, a major crop, is moderately salt tolerant, but the other major crop is maize, which is moderately salt-sensitive and can fail if irrigated twice using saline groundwater. The area 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.

Increased production from tubewells also reduces pressure on marginal lands and increases land values, thus providing incentives for conservation. Benefits from tubewells can influence water markets as well. In Pakistan, for example, tubewell owners are sometimes active water sellers to neighbors. Well productivity, delivery potential, and the cost of operation and maintenance (O&M) have a significant impact on the price of water.

POLICY AND IMPLEMENTATION ISSUES

SUSTAINABILITY. In the past, the issue of groundwater resource sustainability was ignored. Insufficient investments (sometimes none at all) were made in groundwater resource assessments and local management institutions. Pumping from shallow aquifers by many wells, in an attempt to irrigate a larger area than possible given the average groundwater recharge, can reduce the water supply of neighboring tubewells, lower water tables, diminish economic returns, degrade water quality, compact the soil, and increase soil salinity (box 4.3). Policies to calibrate the spread of wells to the groundwater recharge potential are critical to sustainability. It is normally the responsibility of governments to monitor and evaluate groundwater and develop rules that control wells. The simplest regulation consists of promoting and enforcing a socially accepted compact for minimum spacing and maximum pump capacity, rather than a full-fledged groundwater use rights and obligations system separated from land ownership rights.

WATER QUALITY. Groundwater quality is important because deterioration from salt or mineral buildup can affect the water's usefulness. Government policies should require evaluation of groundwater quality and the likelihood of changes in quality over time—before well installation. Water quality evaluation is also important to minimize future maintenance costs since 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 crop root zones degrade the water. Over time, dissolved salts and nutrients build up, and the extracted

water gradually declines in quality and contributes to soil salinization. This is what is happening 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 a private good that should be the responsibility of the beneficiaries of the investment. The public sector role should generally be limited to establishing a policy and institutional environment conducive to 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 useful in situations of great poverty and poorly functioning financial markets.

Water user associations (WUAs) in areas where groundwater irrigation predominates are valuable for organizing hardware and infrastructure maintenance; they can represent users, for example, by holding a community water right and overseeing water use. For resource management, by contrast, appropriately scaled aquifer management organizations are needed on which irrigation WUAs should be represented. In areas where surface water irrigation predominates and canal WUAs are established, WUAs are often unwilling to address the interests of groundwater-only irrigators, because these irrigators do not want to pay the WUA a fee without receiving any surface water supply benefits. In this case also, aquifer management organizations under the umbrella of the river basin committee or authority is probably the best way forward on groundwater resource management.

Surveying, drilling test wells, water sampling, and water level monitoring are useful for building a database and tracking long-term trends. The rational management of the groundwater resource is difficult without a basic understanding of the distribution and yields of aquifers and their vulnerability to pollution and overdraft. These monitoring activities are usually 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 (box 4.4). However, lack of political will and lack of awareness among some farmers, but also 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 the following:

- A system of licensing for extracting and using groundwater
- Registration of current groundwater users and penalties for noncompliance with licensing provisions
- Arrangements to protect the rights of shallow tubewell users from more influential farmers who can drill and power deep wells that lower the water table and deprive these tubewell users of access to water

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.

Box 4.4 Groundwater Regulation

The Punjab Private Sector Groundwater Development project's experience with introducing groundwater regulation offers these lessons:

- A public awareness program must precede groundwater regulation.
- Where groundwater is a significant source of poor farmers' livelihoods, a regulatory framework must address the linkage of groundwater to surface water rights and actual surface water deliveries and the involvement of groundwater users in groundwater monitoring and "social recharge" (voluntary self-regulation).
- When groundwater abstraction will be curtailed as a result of regulation, poverty alleviation interventions must accompany regulation to help identify and create alternative means of income for the affected communities.

Source: Usman Qamar (personal communication).

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 (see Investment Opportunities below).

Experience with shallow tubewell projects emphasizes the need for investments to address the following:

- Evaluate the groundwater hydrology and management to be certain that the groundwater recharge potential is in balance with projected water use.
- Monitor groundwater quality to ensure suitability for irrigation, and make realistic projections on 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 products that are new or more abundant in the area may also require advisory services.

INVESTMENT OPPORTUNITIES

- 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; pumpsets with engines, hand pumps, or bailer systems;

small canals or pipe to distribute water to fields; and micro-irrigation (such as drip or minisprinkler set-ups) if justified by the 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.

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INVESTMENT NOTE 4.2

DEEP TUBEWELL IRRIGATION

This Investment Note summarizes the technical, socioeconomic, and institutional factors that go into investment decisions for deep tubewell irrigation. Groundwater irrigation has some advantages over surface water in ensuring good quality and reliable supply, but it also poses important challenges and risks, as past projects show. Correct resources assessment and adequate institutional capacity are especially important for sustainability.

As pump technologies improve and costs drop, millions of farmers have been deciding to irrigate their crops with groundwater from wells. Some countries rely very heavily on groundwater for irrigation because of its many advantages over other irrigation water sources (table 4.1).

Deep tubewell irrigation has unique strong points where extensive aquifers with sufficient recharge allow for large-capacity wells. Availability at the point of use, drought resilience, suitability for user O&M, rewards for efficient water use, and the possibility of switching to high-value crops make deep well irrigation an attractive alternative or complement to surface water irrigation. But without government guidance on resources assessment and local management, the risk of diminishing returns and negative environmental side effects is high.

INVESTMENT AREA

Pumping wells abstract groundwater from an aquifer. They are called “shallow” when the drills or picks and spades do not excavate deeper than 50 meters. They are called “deep” when the well, in that case nearly always drilled, reaches a depth of 40–200 meters and discharges 100–1,000 cubic meters a day. The pump engines are diesel or electricity driven, and the well diameter may range from 200 to 600 millimeters.

Farmers may apply groundwater where there is no surface water but also use groundwater to complement surface water (or as a back-up). Depending on the number of hours of operation and the type of irrigation (full or supplementary), a deep tubewell may irrigate 10–200 hectares.

Groundwater from major aquifers is usually of good quality, available at the point of use, and offers the option to phase development of the irrigation infrastructure. Other advantages are the natural storage capacity and drought resilience of aquifers and the possibility for underground storage and reuse of excess water from surface water irrigation and irrigation return flow, a practice widespread in India.

In a deep aquifer, drilling wells should always allow large short-term well yields, mainly because of large “available well drawdown.” But drilling finds new or additional groundwater resources only where regional sedimentary or volcanic aquifers have major unexploited recharge areas, usually distant. Where the alluvial

Table 4.1 Importance of Groundwater in Irrigation

Country	Period	Irrigation water use (million m ³ /year)	Groundwater (percent)
Bangladesh	1990–5	12,600	69
China	1993–5	407,770	18
India	1990–3	460,000	53
Pakistan	1990–1	150,600	34
Mexico	1995–7	61,200	27

Source: United Nations–FAO Aquastat Database.

aquifer systems are small, they will be interconnected with deep aquifers and depend on the same recharge area.

It is important to distinguish between the scales of groundwater irrigation, because the extent of external impacts is largely determined by scale:

- A smallholder operating a low- or medium-capacity tubewell, sometimes as an extension in the bottom of a dug well using a centrifugal pump
- A group of 20–100 farmers sharing one high-capacity deep tubewell and organized in a WUA
- Large farmers or agricultural companies that own one or more high-capacity tubewells

Deep tubewell irrigation can be applied under different conditions. Some examples follow:

- As a complement to rainfed agriculture or protection of vulnerable high-yielding crops

against dry spells or unreliable delivery of surface water

- As an alternative to, or extension of, shallow dug well irrigation
- As a supplement to surface water irrigation during reduced supply (tail-end users) to grow an extra harvest during dry season or to mitigate the impact of changes in land use or climate
- As the original water source in new irrigated agricultural projects such as land reclamation projects

Each case has specific requirements in addressing such issues as knowledge and management of the resource, reaching the main poverty goal, establishing WUAs, and raising incomes (profitability, markets, switches to high-value crops). The assessment and evaluation of these pre-tubewell conditions is an important starting point in exploring the feasibility of investments in deep tubewell irrigation (table 4.2).

Table 4.2 Issues Related to Pre-Tubewell Conditions

Pre-tubewell conditions	Resource issues	Social and institutional issues	Agro-economic issues
Rainfed agriculture	Aquifer characteristics and sustainable yield to be determined	Farmers may be organized but water management agency and WUA not yet in existence	Farmers will shift to higher-value crops and introduce water-saving irrigation techniques (drip, sprinkler)
Shallow well irrigation (dug well, shallow tubewell)	Shallow groundwater is available, but information to be extended for deeper aquifers	Farmers are used to irrigation through individual water supply provision; WUA may not yet exist	Agro-economic conditions may not match new situation
Surface water irrigation	Aquifer characteristics and sustainable yield to be determined in relation to changes in recharge)	WUA may exist but require a change in tasks and organizational structure	Farmers will expand agricultural production
No irrigation, as in land reclamation in (semi-)arid regions	Aquifer characteristics and its sustainable yield to be determined; irrigation return flow	No social infrastructure. Irrigation; water management system/agency and WUA are still to be established	Agricultural production will expand in the area to include new crops and new irrigation methods

Source: Author.

POTENTIAL BENEFITS

Groundwater is more productive than most surface water: it is abstracted at the point of use and suffers few transport losses; it offers the individual farmer “on demand” irrigation that few surface systems can match; and it brings incentives to maximize application efficiency because of the cost of lift.

On groundwater-irrigated farms in India, crop yield per cubic meter is 1.2–3 times as high as on farms irrigated with surface water (Dhawan 1989). Similar findings come from Spain. The explanation is economic. In response to the high cost of groundwater lift, irrigators often use sparse, life-saving irrigation instead of aiming for the maximum production per unit area through full irrigation, which is at the basis of the irrigation practices of surface water irrigators, and of the water requirement recommendations of agronomists. In so doing, groundwater irrigators achieve more crop per drop than do their surface water colleagues and, at the same time, increase yields per unit area compared to rainfed cultivation. Some irrigators in South Asia purchase water from well owners at US\$0.10–\$0.14 per cubic meter, while their canal irrigator colleagues pay only a fraction of a cent. Even some of the poorest irrigators make a living paying these groundwater rates.

Groundwater development is more amenable than large surface systems to poverty targeting. The design of large systems is driven by topography and hydraulics. Groundwater development has become the central component of livelihood creation programs for the poor in Africa and Asia (Shah 1993 for India; Kahnert and Levine 1993 for the GBM basin; Calow et al. 1997 for Africa).

The benefits of deep tubewell irrigation can be summarized as follows:

Economic benefits

- Energy costs give incentives to raise yield per unit of water, raising income through switches to higher-value crops.

- Reliability during drought and its lack of sediment allow use of water-efficient irrigation technology.
- Reliability opens access to new markets, for it protects high-value crops and inputs against dry spells.
- Groundwater allows tail-end users on surface systems to cope with shortages in irrigation water supply.
- Groundwater suffers little from evaporation losses.
- Groundwater pumping can improve drainage.
- Investment risk can be reduced through phased construction of the hydraulic infrastructure.

Social benefits

- Groundwater management requires decentralized aquifer management, and hence institutional strengthening of farmers.
- Groundwater enables small farmers to invest in irrigation, individually or as group members, through rural credit programs.

Environmental benefits

- Groundwater pumping has mitigated and prevented waterlogging and salinization on surface systems in the Arab Republic of Egypt and Pakistan.

POLICY AND IMPLEMENTATION

Policies need to create enabling environments to manage and use the resource. Management of the resource presupposes the following:

- Knowledge of the aquifer and natural recharge and the amounts of water that can be safely withdrawn without undesired side effects
- Monitoring of abstraction rates and groundwater levels

- Regulations with sanctions for abstraction of more groundwater than planned and agreed
- Institutions such as aquifer associations and courts empowered to enforce regulations
- Controls on energy subsidies in order to avoid overabstraction
- Licenses stipulating abstraction quotas
- Registration and licensing of drilling contractors to prevent illegal drilling and to ensure the quality of well construction
- Definition of technical standards for equipment and infrastructure

Use of groundwater resources presupposes the following:

- Credit facilities to enable investments
- Local commercial services for supply and repair of equipment
- Definition of social criteria for the formation of WUAs
- Clarity of water rights
- Extension and agricultural research institutes to test new cash crops
- Equal access and voting rights for male and female farmers

LESSONS LEARNED

Groundwater abstraction depends on a seamless web of technologies and institutions. A break anywhere in this web causes the project to fail and the system to eventually shut down. Useful lessons can be learned from past, unsuccessful projects for groundwater development (box 4.5).

After construction, a main cause of failure is uncontrolled increase of abstraction, which causes water tables to drop, especially where recharge is limited. Overabstraction has resulted

from the introduction of mechanical pumps, in combination with energy subsidies and weak regulations concerning impact monitoring and demand management. Overabstraction has many consequences: water quality deteriorates because low-quality water fills the void; land subsides; small farmers' wells run dry because only rich farmers can deepen their wells; and the base flow to rivers and wetlands diminishes.

Another main cause is poor standards of well construction, impairing system reliability and increasing pumping costs when wells clog. Regenerating clogged wells is expensive and may not lead to a full recovery.

A third cause is recirculation when fertilizer- and pesticide-laden runoff reenters the aquifer, reducing groundwater quality.

Customary water rights, local rivalries, and disputes over land may prevent the establishment and operation of aquifer associations and WUAs. In the projects in Pakistan, government operation of deep tubewells was costlier but less user responsive than private operation.

Finally, the absence of markets and the lack of support structures to provide spare parts for pumping equipment and interruptions in electricity supply may cause failure.

RECOMMENDATIONS FOR PRACTITIONERS

Investments in deep tubewell irrigation must be accompanied by facilities to invest in water-saving irrigation techniques and by effective aquifer management, based on a good understanding of the resource base. Potential investments in deep tubewell irrigation should strongly support this approach (box 4.5).

INVESTMENT OPPORTUNITIES

Potential investments in deep tubewell irrigation include the following:

- Evaluating groundwater resources, quality, and sustainable yield

Box 4.5 Lessons Learned from the Indonesia Groundwater Development Project

The major objective of the Indonesia Groundwater Development project was to develop groundwater irrigation in less-developed regions in 11 provinces to help alleviate extreme poverty. Major components included the survey, investigation, and design; construction of deep tubewell and intermediate technology tubewell systems serving about 25,000 hectares; initial O&M support for two years after the commissioning of tubewell systems; provision of domestic water supply and home garden irrigation facilities; agricultural development activities, including strengthening of extension services; community support, including training and strengthening of WUAs and activities related to the role of women; and institutional support for design, implementation, supervision, and monitoring and evaluation of project performance. The project would also strengthen groundwater monitoring networks by constructing and equipping observation wells, providing water quality monitoring equipment, and training provincial water resources development service staff on groundwater resources monitoring.

After a slow start, project performance rapidly deteriorated owing to a multitude of problems. The most important of these were significant cost overruns in groundwater exploration and the construction of wells, poor or untimely procurement of equipment, and development of wells with low water outputs. The World Bank seriously considered closing down the project in 1996. After lengthy discussions with the government, the Bank agreed to restructure the project and continue drilling activities in only two provinces (East Java and South Sulawesi) where project implementation had less serious problems—owing to significant upfront investment commitment, proven groundwater aquifers, and responsive farmers. As a result of the decision to concentrate on two provinces, the main focus of the project shifted to achieving economic and technical success, with diminished emphasis on helping to alleviate extreme poverty in less-developed regions. Because of the unsatisfactory performance during preparation and appraisal and poor project outcome, overall Bank performance was rated unsatisfactory.

Some of the lessons outlined in the Implementation Completion Report follow.

- *Project design must be in line with the implementation capacities of the designated institutions.* The original design was too ambitious and led to serious operational and implementation management difficulties including drastic restructuring. Intended stakeholders must be involved with the conceptualization, planning, design and implementation of the project, to ensure realistic programs and phasing. In this project, the lack of participatory approaches; lack of full assessment of capacities and roles of the government, private sector providers, and users; and lack of demand-driven implementation led to faulty siting of many wells, less than optimal adoption and utilization of the technology, and procurement of inferior quality equipment and installations.
- *Quality control and assurance of tubewells must be rigorously pursued by project management.* Because critical structures of tubewells are underground, repairs and replacement are difficult after installation. Provision should be made for assessing implementation capacities and for requiring technical assistance to be structured to support capacity building so that client agencies and private sector service providers can meet industry standards. The pumps and engines selected should be the ones preferred by the farmer groups that will manage them if spare parts will be available locally.
- *Government must transfer ownership of equipment and wells to WUAs, in addition to O&M responsibility, after providing adequate guidance and training, and consider the establishing of a locally administered asset replacement fund in order to prolong sustainable O&M of installed works beyond the expected project period.* The transfer of management and assets to users is considered essential to establishing ownership and responsibility for longer-term operational sustainability.

Source: Indonesia "Groundwater Development Project" Implementation Completion Report 2000.

- Reforming policy and regulations governing deep tubewell irrigation systems
- Strengthening WUAs to manage deep tubewell systems
- Developing and implementing systems for monitoring groundwater levels and groundwater quality
- Providing financial services to enable producers to finance the drilling of deep tubewells
- and purchase of pumping equipment, construction of distribution canals, and installation of micro-irrigation options such as drip and sprinkler
- Training WUAs to operate and maintain the deep tubewell systems
- Providing guidance in irrigation water management, agronomy, and marketing through extension and training.

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Briefing Notes by GW-MATE are also useful references because they are written for Bank task managers and are only six pages long. PDF files are available at <http://www.world-bank.org/gwmate>.

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INVESTMENT NOTE 4.3

CONJUNCTIVE USE OF GROUNDWATER AND SURFACE WATER

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.

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 tubewells raise the productivity of irrigation

systems (box 4.6), 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).

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 4.7). 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 (see IN 4.4).

Because 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.

INVESTMENT AREA

Five areas of investment opportunities appropriate for different conditions need to be considered; these are summarized below.

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. One such assumption concerns the density of groundwater structures in the command area, which commonly is much higher than before the system was commissioned. Reconfiguring the main system, rationalizing the

Box 4.6 Conjunctive Use by Default: Punjab and Mula Command, Maharashtra, India

Mushrooming wells changed the profile of water use in Mula command in Maharashtra, India. Indirect benefits of canal irrigation through groundwater recharge are even greater than direct benefits from flow irrigation. Dhawan and Satya Sai (1988) found that area irrigated per well rose from 1.4 hectares to 2.6 hectares; land productivity increased from 17 to 50 quintals of food grains per hectare; and the number of wells in the canal command rose from 6,000 to 9,000. The benefits of conjunctive use were also reflected in canal irrigation in Punjab, as summarized in the table.

Command	Direct land productivity (qtl/ha)	Indirect land productivity (qtl/ha)	Total land productivity (qtl/ha)
Mula command, Maharashtra	21	33	54
Punjab	35	51–72	86–107

Source: Dhawan and Satya Sai 1988.

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 4.8).

CONJUNCTIVE MANAGEMENT OPPORTUNITIES IN TOWNS. Rapid urbanization in many parts of the world have created new threats for periurban agriculture. However, conjunctive management

Box 4.7 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 course of a 10-year collaborative study, scientists from 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.

of rainfall, surface water, and groundwater creates new opportunities to meet these threats (box 4.9).

CONJUNCTIVE USE WITH SALINE GROUNDWATER. In regions with primary salinity—such as the Indus Basin in Pakistan and northwest India, the Nile Basin, and the Yellow River Basin in North China—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

Box 4.8 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.

Box 4.9 Conjunctive Management Challenge of Towns and Cities

Most Indian cities face massive urban groundwater depletion because municipal authorities can neither keep pace with growing water demand nor check runaway growth in urban groundwater structures. To meet growing demand, cities begin to compete for water with periurban farmers. In the Indian state of Karnataka, the government plugged the sluices of irrigation tanks surrounding all towns and cities to counter urban groundwater depletion. In this case, farmers lost their water rights without any compensation. However, informal water markets—in which periurban farmers give up irrigated agriculture to become water sellers—create other negative externalities. Such water suppliers play an important role in bridging the demand-supply gap. In Chennai, for instance, they add 21 percent to the municipal supply; and in Indore and Jaipur, they add 12 percent and 10 percent, respectively.

Municipal authorities also draw water from periurban well fields. Chennai's Metrowater draws water from wells drilled on common or government land so that it does not have to buy water rights from farmers, making them vulnerable to water resources depletion. In Panjetty village near Chennai, of the 69 wells, 13 are leased out to Metrowater, which pumps them daily. As a result, water tables have fallen, and well yields have declined (Londhe et al. 2004). Since cities commonly have to import surface water to meet growing urban water demand, there are great opportunities for conjunctive management of imported surface water and urban and periurban groundwater.

Source: Londhe et al. 2004; IWMI 2002.

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 (box 4.10).

POTENTIAL BENEFITS

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 river-basin level, but this cannot be done until the river basin becomes the unit of water and land management.

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,

Box 4.10 Conjunctive Management in Lerma Chapala Basin, Mexico

Rehabilitation and modernization programs to save water often neglect the influence of surface water management on groundwater levels. During 1982–98, net aquifer extraction was predicted to result in an average static water level decline of 2.12 meters a year, compared to a 1.81 meters a year historical average in 398 wells in six aquifers in the basin. Eight alternative scenarios (producing average declines between 0.00 and 3.21 meters a year) were generated to show that feasible changes in grain and vegetable cropping patterns and water management are unlikely to bring static groundwater depths back to historical levels. Decreasing the relative water supply of surface irrigation (defined as the ratio of total surface water supply to crop demand) by 10 percent, as for instance through surface irrigation system rehabilitation, was simulated to result in an additional average decline of 0.91 meters a year (combined average 3.03 meters a year). Increasing the relative surface water supply by 10 percent (equivalent to increasing reservoir releases by 25 percent) was simulated to reduce average decline to 1.21 meters a year. Increasing surface water supply by 23 percent (increasing reservoir releases by 57 percent, a level considered unfeasible [Scott and Garcés Restrepo 2001]) was simulated to produce zero average decline. The results indicate that, in water-short basins, the sustainability of groundwater trends is inextricably linked to the management of surface water—and is highly sensitive to the area and type of crops irrigated, as well as surface water management practices.

Source: Scott and Garcés Restrepo 2001.

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 arrest 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 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. Often, level control can be greatly improved by replacing gates by overshot weirs or duckbills. 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 FOR PRACTITIONERS

- 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.

INVESTMENT OPPORTUNITIES

- Capacity building of irrigation system managers to improve main system management for better conjunctive use
- Reshaping hydraulic infrastructure of large- and small-surface systems for optimal conjunctive use
- Enhancing recharge from precipitation and surface water imports to sustain intensive groundwater use in tubewell-irrigated areas
- 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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This Note was prepared by Tushar Shah of IWMI with inputs by Karin Kemper. It was reviewed by Stephen Foster of BNWPP GW-MATE.

GROUNDWATER GOVERNANCE AND MANAGEMENT

Groundwater management is becoming more and more a must in developing countries to forestall overexploitation and to foster sustainable use of the water resources. Nevertheless, sound management of groundwater requires an efficient institutional and regulatory framework, which only the full commitment of the government can ensure. This Investment Note deals with the laws, regulations, and institutions involved in the governance of groundwater resources and with management and enforcement of these rights for the public good.

A stored water resource available in most countries, groundwater has long been treated as an infinite resource that can be endlessly exploited. The idea that groundwater, though a common good, belongs to the overlying landowner has shaped thinking about water, even in the developed world. Only after this resource has been overexploited and polluted do governments and users begin to worry about managing its use. Attempts to allocate groundwater and manage these entitlements in a sustainable manner have achieved only limited success and still pose a major challenge to the water sector.

INVESTMENT AREA

The World Bank considers investments in groundwater and its governance worthwhile. Because groundwater is invisible and erratically developed, many governments ignore the need for its regulation and management. As the concept of integrated water resources management is now a primary policy, a detailed understanding of groundwater within a river basin and its interaction with surface resources becomes imperative. Because the use of groundwater in most developing countries is largely unregulated, well digging and water abstraction from wells in those countries frequently overexploit the resource and cause hardships, especially for small users and the poor. Investment in ground-

water governance is needed to manage this resource in a sustainable manner and to educate users and governments about the need for a sound system of entitlements and allocation, based on a factual knowledge of the aquifers and systemic geohydrology.

A recent Bank investment program in Mexico (box 4.11) and a potential lending project in the Republic of Yemen focus on the sustainable development and management of groundwater. These programs are breaking new ground in investment for groundwater governance and will address entrenched exploitation of the resource. The continued overexploitation and pollution of critical groundwater resources in many countries creates a critical need for multilateral investment in the legal and institutional framework for groundwater governance to ensure sustainable management over the long term for the public good.

POTENTIAL BENEFITS

The efficient use of groundwater, either conjunctively with surface water supplies or as a sole source, requires the development of aquifer parameters, modeling of hydrologic characteristics, and development of a sound entitlement and management system. Investment in these management tools can result in a reliable and stable source of water for economic development, drought alleviation, and an effective and economic water supply complement to surface water. Little of the water stored in aquifers is lost through evaporation. Use of groundwater therefore has significantly less impact on river systems and riparian and lacustrine habitat than does use of surface water. It provides a reliable buffer to cyclical or annual shortages of surface supplies; recharge during wet years and extraction during dry years can limit the impact of cyclical droughts. Groundwater can provide a reliable source of water for small users to help alleviate rural poverty.

POLICY AND IMPLEMENTATION

The governance of groundwater requires a strong policy decision at the highest governmental

Box 4.11 Mexico: Groundwater Management

Groundwater has historically been overexploited in Mexico. In the Mexico City area and many other regions, it has resulted in subsidence, lowered groundwater tables, increased pumping costs, shortages, and aquifer pollution. The country has been attempting to resolve overextraction for many years and has passed enabling legislation that provides the legal framework for dealing with the groundwater management problem, but overexploitation has continued. This can be partially attributed to a continuation of energy subsidies. In addition, the administration and enforcement of the groundwater entitlement system has been top-down rather than participatory. Control over well drillers and well-drilling equipment has been insufficient to curtail the construction of illegal wells.

The World Bank–financed *Programa de Modernización del Manejo de Agua (PROMMA)* incorporated a groundwater management component and is establishing water entitlement management pilots in selected aquifers. This pilot program will test the concepts of decentralized aquifer management through volumetric entitlements, measurement of extractions, and extraction limitations based on the safe yield of the aquifer. It will utilize the local user-oriented technical commissions of water (Comite Técnico de Aguas Subterráneas—COTAS) as a primary factor in the management of the aquifer, attempting to involve users through education, capacity building, and institutional development.

Deterioration of groundwater quality poses another problem. Knowledge is insufficient about the long-term impacts of industrial waste discharges, petroleum leakage, and agricultural pesticides, fertilizers, and chemicals. Overexploitation of aquifers in coastal areas has caused saline intrusion. Subsidence, principally in the Mexico City urban area, has also caused grave economic damage and put both historic and modern structures at risk.

Resolution of these problems requires strong political support, a public education and information program, and user involvement. They can be solved only basin by basin and aquifer by aquifer. Limitation of energy subsidies will help mitigate the problem, but it must be resolved locally. The empowerment of local COTAS is being encouraged, in part through financial assistance, to create local rewards for the sustainable management of aquifers.

The project benefits from a strong legal framework. It is designed to build the institutional capacity of user-level organizations in order to transfer groundwater administration and management in specific aquifers to those who have the greatest vested interest in sustainable use of the resource. Care must be taken to assure all users of the equal treatment of all, regardless of user size, political connections, or wealth. Failure to secure trust in the reciprocity of sacrifices made for the good of all will perpetuate unregulated overexploitation of the aquifers.

Source: Garcés-Restrepo 2001; Garduno 1999; Mexico "Water Resources Management Project"; Foster and Garduño 2002.

levels to create the legal and institutional framework for sustainable use. Groundwater is viewed in most countries as belonging to the overlying landowner, not to the sovereign, and resistance to regulation of its use can be strong. Adoption, monitoring, and enforcement of entitlements will therefore require major policy decisions, strong laws and regulations, and formation of a participatory institutional framework to carry out those policies.

A successful groundwater governance policy depends on a country's physical, political, and cultural setting. The physical parameters include hydrogeology, aquifer endowment, and the use made of the water supply. Best practice in groundwater development, regulation, and management is still evolving, but there are some excellent, time-tested examples of well-

organized and regulated groundwater governance, as in the U.S. states of California and Colorado (boxes 4.12 and 4.13).

Management policy must deal with two major categories: groundwater that is conjunctive with the surface water (that is, tributary aquifers), and groundwater that is extracted from aquifers not connected to surface supplies (that is, nontributary aquifers). Nontributary aquifers can be further split into aquifers that have reasonable recharge from outlying recharge areas and aquifers that receive such limited recharge as to be considered nonrenewable, where water extraction can be considered mining of a nonrenewable resource. Depending on the groundwater situation, the appropriate level of aggregation of water resources management has to be chosen. To monitor and manage quality,

Box 4.12 Southern California: Groundwater Management

Groundwater is still a key source of water for Southern California, although imported water supplies have become the main source. The state's procedures for the issuance, administration, and management of groundwater entitlements suggest some useful principles and ideas for groundwater governance.

The state cannot administer entitlements or manage groundwater. Landowners have a correlative right to use all groundwater they can extract and use beneficially from beneath their property. This approach has led to overexploitation and relative anarchy in many basins, and many users have taken their water rights disputes to court.

Users in the Raymond Basin near Los Angeles filed a court action in 1937 and the court rendered a precedent-setting decision in 1944, adjudicating the groundwater entitlements in the basin and establishing a court-appointed water master to enforce and manage them. The decision led to a practice whereby each well was entitled to a proportional annual volumetric extraction, as determined by the water master, who measured and recorded the extractions. The water master, or a designated agency, also monitored the piezometric levels within the aquifer and maintained and published records. Extraction beyond an allocation was punishable by fines. Trading of annual allotments was permitted so that users needing more water could purchase or rent the allocations of others who did not use their annual allotment.

Utilizing the powers of the courts to adjudicate groundwater entitlements in a basin became the norm, one used in the adjudication of the Main San Gabriel River Basin near Los Angeles. That basin had a combination of tributary surface water use, dating to the previous century, and underlying aquifers that were conjunctive with the surface system. Because of the region's hydrological seasonality, surface water was stored in the upper reaches of the San Gabriel River for later use, and groundwater use had minimal effect on the rights of surface users. However, groundwater overexploitation resulted in a major drawdown of the aquifer and caused saline intrusion along the Pacific Coast. The Los Angeles County Flood Control District developed major groundwater recharge basins in the main San Gabriel Basin to capture winter and spring runoff that would otherwise be lost to the ocean. Even with these facilities, overexploitation continued, and the users went to court in 1968.

In 1973, the court allocated the entitlements to users, appointed a water master, and established a nine-member basin management board. This board is elected by the water districts and water purveyors in the basin. It is responsible for managing entitlements and extractions in the basin, administering and accounting for water augmentation plans including groundwater recharge, and administering exchanges, water transfers, and credits. During its 25 years of operation, the system has matured into a well-accepted, participatory groundwater management system. The board is now confronting continued and pervasive saline intrusion and pollution of the aquifer by urban chemicals, lawn and yard pesticides, and pollutants from petroleum and other industries.

Source: DWR-CA 2000, 2003a, 2003b.

nontributary groundwater basins should be managed at the spatial level corresponding to hydrogeological aquifer boundaries. The appropriate level of management for tributary groundwater is not straightforward, because surface water resources are generally best managed at the river basin level, with authority aggregated to river basin commissions or other administrative bodies. To avoid water management conflicts and inconsistencies in policies addressing groundwater and surface water management, regulation and agency reforms have to be coordinated.

Policy for managing these conjunctive resources must also be coordinated. If it is not, a disproportionate share of the available water may come from wells, particularly during droughts. The allocation and management of entitlements in a tributary system must be designed so that

the groundwater and surface water are treated as an integrated supply, and a safe yield of groundwater extraction is part of the integrated annual sustainable yield of water from the basin.

Groundwater management policy for nontributary aquifers requires a solid understanding of the aquifers and their hydrogeologic characteristics. The management of these types of aquifers necessitates a hydrologic model of the aquifer for estimating the finite amount of extractable water that is available within the aquifer. This allows the determination of an annual safe yield from the aquifer, or the determination of the annual volume of water that may be extracted over a preselected finite life for the aquifer. The selection of the finite life is a combination of economic and political policy decisions by users and government. Once this annual extractable

Box 4.13 Colorado: Groundwater Administration

Colorado has a highly organized system of governance for groundwater entitlements, divided into nondesignated (or tributary) groundwater and designated (or nontributary) groundwater. The nondesignated groundwater entitlements are incorporated in the surface water entitlement system and are conjunctively administered by the state engineer in order of priority along with surface water supplies. Entitlements are issued through the water court system in accordance with Colorado's priority doctrine. To pump wells when those entitlements are not in priority, the well owner, or more frequently, an association of groundwater users, must develop an augmentation plan through the purchase or rental of surface entitlements or through groundwater recharge schemes that must be approved by the state engineer. During a recent drought, the Colorado Supreme Court decided that the use of annually rented water was not sufficient and that augmentation plans had to have assurance of a permanent water supply, as approved by the water court. This decision caused a major dilemma in the midst of the drought, as refusal of temporary augmentation plans resulted in political turmoil. In February 2004 it was still being debated in the legislature and the water community. The end result was the inefficient use of the conjunctive groundwater aquifers during the drought, right when the use of this valuable reserve water resource should have been maximized. This demonstrates how well-meant but rigid law may hinder good water management.

In designated or nontributary groundwater basins, the issuance, administration, and regulation of entitlements are under the jurisdiction of a groundwater commission. Its members are water users from within the basins and are appointed by the state governor, subject to Colorado Senate approval. The Groundwater Commission has full jurisdiction over the basins it designates as nontributary, but uses the State Engineer's Office (SEO) to administer entitlements and regulations. "Water available" for allocation in each designated basin is based on yield determinations for withdrawals that would deplete the basin over 100 years. The allocations are reserved for overlying landholders in the designated basins, with consideration given to interaction between wells. These designated basins include the portion of the Ogallala aquifer underlying Colorado. Within these designated basins, the SEO conducts a hydrogeologic evaluation of the designated basin and develops a model or scenario for the annual permissible extraction, based on a finite life of the supply as determined by the Groundwater Commission, and criteria for well spacing and permissible well yield. This model is used by the SEO in the issuance and administration of groundwater entitlements.

The SEO is also responsible for promulgating and enforcing the technical and physical criteria for well construction and for regulating licensed well drillers and the abandonment of wells, so that illegal wells do not threaten the integrity of the aquifers and public safety is protected. Finally, the SEO is responsible for maintaining a registry of all wells including extraction records, physical characteristics, and ownership.

This system of groundwater governance has worked well for both designated and nondesignated groundwater, but the conjunctive management of the tributary groundwater and surface water systems has been hampered by judicial decisions. While any system of groundwater management must have a system of dispute resolution and last recourse appeal, care should be taken to minimize the ability of those unfamiliar with integrated management to upset the integrity of the management system in the interest of legal correctness.

Source: CRS 2003; SEO 2003.

volume is determined and the finite life of the aquifer is set, reliable investment decisions can be made regarding use of the water supply. This allows a monitoring, measurement, and management system to be designed to manage the available resource equitably and to provide for reserves for future development.

Experience has shown that the most successful management systems have strong, participatory self-governance by user organizations, with regulatory oversight by the government or the court system (see IN 2.1). The policy decision to incorporate participatory management is frequently met with resistance from entrenched bureaucra-

cies and by people who think water users cannot manage their own affairs. The most successful examples of the management of nonrenewable groundwater aquifers have been those managed by a commission of elected water users, operating under the guidance and oversight of a state-level regulatory authority. This peer-level management is more acceptable to the user community. An independent entity is needed to certify the hydrologic data regarding the aquifer and to assure users and the public that the aquifer is being managed in accordance with agreed criteria. If nonrenewable supply is to be relied on as the sole source of supply for a developing economic region, long-range

planning for this development must consider that the finite life of the water supply may similarly shorten the economic life of that region. Long-range planning must give serious attention to the development of alternative water sources if the regional economic base is to be maintained.

LESSONS LEARNED

- Groundwater has historically been considered a common good, but its use has not been easily regulated by governing bodies or self-regulated by individual users. This dilemma has an impact on the management of many natural resources.
- Only in the past century has there been some success in the formulation of legal, regulatory, and institutional framework to manage groundwater.
- A program of groundwater governance must be tailored to each region's political, cultural, and geologic circumstances.
- Most users want to maximize their own water extractions and have little confidence that other users will collectively limit their extractions to a theoretically safe yield. This "dog-eat-dog" attitude can be modified only if all water users can have confidence in the equity of the water allocation and management system so that they are convinced that all users equally share scarcity and limitations.
- Experience in areas of water scarcity and overexploitation, such as Colorado and California in the United States, Mexico, and the Middle East has shown that a strong legal framework, without a similarly strong institutional framework at the user level, cannot resolve the problem of overexploitation. This job becomes even more difficult when dealing with a multitude of users large and small.
- Peer-level management at the user level with governmental oversight has the best chance of success.
- To allocate and manage groundwater intelligently, sound knowledge is needed about resources, reserves, recharge, and safe yield. This knowledge should be coupled with reliable monitoring of extractions, water levels, and water quality, in that order. Investments should include the development and maintenance of such an information system.
- Because of cultural bias and the complexities governing groundwater, attempts to develop and implement a program will require a strong governmental commitment, a strong legal framework, supporting regulations, a participatory process of governance, a well-designed and transparent education and public information program, an equitable allocation system with registered entitlements, a sound hydrologic information system, and a dispute resolution system with peer-level enforcement that creates incentives, instead of just penalizing infractions.
- To control overexploitation, there must be a strong program to regulate and license ownership and use of well-drilling equipment, with criteria for new well construction.
- The development of a successful program of groundwater governance will not be easy; it will require extremely strong leadership within the government. The development and implementation of an effective water system will be an evolutionary process that may take generations to become accepted and effective. Realistic expectations must therefore be maintained concerning any water investments.
- Any investment in this area must strongly emphasize the legal and institutional development, as well as development of capacity at the user level, and should start in pilot areas where scarcity has created sufficient concern among users that they are ready to accept the new ideas. This will provide a platform for testing the management concepts to show that they work in the political and cultural context.

RECOMMENDATIONS FOR PRACTITIONERS

The following recommendations are provided for the consideration of planners attempting to prepare an investment project in the area of groundwater management and governance.

- Make sure that the development and implementation of a governance system has strong support from the political leadership of both the government and the water sector. Identify champions in political, bureaucratic, and private sectors who can ensure the necessary national and local commitment.
- Analyze the region's historical and cultural background to identify any strong biases or impediments to the implementation of groundwater entitlement and management, and devise a strategy to deal with them.
- Analyze the existing legal and institutional framework for groundwater use, entitlements, and management, and recommend modifications to adapt modern management ideas for use in the particular situation.
- Analyze knowledge about the aquifers' physical parameters, sustainability, and degree of exploitation. Incorporate in the investment project a plan to augment this information with additional data collection, modeling, and studies in order to develop a strong estimate of the safe yield of each aquifer and a plan for sustainable exploitation. This process should have strong input and participation from the user community.
- Develop a participatory program of equitable entitlements that considers historic beneficial use, safe yield of the aquifer, the geologic parameters of well interaction, and the cultural and socioeconomic impacts of the entitlement program.
- Implement the basic legal, institutional, and administrative frameworks to support the proposed entitlement program in advance of the investment appraisal to make sure that the proposed project does not die awaiting political action.

- Provide sufficient infrastructure investment components in the investment package to create incentives for espousing the new management ideas. However, tie the schedule for building infrastructure to benchmarks of progress in the legal and institutional development components to ensure priority for the institutional components.
- Identify and incorporate a pilot component that provides a realistic test of the proposed program and that also provides some degree of optimism about achieving success. Provide a roadmap for using pilot results for expansion to the entire region.
- Maintain a strong and transparent information, education, and participatory program during project implementation to gain the confidence of the users and political leadership in the program's basic directions and fairness.
- Be realistic. The introduction of modern management ideas will represent a major change in the historic and cultural approach to groundwater governance and will meet with resistance from vested interests and others that may feel threatened by any form of groundwater resources regulation.

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INNOVATION PROFILE 4.1

THE REPUBLIC OF YEMEN'S SANA'A BASIN WATER MANAGEMENT PROJECT

What is new? The Republic of Yemen, at the southern tip of the Arabian Peninsula, faces extreme water shortages. The Sana'a Basin Water Management project aims to both increase the volume and lengthen the useful life of the available water resources within the Sana'a Basin, where the country's capital city is located. To reach its goals, the project seeks to increase the efficiency of agricultural water use, accelerate aquifer recharge, and buy time for a gradual shift to a less water-based economy.

Water availability in Sana'a, the capital, is one of the lowest in the world. Bringing in water from outside the basin is highly uneconomical—the cost would exceed US\$1 per cubic meter, and could go as high as \$8 per cubic meter—and socially controversial.

The project has to contend with the following hydrological facts:

- There is no perennial surface water anywhere in the Republic of Yemen.
- Annual average precipitation in the Sana'a Basin is 700 to 800 million cubic meters (MCM), and only 5 percent of it infiltrates in the soil. The remaining 95 percent evaporates.
- Another 40 MCM to 80 MCM seeps into the ground from irrigation and sewage return flows.
- Total recharge is estimated between 80 MCM and 120 MCM.
- Total abstraction is about 250 MCM a year, which is 100 percent to 150 percent higher than recharge.
- More than 80 percent goes to irrigation, and the balance to domestic and industrial use.

- Water abstraction is uncontrolled, unmetered, unlicensed, and unpaid for.
- In August 2002, there were 13,000 wells in the Sana'a Basin, and this number was growing rapidly. Of these, only about 70 were state owned for public water supply.
- The simplified groundwater configuration consists of a shallow aquifer (alluvium and volcanic), at depths of 30 to 80 meters and a deep aquifer, known as the Tawilah aquifer, at depths of less than 100 meters to more than 1,000 meters.
- There is no perceptible recharge from the shallow to the deep aquifers. Horizontal transmissivity is minimal. The Tawilah water is practically a fossil aquifer.
- The water resources database is poor.
- According to estimates derived from earlier studies, the economically exploitable deep aquifer stock is between 2 billion cubic meters (BCM) and 3 BCM.

The Sana'a wastewater treatment plant was completed in mid-2000, but the quality of the treated effluent has been variable. The plant is often bypassed, especially during peak flows, owing to energy blackouts, when oil and slaughterhouse waste arrives with sewage. The plant then releases untreated effluent into the wadi. The effluent, treated or untreated, is used by about 600 farmers to irrigate about 300 hectares of crops, including vegetables. This practice poses a high risk of aquifer contamination and endangers the health of both farmers and vegetable consumers. Infiltration from cess pits and inadequate treatment of urban sewage result in heavy biological contamination in the shallow alluvial aquifer under Sana'a and often causes flooding in parts of the city.

The water law of August 2002 is a step in the right direction but still allows water abstraction without license up to 80 meters. It imposes neither water abstraction metering nor a levy for irrigation. At this writing, bylaws or regulations were still pending.

About half of the irrigation water and half of the irrigated area in the basin are used to grow *qat*, a leaf from a tree or bush with stimulating effects when chewed. Qat chewing is socially controversial, because it devours up to half of an average family's income. Cultivation poses severe health hazards linked to uncontrolled pesticide spraying. A qat pest-management plan is foreseen under the project. The project does *not* support qat but cannot ignore it. Water saving from improved qat irrigation could make a big difference in the basin's overall water balance. Qat cannot therefore be excluded from the project. Besides, next to selling water to the city, no activity is as profitable for farmers.

OBJECTIVES AND DESCRIPTION

The government and the Bank have concluded that tackling these complex issues requires an innovative and programmatic approach. They have agreed on an Adjustable Program Loan (APL) with three phases during a 12-year period. They do not pretend that this high-risk and high-reward operation will reinstate a water balance. Many methods are untested in the Republic of Yemen and require close monitoring. Their joint use amounts largely to a trial-and-error approach.

Key triggers for passage from phase one to phase two of the project include (1) a well-functioning O&M system for the demand and supply management components; (2) considerable reduction in the diesel subsidy that encourages unlimited pumping; (3) compliance with effluent standards by Sana'a's wastewater treatment plant; (4) conversion of two-thirds of the project-targeted areas to improved irrigation systems by December 31, 2006; and (5) a halt to expansion of irrigated zones.

Total program cost is estimated at US\$120 million at 2002 prices, with a first phase of US\$30 million and a first phase International Development Association (IDA) credit of US\$24 million.

Out of about 110,000 hectares of arable land, 24,000 hectares are irrigated. About 12,000 hectares are in the project area of phase 1 of the

APL, of which about 4,000 hectares are the first targets for improved irrigation.

The project aims at increasing the volume and lengthening the useful life of water within the Sana'a Basin by raising the efficiency of agricultural water use (demand management) and accelerating aquifer recharge (supply management). These measures will buy time for the rural economy to gradually decrease its dependence on water. The project is demand driven and community based.

The project has four components, outlined below.

DEMAND MANAGEMENT—expose farmers to equipment and methods that may save up to 40 percent of water; change pumping and water use behavior through a comprehensive information and public awareness campaign to reach every segment of the basin population.

SUPPLY MANAGEMENT—accelerate recharge, and save precipitation runoff from evaporation by building 5 small retention dams and rehabilitating 11 dams; gain better understanding of the hydraulic situation, through systematic monitoring of precipitation and water use, to improve water management.

INSTITUTIONAL DEVELOPMENT—build a strong and sustainable legal and regulatory base for central and local water basin management, including water regulation and enforcement, planning, and water allocation that can be replicated in other basins.

ENVIRONMENTAL MANAGEMENT—the project falls under environment category "A," which means it requires a detailed environmental assessment and mitigation plan; therefore, its implementation and monitoring is a project component.

OUTPUT AND IMPACT

The main beneficiaries of this project would be the people in the project area, including the inhabitants of Sana'a, where nearly all of the basin's 1.5 million people live. The expected results may be summarized as follows:

Benefits

- Extended useful life of groundwater resources
- Increased value of agricultural production per unit of water pumped
- Decreased likelihood of human and socioeconomic losses due to dam failure
- A model for basin management applicable elsewhere in the Republic of Yemen and the Middle East and North Africa region

Risks

- Government does not put adequate institutional arrangements in place or the approach fails. For example, staffing may be inadequate in the participation section of the Sana'a branch of the National Water Resources Authority; water management, regulation, and enforcement may not be delegated to stakeholders (delegation is essential because central enforcement is impossible owing to the absence of a regulatory system and sufficiently trained staff); the partnership approach to water management and self-regulation may not work.
- No water is saved from improved irrigation because farmers may use water saved to increase their irrigated area, or because farmers may not be interested in investing in water-saving irrigation technologies and stick to their tradition of unlimited free access to groundwater.
- Phase one of the program does not achieve “triggers” for basinwide expansion.
- Outsiders see the project as favoring qat production and attack it for that.

ISSUES FOR WIDER APPLICABILITY

The program is a fully integrated water resources management operation. In the Yemeni context, it presents innovations in at least four domains:

- *Water rights*—the program recognizes existing groundwater rights, and regulates future

abstraction through well registration, licensing, and metering.

- *Institutional partnership*—the program establishes a partnership between central and local authorities.
- *Decentralized water resources management and self-regulation*—the program marshals peer pressure through WUAs to achieve self-regulation of water use.
- *Incentives and regulations*—the program wages an intensive information and public awareness campaign; it subsidizes water saving irrigation equipment (and eligibility means commitment to reduce pumping and *not* expand irrigation); and water users are involved in regulation and enforcement.

LESSONS LEARNED

Implementation had just begun at the time of writing, so it is too soon to evaluate program success. Some lessons have, however, been learned from the design stage. They include the following:

- Participation and ownership are essential at all levels.
- Staff continuity and adequate staff remuneration are essential. Their absence in the Republic of Yemen slowed and disrupted project preparation.
- A realistic institutional and legal framework is important for this approach to work. In the Republic of Yemen, it has to be built up from scratch.
- A well-developed database on available water resources and current uses is a must. The Republic of Yemen's database is mediocre and has to be improved during project implementation.

This Profile was prepared by Peter Koenig and reviewed by Keizrul Abdullah of the International Commission on Irrigation and Drainage.

5

INVESTING IN DRAINAGE AND WATER QUALITY MANAGEMENT

- Investment Note 5.1 Investing in Land Drainage
- Investment Note 5.2 Investing in the Reuse of Agricultural Drainage Water
- Investment Note 5.3 Investing in the Reuse of Treated Wastewater
- Innovation Profile 5.1 Drainage Investments in the Context of Integrated Water Resources Management
- Innovation Profile 5.2 Investing in Controlled Drainage
- Innovation Profile 5.3 Investing in Evaporation Ponds
- Innovation Profile 5.4 Investing in Biodrainage
- Innovation Profile 5.5 Investing in User Operation and Maintenance of Drainage

OVERVIEW

This chapter discusses how to get the best out of used water.

INVESTMENT IN COUNTERING PROBLEMS OF WATERLOGGING, SALINITY, AND WASTEWATER CAN BRING ECONOMIC, ENVIRONMENTAL, AND SOCIAL BENEFITS, PARTICULARLY FOR POOR PEOPLE. To be able to do this, however, it needs an integrated approach. Waterlogging and salinity are reducing water productivity over wide areas, yet investment in drainage is usually neglected in developing countries. Floods affect more people—140 million in an average year—than do all other disasters put together, and the risk is growing. Ever more water is being used in towns, reducing volumes available to agriculture, and treated and untreated effluent poses a major threat to the environment and health. The costs of these problems fall mainly on the poor, whose farms are most vulnerable to water shortages, waterlogging, and flooding. Yet these problems can be turned to good account, usually to the benefit of the poor. Drainage and urban wastewater flows represent precious extra resources, and floods can contribute to recharge and irrigation resources.

The innovations described in this chapter have been proven beneficial. An integrated approach is needed for these investments because wastewater management involves several sectors and their institutional structures: urban utilities, agriculture, public health, environmental protection, and treatment and reuse must be agreed on and coordinated. Drainage water reuse requires also an integrated approach to irrigation design and management. Flood management requires a basin approach and multisectoral investments. (See IN 5.1 and IP 5.2 on waterlogging and salinity, IN 5.3 on urban wastewater, and IN 5.2 for reuse of agricultural drainage water. On floods, see chapter 8, especially IN 8.2.)

WATERLOGGING AND SALINIZATION HAVE BECOME CRITICAL CONSTRAINTS, WITH AT LEAST 20 MILLION TO 30 MILLION HECTARES REQUIRING DRAINAGE INVESTMENTS. Irrigated land may become waterlogged and salinized as water tables rise and salts build up. Most drainage projects have produced good rates of return and improved farmer incomes, yet investment has dwindled as projects have concentrated on upstream irrigation and farming. Investment costs are generally low, ranging from on-farm surface drainage systems at US\$100 to \$200 per hectare up to US\$1,000 per hectare for pipe drainage in arid areas. Beyond individual economic benefit, drainage can contribute to overall land and water management and the environment. Drainage is a proven but demanding discipline and technology. Best investments are often highly case and site specific, and careful research and piloting are required. Integrated approaches address all on-site and off-site impacts of drainage. Although governments usually have to take the initiative, investment sustainability requires farmer involvement, as experience from pilots has shown, for example, in the Arab Republic of Egypt. (See IP 5.1 and IN 5.1. For a case study on Egypt, see IP 5.5. See also “Investments in Waterlogging and Salinity Control,” in *Agriculture Investment Sourcebook* (AIS), Module 8.)

DRAINAGE IS A COMPLEX, MULTIFUNCTIONAL INVESTMENT THAT HAS TO BE CONSIDERED WITHIN AN INTEGRATED WATER RESOURCE MANAGEMENT FRAMEWORK. Drainage is a complex phenomenon with multiple impacts, positive and negative, on other functions of the resource system. Integrated resource management requires a new focus on drainage, which has to be analyzed within the context of a hydrological unit such as a basin, using an integrated approach and addressing all positive and negative impacts of drainage on and off site. A new methodology (“DRAINFRAME,” an acronym that stands for Drainage Integrated Analytical Framework) is described in this chapter. It shows how a participatory planning methodology looking at every aspect of the resource system and all the stakeholders can untangle the multiple impacts, costs, and benefits; prioritize investments; and begin to locate benefits and mitigate side effects. (See IP 5.1 on drainage and on DRAINFRAME. See IP 9.1 on assessing costs and benefits.)

THERE HAVE BEEN SIGNIFICANT INNOVATIONS IN DRAINAGE TECHNOLOGY RECENTLY. Several entries in this chapter describe these innovations. One discusses how controlled drainage can be used for water table management. Land drainage systems often allow water to move too quickly through the soil profile. Controlled drainage slows down the loss through the drainage system. A second innovation described is the use of evaporation ponds. Costs are low, useful life can be up to a half century, and environmental problems are largely manageable. Finally, biodrainage can be used to remove excess water by using the uptake capacity of vegetation, especially trees. (See IP 5.2 for controlled drainage, IP 5.3 for evaporation ponds, and IP 5.4 for biodrainage.)

INVESTMENT IN REUSE OF TREATED WASTE AND DRAINAGE WATER CAN OFFSET WATER SCARCITY. Investment in reuse of poor quality water in agriculture can offset water scarcity and preserve better-quality water for higher-value uses. Both wastewater reuse and drainage

water recycling represent an important agricultural water management investment opportunity. Large and reliable volumes of drainage water are available close to reuse sites, and investments to enable reuse are low and can be added on to existing schemes. In Egypt, reuse of agricultural drainage water became national policy in the 1980s, and now reuse is practiced on 90 percent of the irrigated area. Investment in reuse of both resources often disproportionately benefits the poor, contributing to livelihoods and household food security. (See IN 5.2 for treated wastewater and IN 5.2 for reuse of agricultural drainage water.)

A WIN-WIN SCENARIO IS ELUSIVE IN INVESTING IN NONCONVENTIONAL WATER, AND GOOD POLICY, PLANNING, AND PARTICIPATORY APPROACHES ARE INDICATED. Inevitably, some conflicts and downside risks are connected with drainage and use of low-quality water in irrigation. Environmental aspects need careful attention. Tradeoffs between different users may be essential, cost recovery is problematic, and technical innovations may be hard to accept culturally and difficult to manage, all of which underlines the need for good policy and planning and for integrated and participatory approaches. (See IP 5.1, IN 5.3, and IN 5.2.)

TYPICAL INVESTMENTS

For technical assistance investments, the following should be considered:

- Research, capacity building, and institutional development for drainage
- Flood mapping and flood management plans
- Research on reuse
- DRAINFRAME for a participatory approach to drainage

Project investments may include the following:

- Drainage on the estimated 20 million to 30 million hectares of irrigated land in the developing countries badly affected by waterlogging
- Wastewater treatment and storage
- Measures for water retention, flood mitigation, and flood protection

Policy-based investments may include water swap programs.

Finally, an option for pilot investment is controlled drainage and biodrainage.

INVESTMENT NOTE 5.1

INVESTING IN LAND DRAINAGE

In an arid zone, combating waterlogging and salinization of irrigated land remains a priority. Some developing countries in the humid tropics are also ready for prudent investments in drainage for rainfed agriculture. Without such investment, the growth of a more diversified and competitive type of farming in parts of Asia and Central and South America may stagnate. Drainage development can greatly enhance the well-being of the population and further environmentally appropriate land use. These three functions make drainage investment a highly suitable instrument for broad-based rural development and integrated land and water resources management.

In Europe and North America, 30–40 percent of the agricultural land has land drainage systems (box 5.1), but in the developing countries this share drops to 5–10 percent. This difference is most plausibly explained by the fact that investment in drainage is not warranted when the productivity of the land is low. Farmers adapt to

poor drainage by selecting tolerant but low-yielding or low-value crops and by applying minimal inputs. Many developing countries have, however, reached the stage in which lack of drainage is keeping ambitious farmers from achieving higher and more secure yields and from diversifying their crops. Where a lack of drainage is a constraint, agricultural development risks stagnation and lack of competitiveness. (See also IP 9.1.)

INVESTMENT AREA

Current drainage investment in the developing countries is restricted mostly to the control of waterlogging and salinization of irrigated land. The backlog in unmet drainage needs here is conservatively estimated at 20 million to 30 million hectares and is growing by an estimated 0.25 million to 0.50 million hectares a year. The current rate of subsurface drainage development is estimated at only 0.1 million to 0.2 million hectares a year.

Developing countries make hardly any investments in improving the drainage of rainfed land. Whatever drainage they have or construct is mostly main drainage. Viable investment opportunities for drainage of rainfed land are estimated at 25 million to 50 million hectares, most of it in the advanced countries of Southeast Asia and Central and South America (box 5.2).

Many countries in Eastern Europe and in the former Soviet Union are in great need of drainage system rehabilitation and modernization.

POTENTIAL BENEFITS

The traditional purpose of drainage is to remove excess water from waterlogged land to improve aeration of the root zone and the growth of crops. Improved drainage therefore enhances the impact of fertilizers and other inputs, provides better planting and harvesting conditions, and allows farmers to grow more rewarding crops. It also improves the workability of farm machinery and the efficiency of farm operations. Drainage is no longer the food machine it was

Drainage systems are composed of on-farm systems and main systems. The on-farm systems collect excess water from the farmers' fields and release it into the main systems. The main systems transport the drainage water to the outlet where it flows into a major element of the regional hydrological system (sea, river, or lake). On-farm systems can be either of the surface drainage type (collecting excess water from the surface of the land) or the subsurface drainage type (collecting excess water deeper in the soil by controlling the depth of the water table). Water tables may be controlled by parallel lines of deep ditches or buried pipe (horizontal drainage). In drainage for waterlogging and salinity control of irrigated land, pumped wells (vertical drainage) are also widely used, particularly in fresh groundwater areas where they serve both the irrigation and drainage functions.

Source: Smedema, Abdel-Dayem, and Ochs 2000.

during the nineteenth and early twentieth centuries, when governments reclaimed large areas of waterlogged land for agricultural use. But its contribution to food security is still quite significant and carries a relatively low cost (box 5.3).

Irrigated land in the arid and semi-arid zones that is not adequately drained is at risk of becoming waterlogged and salinized because water tables rise and salts accumulate in the root zone. Toxic salts inhibit crop growth, even at low concentrations, while sodium salts may severely deteriorate soil structure and indirectly affect crop growth. Good drainage also contributes to rural development in areas unrelated to agriculture, reducing damage caused by the high water table to buildings and risk of waterborne diseases (box 5.4).

POLICY AND IMPLEMENTATION

Drainage development and management in almost all developing countries relies on government initiative and support, but strong involvement and commitment of the users is essential for sustainability and maintenance. The drainage development and management model that is generally most appropriate places the responsibility for the main system with the government or another public body and the responsibility for the on-farm system with the farmers. The role of the government in on-farm investment is restricted mostly to creating the enabling conditions in terms of policy and legal framework, incentives, research, and technical assistance (box 5.5). So far, no institutional models for participatory drainage development and public-private partnerships have been tested. Recent sector work advocates a new approach for participatory planning of multi-purpose drainage interventions under the acronym DRAINFRAME (see IP 5.1). It broadly addresses all costs and benefits of a drainage system through functions-values analyses and optimizes the economic and social outcomes while safeguarding ecological functions.

Drainage interconnects with the water control system and may harm the environment (FAO

Box 5.2 Drainage in the Humid Tropics

Drainage development could help the rice-growing countries in Southeast Asia and similar regions to intensify and diversify their agricultural sectors. It would allow farmers to grow higher-yielding rice varieties and apply more advanced farm practices such as direct seeding and simple farm mechanization. It would also allow them to grow a wider range of upland crops. Full control of the widespread monsoonal flooding and waterlogging would require large-scale works and high investments. Substantial progress can, however, be made with limited means at the local level.

Source: Nedeco 1991.

Box 5.3 Cost

The costs of drainage are low compared to irrigation. Simple types of on-farm surface drainage systems that do not require extensive earth movement can be installed for US\$100 to \$200 per hectare. Cost could be further reduced when farmers participate in the work. On-farm subsurface drainage systems are more costly with investments ranging from US\$500 per hectare in the temperate zones to US\$1,000 per hectare for salinity control of irrigated land in arid zones. The cost for the main systems would be US\$250 to \$500 per hectare. Operation and maintenance (O&M) costs may be estimated at 2–3 percent of the capital costs. Costs tend to drop as a drainage industry gains experience.

Source: Author.

Box 5.4 Drainage as an Instrument for Rural Development

Drainage can improve public health and sanitary conditions in villages, lower maintenance costs of rural roads, enhance the durability of foundations and mud-based houses, and reduce flooding-related infrastructural damage and disruption. Drainage investment can also target pockets of rural poverty where caused by waterlogging, as has been established in Pakistan. The total mix of benefits makes drainage a suitable instrument for broad-based rural development, which is why Europe's rural development programs of the 1960s and 1970s almost always included a large drainage component.

Source: Smedema, Abdel-Dayem, and Ochs 2000.

Box 5.5 Drainage Development in Europe and North America

Much of the main and on-farm drainage infrastructure in Europe and in North America was developed in the course of the nineteenth and twentieth centuries, almost always with strong government involvement and support. Main systems were fully financed from public funds, while on-farm development was substantially subsidized. Between 1950 and 1970, Europe's direct subsidies for on-farm drainage development ranged from 20 percent to 50 percent.

Source: Smedema, Abdel-Dayem, and Ochs 2000.

Box 5.6 Egypt's Drainage

Egypt has invested about US\$3 billion (in fiscal 2001 dollars) since the 1970s to provide drainage for 2 million hectares. Drainage has mitigated the effect of irrigation-induced waterlogging and salinity despite year-round irrigation since the construction of Aswan High Dam. The government and farmers have shown strong commitment to the program, adopting appropriate technologies, improving irrigation systems, transferring management to water user associations, and adopting a well-functioning system of cost recovery. The country has an intensive and diversified cropping system, and its wheat, rice, and cotton yields are among the highest in the world. Improved drainage accounts for 15–25 percent of recent 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 world's highest.

Source: Adapted from World Bank 2003.

Many governments give too little attention to financing. Even in places with well-developed drainage infrastructure, O&M often receives low budget priority. Inadequate O&M financing is the single biggest threat to drainage system sustainability. Reversing this situation requires exploring new ways to improve cost recovery and new sources of financing. Governments should share in the costs of drainage infrastructure and management because they produce public goods such as human and environmental health and biodiversity. All users and beneficiaries who enjoy direct benefits should share in the investment costs and pay the full O&M costs of the tertiary and field systems. Nonagricultural beneficiaries should also share in the costs, and the “polluter pays” principle should be enforced, particularly on those releasing untreated wastewater into the drainage systems. Policies and measures to control and regulate the use of agricultural chemicals should be adopted. The potential for private sector participation in drainage investment and provision of O&M services should also be explored. Drainage development is theoretically governed by economic opportunities, but investments will generally be made only in a suitable environment. A most important component of such an environment is a long-term, committed government policy (box 5.6).

LESSONS LEARNED

Of the drainage projects that did not meet expectations, many suffered from a faulty diagnosis of the drainage problem and exaggerated expectations of the impact of the proposed drainage system. Drainage is a proven—but demanding—discipline and technology. The best solutions are case and site specific, and the appropriateness and cost effectiveness of technical and institutional proposals depend on the experience, diagnostic perception, and multidisciplinary skills of the investment preparation team.

Long-term partnerships between emerging drainage countries and established drainage countries have contributed to the expansion of drainage in some developing countries.

1995; Abdel-Dayem et al. 2004). The most serious threat is the degradation of water quality in downstream water bodies owing to the disposal of saline or polluted drainage water. Where farmers use many agrochemicals, aquatic life may suffer from the disposal of nutrient-rich drainage water in lakes and estuaries that have insufficient assimilation capacity or through-flow. Irrigation-induced river salinization is becoming a serious problem in an increasing number of basins in the arid zone (FAO 1997). (See also IN 5.3 and IN 8.2.) Therefore, environmental impact assessment procedures should be followed during project preparation. A functions-values analysis would add the social dimension and prove useful in preparing an environmental management plan for the project.

Outstanding examples are the partnerships between Canada and the Netherlands on the one hand and Egypt and Pakistan on the other. Similar successful experience comes through the activities of the International Programme for Technology and Research in Irrigation and Drainage (IPTRID) and its networks for knowledge sharing and capacity building in several developing countries.

Drainage systems are the sinks of the landscape, collecting agricultural wastewater as well as residential and industrial wastewater, the latter usually unplanned. Until regulatory measures are enforced, the unplanned pollution of agricultural drainage systems will continue. Participatory approaches to planning and managing drainage systems, in which all stakeholders are involved and share the benefits and costs, could significantly help control misuse and raise cost recovery. Egypt's new water boards showed great interest and took important initiatives to control pollution in the irrigation and drainage canals.

Drainage systems operate mostly by uncontrolled gravity. This sometimes leads to excessive drainage when water tables fall undesirably deep and deprive crops and natural vegetation of water to survive dry periods. Where a sensitive balance between water removal and water conservation needs to be maintained, drainage should be controlled. This endorses a new understanding of drainage as a management tool to remove or retain water as desired (Abdel-Dayem et al. 2004). Controlled drainage can also help reduce undesirable mobilization of solutes and protect downstream water qualities (see IP 5.2).

RECOMMENDATIONS FOR PRACTITIONERS

- Drainage investment should be made when natural drainage has become a critical constraint to further agricultural development.
- Absolute assurance should be established—based on careful analysis of the technical and financial requirements, governance and institutional capacities, and farmers and

other beneficiaries' commitments—that the installed drainage systems will be properly maintained. If there are no such assurances, the planned drainage investments should be postponed. Instead, the focus should be on advocacy and institutional and technical capacity building.

- Drainage issues should be assessed through remote sensing, combined with geographic information system (GIS) and modeling technologies that facilitate applying integrated approaches in drainage system planning and management. These technologies are useful when assessing how drainage interventions will change the natural (agro) hydrological conditions in the resource systems, how the social and environmental values may change, and which benefits and losses may materialize.
- Research and studies should be encouraged into quantifying in monetary terms the intangible drainage benefits (such as improving health, protecting buildings and rural infrastructure, enhancing biodiversity); developing models for cost sharing and cost recovery of nonagricultural drainage services (such as disposal of domestic and industrial wastewater); and the impact of “with” and “without” drainage on rural poverty and livelihoods.
- Expert review of drainage plans almost always pays.

INVESTMENT OPPORTUNITIES

Between 20 million and 30 million hectares of irrigated land in developing countries urgently await improved drainage. There is also a considerable viable need for drainage rehabilitation in Eastern Europe and the former Soviet Union. Time is also ripe for drainage development in some countries in the humid tropical zone of Southeast Asia and Central and South America. Investments should generally not be restricted to the construction or rehabilitation of drainage systems and related physical infrastructure; they should also strengthen research, capacity building, and institutional developments.

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This Note was prepared by Bert Smedema and reviewed by Bart Snellen of the International Institute for Land Reclamation and Improvement (ILRI).

INVESTMENT NOTE 5.2

INVESTING IN THE REUSE OF AGRICULTURAL DRAINAGE WATER

Mounting water scarcity has forced countries to include reuse of agricultural drainage water in their national water programs. Drainage water is often available in large volumes, and therefore could cover a significant part of total irrigation demand, if adequately managed. Investment for reuse is usually a small add-on component of irrigation projects.

With growing demands on freshwater resources in water-scarce countries, pressure is mounting on the agricultural sector to give up part of its allocation to prime use sectors such as households and industries. Meanwhile, agriculture has to continue producing food and fiber to satisfy current and future demand for food security. Under such conditions, reuse of agricultural water in irrigation could become important to not only fill in a gap in supply, but also maximize water use efficiency. Reuse of agricultural water also offers a solution in situations where disposal of drainage water is a problem.

INVESTMENT AREA

Agricultural drainage systems collect, evacuate, and dispose of excess surface and subsurface water from cropped fields. Farmers in water-scarce countries may reuse this drainage water for irrigation, if it is of sufficiently good quality, either as a sole source or as drainage water mixed with fresh canal water or with rainwater, each applied separately. The choice of the reuse option depends on the volume and quality of drainage water, soil type, crop tolerance to salinity, agroclimatic conditions, and availability of freshwater resources.

Reuse of drainage water for irrigation requires a transformation in the drainage from a disposal-based linear system to a recovery-based loop system conserving water and nutrient resources.

Drainage water reuse requires low investments, and such investments are add-ons to already existing schemes. Typical add-ons are the construction, operation, and maintenance of pumping facilities to lift water from drains to canals and, in some cases, civil works such as link canals, culverts, and mixing basins. The type and size of the work needed is site specific and depends largely on the volume of drainage water available and the layout of the irrigation and drainage systems. It may be a small pump operated by individuals or a group of farmers, or a large project implemented and operated by the government (box 5.7).

Investments in reuse also require building systems to monitor the volume and quality of drainage water and to build and manage information systems for decision making. Investment in research is needed to develop evaluation criteria and guidelines for the impact of reuse on the soil, crops, and the environment. Farmer awareness and training for using and managing relatively saline water on different crops is another important investment area. Examples of sensible ways to invest World Bank capital are given in the subsection on Investment Opportunities.

INVESTMENT OPPORTUNITIES

- Technical assistance to develop management tools such as monitoring programs and guidelines for safe drainage water reuse
- Research studies on different reuse options and their implications, and for developing more salt-tolerant crop species
- Capacity-building and training programs
- Reform policy and regulations to govern drainage water development and management
- Strengthening of water user organizations to develop local solutions that promote sustainable management
- Hardware purchases and contracting of civil works

Box 5.7 Egypt: Reuse of Drainage Water

Egypt's freshwater supply is constant at 55.5 billion m³ a year, but the country faces a double challenge. It has to supply water to newly reclaimed areas, which means it has to increase crop production on all new and existing irrigated areas using the same total water supply. In response, reuse of agricultural drainage water became national policy during the 1980s. Currently, 5 billion m³ of drainage water, with an average salinity of 1.8 dS/m, is reused each year. Another 3 billion m³ of drainage water is committed for reuse in the new reclamation areas in the near future.

This reuse strategy has not deteriorated the salt balance in the Nile Delta. This favorable result was achieved with the help of a World Bank-funded drainage program that implements drainage systems on 90 percent of the irrigated lands. Resulting drainage water is reused after mixing with freshwater that has a low salinity content. Tools including functional water volume and quality monitoring systems have been developed for planning and management. The impact of drainage water reuse on soil, crops, and environment has been a main subject on the agenda of Egypt's Drainage Research Institute.

Source: Author.

POTENTIAL BENEFITS

Reuse of drainage water holds great potential for saving valuable freshwater resources for competing prime uses that require more stringent water quality standards. It can provide a reliable supply of irrigation water and rich nutrients to cropped fields. Furthermore, reuse may alleviate drainage disposal problems in rivers and streams by reducing the volume of drainage water as well as helping in the restoration of natural wetlands.

Agricultural drainage water has the advantage of coming in large volumes, uncontaminated by pathogens, and of often being located close to or even inside the reuse areas. Reuse of drainage water for irrigation reinforces the potential for implementing sustainable integrated water resources management and reducing the number of people deprived of potable water.

POLICY AND IMPLEMENTATION

Drainage water is a large component of the hydrological cycle. It involves primarily disposal issues that allow society to exploit the resources base for maximum economic, social,

and environmental benefits. However, in many water-short areas, drainage water turns out to be an important resource with economic value. Policies for integrated water resources management, therefore, give drainage water adequate attention, and many countries now include drainage water management and reuse in their national plans.

The main quality concern regarding reuse of drainage water for irrigation is its salt content and potential adverse impact on crop productivity. Agricultural chemical residues (nutrients and pesticides) become a concern when drainage water is mixed with canal water that is used for drinking purposes. Moreover, as soon as agricultural water gets into main drainage canals it may mix with wastewater from domestic and industrial sources, which adds another quality concern about human health. These possible impacts call for careful planning and management. Failure to properly evaluate the risks of reuse and to put tools in place for safe practices may jeopardize crop production, human health, and the environment.

Over the last 20 years, drainage water quality has been equated with salinity, but sustainable reuse requires attention beyond salinity. It is now recognized that planning and management of drainage reuse requires other disciplines in addition to engineering. Nowadays, reuse practices are guided by Food and Agriculture Organization (FAO) guidelines on crop tolerance for various salinity levels and the impact on crops of various chemicals in drainage water (FAO 1985, 1992, 1997); World Health Organization (WHO) guidelines on chemical and biological contents for human health; and local criteria and guidelines based on experimentation and pilots (WHO 1989, 1995).

Where drainage systems are used for disposing of domestic and industrial effluent, the quality of drainage water is threatened unless adequate standards and regulations are enforced. Laws and regulations on water quality and pollution control provide a framework for drainage water management. Regulations vary in scope, depending on the context of a specific locality, ecology, and country. In many countries, laws, regulations,

and institutions require reform to meet water quality and environmental needs. Standards should be only as stringent as necessary to prevent pollution.

Reuse of drainage water at the lower (secondary or tertiary) level reduces the risk of pollution from domestic and industrial sources. This scale of reuse is important and offers potential for user-managed reuse projects.

LESSONS LEARNED

Reuse of drainage water has met the increased water demand for irrigated agriculture in some countries, but many drainage water reuse plans have been implemented without due regard for likely impacts or secondary effects. This has generated new problems as well as tension between water supply agencies and irrigators and between environmentalists and irrigators.

The quality of surface water, including drainage water, is threatened in many countries by the uncontrolled disposal of polluted effluents (domestic, industrial) and the improper disposal of solid and toxic wastes from agricultural and human activities. Experience from Egypt shows that 6 of the 22 reuse-mixing stations in the Nile Delta have been entirely or periodically closed owing to the increasing degradation of water quality. The capital cost of a typical reuse station with five units, each processing 12.5 cubic meters of water a second, could reach US\$10 million.

Decisions to increase reuse of drainage water that reduce return flows to rivers could backfire. The case from Australia in box 5.8 shows the adverse effect of a single-objective policy on the return flow to the Murray Darling River.

World Bank participation in ongoing drainage programs in developing countries has helped these countries attract resources from other bilateral and multilateral donors to build local capacity in water management. Long-term partnerships between well-developed and less-developed drainage countries have greatly contributed to building local capacities. An excellent example of this is the partnership

between the Netherlands and Egypt, which includes a joint Advisory Panel.

Water user associations established under Bank-financed projects in Egypt and India have successfully contributed to the development of local solutions, thus promoting sustainable management of drainage water. Egypt's newly established water boards are taking impressive water quality management initiatives that were very difficult to implement by the government at the grassroots level in the past.

RECOMMENDATIONS FOR PRACTITIONERS

- Ensure that investment in drainage is not restricted to construction/improvement/rehabilitation of drainage systems and related infrastructure; it should also be extended to promote drainage water management, including reuse programs.
- Ensure that the reuse project or program includes a feasibility study and an environmental impact assessment, before lending. Understanding the tradeoffs in reusing drainage water and its impacts on the environment will ensure that reuse projects can be designed and maintained in a way that satisfies health and environmental requirements within existing institutional constraints.

Box 5.8 Australia: Drainage Interventions in the Murray Darling Basin

The dual pressure of increasing competition for water and declining water quality in the Murray Darling Basin have resulted in many policy initiatives, among which are reducing drainage volumes from irrigated areas and recycling and reuse of drainage water. These policies have resulted in reduced salinity in the river and more crops grown with less water wastage. However, the argument is that all these efforts and the increased irrigated areas have reduced return flow to the river to environmentally damaging levels that cannot sustain the natural ecosystems. This raises the question, "Were these the right policies?" Could the current situation have been predicted and avoided had a more comprehensive planning approach been considered?

Source: Christen and Hornbuckle 2003.

- Support investments in small but full-sized, reuse pilots in countries with little previous experience that, if successful, could lead to mainstreaming the learning from initial results into larger projects.
- Invest in research to explore reuse opportunities and options and understand their implications on water quality, public health, and the environment.
- Support full use and development of well-designed monitoring programs, reuse guidelines, and modeling techniques to assess how the proposed reuse program will change the natural agrohydrological conditions, how environmental values may be affected, and which benefits may be reasonably expected.
- Promote well-established design criteria for reuse schemes, based on successful projects financed by the Bank or other investors.
- Invest in the development of the institutional capacity to plan, implement, monitor, and regulate the reuse program. This involves strengthening the organizations that will carry out the program.
- Support environmental training to promote environmental awareness, monitoring aspects, environmental and health concerns associated with drainage reuse, legislation, and policy development.
- Create awareness through the proper management and dissemination of environmental data and information. Dissemination to farmers should also be supported through the participation of public agencies, non-governmental organizations (NGOs), and user organizations.

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This Note was prepared by Shade Abdel-Gnawed of the National Water Research Center in Egypt. It was reviewed by Bart Smelled of ILRI.

INVESTMENT NOTE 5.3

INVESTING IN THE REUSE OF TREATED WASTEWATER

Reuse of treated wastewater often disproportionately benefits the poor. It must be combined with strategies to prevent or mitigate health risks from pathogens, heavy metals, pesticides, and endocrine disruptors and environmental damage from heavy metals and salinity. Long-term institutional coordination among urban, agricultural, and environmental authorities and end users is a requirement for water reuse investments to pay off. This Investment Note outlines technological and management interventions suitable for World Bank lending.

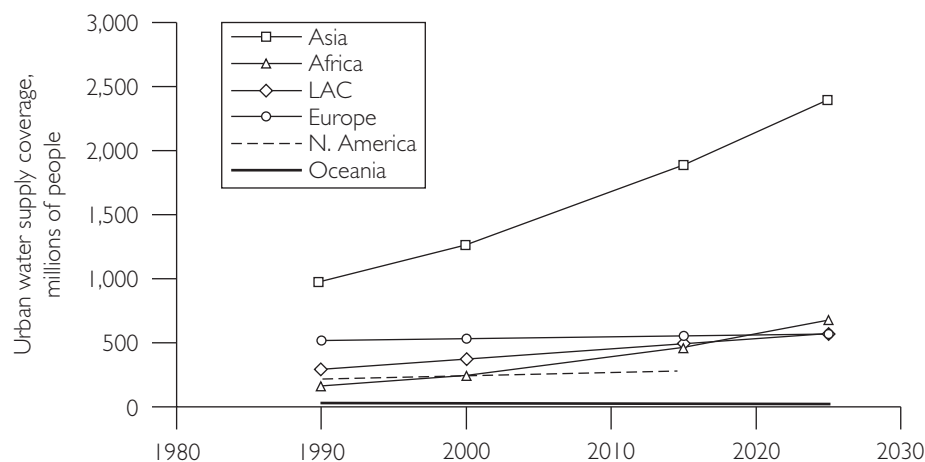
Of the projected 1 billion growth in global population by 2015, 88 percent will take place in cities, nearly all of it in developing countries (UNDP 1998). Investments in urban water supply and sewerage coverage are rising, as shown in figure 5.1. However, as shown in table 5.1, adequate treatment for agricultural reuse with acceptable risk mitigation for human health and the environment will require further investment (World Bank and Swiss Development Corporation 2001). While this Investment Note addresses reuse after treatment, it is critical to ensure that investments in

treatment appropriate for reuse schemes will be made. Urban wastewater is well suited to agricultural reuse and landscaping because of the reliability of supply, proximity to urban markets, and its nutrient content (depending on the treatment technology). To have an impact on scarcity, reuse of wastewater must substitute for, not add to, existing uses of higher-quality water.

INVESTMENT AREA

Water reuse has become part of integrated water resources management policy in several economies facing acute physical water scarcity, including Tunisia, Jordan, the West Bank and Gaza, and Israel (box 5.9). In other countries such as Australia and the United States, beneficial reuse has been practiced for decades. In situations where the investment costs to develop new freshwater resources are high, water reuse should be given priority consideration. Owing to water quality and associated risk considerations, agricultural reuse of treated wastewater is more feasible than potable reuse (although direct potable reuse is now practiced in Singapore). Reuse through surface irrigation, particularly drip but also controlled furrow irrigation, appears to present less risk of contaminant transmission than does groundwater recharge and recovery, although Israel, the United States, and Australia are gaining experience with safe

FIGURE 5.1 URBAN WATER SUPPLY GROWTH, 1980–2015



Source: UNDP 1998.

Table 5.1 Water Treatment Gaps

Region	Percentage of seweraged population in large cities	Percentage of seweraged wastewater that is treated to secondary level
Africa	18	0
Asia	45	35
Latin America and the Caribbean	35	14
Oceania	15	Not reported
North America	96	90
Europe	92	66

Source: WHO and UNICEF 2000.

injection and recovery, soil-aquifer treatment, and related groundwater-based technologies. Landscaping uses with suitable controls over contaminant transmission to the public represent an important investment opportunity but benefits and cost recovery may be limited to specific high-value uses such as golf courses.

Box 5.9 Tunisia: Water Reuse

Tunisia, with per capita freshwater availability of about 450 cubic meters a year, is recognized as a leader in the area of treated wastewater reuse. From 1996 to 2030, the share of treated wastewater as a percentage of total available water resources is projected to more than double from 4.4 percent to 10.9 percent. Despite strong institutional support, including the 2002 consolidation of the Ministry of Agriculture, Environment, and Water Resources to oversee integrated water management and water reuse, only 18 percent of reclaimed water is currently used. Treated wastewater use has faced several constraints—social acceptance, salinity levels too high for some crops, restrictive regulations, and volumetric pricing in the range of US\$0.02 to \$0.05 per cubic meter (between 50 percent and 95 percent of the cost of freshwater for irrigation)—and these have limited its full potential for development. Through its carefully phased approach to treated wastewater use and the concomitant development of a regulatory framework prohibiting untreated wastewater use, Tunisia has significantly mitigated environmental and public health risks associated with the practice elsewhere in the world.

Source: Author.

POTENTIAL BENEFITS

If reuse substitutes for an existing use, freshwater is saved. Finding new uses for treated wastewater may generate additional economic benefits but does not translate into water savings. Because of water competition in water-scarce situations, farmers' livelihoods are often threatened, as cuts in allocation come at the expense of the agricultural uses. Water reuse with some tenure security for farmers can result in significant economic benefits. Environmental quality is often an important benefit of reuse programs because poor-quality water is used in agriculture instead of being discharged into cleaner surface water bodies or groundwater. Finally, water reuse may reduce the investment costs of developing new resources for agriculture or other uses for which it is substituted (swapped).

Based on international experience, it is increasingly apparent that economic win-win solutions are not easy. Instead, potential Bank investments in the water sector need to address alternatives and consider the economic tradeoffs, for example:

- Should a sea outfall be built to discharge wastewater from a coastal city, if permitted by national and regional regulations and treaties, or should wastewater be reused, possibly incurring much higher costs for the treatment, storage, and especially the transfer of reclaimed water?
- Should a reservoir for reclaimed water be built to increase its availability during the irrigation season or should treated water be discharged during the wet season?
- Are more expensive treatment and unrestricted irrigation preferable to simpler treatment and crop restrictions?

POLICY AND IMPLEMENTATION

Planned reuse is not just about treatment; it requires an integrated approach. Where the Bank lends for wastewater treatment, the planned reuse of effluent should be integrated into the decision to invest in intensive (for example, activated sludge) or extensive (for

example, stabilization ponds) technologies, or centralized versus decentralized systems.

Because collection and treatment of wastewater are usually under the jurisdiction of a different sector (such as urban water supply and sanitation) from the reuse sectors (such as agriculture and municipalities), intersectoral coordination in planning and management is extremely important. The Country Water Assistance Strategies offer an opportunity to ensure such coordination (see IP 1.1). On the demand side, users should be involved in planning and monitoring the quality of the supplied effluent. Effective advisory/extension services are also extremely important.

Key to the success of planned strategic reuse programs are a coherent legal and institutional framework with formal mechanisms to coordinate the actions of multiple government authorities; policies to reduce waste loads through application of the “polluter pays” principle; appropriate practices for wastewater use through crop choice, landscaping, and the like; public awareness campaigns to establish social acceptability for reuse; and consistent government commitment over the long term.

The private sector can play an important role in promoting treated wastewater reuse. It would be even more attractive for the private sector to invest in wastewater treatment when markets for the treated effluent exist (box 5.10). This arrangement requires policies and regulations that allow the private sector to function and provide reliable services.

LESSONS LEARNED

Based on international best practices, the following should be borne in mind when developing wastewater investment plans.

- Wastewater treatment must result in water quality that is suitable for the particular reuse application—for example, nutrient removal may be counterproductive unless enrichment or eutrophication of surface or coastal waters is a risk.

Box 5.10 Private Participation in Wastewater Treatment and Management

An example of private participation in wastewater treatment and reuse comes from Australia. The city of Adelaide in the south was operating a wastewater treatment plant where disposal of the treated effluent caused environmental concerns. Meanwhile, orchards 120 kilometers away from the city were suffering from water scarcity after exhaustion of the groundwater aquifer on which they relied for irrigation. The private sector, under a contract to the city government, constructed a treatment plant and pipeline (the “Virginia pipeline scheme”) to transport the treated effluent to these farms for irrigation at an agreed tariff. This commercial solution was successful, and the private investor considered further investment to expand the treatment plant to serve other irrigated areas.

Source: Croke, Kracman, and Wright 1999.

- Guidelines linked to reuse must adequately protect human health. The international standard WHO guidelines (WHO 1989) are being revised, based on the Stockholm Framework encouraging flexible, stepwise implementation of guidelines that consider other sources of risk.
- Source control of contaminants is a must, particularly for industrial wastewater; otherwise reuse programs will be unsustainable.
- Cultural values play an important part in the acceptability of water reuse, particularly where religious views on ritual purity are highly articulated, for example in Islam and Hinduism.
- Sustained, long-term public awareness campaigns among the reuse target group (such as farmers or urban landscaping authorities) are needed for acceptance of water reuse.
- Irrigation methods must be suitable for the type of reclaimed water (high suspended, dissolved solids). Where possible, high-water-productivity drip irrigation should be encouraged. Sprinklers can lead to airborne transmission of viruses and other contaminants. It should be stressed that to *save* water, reuse must substitute for an existing use.

- Crop restrictions applied sensibly may be essential, particularly in view of increased phytosanitary controls required in export agriculture.
- Institutional coordination is essential among various government authorities, civil society, and farmer associations of water user groups.

INVESTMENT OPPORTUNITIES

Examples of sound investments in treated wastewater use include the following:

- Water swaps as a substitute for existing uses of (raw or potable) water for reclaimed water
- Rehabilitation of wastewater treatment plants
- Construction of new wastewater treatment plants using appropriate technologies
- Sewer systems that separate municipal from industrial wastewater
- Surface storage reservoirs for reclaimed water
- Pilot projects on separate reuse of urine and feces through decentralized systems (ecological sanitation) in small towns and peri-urban areas.

RECOMMENDATIONS FOR PRACTITIONERS

Recommendations for countries experienced in reuse are different from those for countries just embarking on reuse. Comprehensive recommendations include the following:

- Support for master plans that integrate reuse in the planning and design of sanitation projects and that build it into agricultural programs
- National reviews of reuse policies, including multistakeholder workshops
- Creation of interdepartmental working groups at the national and/or local levels
- Awareness building on health and environmental risks for farmers using untreated wastewater or reclaimed water

- Development of economic and environmental models to support decision making about reuse investments and policies, including policies on subsidies
- Promotion of regional exchange of experiences through professional networks
- Support for research on reuse technology and biophysical sustainability, on institutional arrangements for reuse as part of master planning, on factors that enhance or inhibit social acceptability, and on farmers' and users' innovations with water reuse.

For countries embarking on reuse, the following apply:

- Introduction of appropriate national reuse standards
- Introduction of appropriate crop restrictions.

And for countries that have made progress in reuse, the following apply:

- Formal arrangements between farmers and utilities specifying mutual rights and responsibilities
- Design of tariffs for reclaimed water.

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This Note was prepared by Chris Scott of International Water Management Institute (IWMI) with input by Manuel Schiffler. It was reviewed by Bart Snellen of ILRI.

INNOVATION PROFILE 5.1

DRAINAGE INVESTMENTS IN THE CONTEXT OF INTEGRATED WATER RESOURCES MANAGEMENT

What is new? The nonagricultural impacts of land drainage are real but rarely noted, among them poverty reduction and public health. This profile offers a new investment approach that considers all functions of the resources system that are affected by drainage intervention and integrates them into an infrastructural and institutional design by engaging all stakeholders.

Because drainage is indispensable to both water resources management and crop production, the World Bank lends for drainage and flood control projects. Over the last 30 years, 60 countries have signed loans for a total US\$7.2 billion. Economic rates of return have been fully acceptable (box 5.11), yet lending dropped from US\$1 billion a year during the 1980s to an average of less than US\$200 million a year in the last decade.

One reason for the decline lies in the exclusive focus on agriculture in project design, which has excluded drainage from the discourse on

integrated water resources management. Drainage has many effects and multiple impacts, positive and negative, on other functions¹ of the resources system, including floods, fisheries, sanitation, built-up property, infrastructure, health, transportation, and the environment. Many of these currently go unnoticed and therefore do not attract investment. A second reason is that drainage has been seen only as a remedy for irrigation-induced problems in arid zones, although it is equally important in humid regions.

OBJECTIVES AND DESCRIPTION

Drainage affects the multiple functions of the resources system in different ways. It is therefore necessary to optimize its economic and social development outcomes, while safeguarding ecological functions.

Optimization requires the following:

- Understanding and managing the diversity of drainage situations
- Participation of all stakeholders in the decision-making process
- Inclusive modes of governance, decision making, and stakeholder representation
- Improving sustainability through research and wise management

Each drainage situation is unique and warrants consideration on its own merits. The planning and design of drainage in a multifunctional resources system requires a stepwise analysis of the system's functions and values.² The analysis identifies the first- and higher-order changes in the resources system due to a drainage intervention, the geographical and time range of changes, the functions affected and their stakeholders, and assesses the economic, social, and environmental impacts (box 5.12). The process allows stakeholders to negotiate and discuss tradeoffs, examine alternatives, and design mitigation measures. The analysis considers landscapes within hydrological units or even river basins.

Box 5.11 The Impact of Drainage on Agricultural Production

Economic rates of return (ERRs) of the drainage subprojects of Mexico's Rural Development Program for the Tropical Areas (PRODERITH) have ranged from 14.7 percent to 21.5 percent. In Bangladesh, 9 out of 17 inland flood control cum drainage projects were economically viable, with ERRs between 22 percent and 96 percent (median 54 percent). In Egypt, the ERR of the National Drainage Project was estimated at 31 percent upon completion. Annual farm income in the Nile Delta increased by US\$200–US\$350 per hectare. In Pakistan, yield increased by 27–150 percent.

Source: World Bank 2004; Project Implementation Completion Reports.

OUTPUT AND IMPACTS

A tool for integrated and participatory planning of drainage intervention, known as DRAIN-FRAME, allows function-values analysis and communication and negotiation of tradeoffs between stakeholders engaged in a participatory planning process. The expected result is optimization and sharing of all costs and benefits. Its capacity to integrate functions improves the potential for cost recovery and may help secure new financing sources by charging beneficiaries for nonagricultural functions and increased land value. It may also attract private investment.

Use of the tool has institutional as well as technological implications. A polycentric governance structure generally offers great promise for drainage development and management. Reform in the direction of integration is needed and would strengthen the role of local governments, the private sector, and user organizations in natural resources management at the expense of drainage line agencies. Governments and other public and user organizations may get involved at different levels of services provision.

A multipurpose drainage system requires new design approaches and operating practices. This requires infrastructure and management rules with capacity to manage water levels for removal or retention of excess water, improvements in water quality, reuse of drainage water, and the management of disease vectors. For example, controlled drainage is a promising option to achieve different management objectives (see IP 5.2).

ISSUES FOR WIDER APPLICABILITY

An integrated approach to drainage requires the following:

- Formulating policies that facilitate integrated planning and management
- Creating an enabling environment by reforming drainage governance and institutions
- Planning, involving all stakeholders in decision making

Box 5.12 Egypt and Bangladesh: A Functions and Values Analysis

Egypt

Land drainage investment improved soil fertility and increased agricultural production (function). It raised incomes for producers (value) and had farmers as direct stakeholders and urban food consumers as indirect ones. The investments lowered the groundwater table in neighboring settlement areas, which improved living conditions and reduced transmission of diseases (functions), improving livelihoods (social value), reduced damage to property (economic value), and improved public health (social and economic value). The main stakeholders were rural inhabitants in general and particular groups among them, depending on how effects were distributed spatially and socially. The quality of the drainage water conveyed to coastal lagoons affected fisheries and ecological functions.

Bangladesh

Reduction of local floods raised productivity (function) and farmer income (value) but lowered fisheries potential (function) and fisherfolks' income (value). Farmers and fisherfolk are the main stakeholders, but their interests clash. Downstream, this stakeholder antagonism reverses. There, increased floods cause agricultural damage and reduce farmer income but increase fisherfolks' income.

Source: Abdel-Dayem et al. 2004.

- Raising awareness about the value added by integrated drainage management
- Building technical capacity to design and manage drainage for multifunctional objectives
- Encouraging research on social, economic, and technological aspects of integration in drainage planning and management

The World Bank has started to use the integrated approach in its drainage projects, for example, the pipeline “Integrated Irrigation Improvement Management Project” in Egypt and the “Drainage Master Plan” and the “National Drainage Project” in Pakistan. These projects are expected to provide useful lessons for wider application, which could improve the planning and design of interventions and safeguard ecological values (box 5.13).

Box 5.13 DRAINFRAME Applications

Egypt

A DRAINFRAME-based study in the Mahmoudiya Command Area, during the prefeasibility of the “Integrated Irrigation Improvement Management Project” in Egypt identified four landscapes within the command area and two outside the area, whose functions would be affected by irrigation and drainage interventions. The stakeholders identified opportunities to be captured and problems to be solved for consideration during the project planning process. Project impacts on fish farms, the impact of agricultural development on drainage water from the canal command, and the ecology of a coastal lake were identified as primary economic, social, and environmental issues to be addressed in the project design.

Pakistan

The Kotri Left Bank is the farthest downstream drainage basin in Sindh province, Pakistan. Past experience with Left Bank Outfall Drain (LBOD) and problems after the breaching of the Kotri weir and the banks of the Tidal Link made local stakeholders sensitive and turned them against any further drainage intervention planned and designed at the federal level. Stakeholder consultations based on the outcome of a DRAINFRAME rapid assessment convinced the local government, NGOs, and farmers that sound drainage and related water management plans could be developed through such an integrated and participatory approach. A local planning team at the provincial level was established to carry out full analyses and planning based on the DRAINFRAME methodology.

Source: Author.

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ENDNOTES

1. The concept of functions summarizes which goods and services the natural resources system provides or performs. These functions include production, processing, regulation, and transportation.
2. “Values” is the concept through which societal preferences, perceptions, and interests with regard to functions provided by natural resources are summarized.

This Profile was prepared by Safwat Abdel-Dayem with inputs by Peter Koenig. It was reviewed by Keizrul Abdullah of the International Commission on Irrigation and Drainage.

INNOVATION PROFILE 5.2

INVESTING IN CONTROLLED DRAINAGE

What is new? Adoption of proven technology and management practices for drainage practices in developing countries may save time, water, and fertilizer, as well as raise yields and reduce pollution. Controlled drainage is a technique for regulating the water table level. It allows harvesting “more crop per drop” in both the scheme and the basin. The technique can be part of new drainage systems and retrofitted in existing ones. It is particularly suitable in irrigated regions threatened by water scarcity.

Conventional land drainage acts coarsely and moves too much water through the soil profile and away through the drain. Farmers respond frequently by overirrigating to compensate for the rapid removal of water. Such practices increase the drainage water volume and the salt and nutrient loads and make irrigation operations less efficient. North America and Northern Europe have invested millions of dollars in research and development on controlled drainage to combat nonpoint source pollution by nitrates. The field scale results were quite rewarding through reduced drainage flows and pollutant loads, and increased crop yield (box 5.14). Unfortunately, other countries have made no significant investment in adapting the technique to their conditions. Egypt and China have carried out research and development programs, but even they lacked either a strategy or investment support to launch controlled drainage countrywide.

OBJECTIVES AND DESCRIPTION

The objective of controlled drainage is to manage water tables in farmland by retaining or removing water from the soil profile, to achieve optimum benefits from the available water while improving the quality of the drainage effluent.

Maintained at predetermined depths during the growing season, the water table can supply

moisture to the root zone through capillary rise. Controlled drainage requires low-cost structural provisions appropriate to the type of drainage system.

For pipe drains, controlled drainage involves installing an L-shaped pipe to the drain outlet, so that water flows only when the water table rises above the height of the top section. The height can be adjusted by rotating the pipe. And for open drainage ditches, controlled drainage involves installing a weir with a movable sill at the drain ditch outlet.

BENEFITS AND IMPACTS

Controlled drainage can bring major improvements to a situation where crop yields are low because of unreliable water supply or shortages. The main benefits of controlled drainage are as follows (Brabben and Abbott 2002):

- Water savings—more efficient irrigation and drainage management
- Energy and labor savings—reduced pumping for both irrigation delivery and drainage water evacuation
- Water quality improvement—less leaching of agrofertilizers and less potential for eutrophication in downstream water bodies
- Yield increases—better water availability for crops after irrigation events

The benefits are shared by farmers and the state. Farmers gain directly by saving time and money

Box 5.14 Controlled Drainage in North America

Controlled drainage in the Conetoe Creek project in North Carolina, United States, increased corn yields by 25 percent in nonirrigated fields and by 15 percent in irrigated fields. Meanwhile, data from 125 site-years with controlled drainage in North Carolina showed an average decrease of 30 percent in drainage outflows compared to uncontrolled drainage systems. Average reduction of nitrogen to surface water were 55 percent and of phosphate 35 percent.

Source: Skaggs 1999.

in on-farm water management and by increased crop yields (box 5.15). The state gains through savings of valuable water resources and reduction in environmental damage.

Managing drainage under controlled conditions also reduces conflicts between farmers who have different management preferences. This is particularly true in the case of mixed crop pattern agriculture (for example rice, cotton, and corn) on small holdings that share a drainage system.

ISSUES FOR WIDER APPLICABILITY

Controlled drainage has great potential for wider applicability. It is regarded as a promising technological option for managing drainage from an integrated perspective (see IP 5.1). However, several issues should be considered.

Controlled drainage, to be successful, requires certain management and organizational arrangements. The main institutional requirement is that farmers make group decisions on crop selection, operational guidelines, and cost and benefit distribution (Abbott et al. 2002a). Farmers must coordinate their cropping patterns with each other. Planting similar crops along the drain lines will minimize subsurface interaction beneath the fields. Farmer groups such as water user associations are suitable coordination mechanisms for controlled drainage management. Controlled drainage is more likely to be successful if the farmers have an entrepreneurial attitude and are willing to

grow more or more valuable crops. The uptake of controlled drainage can be promoted through a training and awareness-building campaign (Abbott et al. 2002b). Farmers can best be trained through an existing extension service.

As controlled drainage maintains high water tables for a fairly long time and reduces water flow through drains during the growing season, there is a risk of salt accumulation, particularly with saline groundwater. The operating regime of a controlled drainage system and associated irrigation scheduling should allow a constant salt balance in the root zone. If the soils are medium textured and the irrigation water has only a low to moderate salinity, the chance of success in controlling salinity control increases.

Controlled drainage is most applicable when water supply varies between wet and dry spells and is insufficient or unreliable. It is also effective for the protection of sensitive aquatic bodies receiving drainage effluent because the method reduces nutrient loads.

Areas where irrigation and drainage are already widespread are the most likely candidates for controlled drainage. These include:

- North Africa: Algeria, Egypt
- Middle East: Israel, the Syrian Arab Republic, Iraq, Bahrain
- Central and South Asia: India (Punjab, Haryana, Rajasthan), Pakistan, Northern China, Uzbekistan, Tajikistan, Turkmenistan

All of these countries are strongly threatened by water scarcity over next 25 years (Abbott 2002b).

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Box 5.15 Benefits of Controlled Drainage in Egypt

In response to rising water tables in the Nile Delta, a free-flowing subsurface drainage system has been installed across most of the agricultural sector of the Nile Delta. Recent controlled drainage pilots in rice growing areas showed water savings of up to 40 percent. Research work was done in small field plots planted to corn and wheat. Farmers can recoup the costs of controlled drainage in two or three seasons, owing to increased crop yield. In circumstances where high water savings can be achieved, the internal rate of return is 100 percent, meaning that the investment is recouped within one year.

Sources: DRI 1998; Abbott et al. 2001; Abdel-Gawad 2002.

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This Profile was prepared by Geoff Pearce and was reviewed by Bart Snellen of ILRI.

INNOVATION PROFILE 5.3

INVESTING IN EVAPORATION PONDS

What is new? Until recently, releasing saline drainage water from irrigated land into an evaporation pond was acceptable only if the practice was temporary. But experience since the 1960s has been mostly positive. Environmental problems have been incidental and in retrospect could have been easily mitigated or prevented by careful design and management. In the arid zone, evaporation ponds are now widely accepted as a credible medium- and long-term solution.

The natural and time-honored disposal of saline drainage is by way of a river to the sea or other terminal site. Where river disposal would render the river water unsuitable for downstream use, other disposal solutions have to be explored. In some irrigated basins, outfall drains have been constructed to transport the saline drainage water directly to a terminal site. The best-known ones are the drainage network of the Nile Delta in Egypt and LBOD in Pakistan. Another option is disposal in evaporation ponds, shallow depressions into which the drainage water can readily be discharged and left to evaporate.

OBJECTIVES AND DESCRIPTION

Evaporation ponds are best suited for the disposal of the irrigation effluent of subsurface drainage systems in the arid zone. These systems have an annual discharge of less than 100

millimeters, while annual evaporation losses are 1,500–2,000 millimeters (box 5.16). Seepage losses from the pond are often about the same as evaporation. As result, 1 hectare of pond suffices for every 40 to 70 hectares of irrigated land.

Storm drainage water should generally be diverted from the ponds. Pond water can rarely be reused while stormwater would also significantly increase the required pond area. The World Bank–supported National Drainage Program in Pakistan builds on this principle.

Natural depressions in desert land outside the irrigation perimeter are suitable sites, but evaporation ponds may also be constructed on low-lying wasteland inside irrigation commands. Pond sizes vary from 1–5 hectares when located on-farm or near villages to 1,000–25,000 hectares in desert depressions serving large irrigation systems. In large ponds, drainage water is usually routed through increasingly saline compartments, designed and operated so that the salt is deposited in the end compartment.

OUTPUTS AND IMPACTS

Ponds will generally form new water bodies in their rather dry environments and attract pioneer flora and fauna that are adapted to the hydrologic and water quality regime, as happened in the Wadi El-Rayan in Egypt. Over time, the pond usually becomes half to several times more saline than seawater. Fishery development has met with mixed results and is subject to further research. Design and management should be based on careful environmental assessment and monitoring (box 5.17).

Evaporation ponds require some infrastructure, but costs are low compared to other irrigation works built on marginal land. Initially, high seepage losses will usually decline because of sealing, but ponds underlain by permeable soils and strata will maintain high rates throughout their lifetime (box 5.18).

EXPERIENCES AND APPLICABILITY

Natural salt lakes have been used to dispose of drainage water from irrigated land, but this

Box 5.16 Evaporation Rates

Saline water surfaces evaporate less than freshwater surfaces. Under average operational conditions, pond evaporation losses are typically 20–30 percent less than the Penman open water evaporation. Evaporation becomes minimal when salt concentration approaches the saturation point, and salt starts to crystallize. But usually this crust covers only a small part of the pond surface.

Source: FAO 1997.

practice was little noted until the 1970s and 1980s, when irrigation expansion, the green revolution, and population growth made drainage disposal a concern. Some natural evaporation ponds such as Lake Karoon in Egypt have been in existence for centuries. Only recently signs of aging and pollution have forced integrated approaches to regulate the volume and quality of the inflow.

Little is known about the lifetime of artificial evaporation ponds. Known histories cover only the last 40 years and do not include ponds reaching their nonfunctional state. Rates of salt deposition depend on evaporation, seepage losses, and inflow of drainage water, but where the latter two are minimal, ponds may be expected to fill up with solid salts. Present views are that ponds may function for at least a half century before needing rehabilitation. Initially, most evaporation ponds were planned to hold drainage water only temporarily, until it could be released into a nearby river during high flow or until a final disposal solution was in place. But most have now become permanent or semi-permanent. Long-term operational experience is limited, and no authoritative technical performance assessments have yet been made.

Evaporation ponds for the disposal of saline drainage water are used most extensively in the Aral Sea Basin, particularly the basins of the Amu Darya and Syr Darya rivers. In both basins, evaporation ponds receive about 80 percent of the drainage water and only 20 percent is released into the rivers. Most ponds are large and located outside irrigation perimeters. They have been functioning satisfactorily since they were established in the 1960s and 1970s but have now reached their maximum capacity.

In Pakistan, some 25,000 hectares of interconnected evaporation ponds are under construction in the eastern deserts to receive discharges from tubewell and pipe drainage schemes in Southern Punjab. It is still being debated whether these ponds will be operated as final disposal

Box 5.17 The Kesterson Reservoir

This Kesterson Reservoir was originally planned as a regulating body in a drainage system serving the northern part of the San Joaquin Valley in the U.S. state of California, but it turned into an evaporation pond when the system was not completed. Evapoconcentration and bioaccumulation raised the concentration of selenium, a trace element that the drainage water picked up from natural geologic formations. The selenium buildup affected the aquatic food chain, reducing reproduction, causing birth defects, and killing waterbirds. These and similar isolated incidents are reminders of the need for detailed chemical analysis of incoming drainage water.

Source: California Department of Water Resources 1999.

Box 5.18 Seepage Problems

Seepage losses from ponds have caused waterlogging in nearby irrigated land in the sixth Salinity Control and Reclamation project area in Pakistan and in the Murray Darling Basin in Australia. Where such impacts are likely, geohydrological investigation and groundwater modeling should be done to assess hazards and plan remedial measures.

Source: IWASRI 1991.

sites or eventually be linked to the LBOD outfall system that empties into the Arabian Sea.

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This Profile was prepared by Bert Smedema and reviewed by Bart Snellen of ILRI.

INNOVATION PROFILE 5.4

INVESTING IN BIODRAINAGE

What is new? Biodrainage controls excess water by using the water uptake capacity of vegetation, especially trees. Its potential is greatest in arid climates. India, Australia, and other countries have demonstrated that tree plantations can help control shallow water tables and reclaim waterlogged areas. But biodrainage removes more water than it does salts. Salts accumulate when water is mineralized unless salt balances are maintained by natural or artificial drainage. Biodrainage can assist but generally not replace conventional subsurface drainage for salinity control of irrigated land.

Unlike conventional drainage, biodrainage does not need ditches, canals, pumps, or other physical means to collect and transport excess water. Nor does disposal of drainage effluent present a problem. Capital and O&M costs are restricted to the costs of establishing and maintaining the plantations. Biodrainage is not yet practiced on a sufficiently large operational scale to permit cost comparisons with conventional drainage.

Interest in biodrainage is strong in Australia, where it is considered an environmentally attractive option to restore water balances disturbed by past changes in land use, and in China, India, and some arid developing coun-

tries that see biodrainage as a low-cost option for combating waterlogging and salinization of irrigated land.

OBJECTIVES AND DESCRIPTION

Biodrainage is best achieved by planting tree species that are heavy consumers of water and also tolerant of waterlogged and saline conditions (box 5.19). Planting in belts and blocks is most common and also most effective. Trees have also been planted in narrow strips of three or more rows, resembling pipe- or ditch-type field drainage systems. These strips also act as windbreaks. Biodrainage is best suited to combat waterlogging that is localized, as along canals, not areawide.

Biodrainage design requires a good understanding of local hydrology and the causes and nature of the waterlogging problem. Waterlogging in depressions and valley bottoms may be addressed by planting in the affected areas, in the upslope source areas, or wherever the plantations intercept seepage flows.

Establishment costs are considerable in sites with poor soil conditions that require ameliorative and protective measures to achieve reasonable seedling survival rates. Examples of such measures are ripping of impeding layers, liming, fertilizing, and fencing. Products such as low-quality wood and fodder generally do not recover the plantation costs, and the justification must almost always derive from the drainage benefits. Environmental benefits such as water quality protection and enhanced biodiversity may also be significant. Biodrainage can be undertaken on different scales, by individual farmers or by communities through participatory programs.

OUTPUTS AND IMPACTS

Plantations have in several cases been effective at intercepting seepage flow, controlling shallow water tables, and positively amending water balances. Biodrainage has most potential where drainable surpluses are small compared to the water uptake of the plantations and where the

Box 5.19 Suitable Species

Trees generally have extensive and deeply penetrating root systems and high aerodynamic roughness. These features make them better biodrainage performers than bushes, but bushes outperform crops. A tree plantation normally evapotranspires 25 to 50 percent more water than a cropped area. Eucalyptic species are widely used, but good experiences have also been recorded with *Acacia*, *Prosopis*, and *Tamarix spp.* Poplar and willow *spp.* are used in north China. Plantations may have one or more species, sometimes with an undergrowth of resistant bushes or crops.

Source: IPTRID 2002.

focus is on maintaining seasonal or annual balances. This makes biodrainage generally better suited for arid than for temperate climates and for subsurface rather than surface drainage needs (box 5.20).

Biodrainage plantations will also take up and remove salts with the harvested products, but usually too little salt is removed to maintain salt balances. Biodrainage in the arid zone is therefore generally sustainable only when salt accumulation in the root zone is minimal as a result of efficient irrigation with high-quality water or when natural or supplemental artificial drainage removes a sufficient amount of salt from the root zone. On the downside, where water is scarce biodrainage may evaporate water that could be used more beneficially.

APPLICABILITY

In the Indira Gandhi Nahar project in India, eucalyptus and acacia plantations reclaimed seepage zones along leaking irrigation canals and waterlogged depressions. The best approach was to start planting trees away from the most affected areas and move toward these areas by the time the first areas had somewhat dried out. Reclamation took only a few years. The plantation water tables reached depths of 15 meters in six to seven years, and the root systems were 10 meters deep.

Biodrainage has worked well in a variety of other situations. In Croatia, spring land preparation on poorly drained, heavy clay soils was able to start earlier when the land had a light cover left from the previous grain crop. In the Netherlands, reed was planted to accelerate the reclamation of polders; the seed was broadcast from the air when land emerged from the water. In Tanzania, actively growing full canopy sugarcane suffered fewer drainage problems during the rainy season than the less transpiring, newly planted, or ratooned crops.

In Australia, biodrainage is favored where the natural water table regimes are disturbed after the conversion of forests into rangeland or rain-

Box 5.20 Sequential Biological Concentration

Plants may be used to concentrate saline drainage water to facilitate its disposal. If small in scale, this solution is feasible where evaporation ponds or other regular means of disposal cannot be used. Biological concentration has been piloted in the San Joaquin Valley, California. The subsurface drainage effluent from land planted with regular crops and halophytes (salt-tolerant crops, trees, and bushes) is sequentially reused and finally released into a small evaporation pond. Each next reuse area is only a fraction of the source area. In the process, the drainage water is reduced in volume, but its salt concentration increases to end up in solid form in the evaporator.

Source: USBR 1999.

fed cropland. Because rainfed crops allow less evapotranspiration than does deep-rooted tree cover, and deeper percolation of rainwater, saline groundwater rises, causing widespread waterlogging and salinization—known as dry-land salinity, to distinguish it from irrigation-induced salinity. Considerable success in controlling water tables has been achieved by the establishment of eucalyptus plantations. In waterlogged areas, the trees lower the water table by on-site uptake of water, and upslope from these areas they lower the water tables by intercepting the recharge flow to waterlogged areas. Biodrainage plantations are also valued for their contribution to environmental diversity and the landscape.

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This Profile was prepared by Bert Smedema and reviewed
by Bart Snellen of ILRI.

INNOVATION PROFILE 5.5

INVESTING IN USER OPERATION AND MAINTENANCE OF DRAINAGE

What is new? Drainage management has been a top-down agency activity with little user responsiveness, but this needs to change. For one, the government needs user fees to fund O&M. Second, farmers need finely tuned water table levels that allow them to raise yields and diversify their crops to meet market demand. Egypt's Ministry of Water Resources and Irrigation, took a successful process approach in which it gradually built support for reform.

Egypt's Public Authority for Drainage Projects (EPADP) brought massive and rapid drainage development soon after its establishment, but the way it operates is outdated by today's rapidly changing environment and the mounting costs of operation, maintenance, and replacement. The agency needs to shift from construction to maintenance, tailor designs to users as well as to sites, decentralize water management, and privatize service delivery.

In an effort to adapt to this changed environment, the MWRI invited two donor-funded programs to join forces and develop practical methodology for user participation in drainage design, implementation, and maintenance.

OBJECTIVES AND DESCRIPTION

EPADP itself identified the need for greater user participation and chose water boards as its main vehicle. Water boards are water management organizations set up and run by irrigation and drainage users at the branch canal command level. Long-term policy foresees that they assume responsibility for O&M of the drainage system to the field level in subsurface pipe-drained areas.

The two MWRI programs opted for a change process, as opposed to a project, because a multitude of new behaviors was needed. They

formed a working group of high-level EPADP officials and program staff that formulated four objectives:

- Test a process that is acceptable to users, EPADP management, and its design and field staff
- Develop training modules for both staff and users
- Draft all new legal documents such as contracts, memoranda of understanding, and transfer deeds
- Transfer responsibility for O&M to user organizations.

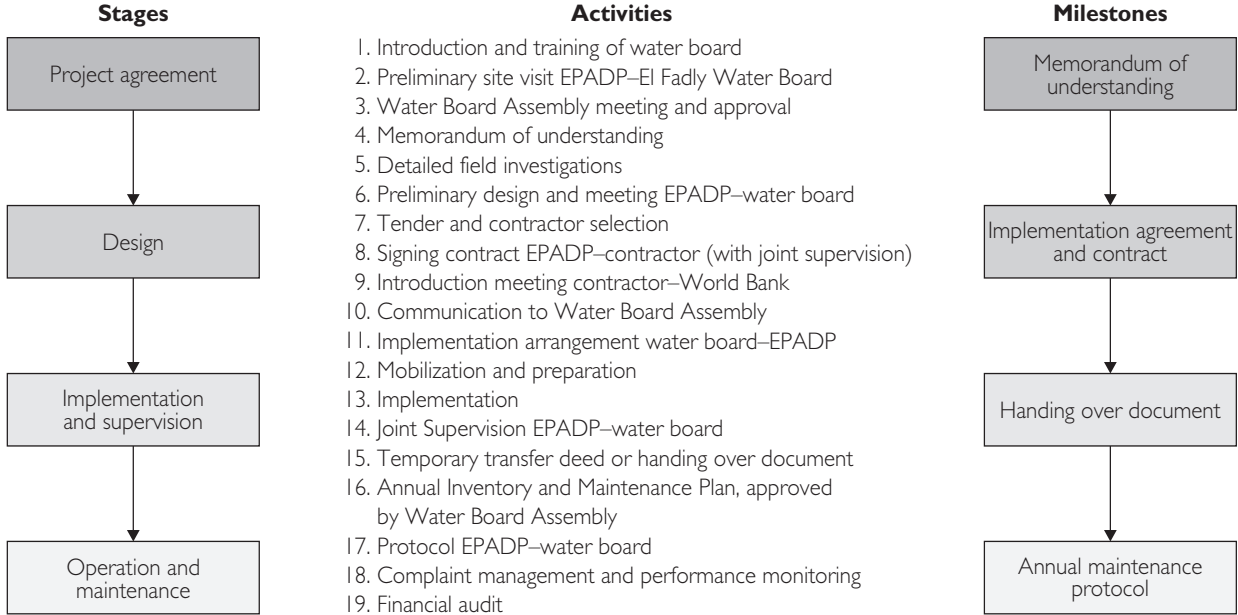
Building on institutional reform efforts in EPADP, the working group identified the required changes. Following the principles of the process approach, it aligned the new activities with existing EPADP procedures instead of designing a totally new, project-type approach. As a result, it recommended training water board and EPADP staff, developing procedures for participatory field investigation and design, and formalizing the partnership among agency, users, and contractors.

The working group debated the recommendations in the agency and incorporated output into a draft approach that it piloted with the El Fadly Water Board in Kafr el Sheikh, established in 2001. The desired outcomes of the pilot were as follows:

- High quality of implemented infrastructure
- Responsibility for O&M assigned to the water board
- Water board trained, motivated, and organized to handle maintenance
- Changed working relationship between farmers and EPADP

The new process features the usual EPADP activities. The changes lie mostly in activities built in to ensure participation and strengthen both EPADP and water board organization (figure 5.2).

FIGURE 5.2 PARTICIPATORY DRAINAGE PROCESS STEPS



Source: Author.
EPADP: Egypt's Public Authority for Drainage Projects.

OUTPUT AND IMPACTS

INCORPORATION OF FARMER TRAINING INTO THE PROCESS. A two-day practical training course was given to prepare the water board for its new tasks in design and quality control. A visit to a pipe factory and the use of large drawings and maps proved successful teaching tools. The trainers paid special attention to the option of controlled drainage and crop consolidation, a major issue in the area (see IP 5.2). Cotton and rice growers need different water levels, and their conflicting interests sometimes lead to open confrontation. With controlled drainage, farmers can reduce pumping costs for rice production and avoid waterlogging in cotton cultivation, if the individual farmers agree to consolidate their cropping patterns around drainage (sub-)collectors.

TAILORING THE DESIGN TO THE SITE AND USERS. The participatory design process consisted of three main steps:

- Joint field investigations to make maximum use of local knowledge of trained water board members.

- A structured design meeting where engineers presented the design, explained options, and reached a consensus with the executive committee on the optimal design. The water board executive committee considered that controlled drainage was feasible for its area, although it expected difficulties organizing farmers for this purpose. It decided that the additional investment of some 20 percent was worthwhile and took this expensive option to the assembly for approval.
- The water board held a large assembly meeting and a series of smaller public information meetings throughout the command area to present the preferred design option and justify its higher costs. It also discussed subjects such as compensation for crop damage during construction and stressed the importance of smooth implementation by allowing equipment free access to the area.

Despite more intensive consultation, EPADP design staff halved its time input in El Fadly as a result of water board assistance during field

investigations. More important, both the water board and EPADP field engineers judged that design quality had been greatly enhanced and better adapted to the agronomic and organizational conditions of the area. The training, design, and consultation process took six months.

FORMALIZING THE PARTNERSHIP BETWEEN WATER BOARD, AGENCY, AND CONTRACTORS. In 2003, the water board and EPADP signed their first memorandum of understanding. It defined the rights and obligations of both parties. EPADP then included provisions in its implementation contract with the contractor that defined the role and responsibilities of the water board in supervision and quality control. Supervision of contractors by a well-trained water board, instead of an overstretched EPADP field engineer, is expected to improve quality, ownership, and maintenance. In addition, the water board and EPADP agreed to sign a handover protocol that specified the role and obligations of the water board in maintenance, until now an exclusive EPADP task.

MAINSTREAMING THE PILOT IN EPADP PROCEDURES. When EPADP engineers saw the reduction in design time and the user preference for controlled drainage, their feedback convinced top management that the approach should be disseminated among middle-level managers and engineers. A workshop decided to replicate the process in other areas with water boards; develop a similar approach for non-water board areas, emphasizing public consultation and temporary implementation

committees; and incorporate the water board training module into the curriculum of the Drainage Training Center and hold such courses for all user organizations dealing with drainage development.

ISSUES FOR WIDER APPLICABILITY

The institutional reform process within the authority had already raised staff awareness about the need for change. Sometimes abstract discussions were shown to lead to a practical approach that would improve drainage design and implementation.

High-level management supported the process. It allocated budgets for training, approved amending the contracts with contractors, and signed the memorandum of understanding with the water boards that transferred O&M responsibilities. Earlier in the process, the chair and vice chair made their support and commitment visible by attending meetings organized for the managers reporting to them.

The positive and trusting attitude of the water board convinced skeptical managers and engineers of the value of accepting users' opinions and decisions. Board members trusted and engaged the EPADP engineers and were eager to learn both practical and technical details of drainage design and implementation.

This Profile was prepared by William Oliemans of Royal Haskoning with input by Adel Bichara. It was reviewed by Bart Snellen of ILRI.

6

INVESTING IN WATER MANAGEMENT IN RAINFED AGRICULTURE

- Investment Note 6.1 Investing in Supplemental Irrigation
- Investment Note 6.2 Investing in Watershed Management
- Investment Note 6.3 Investing in Water and Soil Fertility Management
- Innovation Profile 6.1 Investing in Community-Based Soil Conservation and Watershed Management Projects
- Innovation Profile 6.2 Investing in Watershed Management in China's Loess Plateau
- Innovation Profile 6.3 Integrated Water Management to Enhance Watershed Functions and to Capture Payments for Environmental Services

OVERVIEW

Investments to improve incomes and reduce vulnerability in rainfed farming systems are covered in this chapter. These systems are characterized by poor and variable water availability and by pervasive poverty. Successful investments described include supplementary irrigation, combined water and soil fertility management, and broader rural development and livelihoods investments within a watershed management approach. User groups are central to many of the investments described in this *Sourcebook*. These groups' roles in investments in supplementary irrigation, watershed management, and drought management are described in this chapter.

RISK WEIGHS ON THE DAILY LIVES OF POOR RAINFED FARMERS, AND INVESTMENT PACKAGES HAVE TO HELP REDUCE THAT RISK. Risks include not only climatic risk and limited access to reliable technology and water sources but also risks from unstable land tenure and from poorly functioning product and credit markets. Some approaches described in the chapter and elsewhere in the *Sourcebook* were

successful in overcoming these risks. For example, investments in supplemental irrigation, in holistic and integrated watershed management, and in drought management can reduce the risk of uncertain rainfall. (See IN 6.1 on supplemental irrigation and IN 6.2 on watershed management. For the problem of drought and for ways to handle it, see chapter 8, especially IN 8.1.)

SOME TECHNOLOGIES FOR RAINFED AREAS CAN HAVE HIGH RETURNS. Investing in supplemental irrigation—a “just-in-time” dose of water—can have a significant impact on rainfed systems. Returns on water in supplementary irrigation are higher than in conventional irrigation, and are highest at lower-than-recommended applications—a powerful message in water-scarce localities. Farmers readily adopt supplementary irrigation once they are convinced it is profitable and reduces risk. Maximum benefits require an integrated investment package of water-harnessing and irrigation technology, irrigation scheduling, training, and cropping and fertilizing guidance. Combined soil and water management investments can also have a high return. The Loess Plateau watershed rehabilitation project in the Yellow River Basin of China demonstrated on an area of 1.5 million hectares that profitable farming could be compatible with soil and water conservation. (See IN 6.1 on supplementary irrigation, IN 6.3 on combining water with soil fertility management, and IP 6.2 on the Loess Plateau project. See also “Integrated Nutrient Management for Sustaining Soil Fertility,” in *Agriculture Investment Sourcebook* (AIS), Module 4.)

INVESTMENT IN SOIL FERTILITY MUST DEAL WITH COST AND RISK FACTORS. Farmers see *improving fertility as a costly and risky business*. Research and development programs can promote adoption, and in some countries innovation grants to farmers have worked well. Where packages have been developed on a large scale, they have been successful in reducing poverty. One case study on Madagascar shows the broad impact of a nongovernmental organization (NGO) program for transferring soil conservation technology. (See IN 6.3. See also IP 6.1 for the Madagascar program and IP 6.2 for the Loess Plateau project.)

Watershed management investment should focus on poverty reduction. Empirical evidence shows that the most sustainable watershed management projects focus on poverty reduction through improvements to roads, education, diversification, and livelihood improvement. Thus, sustainability starts with the farm family and its livelihood as the unit of development and recognizes the role of watershed communities as “conservation managers.” A typical approach is a participatory project with a poverty focus aimed at changing land use and boosting incomes through higher-value crops and more sustainable practices, combined with conservation investments. Secure land tenure, a cash crop orientation, and investment profitability are crucial. Investments such as planting fruit trees or adopting micro-irrigation have demonstrated success in both income improvement and soil conservation. Early returns are needed to maintain farmer interest. (See IN 6.2. For monitoring and evaluation of watershed projects, see IN 9.1. See also “Community-Based Natural Resource Management,” and “Watershed Management for Agricultural Development,” in AIS, Module 5.)

WOMEN’S ROLE NEEDS TO BE CONSIDERED IN RESOURCE MANAGEMENT INVESTMENTS. Women can play a crucial role as “front-line resource managers” and as the educators of the next generation. Therefore, it is important to invest in lightening women’s workload and diversifying their livelihood source. (See IN 6.2.)

NEW INSTRUMENTS ARE BEING DEVELOPED TO PAY POPULATIONS UPSTREAM IN WATERSHEDS FOR GOOD RESOURCE MANAGEMENT. Watershed management has to give upstream populations incentives to manage the watershed for the benefit of all, including the population downstream. Various market-based methods are being tried for rewarding good natural resource management by paying for the resulting environmental services. There is a need for a clear database and decision-making framework accessible by all stakeholders, such as the Drainage Integrated Analytical Framework (DRAINFRAME) (see IP 5.1). The Carbon Fund under the Kyoto Protocol is an example of a payment mechanism for environmental services. (See IP 6.3.)

SOME TYPICAL INVESTMENTS

Technical assistance investments may include the following:

- Capacity building of farmers and extension workers
- Integrated studies of watersheds and their stakeholders
- Studies to develop market-based mechanisms for paying for environmental services

Project investments may include the following:

- Water resources development for supplementary irrigation
- Low-energy pressurized systems
- Integrated pro-poor watershed management projects

Policy-based investments may include the development and support of national drought policy and preparedness plan. And finally, related investments may include postconflict rehabilitation or emergency projects that aim to restore assets and production and promote supplemental irrigation.

INVESTMENT NOTE 6.1

INVESTING IN SUPPLEMENTAL IRRIGATION

Supplemental irrigation helps stabilize rainfed agriculture. For the greatest benefit, it must be part of an integrated package of farm cultural practices. Overexploitation of groundwater threatens the sustainability of groundwater-based supplemental irrigation in many areas. Supplemental irrigation that is optimized through on-farm water management policies and timely socioeconomic interventions is essential for the sustainable use of limited water resources.

Production is low and unstable in dry farming, dependent on variable rainfall and subject to droughts and land degradation. One option for boosting and stabilizing crop productivity is supplemental irrigation, whose returns to farmers can be overwhelming. *Supplemental irrigation* (SI) is defined as the application of additional water to otherwise rainfed crops, when rainfall fails to provide essential moisture for normal plant growth, to improve and stabilize productivity. Unlike full irrigation, the timing and amount of SI cannot be determined in advance owing to rainfall stochasticity.

Key questions and issues for successful SI are as follows:

- Determining the most appropriate scheduling for farm conditions
- Selecting crops and cropping patterns for maximum returns
- Determining the socioeconomic feasibility of occasionally supplying extra water to rainfed crops
- Promoting water user associations (WUAs) that manage water use in a sustainable manner
- Setting fixed and efficient water delivery schedules

- Providing incentives for local communities to use water efficiently to improve livelihoods
- Managing the economic and environmental consequences of using water in supplemental irrigation
- Developing policies that foster an enabling environment for the adoption of water-efficient technologies to manage rainfed systems in a sustainable manner

INVESTMENT AREA

Alleviating soil moisture stress during the critical crop growth stages is key to improved production. Supplemental irrigation is a highly efficient option to achieve this strategic goal because it provides the crop with a limited amount of water at the critical time (box 6.1).

Water resources management strategies have become more integrated, and current policies look at the whole set of technical, institutional, managerial, legal, social, and operational aspects needed for development on every scale. Sustainability is a major objective of national policies. Optimizing SI in rainfed areas is based on three basic aspects:

- Water is applied to a rainfed crop that would normally produce some yield without irrigation.
- Since rainfall is the principal source of water for rainfed crops, SI is applied only when rainfall fails to provide enough moisture to improve and stabilize production.
- The amount and timing of SI are scheduled not to provide stress-free moisture conditions throughout the growing season, but to ensure a minimum amount of water during the critical stages of crop growth so as to permit optimal instead of maximum yield (box 6.2).

A suitable and sustainable water supply is decisive. If groundwater is used, and it usually is when there is no surface water source, groundwater sustainability can be jeopardized by SI

Box 6.1 Supplemental Irrigation in Northern and Western Syrian Arab Republic

Research has shown the following:

- Wheat yields have been increased from 2 tons per hectare to more than 5 tons per hectare by the conjunctive use and timely application of only 100 millimeters to 200 millimeters of irrigation water. Therefore little water would not support a fully irrigated crop and is only productive as a supplement to rainfall.
- Water productivity under SI is far higher than in conventional full irrigation. Wheat productivity in nonrainfed areas is less than 1 kilogram per cubic meter but up to 2 kilograms per cubic meter under SI. Thus, SI also improves the productivity of limited rainfall.

Extent and economy of implementation:

- The area of wheat under SI in northern and western Syria (where annual rainfall is greater than 300 millimeters) has increased from 74,000 hectares (in 1980) to 418 thousand hectares (in 2000), an increase of 470 percent.
- Estimated mean annual increase in production cost due to SI (including fixed and variable costs) as compared to rainfed equals US\$150 per hectare. Estimated mean increase in net profit between rainfed and SI for wheat equals US\$300 per hectare. Ratio of increase in estimated annual net profit per hectare to estimated difference in annual costs between rainfed and SI is 200 percent, which is highly significant.

Source: Authors.

Box 6.2 Optimizing Supplemental Irrigation

SI led rainwater productivity in northwest Syria to increase from 0.84 kilograms of grain per cubic meter to 1.53 (at one-third SI), 2.14 kilograms per cubic meter (at two-thirds SI), and 1.06 kilograms per cubic meter (at full SI). Similarly, for biomass water productivity, the obtained mean values are 2.37, 2.42, 3.9, and 2.49 kilograms per cubic meter for rainfed, one-third SI, two-thirds SI, and full SI, respectively. The results show more significant improvement in SI water productivity at medium SI application rates than at full SI. Highest water productivity was achieved at rates between one-third and two-thirds of full SI. Water productivity becomes an issue for farmers only if water is the production factor that most constrains yields or if saving water yields immediate benefits.

The association of high water productivity values with high yields has important implications for crop management that aims at efficient use of water resources in water-scarce areas. Raising yields by increasing water productivity is economical only when crop yield gains are not offset by increased costs of other inputs. The curvilinear water productivity-yield relationship makes clear the importance of attaining relatively high yields for efficient use of water. Policies for maximizing yield should be examined from every angle before they are applied under water-scarce conditions. Guidelines for recommending irrigation schedules under normal water availability conditions need to be revised when applied in water-scarce areas.

Source: Oweis and Hachum 2003.

development because of the tendency for over-exploitation. Groundwater levels are indeed dropping rapidly in many areas. As an alternative to groundwater, water harvesting for SI is a sustainable practice and is common in the absence of other sources, as in Sub-Saharan Africa (box 6.3).

POTENTIAL BENEFITS

Benefits associated with SI include increased yield productivity and reduced risk of failed harvests caused by below-average rainfall.

Social benefits are thus derived from increased income reliability. Because economic benefits can be partly offset by higher annual production costs, sound economic analysis of such investments is extremely important, but an increase in annual net profit per hectare is likely (box 6.1, section on the extent and economy of implementation).

In northern Iraq, where most of the country's rainfed grains grow, huge public investments were made in SI schemes. Substantial improvement in yield was achieved by using SI in conjunction

Box 6.3 Supplemental Irrigation in Sub-Saharan Africa

In Sub-Saharan Africa and other tropical semi-arid areas, rain-water harvesting, which collects surface runoff, is used to provide water for SI. Although seasonal rainfall in these environments is higher than around the Mediterranean, its effectiveness is low because of higher evaporation losses and lower soil-water holding capacity at the root zone. Research in Burkina Faso and Kenya has shown that SI of 60 to 80 millimeters can double and even triple grain yields from the traditional 0.5–1 ton per hectare (sorghum and maize) to 1.5–2.5 tons per hectare. However, most beneficial effects of SI were obtained only in combination with soil-fertility management. The major constraint to SI development in Africa is farmers' capacity, both technical and financial, to develop storage systems for runoff water.

Source: Rockstrom, Barron, and Fox 2003.

with appropriate production inputs and system management. In the growing season of 1997–8, rainfed wheat yield increased from 2.16 tons per hectare to 4.61 tons per hectare with the application of only 68 millimeters of irrigation water at critical times. Every week of delay in sowing resulted in wheat yield losses of up to 0.5 tons per hectare. Yield significantly increased with increases in nitrogen fertilizer applications. (See also IN 6.3.)

In the highlands of Turkey, the Islamic Republic of Iran, and Central Asia, frost conditions in winter put field crops into dormancy. Most years, sufficient rainfall to germinate seeds comes late, resulting in weak crop stand during the frost period, slow growth in the spring, and yields that are much lower than potential. Ensuring good stand before winter was achieved by early sowing and applying a small amount of SI. In Turkey's central Anatolia plateau, applying only 50 millimeters of SI to wheat sown early increased rainfed grain yield by more than 60 percent, adding more than 2 tons per hectare to the average rainfed yield of 3.2 tons per hectare.

In northern Syria, water-short farmers apply half the amount of full SI water requirements to their wheat fields. By so doing, the area under SI is doubled using the same amount of

water, and total yields increase by about 25 percent; total farm production increases by 38 percent (box 6.4).

The ecology of the rainfed dry areas is fragile. Resources for the poor are generally limited. Under pressure to eke out a living, farmers often overexploit water resources, jeopardizing the sustainability of their livelihood. Nationally integrated policies to control the use of water resources create an enabling environment for sound technologies. Human capacity building is also crucial for improving the livelihood of the poor in the rainfed dry areas. The challenge in the rainfed areas is to enhance and stabilize productivity of water by promoting strategic and sustainable use of water from conventional and unconventional sources to augment rain during the dry season.

POLICY AND IMPLEMENTATION

Integrated and participatory research and development (R&D) programs offer the best way of bringing SI technologies and practices to their full potential. Any development or applied research program that underestimates the role of farmers is doomed to failure. Acceptance of SI by male and female farmers is a condition for its success. For pilot tests, staff and farmers may select a water basin using agreed criteria. An integrated R&D program will be designed and implemented in a way that involves local communities, institutions, and decision makers. The following issues must be taken into consideration:

- The introduction of SI techniques builds on any existing water conservation measures.
- Farmers should see the benefits of a project as early as possible. Motivating and promoting awareness among farmers with regard to the project objectives and the ways to achieve them are essential. Implementation requires commitment and cooperation of neighboring farmers (or communities) in the coordination and management of their limited water resources. Today, local communities seldom initiate group action and depend on assistance from external agents

Box 6.4 Water Productivity in Farmers' Fields

Applying only 50 percent of full SI requirements for wheat causes a yield reduction of only 10–15 percent. Many farmers overirrigate their wheat fields. When there is not enough water to provide full irrigation to the whole farm, the farmer has two options: to irrigate part of the farm with full irrigation, leaving the other part rainfed, or to apply deficit SI to the whole farm. In areas where water is more limiting than land, applying deficit irrigation increased the benefit by more than 50 percent compared with the farmer's usual practice of overirrigation (see table).

Wheat Grain Production Scenarios for a Four-Hectare Farm with Various Strategies of Supplemental Irrigation in Northern Syria

Irrigation management strategy	Rainfed (342 mm)	Farmer's practice	Applying full SI water	Applying 50 percent of full SI
SI, water depth applied (mm)	0	298	222	111
Grain yield (t/ha)	1.8	4.18	4.46	4.15
Water productivity (kg/m ³)	0.53	0.70	1.06	1.85
Farm production (ton), water is not a limiting factor	7.2	16.7	17.8	16.6
Farm production (ton), if only 50 percent of full irrigation requirement is available	7.2	10.8	12.5	16.6
Per hectare average production (ton)	1.4	2.7	3.12	4.15

Source: Oweis and Hachum 2003.

such as NGOs. The lack of developed local institutions critically constrains exploitation of the potential for improved water management technologies such as SI.

- The specific needs of a local community or a group of beneficiaries must be understood and designed into an appropriate system, bearing in mind the major role often played by women in agricultural works. Farmers' acceptance of a new technology depends on their attitudes toward production risk. It is important to find out whether differences in farmers' adoption behavior are caused by differences in their perceptions about the risks involved in a new technique or by differences in their access to credit and other inputs. Risk-averse farmers will accept a new technology if they perceive that increased returns more than compensate them for any increase in risk.
- To prevent inequality at the village level from widening as a result of the introduction of SI, special care should be taken to make sure that poor and women farmers have equal access to the technique.
- Most dry area ecosystems are fragile and do not adjust easily to change. If the introduction of SI changes suddenly the use of, for instance, natural resources, especially land and water, the environmental consequences can be far greater than foreseen.
- The necessary conditions for adoption of new technologies are often location specific because they are influenced by cultural differences, education, and awareness of a need for change. Users of land and water resources are usually aware of land degradation, but they may not be able to do anything about it if their primary concern is survival. They are unlikely to take up a new practice unless they are convinced it is financially advantageous, does not conflict with other activities they consider important, and does not demand too much of their time for maintenance.
- Institutional capacity building, water resources management policies, and management and maintenance programs are key to success. The institutions could be at the village, regional, or national level, depending on the

size of the SI projects and the extent of a country's decentralization. Multiple plantings to increase rainfall utilization should become standard practice under SI. Therefore, farmers need to be knowledgeable about water-stress-sensitive growth stages and correct timing of water applications.

LESSONS LEARNED

Alleviation of the following constraints will help SI achieve its potential:

- The on-demand water delivery system is best suited to SI. This is what small farms use, drawing water from wells or nearby surface water.
- SI must be properly integrated with other production inputs, including crop and soil management options, improved germplasm, and fertilizers to achieve the desired output.
- Many poor farmers in rainfed dry areas cannot afford to buy inputs. To assist them, socioeconomic intervention should be carefully planned.
- Farmers need to understand the technology and how to use it. Extension and human capacity building should play a major role in this respect. Long-term training and advisory programs should be designed and implemented.
- Natural resources, particularly land and water, are more efficiently utilized collectively than individually. WUAs are a good example of an efficient approach to collective management and use. Any institutional constraints hindering the establishment and transparency of these associations should be studied.

RECOMMENDATIONS FOR PRACTITIONERS

- Use incentives for farmer participation, technology transfer, and water cost recovery to prompt adoption of improved management options.

- In rainfed dry areas, maximize yield per unit of water, not yield per unit of land.
- To maximize the benefits of SI, make sure that other inputs and cultural practices are also optimized.

INVESTMENT OPPORTUNITIES

- Reform policies and regulations to govern groundwater development and operation.
- Strengthen or create WUAs to manage water at the scheme level.
- Develop systems for monitoring groundwater quality through overexploitation.
- Finance water resources development for SI through the source, the conveyance system, and the field irrigation systems.
- Develop low-cost, low-energy irrigation systems such as drip or sprinkler, including a pumping set.
- Build capacity building of extension workers and farmers to install, operate, and maintain their systems.
- Support development of simple and practical tools for SI scheduling. Scheduling is the key to improving water use efficiency.
- Rehabilitate SI systems damaged in conflicts (examples include Iraq and Afghanistan).

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This Note was prepared by Theib Oweis and Ahmed Hachum of ICARDA, and reviewed by Jean-Marc Faurès of the Food and Agriculture Organization (FAO).

INVESTING IN WATERSHED MANAGEMENT

In many watersheds, erosion and siltation result from goal-rational human action. Projects seeking to stem these physical phenomena should first try to help individual families reach their food, shelter, and cash goals in new ways. Once that is accomplished, conservation can be made a community goal. Point sources may be combated by paying upstream watershed users for changed behavior, but the link between upstream action and downstream output cannot always be established, let alone measured. Where nonpoint sources of pollution or erosion and upland poverty are a problem, their reduction through participatory projects for natural resource management by the community is still a valid option.

Sustainability of World Bank watershed management projects suffers from poor enabling environments and inadequate technical support, including overoptimistic assumptions about the long-term net benefits of new technologies. It also suffers from a focus on off-site benefits such as lower siltation rates and improved security and quality of water supply. In addition, the assumption that public and private goods are interchangeable does not always hold. Together, these assumptions result in large investments in conservation with add-on incentives for farmers rather than in projects that are, by themselves, sustainable because they focus on poverty reduction by improving access, education, diversification, and incomes.

For project sustainability, designers must concentrate first on the farm family and all its sources of income as the unit of development. Recognizing that environmental conservation is almost always a community priority—but only after food, shelter, and cash needs are met—will enable task managers to address sustainability issues with individual farmers and their communities. Such an approach recognizes the pivotal role of watershed communities as future conservation man-

agers, and therefore addresses their priority needs first.

INVESTMENT AREA

Past projects emphasizing general rural development have often involved large investments in a comprehensive approach (box 6.5). They can be effective if approaches are adapted to local preferences and are not prescriptive or dogmatic.

About one in four Bank watershed management projects seeks to reduce siltation rates of a major body of water such as a river or reservoir, sometimes to protect irrigation schemes from sedimentation by upstream soil erosion. Targeting riparian communities that have problems such as soil erosion or water pollution from point sources can be more cost effective.

A possible approach is the use of payments to effect change. Payments for environmental services are appropriate where long-term secure funding to change behavior is available. They are therefore often linked to payments by consumers for potable water or other services. Turning responsibility for catchments for potable water over to municipal governments and consumers has been a growing trend in Honduras. In Costa Rica (Chomitz 1998), payments for environmental services from users to landholders under the 1997 Forestry Law were first organized by government from hydropower operators. Now the trend has spread to tour operators and hotels, which strive to maintain scenic and water quality assets. The total of incentive payments (US\$20–US\$30 a hectare per year) is about the same as the rental price of pasturage.

The balance of policy and technology in improving soil and water conservation and reducing soil and water pollution has to vary with the scale of the problem and the likely cost. Where nonpoint sources of pollution or erosion at a watershed or partial watershed are the problem, a participatory project may still be appropriate with a poverty focus on changing land use and boosting incomes through higher-value crops and more sustainable practices (box 6.5).

Box 6.5 China: Soil Stabilization and Poverty Reduction Using a Farm Systems Approach

The Red Soils II Area Development Project in China (1994–2000) addressed soil loss and degradation over some 11 million hectares of acid infertile ultisol and inceptisol soils during the summer drought in the Yangtze and Pearl River catchments. Half of the participants in the project, an improvement program in 266 small demonstration watersheds or partial watersheds in five provinces, had incomes below the poverty line.

Key features to ensure sustainability included the following:

- All farms were required to incorporate livestock in the farming system for manure and early income until higher-value horticultural tree crops were bearing. No major fertilizer imports were used, and locally manufactured superphosphate (containing magnesium) was recommended instead.
- Each farm had a supply of irrigation water, to be distributed by low-cost, handheld hose systems from hilltop tanks.
- A project management structure was embedded in existing line agencies.
- Contour planting and appropriate conservation were carried out according to slope rather than universal terracing.
- Emphasis was on *diversification, not specialization*, at individual farm level, and on the incorporation of a balance of lowland and upland areas for food staples (rice) and cash crops (citrus, stonefruit, and grapes)
- The provincial government granted a 50-year, inheritable land use right to farmers as a prerequisite for provincial participation.

The implementation completion report estimated a financial rate of return of 16–17 percent depending on the province and an economic rate of return of 19 percent. Sustainability was considered highly likely.

Source: “Second China Red Soils Area Development Project,” Implementation Completion Report.

Where a point source can be identified—for example, in siltation of reservoirs or industrial and salinity pollution of waterways—“cap and trade” schemes, based on payments for and trading in pollution, are possible. However, they require accurate measurement technology and a more organized society and rule of law than are usually prevalent. Similarly, a regulatory approach requiring farmers to erect vegetative barriers to streams or buy pollution credits may be tried, as in the catchment of the Wivenhoe Dam, the source of water supply for the city of Brisbane, Australia. The trend is toward pollution credit prices equal to the cost of installing vegetative barriers and income forgone from land lost.

Vetiver grass hedges have proven effective as soil loss barriers but suffer low adoption rates even where climatic conditions favor them, as in India and China, because of planting material requirements and farmers’ preferences for a mix of conservation and fodder supply/cash crop species. In northern Thailand, contour grass strips, 2 to 3 meters wide, for livestock proved as effective as bench terracing in reducing soil loss (from 50 tons per hectare to 2 tons per hectare). Planting

coffee on medium slopes (36–55 percent) released land for reforestation because coffee earns farmers more money per hectare than do lower-value crops. Elsewhere, the adoption of simple pipe and microsprinkler irrigation systems fed by local streams has allowed both income improvement and soil conservation through intensive cultivation of vegetables and fruits.

POTENTIAL BENEFITS

For Costa Rica, Chomitz (1998) summarizes the per hectare benefits of environmental services of forests as shown in table 6.1.

Less quantifiable but important benefits from watershed management interventions include improved food security from a diversified cropping base, better health and sanitation, better access, and an improved ability of resident populations to work with government and seek outside opportunities.

POLICY AND IMPLEMENTATION ISSUES

- Promote locally relevant technologies supported by research and extension.

Table 6.1 Forests' Benefits

Environmental service	Annual value (in 1993 U.S. dollars)
Carbon sequestration	120(20/ton)
Ecotourism	12–25
Hydropower protection	10–20
Hydrological benefits	7–17
Existence and option values	13–32
Pharmaceuticals	0.15
Total	162.15–214.15

Source: Chomitz 1998.

- Support policies encouraging appropriate resource use, in particular the reform of forestry pricing. In addition, any distorting subsidies, particularly on outputs, should be removed.
- Strengthen land tenure. Land tenure and investment in conservation are correlated, particularly in areas with land surplus rather than communal lands (box 6.6).

Box 6.6 Thailand: Unexpected Benefits of Land Titling

The first two land titling projects assisted by the World Bank in Thailand (1985–93) demonstrated that the major benefit of title security in lowlands was the access it gave to secure institutional credit, based on a percentage of collateral value without a predetermined ceiling on loans. Title also increased land values. Private titling of the lowlands led to better practices in the uplands because farmers who had taken over old forest lands could afford to plant and wait for income from tree crops as a result of the newly available capital. Effects on land values were dramatic. Land values increased by 308 percent for lowlands and 425 percent for uplands in project areas (after correction for increase in nonproject areas) in the north. In the northeast, the corresponding figures were only 135 for lowland and 7 percent for upland. Regression showed that private title and presence of wells (for tree planting) explained most of the variation in land value. Most commercial banks now accept provisional title as collateral.

Source: Author.

- Apply integrated planning to the entire watershed. In the Loess Plateau I and Red Soils II Area Development projects in China, both rated as having a high likelihood of sustainability, key elements in gaining understanding of what could be achieved and whether it would be attractive to farmers were initial training, consultation, land use mapping, and improved farm models.
- Use cash contributions from beneficiaries to ensure commitment and realism in the scope and quality of interventions. Most Bank projects require labor contributions from beneficiaries, and a few require a small cash outlay. Both are required in the village self-help learning initiative program (2000–4) under International Development Association and Japanese cofinancing in Sri Lanka; communities must commit all the necessary labor and contribute 10 percent of the total cost in cash.

LESSONS LEARNED

Land tenure availability, a cash crop orientation, and system profitability are crucial as is reliable technical assistance. There is a strong preference for market-driven solutions that offer, first, a financially attractive return to the land owner or user and, second, the desired conservation outcome. Early returns are needed to maintain owner-user interest—promises of future income will not do it.

In addition to these factors, the basic needs of communities, and particularly the needs of women and youth, must be addressed. In the Lao People's Democratic Republic, women are often the major source of labor for crop harvest and processing, livestock husbandry, vegetable growing, weaving, and water supply: they perform most of the value-adding and entrepreneurial activities. Unless project design incorporates means of releasing some women's labor through mechanization of crop processing or piped village water supply, livelihoods will not diversify and improve enough to allow families to make resource conservation a priority.

In most projects, implementation and sustainability are best achieved by units embedded in

line agencies, not in specialized watershed management units with elite staff. Community participation in design, implementation, and funding of works is essential.

RECOMMENDATIONS FOR PRACTITIONERS

- The first unit for consideration must be the family and its ability to earn cash income for basic needs.
- Invest in problem analysis and rapid appraisals to determine poverty status and actual community priorities as well as the status of resource degradation.
- Base design on sound land use capability planning and resource analysis.
- Use low-cost solutions wherever possible and minimal imports of goods.
- The community is the unit that will do the work. The community must therefore be committed to the work without major subsidy and in recognition of the financial and other benefits likely to accrue.

INVESTMENT OPPORTUNITIES

- Economic benefit study to ensure that a watershed management approach is a priority for the nation and the watershed concerned and to establish the cost that can be justified (helps choose a suitable approach)
- Investment in reskilling of stakeholders, data systems, and consultancy for water management and measurement under a basin-level management authority
- Participatory rural appraisal of problems and opportunities
- Land use plan and soil survey
- Market studies for cash crop alternatives
- Identification of water sources (quality, volume) in relation to users
- Initiatives for improving livelihoods of all family members

- Irrigation development and water supply to villages combined with appropriate soil and water conservation technology

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INVESTMENT NOTE 6.3

INVESTING IN WATER AND SOIL FERTILITY MANAGEMENT

Water and soil fertility are both indispensable for crop growth. Supporting their combined management provides more than the sum of the parts. Investments in joint water and soil policies, in irrigation, runoff control, fertilizer supply, and crop improvement at the country level need to go together with investments in curriculum development and capacity building. Market information systems, credit systems, and innovation grants should also be in place. Examples from Burkina Faso, Kenya, and South Asia show how projects narrowed the gaps between potential and actual yields in poorly endowed agro-environments.

Where scope to expand agriculture is limited, additional production needs to come from increased yields and expansion of the harvested area. Both possibilities depend on adequate water and fertilizer inputs (FAO 2002).

Water and soil fertility are key drivers of plant growth. When their availability and quality are below the level that allows plants to reach their full growth and production potential, their role is “growth limiting.” The two are also intertwined: water is a major driver of soil nutrient availability to plants, the nutrient uptake process, and nutrient losses. Soil organic carbon, the single most important indicator of soil fertility, not only provides fertility to plants but also holds moisture and provides a favorable environment for biological soil life, also enhancing biological nitrogen-fixing potential.

Yet projects and governments rarely address water and soil fertility management simultaneously. This note demonstrates that investments and policies for joint improvement of the two production factors offer more than the sum of their parts and discusses projects that followed this approach.

INVESTMENT AREA

(SUB)NATIONAL LEVEL. Country-level investment should aim to improve irrigation water and fertilizer supply systems and to increase production per unit of water and per unit of nutrient. Water productivity can be raised, for example, by clever routing and timing of water and fertilizer nutrients to the plant and by developing crop varieties that use water and nutrients more efficiently than standard varieties.

COMMUNITY AND FARMER LEVEL. Local investments in rainfed agriculture should help farmers conserve soil moisture by extending the time water remains inside the productive system and maintaining or improving soil organic matter content (examples include erosion and runoff control, manuring, mulching, recycling city and household waste, agroforestry, and restricted tillage). Box 6.7 shows how yields in rainfed agriculture in Burkina Faso increased through a combination of water and soil fertility improvement measures. Box 6.8 demonstrates how reliable water supplies favored adoption of soil fertility-improving technologies in semi-arid Eastern Kenya.

Investments in irrigated agriculture may create incentives for various soil- and water-related management activities. These activities include preparation (puddling, leveling) and synchronization of water delivery to the field with fertilizer application and control of salinity, alkalinity, and toxicity. Because water is largely removed as a growth-limiting factor in irrigated systems, sound and clever fertilizer and manure application can lead to quantum-leap yield increases, as shown for the South-Asian Rice-Wheat Consortium (Ladha et al. 2003).

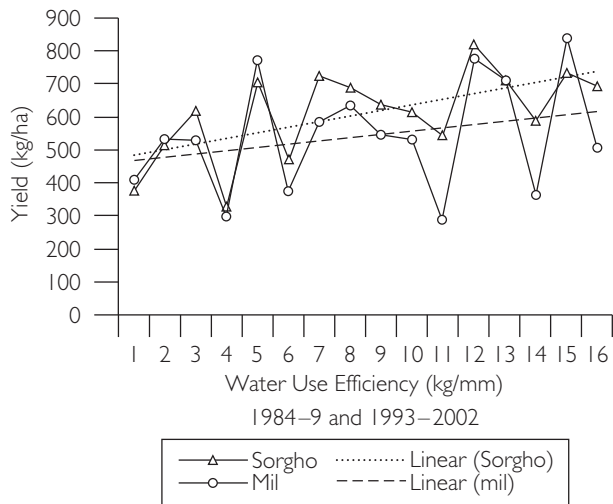
Macro- and micro-level investments are summarized in the subsection on Investment Opportunities.

POTENTIAL BENEFITS

Investments in integrated water and soil fertility management (IWSFM) raise yields and enhance the use efficiency of scarce water and nutrients.

Box 6.7 Joint Water and Soil Fertility Management on the Mossi Plateau, Burkina Faso

Recorded sorghum and millet productivity in Sanmatenga province (north of Ouagadougou) has improved between 1984 and 2002 (see figure). This is due to both better rainfall during the 1990s and adoption of IWVSM such as stone rows, planting pits (*zai*), and compost pits (*fosses fumiers*), enriched by local rock phosphates.



Zougmore et al. (2003) recorded sorghum yields under runoff control of 800–1,200 kg/ha at a water use efficiency of 4–6 kg/mm. Combining stone rows and compost, however, gave 2,300–2,800 kg/ha and 8–12 kg/mm, respectively. Farmer experimentation in Yatenga (central Burkina) gave 200 kg/ha sorghum with planting pits (*zai*) alone, 700 kg/ha in pits enriched by dry dung, 1,400 kg/ha in pits enriched with mineral fertilizers, and 1,700 kg/ha in pits enriched with both dung and fertilizers. Innovative farmers realized between 900 and 1,600 kg/ha of sorghum in good and average years, and still 500 to 900 kg/ha in bad years. Every year these farmers were food secure (Reij and Thiombiano 2003). Farmers that followed IWVSM used more compost and manure than those who did not, saw kilogram production per millimeter of rainfall in the rainy season go up from 3.8 to 6.6 kg for sorghum and from 3.8 to 5.8 kg for millet. Villages with IWVSM harvested (in 2001) 800 kg of grain/ha against 600 kg/ha in villages without IWVSM.

Sources: Burkina Faso 2002; Reij and Thiombiano 2003; Zougmore et al. 2003.

In Burkina Faso (box 6.7), the yields of staple dryland crop increased, as did the yields from vegetable irrigation along the borders of reservoirs. Demand for these vegetables is high and their nutritive value important. In semi-arid eastern Kenya, farmers with access to water,

Box 6.8 Integrated Water and Soil Fertility Management in Semi-Arid Eastern Province, Kenya

Rapid increase in Kenya's population has resulted in rural-urban migration and out-migration from the high-potential to eastern semi-arid and arid areas in search of new farmlands (Makueni and Mwingi Districts). Soils in these ASALs are low in fertility and receive little and unreliable rainfall. During 1998–2003, activities were set up to design, test, implement, demonstrate, and disseminate improved, integrated soil fertility management techniques for various land use zones, soil types, farming systems, and farm types in ASAL through participatory efforts of scientists with all relevant stakeholders.

The experimental results showed that, in rainfed farming systems, low yields and negative nutrient balances can be remedied by applying higher doses of manure and/or fertilizers. Their application in seasons with erratic rainfall, however, barely attained value-cost ratios above 1. Therefore, farmers in rainfed lands consider water harvesting extremely important, and only when that is ensured are they really motivated to invest in soil fertility management.

In the case of (small-scale) irrigated vegetable production in other parts of the area, farmers' management practices were characterized by higher application of mineral and organic fertilizers, higher and more stable yields, and higher financial returns. It shows that as soon as water constraints are alleviated, farmers tend to value soil fertility improving inputs differently.

Source: De Jager, Onduru, and Walaga 2004.

and those living in the nicely terraced environment around Machakos (Tiffen, Mortimore, and Gichuki 1994), have market access and money in their pockets. Such farming systems are viable and stable and invite farmers to invest and take risks.

Examples from the Rice-Wheat Consortium in the Indo-Gangetic plains (see <http://www.rwc-prism.cgiar.org>), and, singled out, those for southern Nepal show that irrigated multiple cropping with high fertilizer and manure application provide much higher yields than those obtained under no-fertilizer conditions. In the Terai, southern Nepal, long-term research trials gave irrigated rice-wheat yields of 2,750 kilograms per hectare

without fertilizer, against 3,790 kilograms per hectare with manure, and 5,310 kilograms per hectare with nitrate, phosphorous, and potassium (NPK) fertilizer. Elsewhere, rice-rice-wheat triple cropping gave 2,000 kilograms per hectare without fertilizer, against 8,140 kilograms per hectare with manure or NPK fertilizer. These results show considerable and promising yield gaps.

Impacts include the following:

- Increased food and income security for farmers
- Healthier and more varied diets for producers and consumers
- Reduced time spent fetching water and fuelwood by replenishment of subsurface water supplies and revegetation of less productive land
- A stop to land degradation and soil fertility depletion and their negative off-site effects such as siltation, flooding, and encroachment of still-less-productive areas

POLICY AND IMPLEMENTATION

KEY POLICY DECISIONS REQUIRED FOR THE INVESTMENT. A joint national policy on both water and soil fertility is required. Limited initial price support may be needed, as well as support to supplying and buying sectors (chain approach). National rural programs such as the World Bank-supported *Programme National de Gestion des Terroirs* in Burkina Faso are important to build local capacity and decentralize public tasks.

INSTITUTIONAL ISSUES. Key components are combining market infrastructure and information support, credit systems, and joint learning and technology development on IWSFM (bringing together farmers, NGOs, and district agricultural staff). The latter requires both strong, client-driven applied research and demand-driven delivery of outcomes to replace earlier ineffective supply-driven delivery.

TRADEOFFS. Full market liberalization and structural adjustment may depress input-output price ratios for farmers with no or limited access to

new markets. These impacts may need to be balanced by investment in market development.

Investment is appropriate where the growth rate of largely rainfed agriculture falls below the rate of population growth. It may also be appropriate in countries dominated by irrigated agriculture facing stagnating and declining yields.

PUBLIC-PRIVATE DIVISIONS OF RESPONSIBILITY. In the field of genetic improvement, the private sector, national agricultural research centers, and centers under the Consultative Group on International Agricultural Research (CGIAR) should distribute tasks. Natural resources management typically is a public duty, but when supplies of water and nutrients are the direct result of a “service” by a supplying agency, they have a price. For a jump start, farmers have to be given innovation grants, which have worked well in *zai* [planting pits] and compost pit development in West Africa and in a series of farmer and community-level programs in East and Southern Africa supported by the Rockefeller Foundation (J. Lynam, pers. comm.).

SOCIAL AND ENVIRONMENTAL IMPLICATIONS. The investments will encourage farmers and other stakeholders to improve their water and soil fertility management. They will also increase their food and income, and physical and cognitive strength.

Land under IWSFM will remain productive yet sustainable. The program may protect less-endowed lands because they will no longer be needed for cultivation and may be revegetated. Subsurface water supplies will be replenished, reducing women’s workload in fetching water and fuelwood.

LESSONS LEARNED

On Burkina Faso’s Mossi Plateau (box 6.7), stone rows reduced runoff and erosion, but their establishment needs a “food for work”-type investment because collection, transport, and placement of the stones is beyond the physical and financial scope of a farm family. Similarly, rock phosphates are badly needed in phosphate-deficient lands and

are applied via compost pits, but grinding rock containing phosphorus, transport, distribution, and pricing need some lending to improve land productivity and reduce expansion of agriculture into marginal lands.

In semi-arid Kenya (box 6.8), farmers did not venture into soil fertility improvement as long as water remained unreliable and scarce. Only farmers with access to water control and commodity markets invested labor and cash in soil fertility management. Similarly, where soil fertility is still a free good to farmers who can regularly occupy new land, farmers will refrain from improving and maintaining their fields. IWSFM will therefore work only where farmers no longer have this exit option and have positive incentives to invest their labor and cash and where the two resources can be made available, as in the once heavily eroded Machakos landscape (Tiffen, Mortimore, and Gichuki 1994).

In Nepal, investments in irrigation and soil fertility management have a prominent place on the national agenda (APP 1997). The ambitious plan is to increase fertilizer use from 22 to 150 kilograms per hectare by 2015, but privatization of the sector has not led to net increases in fertilizer use since 1995. Supply systems are poor, fertilizer types limited (largely nitrogen and phosphorus-based), fertilizer quality low, water supply in some places unreliable, and a comparison with neighboring states in India on agro-economic indicators unfavorable. Therefore, an irrigation and a fertilizer strategy have to go together, in a conducive national and district policy environment, and against the background of attractive factor and commodity prices.

Water conflicts at the scheme level and, as a consequence, unreliable supplies, can make farmers lose interest and yields plummet to very low levels. For the Vallée du Kou, Burkina Faso, Wopereis, Donovan, and Nebié (1999) showed that good crop husbandry (with nitrate fertilizer) can give wet season rice yields of 5 tons per hectare, and dry season yields of 4 tons per hectare. In times of proper scheme management, yields above 4 tons per hectare have been realized, as shown by the Department of Agricultural Statis-

tics. At the time of the Wopereis, Donovan, and Nebié studies (which were conducted during 1995–6), water scarcity during the dry season was a major obstacle, and rice yields were below 2 tons per hectare per year. This was also due to lack of knowledge on optimal timing, dosage, and mode of fertilizer application; optimal sowing and transplanting dates; and the importance of nitrogen as the major limiting factor to yield. At present, upstream water withdrawal by non-tax-paying vegetable farmers still frustrates the profitable running of the scheme. The situation contrasts strongly with the Office du Niger area in neighboring Mali, where a public-private partnership in running the rice-growing area has led to a relatively thriving sector.

RECOMMENDATIONS FOR PRACTITIONERS

- Push for an integrated water and soil fertility management policy at the national level.
- Push for prioritization of national-level investments in crop water control, a fertilizer market (emphasizing the nutrient that limits yields most), crop improvement research, capacity building, and curriculum development for IWSFM.
- Push for the prioritization of local-level investments in IWSFM technologies that best match farmer ambitions and agro-ecological conditions, lighten the workload for women, offer off-season options through small-scale water control, recycling of organic materials from farm and nearby urban areas, and so on.
- Strongly stimulate government facilitation of access to and information on factor and commodity markets and prices. This will help retailers set up businesses and allow farmers to make informed decisions. For farmers, credit systems have to be in place, and cooperative structures should be stimulated to spread risk and forestall excessive profit making by middlemen.
- If opportunities to increase supplies of water and nutrients are limited, start looking for ways to direct the water and nutrients

that are available in a clever way, so as to raise their use efficiency.

- Organize farmers and other stakeholders into groups whose voices are heard at the (sub)national level.

INVESTMENT OPPORTUNITIES

(Sub)national level investments may target the following:

- Delivery of water control infrastructure tailored to the physical and economic conditions in a region (provision of footpumps to access shallow groundwater, government co-investment in small check dams, demand-driven delivery of water conservation technologies)
- Support for a well-functioning fertilizer market with safeguards for quality
- Genetic improvement of food crops where not undertaken by private or public research.

Commodity- and farmer-level investments may target the following:

- Capacity building and curriculum development for farmer groups, NGOs, and district-level agricultural officers on IWSFM. Choice from a basket of options should give farmers satisfactory and sustainable yields at high water and nutrient use efficiency.
- Market information and credit systems: water, fertilizer and commodity prices should be well known to farmers, and credit systems must be in place. Support to and training in scheme-managed water supply is essential.
- Innovation grants for modern farmers who play a lead and exemplary role within their society. The development of planting pits (zaï) in West Africa is a case in point (box 6.7).

Lending for irrigation technologies, fertilizer supply systems, yield response monitoring, and genetic improvement may fall under specific or sector investment loans. Loans for improvement

of markets and information systems, training, capacity building, and joint IWSFM curriculum and technology development may fall under Technical Assistance Loans. Support to innovation can typically come through Learning and Innovation Loans.

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INNOVATION PROFILE 6.1

INVESTING IN COMMUNITY-BASED SOIL CONSERVATION AND WATERSHED MANAGEMENT PROJECTS

What is new? In the absence of an efficient technology transfer system or extension service, the Madagascar Environment Program gave the private sector incentives to bring moisture-saving agricultural production technologies to farmers. These techniques allowed them to improve their production and revenues while protecting soil and water resources.

Farming communities in Madagascar overexploited agricultural and marginal land and encroached on forests and protected areas. With insecure land tenure and few opportunities for cash crop agriculture, farmers expanded their cultivated area using slash-and-burn practices.

In response, the implementing agency for the World Bank Environmental Program Project, approved in 1997, financed community-based soil conservation and watershed management mini-projects, helped formulate community development plans, and set up land-titling operations near protected areas and forests. The goal was to enable farmers to keep land in cultivation longer and increase production and revenues, while reducing biodiversity loss from incursions into forests and protected areas. In the absence of effective government extension services, the agency contracted local NGOs and private consultants (operators) located in small cities and rural towns to guide farmers in moisture-saving, zero-tillage techniques and other practices.

OBJECTIVES AND DESCRIPTION

The project created an implementation agency known as ANAE, the French-language acronym meaning National Association for Environmental Action. Its purpose was to channel funds to farmers to finance productive and infrastructure mini-projects, transfer technologies, help farmers

devise community development plans, supervise these activities, and facilitate land-titling operations (box 6.9).

Individual mini-projects typically consisted of a range of measures combining shorter-term productivity gains such as rehabilitation of small-scale irrigation infrastructure or the introduction of vegetable cash crops, with soil conservation techniques that yield longer-term productivity gains such as alley-cropping or planting of eucalyptus trees on hill slopes. In the longer term, the gradual spread of mini-projects in a region, combined with some spontaneous adoption of techniques by other farmers, is expected to reduce the extent and frequency of environmental problems including uncontrolled brush fires, degradation of soil structure and fertility, and sedimentation of irrigation reservoirs and canals. Many mini-projects include associated assistance at marginal cost for rural development such as literacy or health training and provision of potable drinking water.

Soil conservation is relevant for water investments because soil erosion generates considerable

Box 6.9 National Association for Environmental Action ANAE: A Wide Range of Rural Investments

The ANAE in Madagascar intervened in highly populated agro-ecological areas with soil degradation (erosion) but agricultural production potential. Its mini-projects covered four broad categories: (1) management of soil and water resources (cropping on slopes, reforestation, gully stabilization, fruit tree planting); (2) farm production (intensive rice systems, horticulture, out-of-season cropping, small livestock raising, forage production, fish farming and combined rice and fish farming, apiculture, stables, village granaries, composting/green manuring); (3) infrastructure for farm production (small irrigation networks, riverbank protection, bridges, dams, rural roads); and (4) social programs (potable water, protection of springs, construction/rehabilitation of wells and markets, improved ovens, biogas, schools, rural libraries, and literacy programs). To conserve soil moisture and reduce labor requirements, ANAE disseminated through its contracted agents innovative technologies such as direct seeding, which calls for minimum tillage and covering the soils with mulch or a seasonal/perennial green crop.

Source: Bienvenu Rajaonson, personal communication.

management costs to the farming community that depends on the water resources of the reservoirs. Erosion-induced sedimentation of irrigation systems increases investment and maintenance costs, reduces agricultural productivity because of poor water control, and reduces total irrigable area. Maintaining an adequate water supply to the reservoirs for farming entails expensive de-silting operations on irrigation canals and dredging thousands of cubic meters of sediment from the irrigation drainage system. The total erosion mitigation cost can run into several million dollars. Soil conservation can greatly reduce siltation, thus raising the cost-effectiveness of agricultural water investments (box 6.10).

ANAE mini-projects provided farmers with technical assistance, training, and inputs (such as seed, fertilizers, small equipment, tree plantlets,

infrastructure, books, and improved ovens) through the agency's regional offices on a cost-sharing basis. ANAE advertised to attract local NGOs and private consultants and also contracted government extension agents but on a competitive basis.

The providers sought to interest communities in the program. They helped them select, formulate, and submit applications and helped some communities develop community development plans. The operators established a visit schedule for technology transfer and supervision. ANAE built a partial cost-recovery system to strengthen ownership and sustainability of project benefits and to cover partial operating costs. Costs to be recovered were for inputs and small equipment used in income-generating activities. Cost sharing between ANAE and beneficiaries fluctuated between 22 percent and 97 percent. Beneficiaries paid with labor and local materials. ANAE also piloted land-titling operations and paid for the issuance of land titles in selected areas.

Box 6.10 Economics of Erosion Mitigation and Implications for Agricultural Water Projects

An outcome of the economic analysis of the Madagascar Environmental Program Project indicates that, to maintain an adequate water supply to the reservoirs for farming, expensive de-silting operations had to be undertaken on 25 kilometers of irrigation canals, with 25,000 cubic meters of sediment dredged from the irrigation drainage system. The rehabilitation costs to raise the dam on the Amboromalandy reservoir amounted to US\$3.3 million. In addition, rehabilitation of the canal system required additional investments of US\$1.2 million. These costs, combined with the project costs of US\$300,000 for rehabilitation of the Ambilivily and Ambondromifehy watersheds, amounted to a total erosion mitigation cost of US\$4.8 million.

Failure to undertake these corrective actions or to otherwise rehabilitate the degraded watersheds resulted in the sedimentation of 150 hectares of irrigated area every year. The annual loss in production was estimated at US\$13.8 million. While short-term mitigation costs were much lower than the value of lost rice output, such corrective investments were likely to become prohibitively expensive as long as erosion continued unabated. A more sustainable response, and a less costly one in the long term, was to invest in rehabilitating the watershed, which was expected to improve overall regional productivity.

Source: Madagascar "Environmental Program Support Project." Staff Appraisal Report 1997.

OUTPUTS AND IMPACTS

Beneficiary response exceeded expectations. ANAE had hoped to implement 4,000 mini-projects with 100,000 families on a surface of 32,000 hectares. By the end of the project, it had financed 4,791 mini-projects, benefiting 372,014 families on 75,839 hectares. It had provided capacity-building services to 34 producer organizations and helped them become respected interlocutors with government and development agencies. Its titling operations, involving some 15,000 hectares, had touched 20,000 families. Its operators had assisted farmers in the elaboration of some 70 community development plans, some of which attracted ANAE funding for the ensuing activities. Twenty-six percent of the nearby farmers who did not participate in ANAE activities took up the promoted technologies on their own.

PRODUCTIVITY INCREASES AND SOIL EROSION. The most popular technology was a zero-tillage technique with moisture-retaining mulches. It improved soil quality and productivity and, from the first year, increased yields: rainfed rice

by 188 percent, maize by 201 percent, soybeans by 170 percent, and green beans by 99 percent. (Comparisons are with traditional cropping.) Direct seeding also reduced labor time in the field by 40 percent from the second year on, an average labor saving of US\$112 per hectare. Also, over a five-year period, farmers planting trees and direct seeding on slopes of 12 percent decreased soil erosion by 80 percent, from 8 tons to 1.6 tons per hectare.

INCREASED FARMER REVENUES. Revenues increased significantly. The internal rate of return was 12–18 percent for reforestation, 26–82 percent for anti-erosion technology, 26–106 percent for small dams, and 19–202 percent for production intensification and diversification. Using improved ovens saved 1.6 tons per year per household in firewood, equivalent to US\$23 per year per household. The corresponding saving in time previously used to fetch firewood was about 144 person-days a year, equivalent to US\$115 per year per household. Thus, one household could save US\$138 per year, not a small sum for the average household in Madagascar. The impact on the environment is translated into the preservation of 0.11 hectares of forest per year per household.

ENCROACHING ON FORESTS AND PROTECTED AREAS. The annual rate of deforestation, deduced from satellite imagery, decreased to 0.7 percent for the protected areas, and 1.0 percent for the gazetted forests. This can be compared with a 2 percent annual forest loss (FAO statistics) in the absence of any intervention. Analysis conducted on biodiversity loss showed a slowdown, from a 1.66 percent index to 0.62 percent over five years. In addition, the endemism rate index was reported to have increased from 0.6 percent in 1993 to 0.74 percent in 2000, a 23 percent increase.

ISSUES FOR WIDER APPLICABILITY

Investments should incorporate the lessons elaborated below to significantly increase the potential of replicating this experience.

LAND TENURE SECURITY. Adoption of technologies that pay back in the medium to long term requires

capital investments and time and effort on the part of the farmers. Few farmers will seriously invest in their land without an assurance that they can hang on to the soils in which they invest and share equitable benefits over a joint capital investment, particularly when technologies extend over the tenure of several land owners. Hence, improved land security is a means to improve soil, water, and biodiversity conservation.

AGRICULTURAL SERVICES. The training and extension services offered by the private operators were reported as less than adequate in terms of volume and quality in many areas. Some operators were selected because they were the only ones in the area or because the selection process was not rigorous enough. More important, operators were not given an incentive to follow up on farmers after completion of the mini-project.

ADAPTING TECHNOLOGIES. Fitting technologies to the level of farmers' willingness to change their habitual way of farming could have helped improve adoption. Some farmers complained that they had dropped some technologies because the projects were difficult and time-consuming to apply.

ACCESS TO AGRICULTURAL CREDIT. Credit is important for farmers in a country such as Madagascar, where they are among the poorest members of society. This is especially true for women, who generally lack clear title to land or other assets that lenders accept as collateral.

HOLISTIC APPROACH TO TECHNOLOGY GENERATION AND TRANSFER. The example of livestock and forage production is cited. Because farmers use crop residues and biomass as a source of feed, they were reluctant to use them for mulching in direct seeding. Late in the process, research tried to correct this oversight and started to take a farming system approach to resolve the competition for biomass between livestock and crop production.

INFORMATION, EDUCATION, AND COMMUNICATION. To increase the adoption of technologies, information, education, and communication are

essential. Community leaders and government representatives should be brought into the loop and asked to actively encourage farming communities to adopt new technologies to improve their production and revenues while protecting the environment.

DECENTRALIZATION. ANAE operated on a highly centralized basis with few qualified staff in the field. Contracting out to local operators, while having too few ANAE staff in the field to supervise all work contracted out, was not conducive to accountability and best implementation, and exacerbated farmers' risk-aversion behavior.

MARKETS. Market connections and development are often forgotten in the design of income-generating activities. Accessible market opportunities

would give farmers a significant incentive to adopt better farm production technologies.

COST RECOVERY. Cost recovery worked as a disincentive for technology adoption and did not succeed. Farmers might have accepted it, had their payments gone into a joint savings account that they could later use to access the credit system, rather than to ANAE.

WORLD BANK PROJECT DISCUSSED

Madagascar. "Environmental Program Support Project." Closed. Project ID: P001537. Approved: 1997.

This Profile was prepared by Jumana Farah and reviewed by Inès Beernaerts and José Benites of FAO.

INVESTING IN WATERSHED MANAGEMENT IN CHINA'S LOESS PLATEAU

What is new? The project, located in the Yellow River Basin, built moisture-retaining terraces on which poor farmers developed sustainable and productive farms that reduced soil erosion. On 1.5 million hectares, unsustainable crop cultivation on eroding steep slopes was replaced with moisture-retaining broad flat terraces, and trees and shrubs were planted on steep erodible wastelands.

The Loess Plateau region, an area of some 640,000 square kilometers in the Yellow River drainage basin, is subject to severe geological soil erosion (about 85 percent) and human-induced erosion (about 15 percent), which wreak havoc in downstream river management. About 45 percent of the land is farmed, mostly on erodible sloplands, and the rest is steep, uncultivated wasteland with a sparse vegetative cover. The region is one of the poorest in China.

The Loess Plateau was subjected to several campaigns in the 1950s and the 1970s to build terraces and plant trees. These campaigns to reduce soil erosion met with some success, but there was little impact on farm incomes for several reasons. In those days, the government stressed grain production and discouraged individual initiative in the production and marketing of high-value crops. The terraces were narrow and uneven, and lacked the simplest of access roads. Tree plantations were under communal control, which meant that no one felt responsible for tending and protecting them. Above all, there was no control over free-grazing of goats and sheep.

By the early 1990s, recognition was growing in China that profitable and sustainable farming could be made compatible with water conservation. Thus, the stage was set for the Loess Plateau Watershed Rehabilitation project. The project adopted an integrated watershed rehabilitation strategy that converts cultivated farmland

to moisture-retaining terraces, and plants trees and shrubs on the wasteland. Farm households own all the farmland and the plantations under leases of 30 to 50 years. The households also undertake to repay the portion of the cost of each component (between 40 percent and 60 percent) represented by the credit from the International Development Association (IDA). The project has demonstrated on an area of 1.5 million hectares that the conservation of land and moisture allows the development of pro-poor, small-scale agriculture.

Elements of success include close cooperation with the farmers in preparation of detailed plans for changes in land use (based on geographic information system [GIS] data), a focus on income generation, close links between physical investments and policy change (grazing bans and long-term land tenure security), and a strict physical and financial monitoring system at all levels.

OBJECTIVES AND DESCRIPTION

The objectives of the project were to alleviate poverty in the Loess Plateau by increasing agricultural production and incomes and to improve ecological conditions in tributary watersheds of the Yellow River by introducing more efficient and sustainable uses of land and water resources and by reducing erosion and sediment flow into the Yellow River. The project area of 1,560,000 hectares in four provinces contains about 1,000 small watersheds ranging from 1,000 to 3,000 hectares. Typically, a watershed includes several villages.

OUTPUT AND IMPACTS

The main achievements of the project were terraces and farm roads (90,500 hectares), afforestation (290,000 hectares), orchards (57,000 hectares), grasslands (155,000 hectares), sediment control dams (149 key dams, 1,140 warping dams, and 1,956 check dams), and institutional support (training centers, vehicles and equipment, computers and software for GIS and information systems). The project, begun in 1993, was completed in 2002. The

total project cost was US\$252 million. An IDA credit of US\$150-equivalent financed 60 percent of the project cost.

The increase in agricultural production and incomes through more efficient and sustainable use of land and water resources exceeded expectations. More than a million farmers in the project area directly benefited from the project. Annual grain output rose from 427,000 to 700,000 tons, fruit production from 80,000 to 345,000 tons, (unfortunately, because of limited species diversity, a lot of waste occurred with apples all ready for harvest at the same time; with limited available infrastructure, prices collapsed). Per capita income in farm households increased from yuan 360 to yuan 1,263 (US\$44 to US\$154).

Within the watershed, crop cultivation on steep slopes was eliminated and replaced by smaller areas of newly constructed terraces with access roads. Terraced land retains water and resists soil erosion. The improved soil and water regime and better access for inputs and outputs give farmers the opportunity to plant a wider range of crops with much higher yields than on slopeland. In a year of average rainfall (less than 600 millimeters), grain yields on terraces can reach two to three times those on slopelands. The slopelands and uncultivated wastelands were planted to trees and shrubs that were contracted to farmers under long leases. Pasture was planted on large areas of unused land. Sediment control dams were built in the gullies to intercept sediment and create new land for crops.

The project took the approach of working with and developing the existing institutions in China's public administration. Project management offices were established at each level—the province, prefecture, county, and township. These offices brought together specialists in soil and water management, agriculture, horticulture, and forestry. Management at the village level was through a village committee. At each level, there was a group of leaders, composed of senior officials and specialists.

The cultivated land was already held under long-term contracts, but the wasteland was simply

government-owned land. The land planted to trees and shrubs was auctioned, with preference for local villagers, and the buyers were given a 50-year land lease.

Farmers are responsible for repaying about 60 percent of the cost (the portion disbursed from the IDA credit); the balance consisted mainly of farmers' own labor. The repayment responsibility and land tenure security are strong incentives for farmers to preserve and manage the land developed by the project.

A Second Loess Plateau Rehabilitation project, requested by the government, began in 1999. A critical element in the success of the two projects was the ability of local government leaders to mobilize public participation by detailed planning at the village level in close consultation with the farmers. The government is actively preparing a third project.

LESSONS LEARNED

SOIL AND WATER CONSERVATION IN THE LOESS PLATEAU IS COMPATIBLE WITH POVERTY ALLEVIATION THROUGH SUSTAINABLE AND PRODUCTIVE AGRICULTURE. Early efforts to treat the Loess Plateau were not integrated with efforts to raise agricultural productivity and farm incomes. The project has convinced planners and farmers that land conservation is compatible with sustainable and productive agriculture and that they are mutually reinforcing.

INTEGRATED AND COMPREHENSIVE LAND USE PLANS MUST BE PREPARED FOR ALL SMALL WATERSHEDS. A key element of the above strategy is the implementation of detailed land use plans that are designed to create high-quality terraces for field crops and orchards to compensate for taking steep slopeland out of crop production, to take slopeland that is too steep out of crops and plant trees, to ban grazing by goats and sheep, to plant pasture for cut-and-carry feeding of livestock, and to plant trees that can generate incomes in the long term.

FARMERS SHOULD ACQUIRE LONG-TERM LAND CONTRACTS FOR NEWLY DEVELOPED LAND. Land contracts should be signed between farmers and

the authorities for newly developed land. After tree planting, the wasteland should be auctioned to farmers (with competition limited to villagers unless there is insufficient demand), and successful bidders should be given a long-term contract.

COSTS SHOULD BE RECOVERED FROM THE BENEFICIARIES. In the IDA project, about 60 percent of the project cost was recovered from the beneficiaries. This provides incentives to maintain and develop the land and to reduce the burden on public funds.

QUALITY AND FINANCIAL CONTROLS. A detailed physical check of progress and quality of completed work should be made, and spot checks should be made periodically by the prefectures and provinces. These should be based on

detailed maps of the land use plan for each watershed. Funds should be disbursed only after work is inspected and approved.

Disbursement for most forms of land development and afforestation should be based on previously agreed unit prices (costs per hectare).

WORLD BANK PROJECT DISCUSSED

China. "Loess Plateau Watershed Rehabilitation Project." Active. Project ID: P003540. Approved: 1994. Within World Bank, available at <http://projportal.worldbank.org>.

This Profile was prepared by William Smith with inputs from Juergen Voegelé. The Profile was reviewed by Rod Gallacher of FAO.

INTEGRATED WATER MANAGEMENT TO ENHANCE WATERSHED FUNCTIONS AND TO CAPTURE PAYMENTS FOR ENVIRONMENTAL SERVICES

What is new? This Innovation Profile focuses on land management in the context of incentives and arrangements for reducing upstream-downstream negative impacts of water use by irrigators and other stakeholders in the watershed. Market-based mechanisms—if adapted to local conditions—can help promote resources management changes that enhance productivity and ecosystem service synergies, while minimizing undesired tradeoffs.

Natural resources (biodiversity, forests, land, water) use has upstream and downstream impacts not only on soil and water productivity, but also on ecosystem services such as biodiversity niches, water flows and quality, erosion control, and flooding and sedimentation (box 6.11). Watersheds are generally managed to collect the water from the upper parts for use by people living lower down. The protection of vegetation for soil cover in the upper parts of the watershed is fundamental for maintaining soil properties conducive to good water infiltration, ground water recharge, and moderated surface water flow—conditions that can provide adequate volume and quality of water and avoid soil erosion and sediment flows to lower-lying dams, lakes, and ponds. Land and water users in the upper watershed do not necessarily adopt resources management practices that benefit downstream populations. In many cases, practices that support the short-term survival of upstream communities (including high-input, heavily mechanized agriculture, and dairy and hog farms) can be quite detrimental to downstream settlements. Government regulations have generally been ineffective in promoting good natural resources (land, water, forest) stewardship.

OBJECTIVES AND DESCRIPTION

This Innovation Profile highlights the variety of market-based mechanisms and their criteria for rewarding good natural resources management via payments for the resulting environmental services. For trading purposes, the services need to be tangible, scientifically quantified, and in accordance with local legislation. Box 6.12 provides an example of a program that is evaluating environmental service payment opportunities in Asia. The payment mechanisms include private deals, public payments, and open trading schemes among local communities, municipalities, companies, and national governments.

The market-based incentive systems that give rewards, in the hope of promoting sustainable land and water stewardship in catchments and basins, generally subscribe to the concept that enhanced resources management in upper catchments result in both productivity and ecosystem services that can benefit stakeholders in the lower catchments. In most incentive-based systems, the beneficiaries are charged an appropriate amount that is then equitably shared among the land users in the upper catchment (box 6.13).

Emerging markets for payments for ecosystem services in Costa Rica (Miranda, Porras, and Luz Moreno 2003), India, the United States, and Australia, have resulted in some positive behavioral changes in resources management on the part of upstream land users—with significant downstream benefits (Pagiola, Landell-Mills, and Bishop 2002). Watershed services are highly dependent on the watershed or subwatershed scale, however, which limits market scale and size.

OUTPUT AND IMPACTS

The following “best practices” can be envisaged for the assessment of costs and benefits of successful watershed management for equitable upstream-downstream resources management:

- (1) All parties in the watershed should have a stake in the management program and

Box 6.11 Are Forests and Reforestation Beneficial for Hydrology and Groundwater Recharge?

Forests increase runoff? Catchment studies show that because of increased interception, transpiration, and deeper rooting depth in forests than in crop or grass land, annual runoff is generally decreased under forests.

Forests regulate flows? Increased dry season transpiration but increased infiltration and, for cloud forests, cloud water deposition, may augment dry season flows. More and more evidence from catchments worldwide shows that most forests reduce dry season flows. Infiltration properties are critical in partitioning runoff. Effects are site specific, so more research is needed.

Forests reduce erosion? Natural forest is associated with high infiltration rates and low soil erosion, but plantations may not show these benefits because of roads, ditches, or splash erosion. Forest canopies may not protect soil from raindrop impacts. More research is needed on species and drop size.

Forests reduce floods? Canopy interception of rainfall and increased evapotranspiration may reduce floods. However, forest management activities (roads, drains, soil compaction) may increase floods. Studies show flood prevention benefits for small events only in small catchments and little or negative benefit for large rainfall events. Studies in large catchments show no measurable effects on frequency or magnitude of flooding.

Forests improve water quality? In general, forest water is of better quality than unforested catchments under grazing or agriculture. Forest management rather than the presence of forests is critical for water quality. In high-pollution environments, forest catchments and forest water may become acidified.

Source: Calder 1998.

Box 6.12 Rewarding the Upland Poor for Environmental Services: The RUPES Program

RUPES is a program for developing mechanisms for rewarding the upland poor in Asia for the environmental services they provide. The goal of RUPES is to enhance the livelihoods and reduce poverty among the upland poor while supporting environmental conservation on biodiversity protection, watershed management, carbon sequestration, and landscape beauty at local and global levels. The primary impact of RUPES will be to create and study the experience on the use of environmental reward transfers as a tool for promoting effective and sustained environmental management while increasing benefit flows to poor upland communities. The main result will be a deeper and more practical understanding of how to formulate such arrangements, their viability, and the potential for wider use.

Source: RUPES Program of the World Agroforestry Centre, Southeast Asia. Online at <http://www.worldagroforestrycentre.org/sea/Networks/RUPES>.

Box 6.13 Incentive Programs to Avoid Costly Investments in Water Treatment and Reduce Environmental Pollution and Sedimentation

Two well-known examples of payments by lowland communities for ecosystems services provided by upland communities can be found in New York City and in the Cauca Valley in Colombia. In 1989, New York's water, piped in from the Catskills Mountains, was found to contain rising levels of pollutants. The Environmental Protection Agency (EPA) ordered the city to build a water filtration plant at an estimated cost of US\$6 billion to \$8 billion. Instead of building the expensive filtration plant, however, the city opted to work with the residents of the Catskill watershed. They financed reforestation projects, created riparian woodlands to protect the integrity of the streams, and signed conservation easements with local farmers to enhance filtration of sediments and pollutants by the riparian vegetation. The quality of the water improved dramatically, and the cost of this collaborative effort with the residents of the Catskills was less than US\$2 billion—a big saving to New York City taxpayers. Similarly, in Colombia's Cauca Valley, agricultural producers pay fees, via their WUAs, to pay upland communities for soil conservation on steep slopes, reforestation, and the maintenance of riparian vegetation buffers to improve water flows and reduce sedimentation in irrigation canals.

Source: Author.

watershed development functioned as an equity-enhancing mechanism.

- (2) Because irrigation water is often the most valuable resource of watershed management, it is essential to develop mechanisms that allow an equitable sharing of the water. This resource sharing can substitute for direct payments to some stakeholders.
- (3) Where common property is involved, especially in the upper catchments, it is essential that local communities collectively protect the common land so that the irrigation water resource is not compromised by illegal deforestation or overgrazing. Collective action is easier where communities are homogeneous.
- (4) The benefits of good resources management and water harvesting for irrigation in watersheds will vary with agroclimatic and biophysical conditions. If the benefits are not substantial enough to be meaningfully shared, environmental service payments may not be economically viable.
- (5) Leverage for the landless and less powerful stakeholders in the watershed is necessary to enable them to participate effectively in the program. In some cases, external institutions may need to play a facilitating role on behalf of the “weakest” stakeholders.
- (6) If irrigation water is used to produce greater vegetation biomass on common lands, biomass-sharing agreements are needed, especially for landless stakeholders.

If water harvesting results in improved recharge of groundwater aquifers, designating groundwater a common property resource can provide all stakeholders with a powerful incentive to improve natural resources management practices and collective action.

ISSUES FOR WIDER APPLICABILITY

To ensure that incentive-based systems remain sustainable and can successfully facilitate the

improved management of irrigation water and associated natural resources, the following challenges have to be overcome:

- (1) Identifying and reliably quantifying the volume and quality of water flows and associated benefits (vegetation biomass and soil cover, reduced erosion, added food and fiber production) provided by good land and natural resources stewardship.
- (2) Identifying the risks (such as climate change) and opportunities for mitigating the risk to the irrigation water and natural resources management operations (Nobel et al. 2005; Watson et al. 2005).
- (3) Identifying and charging the beneficiaries of the improved volume and quality of water flows to provide the financing mechanism.
- (4) Ensuring that payments are equitably distributed to all stakeholders and the amount not only compensates for the costs of changes in resources management but also reflects the value of the services provided. Since supply price and ecosystem benefits are based on location in the watershed or landscape, Chomitz, Brenes, and Constantino (1998) suggest a framework based on spatial information to guide prioritization and pricing.
- (5) Creating an appropriate decision-making framework and institutional support structure that can be accessed by all stakeholders. The World Bank’s DRAINFRAME, a multistakeholder, landscape-scale tool, can facilitate a transparent and consensus-building approach to priority setting and decisions on access and allocations (Abdel-Dayem et al. 2004; see also IP 5.1). Watershed modeling tools are also very useful in engaging community, research, and policy stakeholders (Calder 1999).

To leverage existing public investment in enhanced watershed management for environmental services, the following opportunities exist:

- (1) The use of irrigation to enhance the productivity of staple food crops per unit area offers significant opportunities for releasing large areas of poorly productive land for afforestation, reforestation, and agroforestry. This can lead to a range of products and ecosystem services such as biodiversity conservation and beautiful landscapes for ecotourism. Afforestation-reforestation per se does not necessarily improve hydrological functions of watersheds, however (box 6.13).
- (2) The Kyoto Protocol is now operational following the Russian Federation's decision to ratify it. Opportunities are emerging for communities to obtain payments for carbon sequestration via reforestation and agroforestry systems adjacent to high-productivity irrigation land (Bass et al. 2000). The World Bank's BioCarbon Fund is currently financing prototype operations of more than US\$410 million, managed in six funds (either approved or under operation).
- (3) The Global Environmental Fund's OP 15 program has dedicated significant grant resources to the rehabilitation of degraded lands. These grants can be used to leverage private investor funds for enhanced water management and environmental benefits.

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USEFUL LINKS

- BioCarbon Fund: <http://carbonfinance.org/biocarbon/home.cfm>
- Conservation Finance Alliance: <http://www.conservationfinance.org/CFPapers.htm#PES>
- Ecosystems Market Place: <http://www.ecosystemsmarketplace.com>.
- RUPES Program, The World Agroforestry Centre, Southeast Asia Web site: <http://www>.

worldagroforestrycentre.org/sea/Networks/
RUPES

United Nations FAO Land and Water Division:

<http://www.fao.org/landandwater/watershed/watershed/en/mainen/index.stm>

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7

INVESTING IN AGRICULTURAL WATER MANAGEMENT IN MULTIPURPOSE OPERATIONS

- Investment Note 7.1 Investing in Agricultural Water through Community-Driven and Social Fund Approaches
- Investment Note 7.2 Investing in Aquaculture Activities
- Innovation Profile 7.1 Rural Water Supply and Irrigation

OVERVIEW

The approaches described in this chapter all deal with multipurpose investments where the cost-benefit relations are complex. These investments require an integrated approach, often within a basin planning framework.

Community-driven development (CDD) investments can be applied to small-scale irrigation and watershed management, improving the quality of development. How CDD programs and related social fund financing mechanisms can be applied to multipurpose investments is discussed in this chapter. Bottom-up stakeholder involvement through CDD can improve the quality of natural resource management investments by building in “holistic” vision and reconciling individual motivation and public goods at the grassroots level where individual farmers may otherwise see only their own interest. Cost sharing is important, because it binds the community and leads to better and

more sustainable investment. It also reduces costs, because it gives the community a stake in economizing. The value of a community-driven approach to water management is confirmed by the the Republic of Yemen case study discussed in chapter 4. Even in a situation resembling “water resources anarchy,” individuals, through local interest groups and using a “partnership” approach, can be motivated to change their water resource management behavior in a way consistent with the public interest. (See IN 7.1 on the benefits from CDD approaches and IP 4.1 on the illustration provided by the Republic of Yemen. On demand drive and community organization generally, see also chapters 2 and 6. On the virtues of cost sharing, see IN 1.4 and IN 1.5, and, for cost sharing in watershed management, IN 6.2. See also “Community-Driven Development for Increased Agricultural Incomes,” in *Agriculture Investment Sourcebook* (AIS), Module 11.)

Aquaculture is the fastest-growing animal food-producing sector. A very different type of multipurpose investment is in aquaculture. Aquaculture has grown by an average 9 percent annually since the 1970s and is expected to provide more than 40 percent of fish consumed by 2020. Aquaculture investment can improve food security and nutrition, and create jobs and livelihoods for the poor. It can bring unproductive land and “unwanted” water (that is, drainage and flood water) into use, and fish can even be sown into canals and cropped fields.

However, intensive systems can harm habitats and affect both water and soil quality through eutrophication and acidification. Extensive, low-input systems dependent on local materials and wastes are good pro-poor investments. (See IN 7.2. See also “Aquaculture Production Systems” and “Income Generation through Aquaculture,” in AIS, Module 4.)

Considering investments together can create technical and economic synergies, as in the case of irrigation and potable water supply. Water investments tend to be made on a sectoral approach, although integrated approaches at the planning level are now more common. At the community level, there can be advantages in considering investments together. For example, joint investment in potable water supply and irrigation can improve both incomes and health. (See IP 7.1 for examples from Vietnam and Guatemala.)

SOME TYPICAL INVESTMENTS

Possible investments in this area include the following:

- Social fund and CDD projects for small-scale irrigation and watershed management
- Integrated drainage investments
- Aquaculture investments
- Joint potable water and irrigation systems

INVESTMENT NOTE 7.1

INVESTING IN AGRICULTURAL WATER THROUGH COMMUNITY-DRIVEN AND SOCIAL FUND APPROACHES

CDD and social fund approaches have been developed to improve the relevance, quality, and sustainability of pro-poor investments. They can be used for small-scale irrigation and watershed management investments, where substantial social capital already exists. They are not suited to large-scale irrigation, where participatory irrigation management is indicated. Both approaches can be efficient for small-scale agricultural water investments, but care has to be taken over equity and environmental impacts.

Governments have promoted large-scale irrigation for millennia. Land and water management within a catchment has similarly often been the domain of the planner and the top-down developer. Formal management institutions have been top down, too. But community-based irrigation and watershed management also has a history, where groups of farmers develop schemes to improve their agriculture, and local institutions manage runoff, forests, and rangeland.

Government-planned and -executed schemes often lack the local information and the institutional control to ensure optimal resource allocation, poverty targeting, and sustainability. In response, CDD approaches have been designed to promote decentralized, participatory, and equitable development, with priority to poor rural communities. CDD takes many forms but has, as a common organizing principle, delegation of powers and responsibilities to communities to turn them into actors for their own development. Nevertheless, major risks and challenges exist. Recent evidence (Mansuri and Rao 2004) suggests that many CDD projects have not been effective in targeting the poor. Moreover, CDD projects may still be dominated by elites, and both poverty targeting and project quality tend to be markedly worse in more unequal communities.¹

First-generation CDD projects focused on asset creation and on building community capacity to operate the new facilities. The current second-generation projects seek, in addition, to create management skills for a broader development agenda. Social funds (SFs) typically adopt CDD approaches, and in this book SF is considered the financing mechanism for CDD approaches. The key feature of SFs is that stakeholders determine the investments through subproject proposals. SFs have decentralized and efficient operating procedures and aim at institutional development for both communities and central and local government. The investments are relevant to the priority needs of the poor and are sustainable.

INVESTMENT AREA

CDD/SF approaches can also be employed for agricultural water management. They are well suited to *small- and medium-scale irrigation*, which usually has a long social and institutional history of community involvement and where the scale is appropriate for local management. The community may consist of all families residing in a village but more frequently consists of only people who, through inheritance or labor investment, are co-owners of an irrigation system.

CDD/SF approaches for *large-scale irrigation* (LSI) are more problematic. Experience shows that incorporating the views of stakeholders is vital, and LSI investments work best when based on a practical “ownership” of the project by farmers and on a practical participation to as high a level as possible. However, LSI can never be fully driven by community imperatives because it requires planning, study, investment, and management capacity way beyond community capability. For LSI, gradations of participatory irrigation management have been employed instead of CDD approaches. Participatory irrigation management allows the essential top-down planning and financing considerations to be reconciled with requirements expressed by users (see IN 2.1). As seen in box 7.1, CDD can, however, be employed at the lowest level of LSI—for example improvement of irrigation turnouts or on-farm efficiency improvements.

For *watershed management*, scale and technical considerations are again often beyond the scope of community capability, and at the basin level, top-down study and planning are clearly needed. However, experience has shown that top-down approaches alone rarely work. Local communities need to “own” the interventions to a degree that planners can rarely induce. CDD/SF approaches can be adapted for watershed management activities (box 7.2). (See also IN 6.2.)

Box 7.1 The Power of Social Capital— An Example from Large-Scale Irrigation

The introduction of farmer organizations for decision making, resource mobilization, management, communication, and conflict resolution turned the Gal Oya irrigation system, once known as the most deteriorated and disorganized irrigation system in Sri Lanka, into one of its most efficient. Production of rice per unit of water increased by 300 percent, and at least two-thirds of the increase was due to the creation of new roles and relationships and the activation of certain norms and attitudes among irrigators.

Source: Kahkonen 2003.

Box 7.2 The Morocco Oued Lakhdar Watershed Management Project

In the early 1990s, Morocco prepared a national watershed management plan and piloted it in the Oued Lakhdar watershed. CDD approaches were used because previous attempts at top-down watershed management had not produced lasting results.

The project worked with community representatives to identify a local agenda comprising production investments such as irrigation, social investments, and conservation measures. This approach was designed to reflect interactions between communities and the environment and between upstream conservation and downstream production. To provide incentives for conservation measures, cost sharing for these was lower, productive investments such as fruit trees or fodder crops were used wherever possible, and the downstream production investments were undertaken first. Now at the end of the project, communities have created their own permanent development associations and are working directly with the local social fund office on projects that include both production and conservation investments.

Source: Author.

Experience has confirmed that CDD/SF approaches can be used for small- and medium-scale irrigation. Recent improvement projects have been based on existing social capital and hydraulic layouts. CDD approaches have proven particularly suitable, for example, in the Republic of Yemen and the Arab Republic of Egypt, for community water basins for agriculture, livestock, and human use. In watershed management, existing resources management institutions (for example, for runoff, forest, and rangeland management) have formed the basis of CDD approaches. In situations of public interest or third-party externalities such as forest conservation or soil protection, where regulation has been used in the past, comanagement approaches are being tried with some success, but the evidence is not yet conclusive.

POTENTIAL BENEFITS

An evaluation of CDD/SF approaches (Carvalho 2002) finds significant advantages in the approach. The first benefit is information. Relying on local demand overcomes the typical information gap about the high-impact investment needs and the correct design of projects. Local demand also has an inbuilt holistic vision of the management of land and water resources. Second, CDD/SF builds on and strengthens existing social capital, with particular emphasis on helping communities adapt to changed environments—for example, adapting to managing groundwater rather than springs or adapting to dealing with a modern state and its projects and financing windows. Third, CDD/SF can help reconcile public and private interests, as in the watershed management example in box 7.1. Fourth, CDD/SF should improve poverty targeting and inclusion. Fifth, demand drive should help improve sustainability through ownership. Finally, SF procedures are usually simple and decentralized, so that communities can participate in design and contracting, and procurement and disbursement can be rapid, which helps build trust and ownership. The more recent evaluation of Mansuri and Rao (2004) emphasizes that these benefits can be achieved only if the approach is applied with

care. Lack of analysis of the necessary preconditions (such as the institutional environment and the level of equity in the community) can reduce the envisaged beneficial effects.

POLICY AND IMPLEMENTATION

The key policy decision is “to let go,” phrased by one practitioner as “losing control—and gaining ownership.” Governments may be reluctant, and need persuading, particularly in planner domains such as irrigation and watershed management. Box 7.3 illustrates the problem.

Where irrigation is offered through CDD/SF, it may crowd out other investments because farming communities usually prefer irrigation to social or conservation investments. This may create a risk of appropriation by an elite because irrigation is ultimately a private benefit, and user rights over water or other natural resources follow an ownership pattern that may be inequitable. But it is usually impossible to provide assistance to the many small plot owners on farmer-managed irrigation systems without also helping owners of larger plots. A reinforced offtake and weir, or an improved main canal, benefits all farmers downstream, small and large. “Losing control” may also lead to farmer choices that do not coincide with environmental concerns about, for example, watershed management or groundwater mining.

One variant on the multisector CDD/SF approach is a project that targets a single sector using a CDD approach (for instance, a project where irrigation or watershed management is the main investment). A CDD project targeting a single main sector can also offer complementary investments in social and community assets, as in the Morocco Irrigation-Based Community Development Project. This approach is appropriate when all or almost all households are irrigators (or herders or forest users).

CDD/SF is not universally applicable. For small- and medium-scale irrigation, there is a risk that “inclusion”—of women, the landless, the absolute poor—may be difficult, unless it is specifically engineered (see box 7.2 for an

example of “engineering”). CDD/SF favors local public goods and communal assets, and care is needed if private or only partly public goods such as irrigation water or rangeland improvement are to be provided. For natural resources management, there is need, too, for appropriate technical framework, and a tailored menu of investments with incentives for conservation and other purposes (box 7.2).

LESSONS LEARNED

Empirical evidence is accumulating about where and how CDD/SF approaches are effective. This section is largely based on recent and ongoing World Bank evaluations of CDD/SF (especially Carvalho [2002]; World Bank [various years]; and Mansuri and Rao [2004]).

- CDD/SF projects have stronger ownership and higher quality and sustainability.² CDD/SF does help in empowering communities and in building capacity, for instance to resolve conflicts in water management or maintenance. For irrigation and natural resources management, CDD/SF works best where social capital and rules already exist. In fact, overall CDD/SF approaches have functioned as users rather than as producers of social capital. CDD/SF approaches could be indicated for small- and medium-scale irrigation and natural resources management,

Box 7.3 Nepal: Farmers Leading the Way in Groundwater Development

Since 1999, a project has been working with 657,000 people in the Nepal Terai to alleviate poverty through community-managed shallow tubewells. Working with communities, NGOs banks, the private sector, and government, the project has transformed an agency-led, supply-driven method favoring big farmers into a demand approach, driven by farmers below the poverty line, and by the private sector. Costs are low, and, by 2003, more than 600 groups had installed wells. More than half the beneficiaries are women. Government has been convinced by this project that social mobilization through NGOs is a reliable and inexpensive way to reach small farmers

Source: CGISP 2003.

where extensive social capital usually exists. However, community size and power distribution are important. CDD works well with smaller groups, based on kinship or residence, and with more homogeneous communities.

- Farmer organizations may not include the poor and marginalized as other community organizations do. CDD/SF approaches generally focus on inclusive community organizations and communal assets for exactly this reason. However, unlike community assets, irrigation systems co-owned by farmers do create incomes. Tradeoffs may be necessary to solve the poverty problem. (See De Janvry et al. 2001).
- If irrigation investment is done through CDD, producer organizations are likely to be the appropriate partner rather than broader community groups, and careful attention will have to be taken to ensure equity. If a CDD project works with producer organizations, it is likely that they will select irrigation investments.
- For irrigation and natural resources management, assessing the resource constraint is important, because moderate scarcity promotes cooperation, but abundance or absolute scarcity have the opposite effect.

- CDD/SF approaches reduce costs, especially where community contributions are high and where communities manage contracts.
- Without clear, but simple, environmental assessment procedures, irrigation and natural resources management projects can create environmental problems under CDD/SF approaches (World Bank 1999).
- CDD/SF approaches are effective in delivering small infrastructure, but the demand mechanism does not necessarily reach the poorest in the community or the poorest communities. This is probably especially true for small- and medium-scale irrigation projects.
- CDD works best with active involvement of local government and line agencies. However, where a social fund program is used rather than integrating CDD into a line ministry's approaches, linkages to line ministries and their programs may be weak. Typically, social funds do not work well with line ministries.

RECOMMENDATIONS FOR PRACTITIONERS

- Where poverty alleviation is the goal, consider CDD/SF approaches to small- and medium-scale irrigation and watershed management, but as part of a package with provisions for the poor and marginalized people with no or little land (box 7.4).
- Where CDD/SF approaches are used, start by evaluating existing social capital carefully because it is key to success.
- Given the risks of "elite" capture where irrigation or any investment for private benefit is concerned, consider participatory planning and research as a first step toward CDD. This precursor stage, before the question of financing arises, will make clear whether the community has the necessary social capital and mechanisms for ensuring equity.
- Look at levels of contribution to projects. For private benefit investments such as irrigation, ensure that beneficiaries invest more than they do for public interest investments.

Box 7.4 Bank Requirements for Using Community-Driven Development/Social Fund Approaches for Agricultural Water

CDD/SF approaches should be preferred where the following apply:

- They are the most *efficient*, in terms of improving investment quality, through better information and solid ownership, and in terms of lower cost, through most appropriate design and implementation procedures.
- They are demonstrably more *equitable* and *pro-poor* because this is a specific objective of CDD/SF approaches. Where there is a risk, appropriate alternative measures to ensure "inclusion" are required.
- They are *environmentally sound* in terms of "no harm" and make a positive contribution to externalities and to common resources management.

Source: Carvalho 2002.

- Ensure that CDD/SF investments in agricultural water are linked to overall agricultural programs such as research and extension.
- Check that the CDD/SF process has adequate environmental safeguards built in.
- Take part in the Poverty Reduction Strategy Paper (PRSP)/Country Assistance Strategy (CAS) process and help assess the relevance of CDD/SF to agricultural water needs.

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SELECTED READING

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ENDNOTES

1. Mansuri and Rao (2004) focus on the following questions: does community participation improve the targeting of private benefits? Are the public goods created by community participation projects better targeted to the poor? Are they of higher quality, or better managed than similar public goods provided by the government? Does participation lead to the empowerment of marginalized groups? Do the characteristics of external agents—donors, governments, nongovernmental organizations (NGOs), and project facilitators—affect the quality of participation or project success or failure? Can community participation projects be scaled up in a sustainable manner?
2. Empirical evidence has not, however, established that the participatory elements are responsible for these improved project outcomes (Mansuri and Rao 2004).

This Note was prepared by Christopher Ward with inputs from Daniel Sellen and Melissa Williams. It was reviewed by Keizrul Abdullah of International Commission on Irrigation and Drainage.

INVESTING IN AQUACULTURE ACTIVITIES

Farming fish, shellfish, and aquatic plants is the fastest growing subsector in agriculture. High-input aquaculture helps supply global consumption and earns foreign exchange. Less intensive forms are suitable for low-income small producers and play a key role in poverty reduction. Pro-poor interventions require definition of public and private sector responsibilities and equitable distribution of benefits in the longer term. All aquaculture investments should be planned within national strategies for fisheries, water use, and the environment. Investments in irrigation and drainage may incorporate an aquaculture component, taking advantage of the possibility of using irrigation canals and drainage water for this purpose. Investments to enhance market-oriented aquaculture will be aided by concurrent development of national capacities in monitoring product safety and health.

The world's capture fisheries have stabilized, at 85 million to 90 million tons a year, but aquaculture has been growing, at a compounded rate of 9.2 percent a year since the 1970s. Its global rate of growth is estimated at 7 percent. Aquaculture is thus critical to meeting future demand for food fish. By 2020, aquaculture will provide an estimated 41 percent of all fish for human consumption—10 percent more than in 1997 (Delgado et al. 2003). Most growth will occur in developing countries, which will account for 79 percent of food fish production in 2020. In China, already the largest single producer of fish, aquaculture has exceeded the production of capture fisheries.

This rapid expansion features diversification, intensification, and technological advances. More than two hundred aquatic organisms are now grown in marine, brackish, and freshwater systems. They include finfish, mollusks, crustaceans (with shrimp the most valuable export commodity), sea cucumbers, and seaweeds. Aquaculture practices range from culture in ponds, pens, cages, and raceways; to stocking

in tanks and reservoirs; and cultivation in rice fields, irrigation ditches, land depressions filled by drainage water, and seasonal water bodies in floodplains. The latter technique is practiced primarily by poor households.

INVESTMENT AREA

Intensive systems for salmon, trout, tilapia, flounder, turbot, shrimp, and other species have high input for seed, formulated feeds, vaccines and chemicals for disease control, improved strains selected for growth, high feed-conversion efficiency, and other production and market characteristics. Globally, operators therefore tend to partner with feed suppliers. Their high-value fish and seafood products are filleted, frozen, canned, or cured for urban and export markets.

Extensive low-input systems are more readily adopted by poorer or subsistence farmers and communities. Such systems use local feeds and fertilizers but few other inputs. Farmers often grow juveniles of indigenous species trapped in the wild together with higher-value species. The farmers' objectives are household consumption, local barter, and trade. These systems have considerable potential to enhance local food security, alleviate poverty, and improve rural livelihoods (Friend and Funge-Smith 2002). Chinese and Indian carp and tilapia dominate freshwater production for local demand.

Between these extremes are many intermediate practices, depending on experience, local support infrastructure, and market access. For example, in Andhra Pradesh, India, the growth of aquaculture followed the availability of efficient road transportation to distant markets such as Calcutta. Tilapia and catfish can be grown in a range of less-demanding culture systems and now have both local and international markets. The world supply of aquatic plants is currently 10.1 million tons, valued at US\$5.6 billion, most of them grown in simple systems, predominantly in China and the Philippines.

A successful experience in northern Cameroon and a recently approved project in Uzbekistan show how investments in agricultural water,

especially drainage, can successfully include an aquaculture component. In northern Cameroon, after the restoration of the hydrological dynamics of former floodplain depressions, in 1982 the Benue River was dammed for hydroelectricity and irrigated agriculture. Large parts of the downstream floodplains could no longer be used. However, after a long rainy season, the dam had to release water. Former floodplain depressions were reconnected with the river and in several weeks were teeming with fish. The restoration of fisheries potential was so impressive that experiments began with management of floodplain depressions, now being filled with drainage water from the irrigation scheme. At the end of the dry season, fish were taken out and the entire depression was drained and left to dry until the next rains as an effective means of vector control (schistosomiasis snails) (Abdel-Dayem et al. 2004). A recent project in Uzbekistan plans to use drainage water to recharge wetlands and foster the production of fish and reeds. Total economic benefits from aquaculture are expected to exceed US\$400,000 (see Uzbekistan in “World Bank Projects Discussed” below).

Asia, and China in particular, dominate aquaculture, but important producers have developed in Latin America, the Caribbean, Europe, Africa, and the Middle East. Markets for higher-value produce will follow rising urban incomes and perceptions of fish as a nutritious and healthy food. Japan, the European Union, and the United States are major importers of high-value produce.

POTENTIAL BENEFITS

Aquaculture can improve local and national food security and earn important foreign exchange, including for low-income food deficit countries (box 7.5). Fitchett et al. (1997) report a successful example, dealing with shrimp aquaculture in Madagascar.

Aquaculture can generate jobs and livelihoods for many, including disadvantaged or displaced people. Women and children have started “own enterprise” initiatives close to the

farm household. Marginalized women and even the landless have been organized in community arrangements for water bodies. People displaced by dam building have engaged in reservoir fisheries, and persons displaced by capture fisheries have developed new livelihoods in coastal aquaculture.

Aquaculture can bring unproductive land into use. An example is the river beach development in the Shanxi Poverty Alleviation project (World Bank 1996) and similar development in other Bank- and World Food Program–assisted aquaculture development in China. China’s Sustainable Coastal Resources Development Project is an advanced coastal management project that includes integrated coastal zone management, marine aquaculture, and seafood processing; it follows international facility design and operation standards.

Aquaculture can help raise the productivity of agricultural water when it uses irrigation canals, drainage water (box 7.6), and rice fields (box 7.7). Also, in deltas such the Ganges and Mekong, dry-season, brackish water shrimp and aquaculture complements wet-season rice farming in the same paddies that are alternately inundated with brackish and freshwater.

Box 7.5 Major Public Sector Investment Approaches for Aquaculture

- Introduction of aquaculture to new entrants as a component of integrated poverty reduction or coastal and water basin management schemes
- Integration of support services and infrastructure to help communities of aquaculture farmers shift from subsistence farming to more market-oriented enterprises
- Provision of training and educational institutions for extension and development of aquaculture technologies appropriate for practitioners and new entrants
- Support for research to advance, identify, test, and evaluate aquaculture applications in local conditions
- Provision of a national regulatory environment to guide aquaculture development and domestic and export marketing initiatives

Source: Author.

Box 7.6 Drainage Water for Fish Farming in Egypt

In the southern vicinity of Lake Edku in Egypt, fish farming with drainage water started 20 years ago. Fish ponds now cover an area of 8,000 acres. The government leases out the land for the ponds at very low rents. A 1-acre pond leased for US\$15 a year can earn the renter about US\$1,000. The average fish yield is 2 tons per acre per year, compared with 500 kilograms per acre per year from the lake. Only drainage water is used in fish ponds, and a fish pond produces more than five times the value of cropped land with the same amount of water.

Source: Scheumann 2004.

Box 7.7 Community-Based Fish Culture in Seasonal Floodplains

Rice-fish systems can bring benefits to many inhabitants of flood-prone areas. Seasonal floodwaters have been regarded as a constraint and been utilized only for occasional fishing. Fish can, however, be stocked concurrently with deepwater rice or by alternating the stocking of fish during the flood season, in an enclosed area such as a fish pen, with rice culture in the dry season.

Alternating rice and fish culture was recently tested in deep, flooded areas of Bangladesh and Vietnam in a community-based management system. The institutional arrangements were designed for sharing benefits in proportion to provision of land, labor, guarding against poaching, and so on, so that all contributors benefited. Loans taken out for fence construction were repayable at the first harvest.

Results indicate that community-based fish culture in rice fields can lead to fish production of 600 kilograms per hectare per year in shallow flooded areas and up to 1.5 tons per hectare per year in deep flooded areas, without reducing rice yield and wild fish catch. Overall profitability, counting rice and fish, rose to US\$690 per hectare a year in Bangladesh, an increase of 20–160 percent. Annual per capita income of the landless laborers in the group increased by 60 percent, and their per capita fish consumption increased by 25–60 percent. These gains are likely to improve through technical modifications.

This approach is applicable to several million hectares of Asian floodplains if aquaculture practices are shaped to match local sociocultural and economic conditions. In Africa, the potential for community-based fish culture is greatest in seasonal floodplains and in irrigation schemes. In West African floodplains, 470,000 hectares used to grow deepwater rice could be used concurrently for fish culture.

Source: World Fish Center 2001.

POLICY AND IMPLEMENTATION

FORMULATION OF COMPREHENSIVE STRATEGIC DEVELOPMENT FRAMEWORKS. Developing initiatives for coastal and inland areas requires consultative and participatory decision-making processes with all key interest groups. Integrated coastal zone development and management plans should identify the place of aquaculture in relation to competing uses by cities and for energy, transport, tourism, and critical natural habitats. The potential for using drainage water, which would otherwise be wasted by discharging it into the sea, to fill aquaculture ponds should also be examined. For inland areas, location of land and water resources for aquaculture should complement investments in water management and in hydropower, reservoirs, and irrigation and drainage schemes.

ENVIRONMENTAL REGULATION. The rapid and unregulated development of intensive practices, particularly for shrimp, has destroyed habitats—both when farmers cleared mangroves to build ponds and when they caused eutrophication of water bodies and acidification of pond soils through excessive use of inputs. Their actions have caused outbreaks of disease and failure of enterprises. They also sparked legal responses and triggered community controversy. Adverse social impacts also resulted where belts of shrimp pond development cut off fishermen's access to the sea, where flooding and water logging were improperly managed, and where groundwater reserves were depleted, causing saltwater intrusion. Some firms have developed management guidelines to address these problems. The World Bank and others have embarked on the development of general guidelines, including codes of conduct for water quality and sustainable shrimp farming. Formulating and enforcing environmental standards is key to meeting the industry's development goals.

ENABLING ENVIRONMENT. Aquaculture requires steady supplies of good quality larval or juvenile fish. National strategies to manage hatcheries, brood stock, and strain quality are required to avoid inbreeding and loss of productivity. These

strategies should include provision of more local seed fish to regions where aquaculture is being introduced or expanded. Adoption and extension of aquaculture will require pilot industry development, locally affordable credit, and capacity building of extension services. Opportunities for entry depend on farmers' land and water tenure. NGOs and community organizations have played key roles in the extension of aquaculture for poverty alleviation in countries such as Bangladesh. Their contributions are valuable but need strengthening with technical assistance.

MANAGEMENT OF OTHER INPUTS AND EFFLUENTS. Input management is mainly a private sector concern, but public policy may have to encompass feeds—to minimize use of wild fish, fishmeal, and fish oils—and water, with attention to quality and effluent management. Moreover, standards should minimize or prohibit use of drugs such as antibiotics and chemicals for pest control or water quality management. Such standards protect both the environment and profitability. In addition, effluent discharge needs to be managed effectively to forestall adverse effects on water quality and habitats nearby and downstream. Solid waste should also be appropriately reused or disposed of to prevent damage to the environment and undesirable social impacts.

MARKET ORIENTATION—GRADES AND STANDARDS. In many cases, aquaculture produce can join postharvest, cold, and marketing chains already established for capture fisheries. Importing countries increasingly impose health and sanitary standards—such as sanitary-phytosanitary standards (SPS) and hazard analysis and critical control point (HACCP) regulations on food imports, in part because seafood is perishable. Some aquaculture industry associations are adopting environmental standards to maintain market acceptability. Governments of export countries can enhance competitiveness by establishing product health and monitoring services that meet the importing countries' certification needs. Such government services would also help small producers join supply chains. Policies should promote biotechnologies that

improve strains in line with national law and acceptability in target importing countries.

BALANCE BETWEEN PRIVATE AND PUBLIC SECTOR RESEARCH AND INVESTMENT. Export-focused aquaculture is pursued by private sector firms and occasionally by joint ventures. However, in some countries, the establishment of aquaculture has clearly been augmented, if not led, by government research and planning support. Examples are Norway and China. Aquaculture industries develop rapidly. Some farmers, once trained and established, quickly shift from low-value species that meet local demand to high-value species for external markets. Public policy goals for investment need careful definition to avoid duplicating private sector responsibilities.

LESSONS LEARNED

FEASIBILITY ASSESSMENT AND PLANNING. Importing technologies from other regions can work if local soil and water quality are taken into account, and if use is made of indigenous species for which artificial propagation methods and hatchery management techniques are well understood, for which feeds can be identified locally or imported. The strategy must also be cost effective, and marketing channels and demand must be ensured. The costs of seed and feed supply have been difficult to sustain without government assistance or differentiation of roles among adopters after completion of pilot projects. Market substitution between fish and seafood products can be quite high. Assessments of target species should therefore take into account availability of local inputs, market competition, production efficiencies, and transport costs, for instance when dealing with unprocessed products, shelled mollusks, and other perishables. Successful industries can ultimately depress market prices and lower profits, as with Norwegian salmon. Labor needs for starting aquaculture industries must be thoroughly evaluated because they have sometimes been overestimated.

POVERTY ALLEVIATION AND ADOPTION. The price of fish compared to starchy food staples makes farmed fish a major component of livelihood

schemes. Women have been quick to access the nutritional and income benefits of rural aquaculture, even in simple forms such as growing fingerlings. Adoption of aquaculture can be slow in rural communities with little experience in water management. However, after adoption, practices may quickly evolve, incomes rise, and fish prices stabilize in the local markets. Equitable access to land and water for the poor and durable institutions are the two most important conditions.

LONG-TERM SUPPORTING RESEARCH IS REQUIRED. Strains of fish improved for growth or other features by selective breeding can augment productivity but must be implemented with care to preclude adverse impacts to the genetics and fitness of wild populations. Public and private sector goals should be defined for strain improvement that meets the goals of subsectors and national biodiversity. Import, propagation, and culture of exotic species must be carefully considered with monitoring and control systems in place before introduction. Analysis of the social mechanisms governing community involvement in aquaculture is needed to sustain equity in the distribution of benefits so that a disproportionate share of the benefits does not go to the better-off.

RISK. Marketing channels must be well understood and established. Increases in the incidence of disease in fish has been a major consequence of unregulated development and has caused some initiatives to collapse. Contamination with antibiotic residues can prevent produce from meeting importing-country health criteria. External sources of pollution can cause morbidity and mortality of cultured organisms or make produce unsaleable. In addition, products such as farmed salmon may contain dioxin and polychlorinated biphenyls (PCBs) that can reduce market interest and pose significant health risk, particularly to children and pregnant women. Similar concerns have been identified for fish caught in the wild, such as tuna, which are high in mercury.

ENVIRONMENT AND INDUSTRY ASSOCIATIONS. The performance and image of aquaculture have been tarnished by people who do not differentiate between ranges of intensification when raising

environmental concerns to address it. Industry associations have responded strongly by adopting and promulgating agreed practices among their members; governments have adopted zoning and other laws to sustain water quality, and environmental certification and labeling that help maintain export-market share.

RECOMMENDATIONS FOR PRACTITIONERS

The World Bank Group's involvement in aquaculture development has included investments in the full range of technologies for production expansion, including infrastructure support (hatcheries, feed-processing plants, seafood-processing plants, improvement and new construction of wholesale markets, disease control facilities, coastal zone management centers, water quality monitoring laboratories, and training and education facilities). Sector work includes a coordinating role with the global shrimp farming and environment study with the Network of Aquaculture Centers in Asia-Pacific, the World Wildlife Fund, and the Food and Agriculture Organization. The work involved 40 case studies and thematic reviews and the publication of a guide on the assessment of source water quality for aquaculture.

Recommendations for practitioners investing in aquaculture can be summarized as follows:

- Plan for aquaculture within comprehensive development frameworks, including the integrated use of water, and not as stand-alone enterprises.
- Take advantage of investment projects in irrigation and drainage and/or integrated water resources management to foster the development of aquaculture.
- Include in feasibility studies an assessment of potential interactions with fisheries (at the level of feed and food uses, water resources, markets, and community interests) and other animal industries.
- Assess realistically the potential for absorption of labor by aquaculture, if job creation is a development goal.

- Tailor flexible packages, in new initiatives, for local conditions, longer-term technical support (including for agricultural extension workers), and establishment or provision of associated services (seed, feed, health, and marketing).
- Plan sufficiently long water or community tenure over aquaculture sites to prevent resource mining.
- Include environmental guidelines and assessments in every aquaculture initiative—and support for the development and implementation of such guidelines where they are lacking.
- Enlist national capacities to monitor product health and safety from production through the postharvest chain to support export-oriented aquaculture development.

Overall, the Bank Group's experience in aquaculture development has been satisfactory, with most investments yielding sustainable outcomes. Projects with doubtful medium- and long-term benefits were often overambitious with regard to scale, complexity of technologies employed, and dependency on public sector management for sustainability. These are important and useful lessons to guide future operations considered for investment.

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INNOVATION PROFILE 7.1

RURAL WATER SUPPLY AND IRRIGATION

What is new? Simultaneous investment in drinking water supply and irrigation is rare, although it is often cost effective in reducing rich-poor gaps in income and health. Rural communities can operate systems using the same source of water for both small-plot irrigation and drinking water as income-generating businesses. The Mekong Delta Water Resources Project shows that a small investment in separate rural water supply hardware, funded through a subcomponent of a large water-resources or irrigation project, can also cost-effectively deliver benefits to the rural poor, especially to those living far from roads.

Combining investment in irrigation with development of water supply for humans has been hard to do in spite of its many advantages: (1) the additional income from irrigation allows users to repay loans for their water supply hardware within two or three years and afterward pay for operation and maintenance (O&M); (2) combining human water supply with crop water supply reduces per capita investment cost, especially in remote areas, and (3) poor health caused by contaminated drinking water often constrains input of labor on the irrigated farm.

Large irrigation projects can include water supply components and take a cue from community-driven investment. The main constraint is institutional, both within the World Bank and in-country.

OBJECTIVES AND DESCRIPTION

The Mekong Delta Water Resources project successfully combined large irrigation development with small-scale water supply development. The government of Vietnam first proposed to the World Bank what was primarily an irrigation project. The line ministry initially opposed the rural water supply and sanitation (RWSS) component on the grounds that RWSS had always been

funded through grants, that it was poorly equipped to handle minor infrastructure, and that RWSS was a matter for the provinces.

During project identification and preparation, the Bank team worked closely with the Vietnamese government and gradually obtained buy-in. It helped that RWSS coverage in the delta was low compared to the rest of the country, that the incidence of sanitation-related disease was high owing to a lack of sanitation facilities and sanitation awareness, and that the Vietnamese government had set a goal of 100 percent rural water supply coverage by 2005 but that the national program was underfunded.

The project supported an integrated approach to improving water resources infrastructure as well as upgrading clean water provision and sanitation for the rural inhabitants. In line with the evolving national RWSS strategy, it tested demand responsiveness and community participation in planning, implementation, and financing. It targeted primarily remote rural households that other programs cannot reach.

The RWSS strategy was carried out by the Ministry for Agriculture and Rural Development. It gave implementation responsibility to the provinces, which delegated it to provincial rural water supply development centers that mobilize communes and conduct awareness campaigns, provide technical assistance, and design and supervise construction through contractors. The centers outsourced the sanitation improvement component to provincial women's unions, which were certified by the provincial authority to operate a sanitation revolving fund. Each women's union has branch units in villages and communes that work with individual women farmers.

Hybrid systems in Guatemala (box 7.8), Nicaragua, Bangladesh, Zimbabwe, Nepal, and Vietnam often do not need grants because users can generate enough income from cash-producing irrigated plots and fees for domestic water use. The increased revenue stream allows them to pay off both their individual loans for the irrigation system and the community loan for the installation of the water supply system. Rural villages, especially in arid regions, often

Box 7.8 The Guatemalan Experience

In Guatemala more than 100 small community-owned and operated irrigation systems supply domestic water to communities that do not have connections to water supply. Hillside farmers installed these systems, which rely on gravity pressure, primarily for irrigation. The average system size is 20 hectares and average farm plot size 0.2 hectares. Each farm plot is served by a tap in the center. Farmers connect a hose to a conventional sprinkler on a tripod and move it around the field to irrigate. The communities repaid the government loans in less than three years with proceeds from their high-value crops marketed in Guatemala City. This experience was successful for three main reasons: technical assistance and credit at reasonable interest rates were available; the participants formed small, tightly knit groups; and they were able to grow and market high-value crops such as fruits and vegetables.

Source: Polak et al. 2002.

already have the organizational infrastructure to operate these systems (for example in Pakistan, Afghanistan, and Tunisia).

OUTPUTS AND IMPACTS

In the Mekong Delta Water Resources project, implementation of the rural water supply sub-component began in 2001 and was planned to end in 2005. Instead, it ended in 2003 because most activities had been completed. Output included 244 schemes for piped clean water, 2,290 wells, 1,060 filter systems, and 13,176 water jars to supply clean water to local communities, benefiting some 314,330 rural poor. At the mid-term review, the Vietnamese government requested a US\$9 million increase to expand the component from 6 provinces to 10.

Evaluations of water supply development through hybrids in Nicaragua and Nepal indicate that rural families quickly repay loans for system construction and also move up the income ladder, from absolute poverty to relative poverty.

ISSUES FOR WIDER APPLICATION

SMALL INVESTMENTS YIELD GREAT BENEFIT AND ARE WORTH THE EXTRA EFFORT. In Vietnam, project investment in irrigation and drainage, flood control, saline intrusion control, and

waterway transport benefited the local inhabitants but did not satisfy their need for clean drinking water. A small investment in RWSS delivered immediate benefits to those living in remote communes, beyond the reach of large system supplies, a group often difficult to serve with a standalone project. The added investment did increase project preparation and supervision costs.

INVOLVE GRASSROOTS ENTITIES. These grassroots connections can mobilize small communities, and in this case, experience with the women's unions contributed to effective organization of awareness campaigns that reached individual women farmers with small group-based credits and training in hygiene.

FOSTER INTERACTION AMONG THE "WATER PLAYERS." Although they inhabited the same ministry, the "irrigation people" and the "RWSS people" interacted little. Project implementation brought interaction through meetings, supervision, and monitoring. Trust grew between these professional groups and between the central and provincial agencies dealing with water, which reinforced integrated water resources management.

- *Balance cost-recovery and poverty goals.* The goals of greater cost recovery and poverty alleviation had to be balanced because the target population lived in remote areas with little market access.
- *Synergies with irrigation development may be the key to the financial sustainability of RWSS.* Irrigation usually raises incomes with which to repay loans and pay O&M of domestic water supply.
- *Strengthening communication and collaboration between the professional communities.* In water supply and sanitation, water resources and irrigation, communication among all actors is key, both in-country and within the Bank. Funding mechanisms and budget provisions should be set aside for joint design and implementation. The RWSS toolkit for multisector projects provides useful support.

HYBRID SYSTEMS ARE SOMETIMES NOT FEASIBLE. They will not work in cases in which (1) water needs to be treated, and treatment would make the water too expensive for irrigation; (2) the construction cost would be too high to pay off a loan from the proceeds of horticultural crops; (3) a village is too far from markets; and (3) clean, affordable drinking water is available from other sources. Experience in Guatemala also shows that hybrids generate income for farmers only if there are market opportunities.

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8

COPING WITH EXTREME CLIMATIC CONDITIONS

- Investment Note 8.1 Investing in Drought Preparedness
- Investment Note 8.2 Investing in Flood Control and Management
- Innovation Profile 8.1 Planning Scarce Water Resources Using Evapotranspiration Quotas:
The Hai Basin Integrated Water and Environment Project in China
- Innovation Profile 8.2 Fighting the Adverse Impacts of Climate Change on Agriculture
- Innovation Profile 8.3 Investing in Participatory Approaches for the Cultivation of New
Varieties and Soil and Water Conservation in India

OVERVIEW

Extreme climatic conditions most seriously affect poor farmers trying to eke out a living in the most vulnerable and marginal of the world's production systems. Climate change is likely to have a particular impact on the poor. Some of the available high-impact technologies and institutional responses to these climatic challenges are discussed in this chapter.

DROUGHT HARMS MORE PEOPLE THAN ANY OTHER NATURAL HAZARD, BUT INVESTMENT IN PROACTIVE MANAGEMENT CAN REDUCE RISKS AND COSTS. Planners in most countries should now assume that climate is variable and that "drought is normal." The common response has been reactive and ineffectual in mitigating impacts on the vulnerable. Recent best practices concentrated on lessening risk through policies to reduce vulnerability, and through investments in preparedness and drought-mitigation planning. Investment in drought management brings benefits by reducing the associated economic, social, and environmental costs. Because the poor are especially vulnerable, drought

preparedness is a critical part of poverty reduction strategies. (See IN 8.1. See also “Kenya: Community-Based Drought Management,” in the *Agriculture Investment Sourcebook* (AIS), Module 10.)

EVEN FLOODS CAN BE TURNED TO GOOD ACCOUNT. Floods can be harnessed beneficially as sources of irrigation water, groundwater recharge, and soil fertility renewal. They can improve water quality and sustain ecosystems and fisheries. Investment in integrated flood management within basin plans improves beneficial use and minimizes losses. Measures include investments to improve water retention, investments to mitigate flood impacts and reduce susceptibility to damage (including disaster preparedness), and flood protection measures such as dikes, levees, and flood embankments. Because poor people are most vulnerable, investment in improved flood management and preparedness is pro-poor. Stakeholder involvement and appropriate environmental policies are essential to investment outcomes. (See IN 8.2. See also IN 4.4 on groundwater recharge in California.)

RESPONSES TO CLIMATE CHANGE ARE POSSIBLE, BUT THEY NEED SITE-SPECIFIC FLEXIBILITY, BACKED UP BY RESEARCH. The future incidence of climate change can only be conjectured, but it is likely to have particular impact on the poor in marginal areas who have the least knowledge and resources to cope. Experience has shown that programs can be adapted to help, particularly through technological innovations such as minimum tillage and improved water management. Future research and technology transfer will have to focus increasingly on helping poor farmers cope with climate change. (See IP 8.2.)

TECHNOLOGIES ARE AVAILABLE FOR EVEN THE MOST UNPROMISING MARGINAL RAINFED SYSTEMS, BUT THEIR ADAPTATION AND ADOPTION IS BEST DONE BY PARTICIPATORY APPROACHES. The Green Revolution depended largely on water availability, and offered little to marginal rainfed areas where the challenge is low productivity caused by environmental and soil problems of drought,

salinity, temperature, and lack of nutrients. Recent pilot projects in India have successfully tested integrated soil, water, and agronomic investments in very marginal watersheds (cf. the Loess Plateau experience). Earlier attempts to “introduce” new technical packages top-down—for example, vetiver grass—had failed. Instead, new investments were based on a “bottom-up” approach, testing, evaluating, and then scaling up innovations. Cost sharing cemented ownership. Uptake has been excellent. Family incomes have increased considerably. The projects have demonstrated a cost-effective investment mechanism for making a large and sustainable impact on the lives of poor people. (See IP 8.3 and IP 6.2.)

INNOVATING INVESTMENTS CAN CONTRIBUTE SIGNIFICANTLY TO AGRICULTURAL WATER MANAGEMENT AND POVERTY REDUCTION WHERE CLIMATIC CONDITIONS ARE ADVERSE AND RESOURCES SCANT, PROVIDED THAT THEY ARE “INTEGRATED” WITHIN A FAVORABLE SOCIAL AND INCENTIVES FRAMEWORK. This chapter shows that even the most difficult technical problems—for example, drought, salinity, and reclamation of sodic soils—can be overcome but that the approaches require both “technical integration” (of soil, water, agronomy, for example) and parallel “socioeconomic integration” (for example, input and output markets, which create incentives and lead to income improvements). Success requires community involvement; a bottom-up approach; development and testing of locally adapted technical packages that address soil, water, and agronomic problems together; the availability of input and output markets; and a flexible approach with participatory monitoring. (See IN 8.3. See also “India: Community Organization for Sodic Lands Reclamation,” in AIS, Module 4.)

SOME TYPICAL INVESTMENTS

Investments in technical assistance may include the following:

- Drought and salinity programs
- Flood mapping and flood management plans

Project investments may include the following:

- Drought and salinity programs
- Water retention
- Flood mitigation
- Flood protection measures

Pilots may include drought and salinity programs. And finally, related investments may include postflood emergency operations.

INVESTING IN DROUGHT PREPAREDNESS

Relief efforts in drought-stricken areas are by definition reactive and increase farmer dependence on national and foreign governments. However well intentioned, they may deprive farmers of incentives to adapt. From a poverty-reduction as well as from a cost-effectiveness point of view, it is preferable to handle drought as a risk for which governments and farmers may prepare, in the hope of mitigating its effects.

Drought is a normal part of climate for virtually every country. It is a slow-onset, creeping phenomenon with serious economic, environmental, and social impacts. It affects more people than any other natural hazard. The common response has been reactive, ineffective, and untimely—usually leading to increased dependency on government and other organizations. The conventional response also adds to vulnerability, because it provides a disincentive to adopt best management practices.

A risk-based management approach is more cost effective. It emphasizes improved monitoring and early warning systems; development of strong decision-support systems; identification and implementation of mitigation actions; education and training of policy makers, natural resources managers, and the public; and drought mitigation plans that reduce the most serious impacts. This approach addresses the underlying causes of vulnerability rather than the symptoms (impacts). Investments in drought-mitigation planning, management, and appropriate policies will provide individuals and governments with the tools necessary to reduce societal vulnerability to future droughts. A possible complement to this kind of investments is offered by the development of financial weather-related risk-management instruments (see box 1.7 in IN 1.3), which are being implemented in several countries such as Morocco, Mexico, and India. For a

more detailed discussion see Hess (2002), dealing with several Indian states.

INVESTMENT AREA

There is no universal definition of “drought,” because its characterization is impact- and application-specific. A conceptual definition of *drought* is a deficiency of precipitation over an extended period of time with serious impacts on human activities and the environment. This definition links intensity and duration to societal impacts. Meteorological drought focuses only on the intensity and duration aspects of drought. As drought conditions persist for months, seasons, or years, other components of the hydrologic system will be affected. For example, agricultural drought is best defined by deficiencies in soil moisture; hydrological drought, by deficiencies in surface and subsurface water supplies. The links between precipitation deficiencies and impacts are less direct for these drought types, with impacts lagging meteorological drought. Conflicts between water users increase as drought persists because competition for surface and subsurface water supplies intensifies. Socioeconomic drought is associated with the supply and demand of some commodity, resource, or product that is influenced, though indirectly, by precipitation amounts, timing, and effectiveness, as well as by resource management practices.

Greater investment should be directed to lessening risk associated with drought. Drought risk is defined by a region’s exposure to the natural hazard and society’s vulnerability to it. Because climate is variable through time, exposure to drought also varies from year to year and decade to decade. Global warming and the probability that drought and other extreme climatic events may become more frequent in the future may translate into increased exposure to drought. Water resources planning should be based on the assumption that climate is variable and extremes are a normal part of climate everywhere.

Vulnerability to drought is defined by social factors such as increases in population and regional migration trends, demographics, urbanization,

land use changes, natural resources policies, water use trends, environmental awareness and degradation, technology, and the like. Vulnerability is dynamic and must be periodically evaluated at the local and national levels. The preparation of vulnerability profiles (who and what is at risk and why) can help individuals and governments at every level to better understand and systematically address drought risk by concentrating on the underlying causes of vulnerability rather than the symptoms (impacts).

Drought early warning systems must have the capacity to detect the first signs of an emerging rainfall deficiency, the best indicator of meteorological drought, but other key drought indicators (reservoir levels, groundwater levels, stream flow) are also important. There are also critical social indicators (market data such as grain prices and changing terms of trade for staple grains and livestock as an indicator of purchasing power in rural communities, migration of household members to search for work, selling of nonproductive assets). All of these indicators provide decision makers with early information on emerging impacts in various sectors. Climate indexes should be used to evaluate the status of climate and water supplies, and potential impacts in specific sectors such as agriculture, energy, and urban water supply. This information should be supplemented by long-range or seasonal forecasts. A drought early warning system must not only encompass mechanisms and procedures for the collection, analysis, and integration of information from multiple sources in a timely manner, but also include procedures for the dissemination of that information to potential end users. Training end users about the value of this information in the decision-making process is essential. Once drought conditions are detected, there should be continuous information flow on the severity of conditions, potential impacts, and possible mitigation or emergency response actions.

Best practices include development of a comprehensive drought early warning system that includes collection of data for all meteorological and hydrological variables and for critical social indicators and which integrates this information

into a timely and reliable assessment of severity and impacts. These data are commonly available from national meteorological, hydrological, and agricultural services units. Development of an automated weather data station network is recommended to collect data from a broader spectrum of meteorological variables and in near-real time for locations representative of the agricultural environment rather than the urban setting. Automated networks can be established in most settings.

POTENTIAL BENEFITS

A comprehensive early warning system can provide decision makers with information for making timely decisions that can reduce the economic, social, and environmental costs and losses associated with drought. Drought management reduces the risk to people, property, and productive capacity. It is a critical part of poverty reduction strategies.

POLICY AND IMPLEMENTATION

Shifting from crisis management to drought risk management is difficult because governments and individuals typically take a reactive approach and little institutional capacity exists in most settings to alter this paradigm. A 10-step drought planning methodology to assist in building institutional capacity is illustrated in box 8.1. Steps 1 through 4 focus on making sure the right people (scientists, policy makers, and stakeholders) are brought together, understand the process, know what the drought plan must accomplish, and are supplied with enough data to make equitable decisions when formulating and writing the drought plan. Step 5 describes the process of developing an organizational structure for completion of the tasks necessary to prepare the plan. One outcome of this step is the conduct of a risk assessment to create a vulnerability profile for key economic sectors, population groups, regions, and communities. It identifies and ranks the most significant drought impacts; examines the underlying environmental, economic, and social causes of these impacts; and guides the choice of actions that address these causes. This process can identify

Box 8.1 The 10-Step Drought Planning Process

The 10-step drought planning process was originally based on interactions with U.S. states but has been modified greatly to incorporate the experiences and lessons learned from many developed and developing countries. It has been the basis for discussions at regional training workshops and seminars on drought management and preparedness. This planning process has evolved to incorporate more emphasis on risk assessment and mitigation tools in response to the increasing interest in drought preparedness planning. The steps are as follows:

1. Appoint a drought task force or committee.
2. State the purpose and objectives of the drought plan.
3. Seek stakeholder input and resolve conflicts.
4. Inventory resources and identify groups at risk.
5. Prepare and write the drought plan.
6. Identify research needs and fill institutional gaps.
7. Integrate science and policy.
8. Publicize the drought plan and build awareness and consensus.
9. Develop education programs.
10. Evaluate and revise drought plans.

Source: Author.

who and what is at risk and why. Understanding why specific impacts occur offers an opportunity to lessen them in the future through mitigating actions.

Steps 6 and 7 describe the need for ongoing research and coordination between scientists and policy makers. Steps 8 and 9 stress the importance of promoting and testing the plan before drought occurs. Finally, Step 10 emphasizes that the plan must be kept current and be constantly evaluated in the postdrought period. Although the steps are sequential, in practice many are taken simultaneously.

Governments, nongovernmental organizations (NGOs), and international organizations have increasingly emphasized the development of a drought policy and preparedness plan. Simply stated, a drought policy establishes a set of principles or operating guidelines. It should be consistent and equitable for all regions, population groups, and economic sectors and consistent with the goals of sustainable development. Its overriding principle is an emphasis on managing

risk through preparedness and mitigation. This principle can be promoted through more, or better, seasonal and shorter-term forecasts; integrated monitoring, drought early warning systems, and associated information delivery systems; preparedness plans at various levels of government; mitigation actions and programs; a safety net of emergency response programs that ensure timely and targeted relief; and an organizational structure that enhances coordination within and among levels of government and with stakeholders.

Australia developed a drought policy in 1992, and South Africa quickly followed. India has in place many long-term strategies and measures to reduce the impacts of drought. The United States has been moving toward, but has not yet enacted, a national drought policy.¹

South Africa has a wide range of institutional capacity to respond to drought emergencies. Its neighbors have no drought policy or plan, although most have some infrastructure to respond to drought conditions, but usually on a reactive or ad hoc basis. In Botswana, drought preparedness planning is part of development planning, and its institutional structure is well defined, with local involvement at the district level. In Swaziland, a consortium of NGOs has been identified to address the needs of vulnerable population groups for drought and other natural hazards.

LESSONS LEARNED

Individuals, governments, and others consider drought a rare and random event. As a result, little, if any, planning is usually completed in preparation for the next event. Because drought is an inevitable feature of climate, strategies for reducing its impacts and responding to emergencies may and should be well defined in advance. Almost without exception, the crisis management approach has been untimely and ineffective and has done little to reduce vulnerability to the next drought. Also, relief measures have been poorly targeted. In fact, drought relief actually increases vulnerability to future events by reducing self-reliance and increasing

dependence on external assistance. If governments and others provide assistance to those most harmed by drought, what incentive do relief recipients have to alter the resource management practices that make them vulnerable? In addition, agricultural producers and natural resource managers that employ best-management practices are usually not eligible for drought relief or assistance programs. In reality, governments not only promote poor management by providing drought relief, but also reward it.

RECOMMENDATIONS FOR PRACTITIONERS

Many drought mitigation actions exist for each impact sector. Conducting a drought risk assessment will help identify the most essential mitigation actions for each of these sectors to reduce drought vulnerability. Recommendations for investment in the agricultural, municipal, and industrial sectors and general recommendations to benefit all sectors are summarized below.

Agriculture

- Train farmers on best-management practices and conservation irrigation.
- Encourage the use of innovative cultivation techniques to reduce crop water use and provide guidance on alternative cropping systems and crop types to employ during droughts.
- Conduct crop irrigation efficiency studies to improve water management.
- Provide farmers with real-time irrigation scheduling and crop evapotranspiration information.
- Monitor soil moisture and provide farmers with real-time data.
- Encourage installation of water-efficient irrigation technology.
- Develop an actuarial-based crop insurance program for agricultural producers.

Municipal and industrial

- Provide guidance to local government and water supply providers on long-term water management issues, including drought planning.
- Encourage water reuse as part of an ongoing water conservation program.
- Provide water efficiency education for industry and business.
- Develop and implement an incentives program to encourage efficient use of existing water supplies.
- Assess and classify the drought vulnerability of individual water supply systems.
- Identify vulnerable water-dependent industries, and fund research to help determine impacts and improve predictive capabilities.

General

- Improve the reliability of seasonal climate forecasts and increase their use to improve decision making for water management.
- Establish an automated weather station network to provide end users with near-real time data to improve decision making.
- Alter operating procedures for reservoir management during drought.
- Augment water storage capacity of surface and subsurface systems to improve drought-coping capacity.
- Conduct feasibility studies to evaluate the potential for desalinization of saltwater.
- Improve information delivery systems and provide technical assistance to improve decision making by government officials, agricultural producers, and water managers during droughts and help create the necessary infrastructure.
- Improve water conservation practices for domestic and agricultural sectors during drought and nondrought periods.

- Monitor the effects of drought on water quality for both surface and groundwater supplies.

The World Bank has several lending instruments to stimulate progress in drought risk management. The Specific Investment Loan program may facilitate development of institutional capacity. Because a shift from the crisis management approach to a risk management approach must be gradual, the Adaptable Program Loan may offer the opportunity to transition to this new paradigm. Moving to risk-based drought management requires restructuring of current emergency assistance programs and building consensus among stakeholders on priorities for mitigation measures. Government agencies possess considerable institutional inertia toward maintaining the status quo (in other words, maintaining current emergency drought relief programs). Effective drought risk management requires building consensus between government and stakeholders. The best time to develop a drought policy and a preparedness plan is right after a disastrous drought. The lessons learned in attempting to manage the drought crisis without a viable plan and the far-reaching impacts associated with drought are fresh in the minds of policy makers, natural resources managers, and the public. The Bank's Emergency Recovery Loan program is intended to restore assets and production levels after a natural disaster. This program could be effective in implementing drought disaster-resilient technology, including creation of a comprehensive and integrated early warning and delivery system and appropriate training programs to avoid or mitigate the impact of future droughts.

INVESTMENT OPPORTUNITIES

Investment opportunities in drought mitigation are numerous and varied. As part of the drought planning process, a critical step is the identification of appropriate mitigation actions that will address those sectors, population groups, and regions most at risk. As potential mitigation options are identified, each should be evaluated in terms of its potential to

decrease both short-term and long-term drought impacts and consistency with sustainable development goals. Below are examples of investment options that should be considered by the World Bank to increase resiliency to drought.

- Establish automated weather networks to provide decision makers with improved and more comprehensive local and national information as part of an integrated drought early warning system.
- Invest in research to improve the reliability of seasonal climate forecasts to provide decision makers with timely information.
- Improve the infrastructure for delivering reliable information to decision makers, including the development of training programs through agricultural extension and other services and others to improve the application of information in making risk-based decisions.
- Develop institutional capacity for risk-based drought management by establishing a national drought policy and preparedness plan through the application of drought planning methodologies.
- Develop national water policies directed at improving water management and facilitating water transfers, especially during water shortages.
- Create water conservation programs and provide local, regional, and national authorities with opportunities for training on the implementation of these programs.
- Establish risk-based crop insurance programs.

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ENDNOTE

1. All "pending" legislation expires and has to be reintroduced in the new Congress. No drought legislation was passed by the outgoing Congress per Steve Lanich, House Environmental Affairs Committee 1-12-05.

This Note was prepared by Donald Wilhite of the International Drought Mitigation Center, with inputs from Shobha Shetty. The Note was reviewed by Jean-Marc Faurès of the Food and Agriculture Organization (FAO).

INVESTING IN FLOOD CONTROL AND MANAGEMENT

In flood management and protection, structural and nonstructural measures need to be balanced in a basin context. The measures often involve sensitive tradeoffs that require well-structured discussion between the main players. The development and sustainability of flood management plans presupposes buy-in by stakeholders, including the poor, and reinforcement of the institutional clout of units favoring nonstructural measures.

Floods affect more people—140 million in an average year—than all other natural and technological disasters put together. From 1998 to 2002, 683 flood disasters were recorded, with most people affected in Asia (97 percent) and the remainder largely in Africa (OFDA/CRED database—see References Cited). Exposure to floods will increase as more people respond to population growth by moving to areas prone to flooding such as floodplains and deltas and as global climate change increases heavy runoff and reduces infiltration.

In many areas, floods are not only hazards, but also sources of groundwater recharge and renewal of soil fertility. Cyclic floods improve water quality, maintain aquatic ecosystems, and sustain inland fisheries. In poor regions, floods are the main source of irrigation water. Investment in improved flood management and preparedness can reduce vulnerabilities and improve the positive effects of floods.

INVESTMENT AREAS

A broad repertoire of flood management measures is required to reduce the negative impact of floods and improve their positive impact. Structural measures such as flood embankments and storage reservoirs have their place, but absolute protection from flooding is often impossible, unaffordable, or simply undesirable. In many cases, a combination of structural

and nonstructural measures and water management improvements offers the best value for money. This combination is summarized as integrated flood management, the process that integrates land and water resources development in a basin, aiming at trading off the benefits from using floodplains and utilizing flood flows against minimizing losses from flooding (WMO/GWP; see References Cited).

Water retention measures improve the capacity of river basins to retain unusual rainfall. In many basins, the original retention capacity has changed, and often diminished, because of deforestation, river training, development of stormwater removal systems, increase in metallic surfaces, blockage of natural drainage patterns, and conversion of natural depressions. Catchment protection, afforestation programs, and mountain stormwater systems slow down runoff and attenuate flood peaks. In West Africa, efforts to integrate road planning and water management, using road levees as barriers, impeded runoff and improved infiltration. In plains, drainage systems play a crucial role in water retention. Drainage systems create soil storage capacity to buffer excess rainfall and runoff. They can slow down stormwater runoff, control water tables, and improve soil chemistry. The benefits of such controlled drainage systems are twofold: improved flood management and increased agricultural production.

Other water retention measures utilize runoff and flood water for irrigation. With measures such as gully plugging, contour bunding, trenching, and recharge wells, monsoon rainfall is controlled in the upper catchments and used to improve soil moisture and recharge shallow aquifers. These programs often trigger individual or small group investments in tanks and wells. Watershed programs in Andhra Pradesh, India, established payback periods of five years or less (Wassan 2004). Water harvesting in high rainfall areas slows down erosive sheet flow and increases shallow groundwater tables, enhancing the reliability of rain-dependent paddy cultivation. In North-east India such investment had short payback periods (CDHI n.d.)

Spate irrigation systems also use runoff and flood flows. Small and medium-scale seasonal floods from ephemeral rivers are diverted for irrigation. Investments in civil head works have complicated the management of the sedimentation processes and shifted control over the flows to upstream land owners, creating substantial social problems. Different and often cheaper modalities merit preference. Support in the shape of earth-moving equipment to build smaller “traditional” systems is often more effective.

The same argument applies to inundation canals and flood recession cultivation, where a rising perennial river overtops its banks and inundates the banks and plains alongside the river, allowing farmers to grow crops on the residual moisture. Water productivity in flood recession agriculture can be high (box 8.2) and, in several dams in Africa, controlled flood releases are part of the operating procedures to continue capturing this benefit.

Even greatly enhanced retention and storage does not offer absolute protection from flooding. *Measures to mitigate flood impacts and reduce susceptibility to damage* offer scope for complementary investments. They include floodplain regulation, design and location of facilities, building codes and flood forecasting, and availability of controlled overflow areas. They may be supported by robust flood forecasting and warning systems. Disaster preparedness will further reduce the impact of flooding—with coordinating and control mechanisms, supported by information campaigns, the construction of safe shelters, and the establishment of coordinated emergency response mechanisms (box 8.3). The challenge is to maintain rigor during periods when there are no major floods.

Flood protection measures such as dikes, levees, and flood embankments are justified in areas with high population densities, historical heritage, and costly assets and infrastructure. An example is the Sfax Flood Protection project (2289-TUN), which protected Tunisia’s second largest city. The year before the project, the city suffered a severe, 1-in-130-years flood that caused US\$80 million in damage. This project

Box 8.2 Northern Nigeria: The Floodplain of the Hadejia-Jama’are Basin

At the confluence of the Hadejia and Jama’are Rivers lies a large floodplain. After construction of the Tiga and Challawa Gorge Dams upstream, this floodplain decreased from 300,000 hectares to less than 100,000 hectares. Net economic benefits from the floodplain (agriculture, fishing, fuelwood) were about US\$32/1,000 cubic meters of water, whereas return from crops grown in the Kano River irrigation scheme was less than US\$2/1,000 cubic meters of water.

Source: World Bank 2003.

Box 8.3 The Orissa Disaster Management Project

In the wake of the catastrophic Super Cyclone of 1999, the Orissa disaster management project introduced flood and disaster preparedness measures in 10 coastal subdistricts in India. The following was achieved:

- Community contingency plans were prepared in 1,600 villages, starting with participatory risk assessment and mapping. The plans called for the construction of school buildings that would double as shelters, installation of raised tubewells, construction of storage for nets and dry fish, road and embankment repair, and alternative building technologies. Mock drills tested the contingency plans.
- The community plans were integrated into subdistrict disaster management plans.
- Local task force groups were created and given training in first aid, rescue evacuation, water and sanitation, shelter management, and carcass disposal.
- A ham radio system was developed for use during emergencies and control rooms were established in the subdistrict centers.

The project was completed in 18 months on a slim budget of US\$211,000 thanks to volunteer input. The preparedness measures were successfully activated in the 2001 floods and the 2002 near-cyclone. The challenge is to maintain alertness in years without threats.

Source: Victoria 2002.

extended a dike, dug a belt canal around the city center, and rehabilitated natural drains at a cost of US\$27.7 million and a postproject economic rate of return (ERR) of 23 percent.

POTENTIAL BENEFITS

The primary benefits of flood management investments derive from reduction of potential

damage—in terms of loss of life, damage to property and infrastructure, crop loss, service disruption, and increased poverty (UN-ESCAP).

Flood damage can be phenomenal. In China in August 1998, floods claimed 2,300 to 3,000 lives and caused damage estimated at US\$20 billion. Two other floods in the Republic of Korea the same year caused US\$1 billion in damage (UN-ESCAP).

POLICY AND IMPLEMENTATION

Flood mapping is useful for assessing an area’s vulnerability to flooding, the value of its assets, and the feasibility and impact of flood management investments. In preparing flood management investments, decision makers must compare packages of flood management measures at basin level (table 8.1). Decision makers should consider not only these measures’ benefits in terms of reduced flood damage, but also their positive or negative effects on inland fish-

eries, riverine ecology, water recharge, soil fertility, and local irrigation.

A second point to acknowledge is that interests in different options vary and may conflict with one another. A good example is the flood control and drainage projects in Bangladesh (box 8.4). In lands that include flood control and drainage, agricultural land in the floodplains was protected against flooding, but this often pitted fisherfolk against farmers. In these circumstances, political and social feasibility comes into play. It is hard to accept the message of “giving up” certain areas, where a braiding river can no longer be controlled. This was a finding in the Bangladesh Drainage and Flood Control Project (864-BD), where local politicians fiercely resisted the retirement of embankments. They pushed for the construction of expensive groynes, but in the end these structures could not reverse the change in the riverbed. The best package may not be the one with maximum economic benefits, but the one that offers the most acceptable tradeoff

Table 8.1 Summary of Strong and Weak Points in Flood Management

Measures	Potential strong points	Potential weak points
Water retention	<ul style="list-style-type: none"> Additional benefits such as recharge, irrigation, and drainage Investment can be multipurpose 	<ul style="list-style-type: none"> May not protect against peak floods, which may still cause substantial damage
Flood mitigation	<ul style="list-style-type: none"> Possibility of extensive coverage at low financial cost No impact on natural processes 	<ul style="list-style-type: none"> Requires discipline, which in case of infrequent floods may be lost Perpetuates insecurity May be politically unacceptable without flood protection
Flood protection	<ul style="list-style-type: none"> Protects critical and high-value assets Protects low-lying areas, where poor neighborhoods are often situated Results in very high demand after flood disasters 	<ul style="list-style-type: none"> May interfere with inland fishery and aquatic systems May reduce river storage capacity May make land acquisition difficult May raise investment costs May generate high recurrent costs that might not be paid

Source: Author.

between divergent interests. It is through stakeholder involvement in assessing options that such solutions can be reached.

Investments in flood management need to be supported by policies that safeguard water retention and storage capacity by protecting upper-catchment vegetation, protecting wetlands for flood storage, restricting sand and gravel mining in rivers, and regulating development of roads, railways, and built-up areas. Investing in the enforcement of such policy measures gives better value for the money than remedying the consequences of the lack of enforcement. The same applies to policy measures regulating access and use of flood-prone areas. Such low-cost measures keep maintenance costs down. In spite of some efforts, there are no cases of cost recovery of flood protection by the direct beneficiaries. This point is made in several Bank Implementation Completion Reports, for instance the Small-Scale Drainage and Flood Control Project (955-BD) in Bangladesh. At best, costs are recovered as a surcharge on a general tax or water

Box 8.4 Conflicts in Flood Protection

The Chalan Beel flood control and drainage project in Bangladesh failed to recognize the different interests that come into play in flood management. The construction of embankments interfered with local floodplain fishery. The many cuts made in the embankment structures to enable fishing ultimately rendered them ineffective.

Source: Abdel-Dayem et al. 2004.

fee—yet this presupposes the existence of a revenue collection system. More commonly, investment in flood protection is inscribed on the government budget and rarely leads to effective preventive maintenance. This is a strong argument in favor of measures with additional functions for which users would be willing to pay.

Given the high negative opportunity costs of not investing in integrated flood management, several lending modalities can be used in flood management and flood protection. Table 8.2 gives an overview of some of these, but it is important to

Table 8.2 Examples of Possible Loans

Loan modality	Type of activity
Sector Investment and Maintenance Loan	Integrated investment packages of water retention measures (drainage, water harvesting, flood irrigation, road embankments), flood mitigation (flood warning, flood preparedness and mitigation, flood zoning, shelters, communication), and flood protection measures (embankments, storages, groyne)s—including the development and implementation of policies (such as flood zoning, cost recovery) and emergency mitigation and relief measures, awareness building, and capacity building
Learning and Innovation Loans (1)	Development of innovative packages of flood mitigation and protection measures, also addressing financing mechanisms—including monitoring of effectiveness
Learning and Innovation Loans (2)	Development of appropriate innovative measures for water retention and nonreservoir water storage—for instance in upstream drainage and flood-based irrigation
Technical Assistance Loans (1)	Flood mapping and development of flood management plans, including consultation and capacity building
Technical Assistance Loans (2)	Strengthening the enforcement of flood mitigation policies and measures, including dam operations
Emergency Recovery Loans	Postflood emergency operations—including regional macroeconomic stability—to augment food stocks and restart economic activities

Source: Author.

be selective in deciding where to invest. This was a major lesson of the Bangladesh Drainage and Flood Control project (864-BD). Investments in relatively simple polders without pumped drainage in shallow flooded areas were economically justified, but similar investments in deeper flooded areas were not.

LESSON LEARNED

The main lesson learned concerns the value of looking at water retention and flood storage capacity at basin level. A package of investments and measures has to be identified to prevent and attenuate flooding, mitigate its impact, and protect areas with high-value assets.

RECOMMENDATIONS FOR PRACTITIONERS

- Avoid isolated perspectives and falling into the trap of assuming that some investment areas—particularly civil engineering works—are always appropriate. This is a challenge in countries where the organizations responsible for flood management have been geared toward flood protection works, and where water management improvements, flood preparedness, and land use planning to help attenuate flood peaks have no institutional home.
- Capacity should be strengthened to enforce nonstructural measures.
- Community-based disaster preparedness is a necessary element in building up response capacity to deal with flood impact.

INVESTMENT OPPORTUNITIES

Investment opportunities for practitioners include the following:

- Developing a basin-level flood management plan
- Preparing an integrated package of water retention measures, flood impact mitigation, and flood protection

- Flood mapping to assess the effectiveness of alternative flood management packages
- Reinforcing capacity to enforce and implement nonstructural measures
- Establishing mechanisms to settle divergent interests and undertake local planning
- Installing water retention measures—including measures to utilize flood flows
- Preparing flood impact mitigation measures, including controlled flooding
- Preparing flood protection measures

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For guidelines on spate irrigation, see <http://www.spate-irrigation.org>.

For information on flood mitigation, see the Web site of the Association of State Floodplain Managers in the United States at <http://www.floods.org/home/>.

For more on disaster preparedness, see the Web site of the Asian Disaster Preparedness Centre at <http://www.adpc.net/>.

This Note was prepared by Frank van Steenbergen, with inputs from Abla Ilham and Alessandro Palmieri. It was reviewed by Bart Snellen of the International Institute for Land Reclamation and Improvement (ILRI).

PLANNING SCARCE WATER RESOURCES USING EVAPOTRANSPIRATION QUOTAS: THE HAI BASIN INTEGRATED WATER AND ENVIRONMENT PROJECT IN CHINA

What is new? Water resources planning and management using units of evapotranspiration (ET) is useful wherever water is scarce. It makes particularly good sense where irrigated agriculture is the major water user. The approach is practical and aims to make the utilization of water resources sustainable and raise farmer incomes. It helps to maximize agricultural production in water-scarce areas in a sustainable way. It raises farmer social capital and improves farmer access to information.

In water-short areas, it is important to manage water resources in terms of the amount lost for other uses. Water mobilized by large irrigation systems can be divided into the portion that crops, trees, and weeds use for ET, and the portion that returns to the surface water or groundwater systems. The portion consumed through ET is the amount lost for users downstream; this is often called the *net extraction*.¹ Managing water resources in terms of net extraction encourages farmers to maximize the benefits from the ET allocated to their area. Farmers will reduce the evaporation and transpiration that does not contribute to plant growth. For example, they will reduce evaporation by reducing waterlogged areas, by irrigating when evaporation is lowest (at night instead of during the day), by using moisture-retaining mulches, and by replacing open canals and ditches with pipes. They may also reduce plant transpiration by weeding, using water stress-resistant varieties, and fine-tuning deficit irrigation.

The Hai Basin project in China will pilot water resources planning through allocation of ET quotas. In this basin, where Beijing is located, water availability is only 305 cubic meters per capita, which is 14 percent of the national average and 4 percent of the world average. Groundwater is pumped at a rate of 26 billion cubic meters a year, mostly for irrigation. Abstraction exceeds recharge at a rate equal to one-third of total abstraction. Excess abstraction is 13 billion cubic meters a year, 9 billion cubic meters of it through groundwater overexploitation and 4 billion cubic meters through overuse of surface water.

OBJECTIVES AND DESCRIPTION

The objective is to increase the volume and value of agricultural production in the demonstration areas using a target ET amount. This amount will be less than the current ET, a goal that can be achieved only by reducing nonbeneficial ET and raising crop water use efficiency in the narrow sense of the word.

The productivity of irrigation water is the result of a host of factors, among them plant breeding, soil fertility, fertilization, plasticulture, tillage, weed control, soil moisture management, drainage, soil salinity, soil sodicity, irrigation scheduling, deficit irrigation, irrigation technologies, and techniques and cropping pattern changes. The project will therefore work with farmers on irrigation and cultivation as well as general management practices to improve their water productivity (WP).

The project will estimate ET in the demonstration areas with remote sensing techniques, drilling down to farm plots if need be. It will target reductions in nonbeneficial ET and increases in crop water use efficiency in selected demonstration areas. It will work with farmers to reduce ET to these target levels, while aiming to maintain, if not raise, farmer incomes. It will correlate this ET information with data on production and farmer income and develop spectrums that show the range of yields and incomes per

unit of ET for several crops. The project will identify irrigation, cultivation, and general management practices with low, average, and high WP and train farmers with low WP in the practices of the high-WP farmers.

OUTPUT AND IMPACT

Water resources management is primarily a bottom-up undertaking that requires individual involvement of the water users. The project will work directly with farmers and farmer groups to achieve its objectives. It will form and strengthen water user associations through which farmers will learn to manage water consumption within allocated (target) amounts of ET while increasing the volume and value of their production, including switching to higher-value, less water-consuming crops.

Output is likely to be sustained, and even expanded, after completion. The objectives are in the interest of both farmers and government. Providing farmers with assistance during the project and keeping water use within the allocated limits, local water bureaus and agriculture bureaus will increase their own knowledge and skills.

WIDER APPLICABILITY

Water resources planning and management using ET units is useful wherever water is scarce. It makes especially good sense where

irrigated agriculture is the major water user. The approach is practical and aims to make the utilization of water resources sustainable and raise farmer incomes. It helps maximize agricultural production in water-scarce areas in a sustainable way. It raises farmer social capital and improves farmer access to information. Reliance on monitoring through remote sensing makes it applicable everywhere because the entire globe is served by satellites.

WORLD BANK PROJECT DISCUSSED

China. “Hai Basin Integrated Water and Environment Management Project.” Active. Project ID P075035. Approved: April 4004. Within World Bank, available at <http://portal.worldbank.org>.

ENDNOTE

1. If return flows are unusable because of poor quality of the return flows or of the receiving water body, they are not recoverable and can be considered “real” losses. In this profile, we are concentrating only on “real” water savings related to ET reduction and not reductions in other nonrecoverable losses, which would also be “real” water savings.

This Profile was prepared by Douglas Olson and reviewed by Jack Keller of International Development Enterprises.

INNOVATION PROFILE 8.2

FIGHTING THE ADVERSE IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

What is new? Agricultural water investment projects can do much to enable rural communities to adapt to negative impacts of climate change such as drought, soil degradation, and waterlogging. To alleviate or reverse negative climate effects, new approaches and technologies such as combining infrastructure investment and economic incentives, diversification, satellite technology, and climate information can be used.

Poor rural people depend on natural resources but live in marginal areas and lack the knowledge and resources to adapt easily to the unexpected. Changes associated with climate are therefore likely to affect them more than any other group.

Table 8.3 summarizes the impact of climate change on seven sectors, among them rainfed agriculture and agriculture with water control.

In what way can World Bank projects address this vulnerability for people already exposed to multiple poverty-associated liabilities? (See box 8.5 for climate-related components in World Bank projects.) For an answer, this profile looks at Brazil's "Land Management II—Santa Catarina" project and China's "Tarim Basin" and "Tarim Basin-II" projects. Components of these projects help farmers mitigate the impact of climate change, even though they were not designed for that purpose.

OBJECTIVES AND DESCRIPTION

THE LAND MANAGEMENT II—SANTA CATARINA PROJECT. The Land Management II project was implemented in Brazil's southern province of Santa Catarina between 1991 and 1997. Its objectives were to increase agricultural production on 81,000 small farms, make land and

Table IP 8.3 Climate Impacts on Natural Resources-Using Sectors and Implications for the Poor

Sectors	Economic impacts	Ecosystem impacts	Welfare indicator	Impacts on the poor
Agriculture	Loss of agricultural production	Pests and diseases	Poverty incidence	Food poverty and malnutrition
Irrigation, drainage, and watershed management	Drought, waterlogging, and electricity shortage	Impact on biodiversity	Percentage of area irrigated	Vulnerability to drought
Drinking water and sanitation	Infectious and waterborne diseases	Unhygienic conditions	Access to water and sanitation	Disease burden and pollution
Public health: malaria	Mortality and morbidity	Epidemics	Disability-adjusted life years	Infectious diseases
Infrastructure: rural roads	Slow regional progress	Impacts on land use	Per capita road network	Income and employment
Renewable energy	Dependence on traditional energy and fossil fuels	Pollution and air quality	Access to electricity	Low access to modern energy
Disaster management	Impacts on multiple sectors	Ecosystem diversity and productivity	Loss prevention through mitigation and adaptation	Extreme vulnerability

Source: Reddy, Dinar, and Mendelsohn 2004.

water management sustainable, improve farm incomes, and protect the environment. The project sought to introduce land and water management methods that would allow farmers to cope with changing climatic conditions that lead to soil degradation. The main project components were agricultural extension, research, incentives for sustainable land management, land use planning, mapping, and monitoring of the environment.

THE CHINA TARIM BASIN I AND TARIM BASIN II PROJECTS. The Tarim Basin in Xinjiang Uygur Autonomous Region in northwest China supports 5 million people. Its arid climate implies significant ET, much of which does not contribute to agricultural production or human use. Basin inhabitants depend mainly on agriculture, which suffers from water shortages, salinity, and waterlogging.

Tarim Basin I was implemented between 1991 and 1997 to improve irrigation and drainage, develop hydropower and agriculture, strengthen support services for agriculture and livestock development, and restore the Tarim River ecosystem. Tarim Basin II is underway. It is expected to improve the productivity of a low-yielding irrigated area of 105,350 hectares, reclaim a nonproductive area of 75,350 hectares, improve drainage, and support institutional development initiatives for water management and delivery.

OUTPUTS AND IMPACTS

THE LAND MANAGEMENT II—SANTA CATARINA PROJECT. Through appropriate extension activities, the project promoted minimum tillage, seed processing, and adaptive research by upgrading agrometeorological stations. Land management initiatives supported moisture conservation on 400,000 hectares in 523 microcatchments, with spontaneous adoption on 480,000 hectares in nonproject catchments. Reduction of soil loss helped reduce the cost of soil enrichment and stabilization, waterborne diseases, and maintenance costs of rural roads. Macroeconomic adjustments and decisions to join Mercosur and the Southern Cone free trade area affected the project through lowered output prices, but

Box 8.5 Reflections on Climate-Related Components in Bank Projects

- Low agricultural productivity and high levels of poverty are associated with marginal climates.
- World Bank project investments tend to concentrate in marginally climatic regions.
- Project implementation reports present anecdotal evidence on climate events but do not provide information on their influence on project outcomes.
- The components show wide variation in their sensitivity to climate variables, which is reflected in the project ERR.

Source: Authors.

farmers who had improved their land management suffered only small income drops.

THE CHINA TARIM BASIN I AND TARIM BASIN II PROJECTS. The Tarim Basin projects increased crop yields by 20–47 percent in high areas and 68–118 percent on low-lying land. The projects achieved an ERR of 33 percent in terms of improved crop production and reclaimed 42,000 hectares, benefiting 104,000 households and 33,000 livestock owners. Per capita incomes grew by 250 percent in six years (from Y400–610 in 1991 to Y1,030–1,510 in 1997). The project used innovative mechanisms to suppress hail, which used to badly damage crops in the Weigan prefecture. The hail was detected by radar and suppressed by seeding the clouds with silver iodide.

Tarim Basin II utilizes remote sensing data from Landsat and the U.S. National Oceanic and Atmospheric Association to map biomass production, maximize consumptive use, and reduce nonbeneficial ET. The project estimates water productivity of the water user associations and establishes water use quotas at sub-basin level so that adequate water is delivered to the middle and lower reaches of the Tarim River when rainfall is low and ET is high.

ISSUES FOR WIDER APPLICABILITY

Some of the techniques used in these projects could be adapted for use in other geographic and institutional settings. Adaptation could be

simple changes in management practices and available technologies at farm level or support through government-sponsored planning and advisory services. In either case, data and appropriate institutions have to be available.

Addressing site-related climate problems is an efficient and cost-effective way to cope with such issues. For example, in the case of the projects in this profile, combining remote sensing with socioeconomic data allows evaluation of the relationships between site productivity, climate, and project performance.

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This Profile was prepared by Ariel Dinar and Rama Chandra Reddy and reviewed by Ian Noble and Peter Jipp.

INNOVATION PROFILE 8.3

INVESTING IN PARTICIPATORY APPROACHES FOR THE CULTIVATION OF NEW VARIETIES AND SOIL AND WATER CONSERVATION IN INDIA

What is new? Stakeholder involvement opened the door to success for two World Bank projects to help poor farmers increase yield from marginal land. The success of the projects is mostly due to the local community's sense of ownership through its involvement in selecting and testing new varieties and technologies, the high priority given to the cultivation of local grasses, and the close collaboration between research institutions and the projects.

Community involvement through village development committees (VDCs) and “ownership” of introduced technical packages has been crucial to meeting project objectives and introducing new technologies in the last decade. Successful pilot projects in integrated watershed development and combating soil sodicity¹ through bilateral and multilateral investments have led to scaling up of further investments.

OBJECTIVES AND DESCRIPTION

Bank investment in watershed development to promote and adopt moisture and soil conservation measures started in the 1980s with pilot operations to test technologies under field conditions. Some bilateral small (village and district-size) investments were also introduced. Moderate success was achieved in introducing soil and water conservation measures, especially in rainfed areas (600 to 1,000 millimeters average annual rainfall). Technical success led to twin investments in integrated watershed development in the geographically contiguous Shivalik hills in India (Jammu and Kashmir, Punjab, Haryana and Himachal Pradesh) and the plains (Orissa and Rajasthan). In both projects, vetiver grass (*vetiveria zizanoides*) was planted for soil conservation through terracing

and contour cultivation, but the benefits of local grasses were not explored.

Beneficiaries did not identify with introduced vetiver grass and considered it a top-down government program. Testing drought-tolerant crops, including fodder, was not a high priority, and the horticultural crops, fruit, and vegetable crops promoted had to have adequate water. During the mid-term review (December 1993), both projects were restructured to rectify shortcomings and realign objectives and priorities by taking on the following:

- Involving communities in testing introduced technologies
- Assigning high priority to use of local grasses with economic benefits in fodder and robe making and using vetiver where applicable
- Streamlining relationships between beneficiaries and forestry departments in grass collection
- Including livestock development in project activities by providing improved feed, making fodder available, and offering artificial insemination and other veterinary services
- Introducing drought-tolerant varieties of crops, particularly grains such as barley, wheat, and maize and horticultural crops such as guava, pomegranate, and *amla* (cape gooseberries)
- Planting napier grass (*pennisetum purpureum*) as a source of green fodder in field borders

To implement proactive participatory concepts, community organizations such as VDCs were formed as incubators for sustainable project objectives. A “show and tell” approach was used in which project staff and community organizations introduced new villagers to the ideas and techniques. This participatory approach was instrumental in designing the Integrated Watershed Development project, known as “Hills II,” which covered the Shivalik hills in five states, including Uttararchal.

Watershed development in India has proven highly cost effective as a mechanism for reaching many of the rural poor (including the landless, women, and disadvantaged groups) and having a large and sustainable impact on their lives. The bottom-up participatory involvement of communities in project formulation and implementation ensured their ownership and effective benefit- and cost-sharing arrangements for project investments. This implied that, if communities and their VDCs were proactive stakeholders, flexibility could be woven into project design and investments. Project implementation plans were proposed by project staff and finalized after consultation with VDCs. Aide-mémoires, signed by VDCs and project staff, specified the rights and responsibilities of everyone involved.

The participatory approach of empowering beneficiaries was also adopted in reclamation of sodic lands in Uttar Pradesh (UP) in two successive Bank-financed projects in 1993 and 1998. Other agencies were involved on a smaller scale in UP: the European Union in three districts in 1994 and the government of the Netherlands in two districts.

The pilot project (UP Sodic I) tested and adopted several technologies based on systematic soil testing, digging surface drainage, drilling tubewells, applying gypsum, leaching with good quality groundwater, crop management, and regular flushing of salts from link drains. NGOs were actively involved in training beneficiaries and in effective, forward-looking project management. The technologies used are based on extensive research by national and international institutions. The Indian Council of Agricultural Research and its affiliated research institutes (particularly the Central Soil Salinity Research Institute at Karnal, Haryana), contributed to the development and implementation of technical packages including varietal development and testing of salt-tolerant barley, wheat, and rice varieties and green manure under field conditions. UP Sodic I brought the first green cover to about 64,000 hectares of barren land, surpassing the initial 50,000-hectare objective. At full development, UP Sodic II (1998) would bring into cultivation about

150,000 hectares and incorporate project activities into the main government-supported program in a unified approach.²

Achieving sustainability in combating drought and salinity is a central objective of Bank investments, particularly in watershed development and reclamation of sodic soils. The project components were broadly based on the following:

- Forming community development groups to proactively empower project beneficiaries including the landless, women, and disadvantaged groups
- Promoting suitably tested technical packages and their adoption and modification according to local conditions
- Sensitizing project staff to the changes needed for a bottom-up approach through effective institutional development programs
- Making inputs available at the time needed, particularly seeds, seedlings, agrochemicals, and soil amendments
- Rationalizing subsidies by enacting evolving benefit- and cost-sharing arrangements
- Upgrading infrastructure for drinking water and farm-to-market roads
- Minimizing water loss and waste through operation and maintenance (O&M) procedures agreed between communities and project management
- Establishing effective monitoring, evaluation, and feedback systems involving beneficiaries

OUTPUT AND IMPACT

At full development the Integrated Wasteland Development Program (IWDP) of Hills II would treat about 200,000 hectares, 75 subwatersheds serving 1,920 villages in the five project states out of a total area of 522,000 hectares. During preparation and early project implementation, visits by groups of beneficiaries to treated subwatersheds in earlier projects proved instrumental in fostering exchanges of ideas not only with

beneficiaries, but also with project management staff. Experience from Uttaranchal was also valuable, because the European Union was involved in promoting participatory aspects and establishing a revolving fund for watershed maintenance with beneficiaries' contributions. The visits also helped in exchanges of technologies, seeds, seedlings, and fodder.

Earlier projects and research efforts identified the most appropriate vegetative technologies for watershed protection and management. However, the use of vetiver grass was perceived to be a Bank-driven technology. This perception was remedied for both Hills I and the plains projects after the 1993 mid-term review. Emphasis is now on selecting locally available grasses and using indigenous technology to reduce soil loss from erosion and increase on-site moisture and crop yields.

In rainfed areas, major crops are maize and pulses in the Kharif season and wheat and grain in the Rabi season. The Hills I project completion report confirmed increase in both crop yields (40–60 percent) and cropping intensity (7 percent) owing to increased availability of moisture and a rise in the groundwater table. In addition, construction of water-harvesting and minor irrigation structures ensured availability of irrigation and drinking water for domestic use and livestock. With increased irrigation, more vegetables and fruits such as mango and guava were planted in the Rabi season. Milk production increased by 20–30 percent as a result of improved availability of fodder and veterinary services.

The mid-term review of IWDP, Hills II (April 23, 2002) and supervision report (October 19, 2003) confirmed that implementation progress is satisfactory, and 1,260 VDCs have been formed (80 percent of target). Wheat yields have increased from 2.3 tons per hectare to 2.9 tons per hectare. Milk production has also risen, by 19–34 percent, as envisaged at appraisal.

As for the UP sodic reclamation projects, the results are impressive—the land, once barren, whitish, and sodic, has become green and productive. Rice and wheat yields are double

the appraisal estimates. Cropping intensity increased from 62 percent to 222 percent, with wheat and rice yields reaching 2.7 and 3.0 tons per hectare, respectively. This has undoubtedly contributed to poverty alleviation and reversal of soil and water degradation.

LESSONS LEARNED

Effective management of natural resources in marginal and wastelands has proven technically and socially feasible. Technically, development of drought- and salt-tolerant crops was integrated with crop management, on-site moisture conservation, and soil conservation. Socially, proactive participation of project stakeholders, particularly beneficiaries, is crucial to effective implementation of investments. The support and coordination of qualified project staff is essential to the realization of project objectives. Some of the key lessons learned are as follows:

- The Adaptable Program Loan is the recommended lending instrument for long-term drought and salinity programs. However, a Learning and Innovation Loan or a pilot operation is suggested, if recommended technologies and approaches have to be tested before scaling up investments.
- Formation of community development groups is essential to proactively empower project beneficiaries, including women, landless, and disadvantaged groups.
- Developing suitably tested technical packages, and their adoption and modification through local field testing, would ensure the sustainability of interventions.
- Project staff should be sensitized, through effective institutional development programs, to the changes needed for a bottom-up, participatory approach.
- Timely availability of financing of inputs, particularly seeds, seedlings, agrochemicals, and soil amendments should be ensured.
- Subsidies should be based on acceptable benefit- and cost-sharing arrangements.

- Infrastructure for drinking water and farm-to-market roads should be included in project activities.
- Agreed operation and maintenance procedures and cost-sharing arrangements should be clearly delineated between communities and project management.

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Within World Bank, available at <http://projportal.worldbank.org>.

ENDNOTES

1. Sodic soils are salt-affected lands dominated by the electrochemical bonding of sodium to clay. This results in the dispersal of the finer soil particles, impedance of water and air movement, and creation of highly alkaline conditions that make the soil unsuitable for crops.
2. Another innovative project in this respect is the National Agricultural Technology Project (NATP) in India. Its goals were to enhance the role of agricultural research for cropping systems and variety development and promote the dissemination of research outcomes on crop varieties and technological innovations for water saving and harvesting. The project supported research to enhance performance and effectiveness in responding to farmers' technological needs and developed technology dissemination techniques based on greater accountability to, and participation by, the farming communities.

This Profile was prepared by Hamdy Eisa with inputs from Shawki Barghouti. It was reviewed by Aly M. Shady of the Canadian International Development Agency.

9

ASSESSING THE SOCIAL, ECONOMIC, AND ENVIRONMENTAL IMPACTS OF AGRICULTURAL WATER INVESTMENTS

- Investment Note 9.1 Monitoring and Evaluating the Poverty Impacts of Agricultural Water Projects
- Innovation Profile 9.1 Assessing the Economic Benefits of Land Drainage
- Innovation Profile 9.2 Guiding Environmental and Social Safeguard Assessment in Agricultural Water Projects
- Innovation Profile 9.3 Estimating the Multiplier Effects of Dams
- Innovation Profile 9.4 Benchmarking for Improved Performance in Irrigation and Drainage
- Innovation Profile 9.5 Applying Environmental and Social Safeguard Policies to Agricultural Water Operations and Monitoring Them during the Project Cycle

OVERVIEW

Selecting the best investments, targeting them to the poor, and managing them efficiently requires measurement and evaluation tools and processes. Social and economic analysis, benchmarking and monitoring, and evaluation are critical to getting the right investment design, targeting, and justifying projects to decision makers who may think them low yielding and diffuse in their impacts. These tools and processes, and the role of safeguards in improving program quality, are discussed in this chapter.

MONITORING AND EVALUATION HELP ASSESS AND IMPROVE THE POVERTY REDUCTION IMPACTS OF AGRICULTURAL WATER MANAGEMENT INVESTMENTS. In a pro-poor operation, monitoring and evaluation should track multidimensional measures of welfare such as data on income and poverty and indicators of health and nutritional status. The resulting knowledge about investment returns and impacts enables choices about the most cost-effective way to reach poverty reduction targets. (See IN 9.1.)

Scientific analysis of benefits can provide powerful support to technical assertions or help overturn prejudices. Rigorous analysis of costs and benefits is highly valuable in steering resource allocation. For example drainage—the “forgotten investment”—is systematically downplayed in investment programming, even though it is relatively cheap and irrigation investments developed without proper drainage may prove unsustainable. A study in India showed that the cost of creating new irrigated land is US\$6,400 per hectare, while the cost of drainage is between \$700 and \$1,000 per hectare. Rigorous analysis provides the material for advocacy to correct this neglect of drainage. (See IN 9.1 on monitoring and evaluation and IP 9.1 on measuring the costs of “absence of drainage.” For more on drainage, see chapter 5.)

ECONOMIC AND FINANCIAL ANALYSIS IMPROVES INVESTMENT QUALITY. Economic and financial analysis can help refine project design and ensure that financial flows improve sustainability. One case study in chapter 7 examines a project where analysis demonstrated that irrigation benefits could pay the costs of a community’s water supply. Capturing indirect benefits and externalities can also improve investment choices. The indirect benefits of dams may double their direct benefits. The same is true for many agricultural water investments, because second-round multiplier effects of creating incomes and wealth in rural areas are high. Evaluation of these linkages is vital to assessing the real impact of agricultural and water investment in rural areas. Analysis is also invaluable in showing the distributional impact of investments. In the case of untargeted programs, this has often revealed unexpected benefits for the poorest. (See IN 9.1 on methodology in general, IP 9.3 on multiplier effects, IP 7.1 on rural water supply and irrigation, and IP 5.1 on evaluating multifunctional investments within an integrated water resources management framework.)

SAFEGUARDS SHOULD IMPROVE INVESTMENT QUALITY AND OWNERSHIP. Safeguard policies are designed to integrate social and environmental concerns into decisions about investment design. They can help to reduce and mitigate adverse environmental and social impacts, and transparency requirements ensure that stakeholders are consulted. Seven of the 10 safeguards may be triggered by agricultural water projects: typical impacts might include downstream and third-party effects from surface and groundwater withdrawals, polluted runoff and drainage water, and loss of farmland and displacement. Safeguards may be seen as imposing a cost on countries and World Bank teams. However, technical support is available and properly applied safeguards should, in fact, improve investment quality and ownership. (See IP 9.2 and IP 9.5.)

BENCHMARKING IS A USEFUL MEANS OF IDENTIFYING SHORTFALLS IN IRRIGATION PERFORMANCE AND OF DESIGNING IMPROVEMENT PROGRAMS. To tackle the problem of poor irrigation performance, benchmarking systems have been developed that allow comparison of performance between similar schemes. Benchmarking allows decision makers to measure performance, to identify reasons for variations between schemes, and to draw up an agenda for change. The approach could be generalized within the World Bank as part of the monitoring of key performance indicators. (See IP 9.4.)

SOME TYPICAL INVESTMENTS

Typical investments in this area may include the following:

- Monitoring and evaluation systems
- Impact evaluation studies
- Economic modeling of multipliers and direct and indirect impacts of multifunctional investments such as dams
- Benchmarking for irrigation modernization

INVESTMENT NOTE 9.1

MONITORING AND EVALUATING THE POVERTY IMPACTS OF AGRICULTURAL WATER PROJECTS

Monitoring and evaluating (M&E) the poverty impact of agricultural water investments may allow some conclusions about returns on different types of investments and their contributions to poverty reduction. M&E of the poverty impact should receive attention early in project preparation to ensure adequate data collection capacity, collection of the right type of data, and a system set-up that allows analysis and interpretation. Broad consultations and early user involvement in the design and implementation of the M&E system are important to build consensus and ownership.

Agricultural water projects contribute in several ways to achieving the Millennium Development Goals of eradicating extreme poverty and hunger and ensuring environmental sustainability. Increased yields and cropping area and shifts to higher-value crops help boost the incomes of farm households, generate employment, and lower consumer food prices. They also stabilize incomes and employment. Community participation and the creation of water user groups have become integral parts of these projects, which have empowered users and made them self-reliant. Mainstreaming M&E will help generate the data to establish the cost-effectiveness of projects in reducing poverty and propose ways to improve it.

INVESTMENT AREA

M&E systems are usually based on four steps:

- Deciding what information is needed
- Assessing the availability and requirements of tools for collecting and analyzing the data needed

- Deciding on outputs of the M&E system, who will produce them, and how they will be used
- Determining the resources needed to set up and run the M&E system

Each step of M&E of agricultural water projects should focus on poverty but the first step is especially important: defining the indicators, the types of data, and the procedures for analyzing and evaluating them.

INDICATORS. In addition to the standard indicators for inputs (resources assigned to project activities) and outputs (for example, the length of irrigation canals upgraded or built), outcome and impact indicators are needed to monitor welfare dimensions such as health status, consumption, and income levels (box 9.1).

These data, collected for different groups of project beneficiaries, measure which target groups receive the most benefits and these groups' satisfaction or dissatisfaction with the benefits. Beneficiary groups may be distinguished according to income status (sometimes proxied by landholding status, if adequate data on income status are unavailable), ethnicity, indigeneity, and gender. Good assessments

Box 9.1 Some Outcome and Impact Indicators for Monitoring Poverty in Agricultural Water Projects

Outcome indicators

- Crop yields, cropping patterns, and production levels
- Output and input prices
- Fisheries and livestock production
- Employment rates and wages

Impact indicators

- Share of population below the nationally established rural poverty line or share of population with less than \$US1 a day pre- and postproject
- Prevalence of underweight and stunted children (measured by height for age and weight-for-height) pre- and postproject.

Source: Author.

have also collected indicators on interventions complementary to agricultural water-related projects (such as the establishment of marketing infrastructure and processing facilities) and have monitored the quality of services affecting the impact of investments. Because projects do not take place in isolation, the inclusion of quantitative and qualitative information on intervening and/or external influences on the selected indicators is recommended. As shown in box 9.1, one would include anything else that might influence the output/input prices or the prevalence of child malnutrition.

TYPES OF DATA. Well-designed baseline surveys are an essential tool for collecting data for investment planning purposes, monitoring, and evaluation. Poverty maps have also proved valuable tools for targeting and monitoring poverty (box 9.2).

Depending on the project interventions, baseline surveys usually collect data at several levels such as the village, watershed, household, plot, and individual through a combination of household and individual surveys and participatory methods. To allow statistically significant inferences from the data, the sampling framework must be appropriate. Surveys have been done in-house by implementing agencies, but they are frequently contracted out to a research or survey firm or an institution. This approach is generally preferred.

Box 9.2 Poverty Maps

Poverty maps are spatial representations of poverty assessments. They combine survey with census data and graphically present indicators of poverty such as per capita income or daily subsistence levels or well-being indicators such as life expectancy, child mortality, and literacy.

In the Peruvian Social Fund project, FONCODES, poverty maps, in conjunction with community poverty assessments, helped target community-based projects including small irrigation projects. Superimposing remote sensing data (publicly available satellite images) with poverty maps provides enormous scope for better water resources planning, poverty targeting, and impact assessments. (See also IP 9.1.)

Sources: Author; World Bank 1998.

A rigorous “with/without” design may be justified to evaluate the impact of an investment that is critical to poverty reduction but which suffers from substantial knowledge gaps about which approaches work best or when a new approach should be tested. With/without evaluation helps determine whether reductions in poverty result from project interventions or other causes. Controlled impact evaluations are demanding in terms of the analytical capacity and resource requirements, and not all investments warrant them.

PROCEDURES FOR ANALYZING AND EVALUATING MONITORING AND EVALUATING (M&E) OUTPUT. Initial planning for M&E includes developing the management information system. It should allow disaggregation of key data by social and economic groups to allow monitoring of the poverty impact of activities. It should also enable an assessment of the inclusiveness of project activities.

Emphasis on poverty M&E early in project preparation can ensure that data collection capacity is adequate, that the right type of data is collected, and that a system is set up that allows analysis and interpretation. Broad consultations and early user involvement in the design and implementation of the M&E system are important to build consensus and ownership (box 9.3).

Early involvement of potential data users (typically the project implementing agency) and broad consultations with researchers, beneficiaries, donors, and implementers during the initial design stage have been helpful in building consensus on what to monitor and how to do it and in generating a sense of ownership among the various stakeholders.

RESOURCE REQUIREMENTS. The resources needed for poverty M&E vary from project to project, depending on the scope of project activities and systems set up for M&E. For example, conducting a full-fledged household survey to collect data on welfare measures may be costly, but alternative rapid assessment methods could provide a more affordable alternative for measuring poverty impacts. Alternatives include approaches such as collecting “core welfare”

indicators (typically assets) that help track changes in consumption and income.

POTENTIAL BENEFITS

Agricultural water-related projects that monitor poverty impacts have improved poverty targeting and tailored activities to maximize benefits during implementation. They have made end-of-project assessments of the returns and impacts from different types of investments, allowing more cost-effective planning and implementation of future investments (box 9.4).

POLICY AND IMPLEMENTATION

CONDUCTING AN IMPACT EVALUATION. The objective of impact evaluation is to measure the results of the project interventions on dimensions of poverty (box 9.5). Impact assessment necessitates answering a counterfactual question, “What would have happened in the absence of the intervention?” Establishing causality is necessary for impact evaluation. Answering the counterfactual requires identifying a comparison or control group that does not receive the project intervention and comparing this group to the treatment group. The control group must match the treatment group in terms of its socioeconomic aspects and the physical characteristics of its site.

Experimental or quasi-experimental designs are generally used to address the counterfactual. In experimental design, the intervention is allocated randomly among all eligible beneficiaries. Experimental designs need to be set up prior to the investment. Quasi-experimental designs, in contrast, attempt to generate control groups after the intervention by means of statistical and econometric methods such as propensity score matching, computing double differences, or using instrumental variables (Baker 2000).

QUANTITATIVE VERSUS QUALITATIVE DATA: Integrating qualitative and quantitative approaches in monitoring and evaluating poverty impacts has proven very effective. Quantitative analysis results in more generalizable results, but qualitative and participatory methods allow in-depth

Box 9.3 India: The Sujala Watershed Project

Plans for the M&E system for the Sujala Watershed project in Karnataka, India, are a good example of how such a system can be set up to evaluate the poverty impacts of an agricultural water project.

Impact indicators to be monitored in the project include the following:

- *Households*—incomes, expenditures (consumption), assets
- *Village/community*—employment and wages, empowerment and equity, including opportunities for women and vulnerable groups and changes in access to services
- *Watershed*—cropping patterns and production, improvements in groundwater levels, and reductions in soil loss

Plans for the baseline surveys include selection of control villages to assess the “without” project situation. Impact assessments are planned at mid-term and at project completion. In addition, the stakeholders will do periodic self-assessments. The project intends to evaluate the poverty impact on small and marginal farmers, landless persons, women, and indigenous people.

Source: Government of Karnataka 2003.

Box 9.4 Monitoring Poverty Impacts in the Uttar Pradesh Sodic Lands Reclamation Projects I and II

Contributing to poverty alleviation by providing land to the landless, together with rehabilitating sodic-affected land, were primary objectives of the Uttar Pradesh projects. Project interventions were targeted to households below the poverty line, and project impacts were monitored by a third party. The evaluation of the pilot project pointed to key areas to strengthen the poverty impact, which received attention in the second project. This included a greater emphasis on strengthening women’s self-help groups and involving them in micro-enterprise activities to augment household incomes. Additionally, to ensure sustainability of reclamation and income from the land, the importance of ensuring that the drainage systems were maintained was emphasized.

Source: Jeeva Perumalpillai, Essex, World Bank, personal communication.

study of selected issues, cases, or events and can provide critical insights into beneficiaries’ perspectives, the dynamics of a particular reform, or the reasons behind results observed in a quantitative analysis. A special attempt can be made to monitor the satisfaction of the poor with the project through focus group or other qualitative methods.

Box 9.5 India: An Example of an Impact Evaluation of Watershed Development Projects

An example of an impact evaluation that also attempted to examine the poverty impact of agricultural water-related projects is a study by the International Food Policy Research Institute (IFPRI) evaluating watershed development projects in India. The primary objectives were to assess the following: (1) Which watershed projects were most successful in raising agricultural productivity, improving natural resources management, and reducing poverty? (2) What approaches enabled projects to succeed? (3) What nonproject factors contributed to achieving these objectives? The study evaluated projects funded and implemented by several donors and state governments, including the World Bank.

The study used mainly quantitative analysis but also drew on qualitative information about the effects on interest groups such as farmers with and without irrigation, landless people, shepherds, and women. The study used a nonexperimental design, relying on an instrumental variable approach to correct for the endogeneity of program placement. Instrumental variables were first used to predict program participation, and then the variation of outcome indicators with predicted values of program participation was examined.

The study covered a 10-year period and relied on baseline survey data from the World Bank and the Indian Council of Agricultural Research villages. The postproject situation was captured through a 1997 survey of 86 villages in Maharashtra and Andhra Pradesh conducted by IFPRI. The survey collected quantitative data at the village, plot, and household level for econometric analysis of the conditions that determined changes before and after the project. Qualitative information on project impacts was collected from interest groups through open-ended discussions. Control villages were selected and roughly matched geographically (data were insufficient for rigorous matching).

The authors measured the impact on household welfare through proxy indicators including the perceived effects of the project on the household, perceived changes in living standards, changes in housing quality, change in percentage of families migrating, perceived changes in real wage and availability of casual employment opportunities. Lack of adequate baseline and monitoring data in the projects was a major limitation to the study.

The study found that participatory projects performed better than top-down approaches. Projects where participation was combined with sound technical inputs performed best of all. The authors also found that equity issues remained a problem and respondents perceived that project benefits rose with landholding size, and that the landless and near-landless people were most likely to report negative effects from projects. For example, across projects while 45 percent of households with 2 or more hectares claimed they had benefited from watershed projects, only 12 percent of the landless and 19 percent of farmers with less than 1 hectare claimed to have benefited. On the other hand, 19 percent of the landless felt that they were harmed by the projects compared to 7 percent of larger farmers. The authors also found that projects run by nongovernmental organizations (NGOs) were associated with higher net returns; however, the econometric results for the model were insignificant.

Source: Kerr, Pangare, and Pangare 2002.

RECOMMENDATIONS FOR PRACTITIONERS

- Involve beneficiaries early in the M&E process. Broad consultations and early involvement of users in the design and implementation of the M&E system will do much to build consensus and ownership.
- Use beneficiary self-assessments and other participatory approaches so that assessments can be made mid-course. There may be a long time lag in realizing a reduction in poverty from agricultural water-related projects, and the poverty impact often cannot be evaluated until well after a project ends.

- Keep the number of indicators collected within manageable proportions.
- Ensure that a good baseline survey is undertaken. Without a proper baseline, it is difficult to monitor progress and evaluate the impacts of investments.

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ASSESSING THE ECONOMIC BENEFITS OF LAND DRAINAGE

What is new? Investment in drainage has the potential to lift out of poverty large numbers of people who live in waterlogged and saline areas. This Innovation Profile discusses how the potential benefits of drainage investment were assessed in two settings. One was dominated by smallholders located on an Indian irrigation system and the other by large farm enterprises typical of Eastern Europe. This Innovation Profile also shows that it is economically feasible to drain a moderately affected area.

In northwest India and other tropical semi-arid areas, irrigation canal systems were built many decades ago, but rising water tables have undone part of the effort, causing waterlogging and soil salinity. In those areas, hundreds of thousands of farmers are watching their already small farms shrink, and their yields and incomes are falling through salinization. This profile discusses a way of assessing the economics of investing in the installation of surface and sub-surface drains in the state of Haryana.

The profile also discusses the method used to estimate the potential benefits of rehabilitating drainage systems in large farm enterprises in the humid lowland areas of Central and Eastern Europe. It is based on work in the East Slovak Lowlands, typical of humid and semi-humid areas in the temperate zone.

The two methods look only at agricultural benefits and do not include estimates of the impact of well-functioning drainage systems on the protection of houses, buildings, roads, and other infrastructure from damage by high groundwater levels and occasional floods or their impact on the quality of drinking water and human and animal health.

OBJECTIVES AND DESCRIPTION: THE NORTHWEST INDIA CASE

The potential benefits of surface and subsurface drainage are equal to the damage caused by waterlogging and soil salinity. This damage can easily and accurately be assessed through a soil salinity classwise analysis, based on sets of data on soil salinity level and crop yield. These data can be collected through systematic samplings within a grid of predetermined dimensions. The required dimensions depend on the size of the project area and the number of samples needed to reflect variations in soils and soil salinity within the area.

To analyze the effect of soil salinity on crop yield and assess the total loss of production due to excess salinity, the data were grouped into classes. Next, the percentage of the project area under each class was determined. The average crop yield at all observation points in a soil salinity class was calculated for all classes. Finally, the relationship between soil salinity level and crop yield was established.

The loss of production due to soil salinity was calculated by subtracting the average crop yield in each of the other soil salinity classes from the average crop yield in soil salinity class I (that is, the soil class unaffected by salinity). Using the proportion of the total area under each class, researchers calculated the weighted average crop loss per hectare. The total crop loss in the project area was calculated by multiplying the average crop loss per hectare by the number of hectares in the area.

From input data also collected at the observation points, the relationship can also be established between soil salinity level and net production value, and the total loss in net production value in the project area can be calculated. This is important, because the loss in net production value due to soil salinity is equal to the loss of net income, and soil salinity affects net crop income much more than it does gross yield. The classification of soil salinity is explained in box 9.6.

If the data are collected by, or under close supervision of, experts who will process and analyze the data, conclusive results can be obtained in one agricultural year (one or two seasons). With 12 expert months, and another 24 laborer months, data collection, processing, and analysis can be completed for an area of 2,000 to 5,000 hectares. The result will be a close assessment of the damage caused by waterlogging and soil salinity and, consequently, a close estimate of the potential benefits of land drainage development.

**OBJECTIVES AND DESCRIPTION:
THE EAST SLOVAK LOWLANDS**

In the East Slovak Lowlands, an assessment was done to determine the financial feasibility of improving the water management systems to attract investment in rehabilitation. To assess the effect on the yield of different crops of subsoiling, flushing the subsurface drainage systems, and cleaning the drainage canals, 12 large experimental fields were divided into two parts, each planted with the same crop. In one part, all three necessary interventions were carried out; in the other part, two out of the three interventions. Both parts received the same amounts of agricultural inputs. At harvest time, in each part an equally wide representative strip was harvested and the yields were compared. Care was taken to ensure comparable soil conditions and microrelief in each strip. The positive yield difference was attributed to the third intervention, and the negative result to its absence.

In addition, daily rainfall was recorded during the entire year. The experiments were repeated twice. By analyzing the collected yield data with the help of a long-term series of annual rainfall data, the long-term effect (or the benefits) of subsoiling, proper subsurface drainage, and canal cleaning could be assessed. In addition to the assessment of the benefits of the three interventions, their costs were also measured through time-and-motion studies.

Box 9.6 Classification of Soil Salinity

Soil salinity classes are categorized based on an interval of four soil salinity units. Soil salinity is expressed as the electrical conductivity of the saturated soil extract (EC_e), and the units are usually expressed in dS/m or mmhos/cm. Class I covers the interval from 0 to 4 dS/m, class II from 4 to 8 dS/m, and so on. Below 4 dS/m, the threshold value for the major agricultural crops, soil salinity barely affects crop yields. Consequently, the class I soils are considered “unaffected,” and the average yield of a specific crop in class I is taken as that crop’s “reference level.” Crop damage due to soil salinity in the higher classes is measured against the class I reference level. Soil salinity in class II is called “marginal,” in class III “moderate,” in class IV “severe,” and in class V “extreme.” In class V, no more crops are grown, because their gross production value scarcely exceeds production costs, excluding labor.

Source: Author.

Box 9.7 Damage from Waterlogging and Soil Salinity in the Gohana Pilot Project

In the project area, 44 percent of the land was unaffected, 33 percent marginally affected, 10 percent moderately affected, 7 percent severely affected, and the remaining 6 percent extremely affected.

- The average per hectare loss in gross production value was 12 percent over the whole project area and 22 percent in the affected area.
- The average per hectare loss in net production value was a good 20 percent over the whole project area, and 37 percent over the affected area.
- Because of the scattered nature of the drainage problem, the losses were “unevenly” spread over the project area.

Source: Author.

**OUTPUT AND IMPACTS:
THE NORTHWEST INDIA CASE**

The study done in the Gohana pilot in northwest India provided reliable estimates of the damage caused by waterlogging and soil salinity in the area. The results of the study are summarized in box 9.7.

General data and results

Even in this area with only a moderate drainage problem, the effect on the weighted average net production value is strong, and it is the loss of net production value that reduces the farmer's income. The experiment was repeated in the (small) Konanki pilot area in Andhra Pradesh in southeast India.

In both Gohana and Konanki, surface and subsurface drains were installed. Cropping intensities, crop yields, and farm incomes substantially increased, demonstrating that land drainage can be central to combating poverty. It is also cost effective, because conserving already irrigated areas by (sub)surface drainage costs only a third as much as building new irrigation systems. Drainage development on the hundreds of thousands of waterlogged hectares in northwest India (Haryana, Punjab, and Rajasthan) could save at least 100,000 farmer families from sinking below the poverty line. Health and living conditions would also strongly improve.

OUTPUT AND IMPACTS:

THE EAST SLOVAK LOWLANDS

The experiments provided an accurate assessment of the benefits and the costs of proper subsurface drainage in the lowland areas of the Eastern Slovak Republic and in similar lowlands in Central and Eastern Europe, as well as a close approximation of the financial feasibility of rehabilitating the drainage systems. At a discount rate of 10 percent, the benefit-cost (B/C) ratio for subsoiling varied from 1.7 to 2.3. The B/C ratio for canal cleaning could not be accurately established because there were not enough suitable sites, but an earlier study indicated that it would be feasible if it increased average yield by only 2 percent. The B/C ratio of the three interventions together was more than 1.25, again at a discount rate of 10 percent. This figure is conservative, because experiments were done in dry years. The inputs were low, however, because of the poor economic state of the farm.

The method is simple and can easily be repeated by trained farm managers, although

analysis of the data requires some expertise. The analysis shows that rehabilitating the drainage systems through canal cleaning, drain-pipe flushing, and subsoiling is financially and economically feasible even when nonagricultural benefits—such as infrastructure protection, reduced waterlogging, flood prevention, and the proper discharge of polluted drainage effluent so that it does not degrade water quality—are not taken into account.

ISSUES FOR WIDER APPLICABILITY

Experiments and studies must be financially independent of the collaborating institutions so that their financial problems will not influence research progress and quality. The availability of machinery and equipment, such as a tractor, a drain flushing machine, and a water tank must be secure at all times. The same applies to equipment for canal cleaning and subsoiling (Eastern Europe only). Progress should be recorded carefully for accurate cost calculation.

Waiting for the drainage component of an irrigation project to become economically feasible is economically and socially questionable. Waiting will only increase crop and income losses, thus increasing impoverishment in the affected rural areas (Asia only).

Areas for project development, whether this is rehabilitation or construction, should be carefully selected, taking due account of soil and water management conditions. In addition, the quality of (farm) management should be considered, as well as the willingness of the prospective beneficiaries.

Project development should include the establishment of (an) institution(s) to secure proper operation and maintenance (O&M) of the newly constructed or rehabilitated drainage systems. The beneficiaries should be closely involved in this O&M.

Good local managers and staff are available. They should be involved from the beginning in planning and implementing the project(s). Expatriate consultants are needed only to coordinate

activities carried out by the multidisciplinary group of local experts and to coach them in the interdisciplinary work.

The M&E of the project activities should be done by a small number of independent foreign consultants with the help of highly competent local consultants willing to do the fieldwork.

If good use is made of the experience gained in earlier projects, successful implementation of financially feasible projects can be achieved. Improving land drainage will have a strong positive effect on the regional economy and poverty. There is no doubt about it.

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This Profile was prepared by Cor de Jong and reviewed by Sarah Cline, Timothy Sulser, and Mark Rosegrant of IFPRI.

GUIDING ENVIRONMENTAL AND SOCIAL SAFEGUARD ASSESSMENT IN AGRICULTURAL WATER PROJECTS

What is new? Safeguard policies aim to integrate social and environmental concerns into project design and the borrowing country's decision-making process. Seven of the World Bank's 10 policies can be triggered by agricultural water projects. To decide whether to apply safeguards to an agricultural water project, Bank staff need to interpret the scope of the policy and may also have to harmonize Bank policies with those of cofunders. Issues for clients include cost and technical demands and the resolution of conflict between national law and the policies.

The World Bank has 10 safeguard policies (box 9.8) designed to achieve the following:

- Be mechanisms for integrating environmental and social issues into decision making
- Provide a set of specialized tools to support development processes
- Support participatory approaches and transparency

OBJECTIVES AND DESCRIPTION

Most safeguard policies require that (1) potentially adverse environmental impacts affecting the physical environment, ecosystem functions and human health, and physical cultural resources, as well as specific social impacts, be identified and assessed early in the project cycle; (2) unavoidable adverse impacts be minimized or mitigated to the extent feasible; and (3) stakeholders be provided with timely information so that they have an opportunity to comment on both the nature and significance of impacts and the proposed mitigation measures.

Mitigation measures are covered by the Disclosure Policy (World Bank 2002a, 2002b), which promotes access to information so that stakeholders in proposed projects can comment on both the impacts and proposed mitigation measures. As a consequence, safeguard policies contribute to democratic processes in developing countries by opening up information sources and promoting the participation of affected populations.

OUTPUTS AND IMPACTS

Water-related agricultural projects are both investment and Development Policy Lending projects where either more water is to be used or the current water supply is to be used more efficiently. These projects include sectoral improvements through the introduction of water use charges, development of water user groups, and devolution of water management responsibilities; development and rehabilitation of infrastructure such as dams, weirs, groundwater pumping, canals, delivery systems as well as dryland water infrastructure such as pans, dams, and bores; improvements in drainage and development of water reuse and water conservation measures; and improved operational practices such as weather forecasting, irrigation scheduling, and O&M activities. Such projects can have both detrimental and beneficial environmental and social impacts.

Typical detrimental environmental impacts from water-related agricultural projects include the effects of surface water withdrawals on downstream ecosystems; effects of increased groundwater use on water-dependent, sensitive ecosystems such as wetlands; and increased concentrations of fertilizers and agrichemicals in runoff and drainage water from agricultural intensification. Water-related agricultural projects can also lead to beneficial environmental impacts—water “saved” through increased agricultural water use efficiencies (water charges, drip irrigation) may reduce pressure on water resources; or improved water application and drainage may reduce environmental degradation and pollutant discharges.

Box 9.8 World Bank Safeguard Policies

OP/BP 4.01 Environmental assessment—An umbrella policy requiring environmental assessments to cover a broad range of potential impacts

OP/BP 4.04 Natural habitats—Avoiding the degradation or conversion of natural habitats unless there are no feasible alternatives and there are significant net benefits

OP 4.09 Pest management—Promoting environmental and biological pest management in both public health and agricultural projects (chemical methods can be supported where justified)

OP/BP 4.12 Involuntary resettlement—Avoiding resettlement where possible and, where not, ensuring that resettled people are fully consulted, share in project benefits, and their standard of living is not reduced

OD 4.20 Indigenous peoples—Ensuring that indigenous peoples are involved in fully informed discussions so that they do not suffer adverse effects, and receive culturally compatible social and economic benefits from Bank-financed projects.

OP 4.36 Forestry—Harnessing the potential of forests to reduce poverty, while integrating forests into sustainable economic development and protecting the environmental services and values of forests

OP/BP 4.37 Safety of dams—Ensuring that new dams are constructed and operated to internationally accepted standards of safety and that existing dams used in a project undergo safety inspection and any necessary upgrades

OPN 11.03 Cultural property—Avoiding or mitigating adverse impacts on cultural resources such as valuable historical and scientific information, assets for economic and social development, and integral parts of a people's cultural identity and practices

OP/BP 7.50 Projects on international waterways—Informing affected riparian countries of proposed projects on international waterways and, if there are objections, referring the proposal to independent experts

OP/BP 7.60 Projects in disputed areas—Ascertaining that the governments concerned agree that the existence of a project in disputed areas does not damage claims made by other governments

BP—Bank procedure; OD—Operational directive; OP—Operational policy; OPN—Operational policy note.

Source: World Bank.

Note: The specific wording and application of these policies can be obtained from the operational procedures and Bank policies themselves. These can be found on the Bank Safeguard Policies Web site at <http://lnweb18.worldbank.org/ESSD/sdvext.nsf/52ByDocName/SafeguardPolicies>.

Typical detrimental social impacts include loss of productive farmland from new or rehabilitated water resources infrastructure, physical displacement of farmers and villages because of new water storage and irrigation schemes, loss of access to traditional water resources by nomadic groups, and disruption to traditional social structures through the influx of people attracted to economic growth areas because of water resources investments.

The policies most likely to be triggered in water-related agricultural projects are *OP/BP 4.01 Environmental assessment*, *OP/BP 4.04 Natural habitats*, *OP 4.09 Pest management*, *OP/BP 4.12 Involuntary resettlement*, *OD 4.20 Indigenous peoples*, *OP/BP 4.37 Safety of Dams*, and *OPN 11.03 Cultural property*. *OP/BP 4.01* is an umbrella policy that allows identification of

potential environmental impacts, some of which may be covered in more detail by other safeguard policies. *OP/BP 4.01* and *OP 4.09* apply to Sector Adjustment Loans as well as to investment loans. All others apply to investment activities.

Projects are categorized by the task team into one of three classes, A, B, or C, representing their possible environmental impacts. Category A projects are likely to have “significant adverse environmental impacts that are sensitive, diverse, or unprecedented”; category B projects are likely to have “adverse environmental impacts”; while category C projects are likely to have “minimal or no adverse environmental impacts.” A fourth category, Financial Intermediaries (FI), is used for projects where the full extent of project investments cannot be foreseen during project preparation, such as

when there is a small grants component. The *Environmental Assessment Sourcebook* (World Bank 1991) and its *Updates* provide information on categorizing projects.

ISSUES FOR WIDER APPLICABILITY

Issues for Bank staff

The wording of the safeguard policies is inevitably somewhat ambiguous and open to interpretation (World Bank 2002c) because not every circumstance can be covered and all ambiguities removed without introducing costly rigidities. Thus, the “significant conversion or degradation of critical natural areas” in the natural habitats policy requires some interpretation, partly because the criticality of an area varies across different interest groups¹ and partly because impacts of agricultural water projects can be difficult to predict. For this reason, the terms of reference of the environmental assessment should include a thorough evaluation of the importance of potentially affected natural areas to different interest groups, the nature and extent of likely impacts in these areas, and possible mitigation measures.

Nor do the policies cover all circumstances. For example, OP/BP 7.50 refers specifically to international surface waters, even though exploitation of transboundary groundwater resources without notifying affected neighboring countries can have just as serious repercussions socially, politically, and environmentally. Thus, projects with transboundary groundwater impacts should be treated in the spirit of this policy so that the underlying purpose of the policy is achieved.

OP/BP 4.12 is one of the most important for water-related agricultural projects, especially those with components involving dams. The policy focuses on involuntary resettlement because of its potential for severe social disruption and loss. However, people accepting voluntary resettlement face many of the same difficulties reestablishing their lives and livelihoods as those involuntarily resettled, but do not benefit from the same level of oversight and protection through the policy.

Only the environmental assessment (OP/BP 4.01) and the pest management (OP/BP 4.09)

policies address development policy lending—an increasingly important component of Bank lending activities (see IN 1.2). Efforts to improve agricultural water resources management through water sector reforms are likely to lead to increases in adjustment loans with their potential for minor social dislocation and environmental improvements.

Most multilateral and bilateral lending agencies have some form of social and environmental safeguard policies. The task team needs to reach an agreement with cofunders and the borrowing country about the application of the safeguard policies. This is not usually difficult, but adds a burden to the work of the task team during project preparation.

Issues for borrowing countries

The safeguard policies can impose a considerable cost on a borrowing country. For example, projects proposed for noncritical natural areas (OP/BP 4.04) have to demonstrate that there are no feasible alternative sites and that the benefits of the project outweigh the loss of the functions of the natural area. Establishing this can be time consuming, costly, and viewed as an impediment to progress by the borrowing country. The longer-term benefits, particularly the ecosystem services supplied by natural areas, should be included in these assessments so that these benefits of protecting natural areas become apparent to the borrowing country.

Borrowing countries may also lack the technical capacity to carry out or oversee environmental assessments for category A and B projects. Impacts such as the downstream effects of changes in river flows from increased irrigation withdrawals can be difficult to assess in any country, let alone those with limited technical capacity. The Bank can assist by assessing the country’s capacity through Economic Sector Work, by providing advice to the country by adding an environmental expert to the task team, and by including components that strengthen the country’s capacity to perform environmental assessments and implement environmental management plans.

The safeguard policies generally represent a higher standard of protection than provided by law in most borrowing countries. Bank disclosure policy requires that more information about projects be made publicly available than is normal in most countries, and the resettlement policy can have more generous eligibility criteria than found in the laws and customs of many borrowing countries (box 9.9).

Discrepancies between the borrowing country and Bank policies can cause resentment about intrusion into internal country affairs. In some cases, the borrowing country may choose to approach another lending institution with less rigorous policies.

Guidance and resources available to Bank staff

The task team should establish the environmental category of a project as early as possible so that an environmental assessment can be commenced, if needed. The assessment of potential environmental and social impacts and possible mitigation measures can then be obtained in time to influence the project design.

The Bank's regional offices and anchor units possess considerable environmental and social expertise. In addition, specialist groups such as the Groundwater Management Advisory Team of the Bank-Netherlands Water Partnership Program (GW-MATE) are available to assist. This expertise should be used to strengthen task teams and to guide country counterparts preparing environmental assessments, social impact assessments, and management plans.

The regional and anchor safeguard staff can advise on interpreting safeguards when the policy appears ambiguous or does not appear to apply directly to project circumstances. In addition, training courses in the application of the safeguard policies are offered by the Quality Assurance and Compliance Unit.

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Box 9.9 Vietnam Water Resources Assistance Project

The Vietnam Water Resources Assistance project will improve farmers' access to irrigation water in six irrigation systems. However, some land will be lost because of canal rehabilitation, and a few households will have to be relocated. The national government's decree on compensation for land acquisition was broadly in conformity with the Bank's policy except that individuals without formal title to land would have been treated less favorably than those with formal title. Through dialogue, it was agreed that all individuals affected, irrespective of their legal status, would be fully compensated.

Source: Author.

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ADDITIONAL INFORMATION

The safeguard policies are available from the Safeguards Web site at <http://lnweb18.worldbank.org/ESSD/sdvext.nsf/52ByDocName/SafeguardPolicies>.

Advice can be obtained from the safeguards units in each of the regional Vice-Presidencies. In addition, the Quality Assurance and Compliance Unit provides training courses in the implementation of the safeguard.

Groundwater Management Advisory Team (GW-MATE) Web site: <http://lnweb18.worldbank.org/ESSD/ardext.nsf/18ByDocName/SectorsandThemesGroundwaterFunctionsandObjectives>.

ENDNOTE

1. Annex A to OP/BP 4.04 provides detail on the definition of significant critical areas.

This Profile was prepared by James Richard Davis and reviewed by Colin Rees and L. Panneer Selvam.

ESTIMATING THE MULTIPLIER EFFECTS OF DAMS

What is new? This Innovation Profile outlines the importance of multiplier effects of large multipurpose water projects and what a multiplier analysis can tell us about their indirect impacts. Multipliers estimate the investment's total (direct and indirect) effects of an investment in relation to its direct effects. Multiplier models based on the Social Accounting Matrix and the Computable General Equilibrium also estimate the impact on income distribution and poverty. This profile also summarizes the first results of a multicountry World Bank study on multiplier effects and income distribution impacts of dams (Bhatia, Scatasta, and Cestti 2005).

Investments in water resources projects including multipurpose dams generate a vast array of economic impacts in their region and at interregional, national, and even global levels. The impacts are both direct and indirect. Indirect impacts are called *multiplier impacts*. Ex post and ex ante evaluations of these projects, when based on a cost-benefit analysis, tend to estimate only direct impacts such as irrigation, hydropower, water supply, fish production, recreational benefits, and flood control. They do not take into account the indirect economic impacts, although they may run up to 90 percent of the direct economic impacts.¹ The multiplier values for large multipurpose dams in Brazil, India, and the Arab Republic of Egypt range from 1.4 to 2.0, meaning that for every one dollar of value added directly by the project, another 40 cents to one dollar were generated through indirect effects.

Recent reports by the Operations Evaluation Department (OED) of the World Bank and the World Commission on Dams also make these points. The OED writes that “dams providing water for irrigation also produce, in general, substantial benefits stemming from linkages between irrigation and other sectors of production,” but no estimates are available on the indirect benefits of

the projects reviewed in the OED report (World Bank 1996, 20). Similarly, the World Commission on Dams states in its final report that “a simple accounting for the direct benefits provided by large dams—the provision of irrigation water, electricity, municipal and industrial water supply, and flood control—often fails to capture the full set of social benefits associated with these services. It also misses . . . their ancillary and indirect economic benefits” (World Commission on Dams 2000, 129).

OBJECTIVES AND DESCRIPTION

The major indirect impacts of dam investments include the following:

- Interindustry impacts from backward and forward linkages that increase demand for outputs of other sectors
- Consumption-induced impacts arising out of income increases generated by the direct dam outputs

Estimating indirect effects is a necessary step to improve our understanding of the impact of dams. Indirect effects are induced by the linkages between the direct effects and the rest of the economy.

Water releases from a dam to irrigate crops increase agricultural output. Raised output requires more seed, fertilizer, pumpsets, diesel engines, electric motors, tractors, fuels, electricity, and so on. Increased output also encourages entrepreneurs to set up food-processing (sugar factories, oil mills, rice mills, bakeries) and other industrial units. Similarly, water releases from a multipurpose dam to provide electricity for households generates new demand for appliances and prompts the establishment of new businesses and factories. Changes in industrial output require more inputs from sectors such as steel, energy, and chemicals, among others. In sum, water releases for power and irrigation generate demand for inputs and opportunities for processing.

Increased industrial and agricultural output generates additional household incomes. Higher incomes raise consumption of goods

and services, which, in turn, encourages production of agricultural and industrial commodities. Changes in wages and prices have both income and substitution effects on expenditure and on saving decisions of owners of the various production factors, which further affects demand for outputs in both the region and the wider economy. Induced impacts reflect the feedbacks associated with these income and expenditure effects and also include impacts on government revenues and expenditures.

For estimating a project multiplier value (table 9.1) for a dam, we need a numerator that estimates the regional value added under a “with project” situation as well as the regional value added under a “without project” situation. We also need a denominator that estimates the value added from the sectors directly affected by the major outputs of the dam (such as agricultural output, hydroelectricity, and water supply).

For example, the multiplier for the Bhakra Dam in India has been estimated at 1.9, meaning that for every 100 paise of value added directly by the dam, another 90 paise were generated in the region through indirect effects.

How to conduct multiplier effect analysis for a project

Multiplier analysis requires a multisectoral macro model of the region with quantitative information on the linkages of sectors and institutions (government, households, firms). Given resources and time constraints, the selection of a multiplier analysis tool takes into account the availability of input/output (I/O) tables or social accounting matrix (SAM) databases and of computable general equilibrium (CGE) models for the region where the project is located.

The World Bank completed a multicountry study (Bhatia, Scatasta, and Cestti 2005) on the multiplier effects of dams (box 9.10) in 2003. The studies include three large dams in Brazil, India, and Egypt with multiregional or economywide impacts; and one small check dam in India with considerable local and spillover effects.

For the Brazilian case study, a semi-input/output (S-I/O) model was calibrated for the northeast

Table 9.1 Values of Variables Required for the Estimation of a Project Multiplier of the Bhakra Dam Project, India	
Definition of project multiplier	Regional value added with project <i>minus</i> regional value added without project Value added of agriculture and electricity with project <i>minus</i> value added of agriculture and electricity without project
Source: Author.	

region, with technical coefficients, shares, and rates computed based on the 1992 regional I/O matrix (Bhatia, Scatasta, and Cestti 2005). One version of the model assumes that the construction of large dams in the northeast would relax supply constraints sufficiently to treat as non-tradables all sectors but those directly affected by the dams. A second version of the model is built with supply constraints on 10 additional sectors, treated as tradables.

SAM-based, fixed-price, multiplier models have been used to provide a quantitative analysis of the direct and indirect impacts and income distribution impacts of the Bhakra Dam and Bunga Check Dam in India (Bhatia, Scatasta, and Cestti 2005, ch. 3 and 4). For estimating the multiplier impacts of increased agricultural production and electricity output available from the Bhakra Dam, a SAM-based multiplier model was calibrated for the state of Punjab for the period 1979–80, almost 20 years after the dam was completed. The effects are divided into direct and indirect. The indicators, capturing the effects, include production and value added, as well as disaggregated household incomes and their distribution. For the Bunga case study, a SAM-based model for the period 2000–1 was used to assess the economic impacts of additional irrigation available from two check dams in the village.

The analysis of the impacts of the Aswan High Dam (Bhatia, Scatasta, and Cestti 2005, vol. 2, ch. 4) is based on an extended version of the

Box 9.10 Multiplier Values and Poverty Impacts of Selected Dams in Brazil, India, and Egypt

The World Bank has just completed a multicountry study on multiplier effects of dams.

Main features of dams and their outputs

1. Sobradinho Dam and cascade of reservoirs in Northeast Brazil
Hydropower: 10.5 GW capacity; irrigation 330,000 hectares
2. Bhakra Dam system in northwest India
Hydropower: 2,880 MW; annual output 14 billion kWh; additional irrigation 7.1 million hectares
3. Aswan High Dam, Egypt
Hydropower: 2100 MW; annual output 8 billion kWh per year; perennial irrigation to 350,000 hectares.
4. Check dam at Bunga village, Haryana, India
Irrigation: 395 hectares

Multiplier values for each case study

Multipliers are summary measures that reflect the total (direct and indirect) effects of a project in relation to its direct effects. The multiplier values, though not strictly comparable across case studies, vary from 1.4 to 2.0. The multiplier values in the case study of Sobradinho Dam in Brazil show for every unit of value (CR\$) generated by the sectors directly affected by the dams, another unit could be generated indirectly in the region. Estimates for the Bhakra Dam indicate that for every rupee (100 paise) generated directly, another 78 to 90 paise were generated in the region as downstream or indirect effects. For the Aswan High Dam, multiplier values range between 1.22 and 1.4 in the three simulations. The multiplier value for the impact of check dams in the Bunga village is estimated as 1.41.

Income distribution and poverty reduction impacts

The multisectoral, economywide models used for multiplier analysis also provide quantitative estimates of income distribution and poverty impacts of dams. For example, in the case of the Bhakra Dam, agricultural labor gained an estimated 65 percent in income as compared to a rural average increase of 38 percent under the “with project” scenario compared with a hypothetical situation where the project had not been undertaken.

For the case study on the Aswan High Dam, household consumption estimates were available in quintiles of rural and urban households. The gain for the lowest quintile of the rural population was a 20 percent increase over a “without” project hypothetical case. The other four quintiles averaged gains of 22 percent.

In the case of the Bunga Check Dam, the household categories are landless workers, marginal farmers, small farmers, and large farmers. The increase in the incomes of marginal farmers was 50 percent compared with the average increase of 48 percent under with/without project situations. The increase in the income of small farmers was 59 percent compared to the average increase of 48 percent under with/without project situations.

Source: Bhatia, Scatasta, and Cestti 2005.

IFPRI standard CGE model. For comparison, the impact has also been simulated with the model run in a fixed-price multiplier mode (replicating a SAM multiplier analysis). The database uses a SAM for 1997. The effects of the dam that have been covered are changes in the supplies of irrigated land and water; changes in the supplies of electric power; and changes in yields and production technology (primarily changes in fertilizer use). The analysis covers the main direct and indirect effects of the dam, including disaggregated household incomes and their distribution, in a typical year during its lifetime.

OUTPUTS AND IMPACTS

The results from the World Bank multicountry study on multiplier effects of dams are given in box 9.10. In addition to multiplier values, the multisectoral, economywide models used for multiplier analysis provide quantitative estimates of income distribution and poverty impacts of dams. The SAM-based, fixed price, multiplier models and CGE models provide income and consumption estimates under with/without project situations for various household groups (rural self-employed, agricultural labor, marginal farmers, household

quintiles in rural and urban areas). These data have been used to compute “gains” or “losses” associated with the dam for each category of household (box 9.10).²

ISSUES FOR WIDER APPLICABILITY

Investments in irrigation and hydropower projects have very significant indirect economic impacts that could be as high as 90–100 percent of direct economic impacts. Such indirect impacts must be taken into account in a comprehensive analysis of the economic, social, and environmental impact of large water projects. The benefits from irrigation and hydropower projects to agricultural labor, the poorest rural group, are sometimes higher than benefits to other households. Thus, investments in large water projects may help reduce poverty in the region and beyond.

Multiplier analysis is important for large water projects—agricultural and other infrastructure projects that have significant regionwide impacts. Such an analysis should be carried out for all projects where it is important to evaluate indirect impacts and impacts on the rural and urban poor or agricultural labor households or tribal populations. Some of the potential investments suitable for a multiplier analysis are as follows:

- Large-scale surface or tubewell irrigation projects
- Multipurpose dam projects
- Hydropower projects
- Projects that include a river-link to bring water to a region
- Water conservation programs

The design and application of modeling techniques that compute multipliers can be used to explore the impacts on expected project outcomes of alternative assumptions about sector characteristics, policy packages, and structure of the economy. Economywide models (SAM-based, fixed price, or CGE) should be used for assessing the full range of direct and indirect development impacts of dam projects, includ-

ing the impacts on income distribution and poverty reduction. Such assessments are necessary in the context of ex post evaluations, which can be a valuable tool for the identification and design of alternatives for new projects.

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ENDNOTES

1. It is sometimes asserted that, in cost-benefit analysis, "Shadow prices that include carefully traced indirect changes in value added include the multiplier effects while minimizing the danger of double counting." And ". . . most of the multiplier effect is accounted for if we shadow-price at opportunity cost" (Gittinger 1982, 61). However, in practice, when cost-benefit analysis is performed for large water projects, shadow prices are not estimated in a regional

framework and the use of shadow prices may not include multiplier effects.

2. Some of the impacts on the poor in other regions are not captured by the multiplier analysis carried out for a particular region. For example, in India, the urban poor have also benefited from surplus foodgrains from Bhakra distributed all over the country through *fairprice* shops. Bhakra Dam contributed 30 million tons, 60 percent of total foodgrains procured by public distribution agencies during 2000–1. Remittances (around Rs 3,548 million or US\$75 million during 1995–6) sent by migrant laborers working in the Bhakra command have benefited millions of poor in the villages in Bihar and Uttar Pradesh, with resulting multiplier and downstream effects.

This Profile was prepared by Ramesh Bahtia of Resources and Environment Group, New Delhi, and reviewed by Sarah Cline, Timothy Sulser, and Mark Rosegrant of IFPRI.

BENCHMARKING FOR IMPROVED PERFORMANCE IN IRRIGATION AND DRAINAGE

What is new? Increasing water demand from nonagricultural sectors is placing severe pressure on the irrigation and drainage sector to reduce the abstraction of water from surface and groundwater systems. Performance assessment within the irrigation and drainage sector has been widely discussed in recent years, and genuine attempts are now needed to improve performance. Benchmarking is a practical approach to set realistic targets for key processes. It introduces competition in a setting characterized by natural monopoly and presents regulators and senior management with a tool for M&E progress in management and resource use. World Bank staff can make the difference in promoting benchmarking, by using such an assessment as part of project preparation.

Irrigation and drainage schemes in many countries are monopoly enterprises managed by government agencies, frequently operating with little accountability to the captive water users. Service delivery, often poor—unreliable, inadequate, and untimely—impairs agricultural production, especially on farms at the tail end of the system. Excess water results in waterlogging and loss of crop production.

Benchmarking offers an opportunity to compare performance between irrigation and drainage schemes, identify best practices, and replicate them on schemes that perform less well. It makes information on performance available to stakeholders—in particular, water users. It is an important addition to performance-assessment procedures because it helps set achievable targets.

Benchmarking is about moving from one level of performance to another. It is about changing the

way in which irrigation and drainage systems are managed and about raising the expectations of all parties as to what performance is achievable. It is a change-management process that requires identification of shortcomings, and then acceptance by key stakeholders of the need, and pathways for achieving the identified goals.

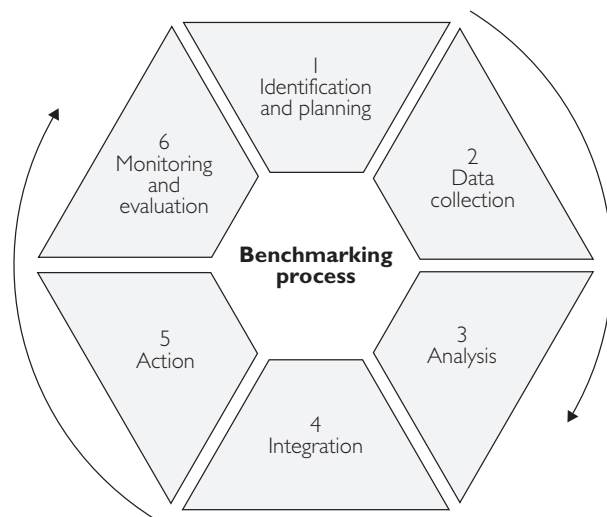
OBJECTIVES AND DESCRIPTION

Benchmarking enables an organization to make an objective comparison between its own performance and that of best practice elsewhere. It is defined as “a systematic process for securing continual improvement through comparison with relevant and achievable internal or external norms and standards” (Malano and Burton 2001).

Benchmarking is part of a strategic planning process that asks and answers such questions as, “Where are we now?” “Where do we want to be?” and “How do we get there?” Of course, farmers and managers may use the same data to compare their schemes with others.

There are six key stages in benchmarking (figure 9.1):

FIGURE 9.1 STAGES IN BENCHMARKING



Source: Malano and Burton 2001.

1. *Identification and planning.* The objectives of the benchmarking program and key processes contributing to performance are defined. Organizations with similar processes are identified, key performance indicators are formulated, and a data acquisition program formulated. Use of key descriptors (box 9.11) enables similar schemes and processes to be identified for comparison.
2. *Data collection.* Data are collected and performance indicators calculated. These data are for the scheme under review and other identified schemes and will include process and output performance indicators. Additional data may have to be collected for the benchmarking exercise beyond those already collected for day-to-day system management, operation, and maintenance.
3. *Analysis.* Data are analyzed and the performance gap(s) identified in the key processes. The analysis also identifies the cause of the performance gap, and the action(s) to close the gap. Recommendations are formulated from the options available, reviewed, and refined. Further data collection may be required for diagnostic analysis if certain processes are not fully understood.
4. *Integration.* To achieve change, the action plan has to be integrated into the operational processes and procedures, requiring acceptance by key stakeholders. Benchmarking programs may fail at this stage if insufficient attention is paid to winning acceptance for the action plan. Increasingly, service contracts between the irrigation and drainage service provider and water users are being introduced, allowing water users to play a key role in setting service delivery performance targets. Information on realistic and achievable targets can be obtained through the benchmarking process of identifying best practices and service providers to be held accountable to levels of performance achieved on similar schemes.

Box 9.11 Descriptors for Irrigation and Drainage Schemes

- Irrigable area
- Drained area
- Annual irrigated area
- Climate
- Water resources availability
- Water source
- Average annual rainfall
- Average annual reference crop potential evapotranspiration (ET)
- Method of water abstraction
- Water delivery infrastructure
- Type of water distribution
- Type of drainage
- Predominant on-farm irrigation practice
- Major crops (with percentages of total irrigated area)
- Average farm size
- Type of irrigation system management
- Type of drainage system management

Source: Malano and Burton 2001.

5. *Action.* Implementation of proposed actions, to which leadership by senior management is key.
6. *Monitoring and evaluation.* An important part of the change-management program is monitoring the implementation of the plan and its impact on the key processes as disclosed through monitoring of the performance indicators (box 9.12). Stakeholder monitoring is key.

OUTPUTS AND IMPACTS

International benchmarking draws on the experience of the program started by the Australian National Committee of the International Commission on Irrigation and Drainage (ANCID) in 1998. During 1997–8, the committee reported that 33 irrigation systems were covered, using a limited set of performance indicators. Subsequent annual benchmarking exercises (ANCID 2000) reported on 46 systems using 47 performance indicators in four key management areas: system operation (7 performance indicators), environmental management (5 performance

indicators), business processes (22 performance indicators), and financial management (13 performance indicators).

Similar initiatives have since been launched in other countries. In Sri Lanka, Jayatillake (2003) reports work by the Irrigation Management Division of the Irrigation Department to benchmark scheme performance across the country. Cropping intensity across 52 schemes was a starting point for identifying relative performance, and a range of between 0.35 and 2.0 was found. In five schemes in one water resources system, benchmarking was used to reduce the period of water issues made from reservoirs during the Maha and Yala seasons in order to conserve limited water supplies (figure 9.2). Further international comparative assessments were then made with other rice-based schemes using the Online Irrigation Benchmarking Service (OIBS 2003) benchmarking tool (figure 9.3) of the International Water Management Institute (IWMI).

Statewide benchmarking of medium- and large-scale irrigation and drainage schemes has been carried out in Maharashtra, India (Sodal 2003). Five key output and process indicators have been identified: irrigation potential created and utilized; seasonal and

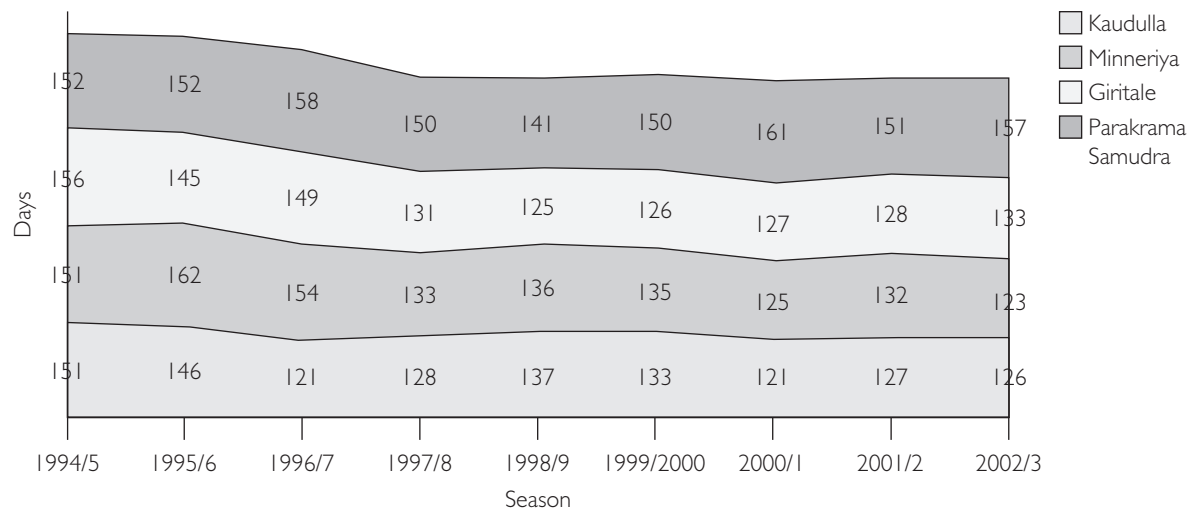
Box 9.12 Widely Accepted Benchmarking Performance Indicators

- Annual irrigation water delivery per unit irrigated area (cubic meters per hectare)
- Main system water delivery efficiency
- Total annual volume of drainage water removal (cubic meters per year, cubic meters per hectare)
- Drainage ratio
- Cost-recovery ratio
- Total management of operation and maintenance (MOM) cost per unit area (dollars per hectare)
- Total maintenance expenditure per unit area (dollars per hectare)
- Total gross annual agricultural production per unit area (tons per hectare)
- Output per unit of irrigated area (dollars per hectare)
- Output per unit of water consumed (dollars per cubic meter)
- Water quality (chemical, biological, salinity)
- Change in water table over time (meters)
- User satisfaction with service delivery
- Complaints by users

Source: Author.

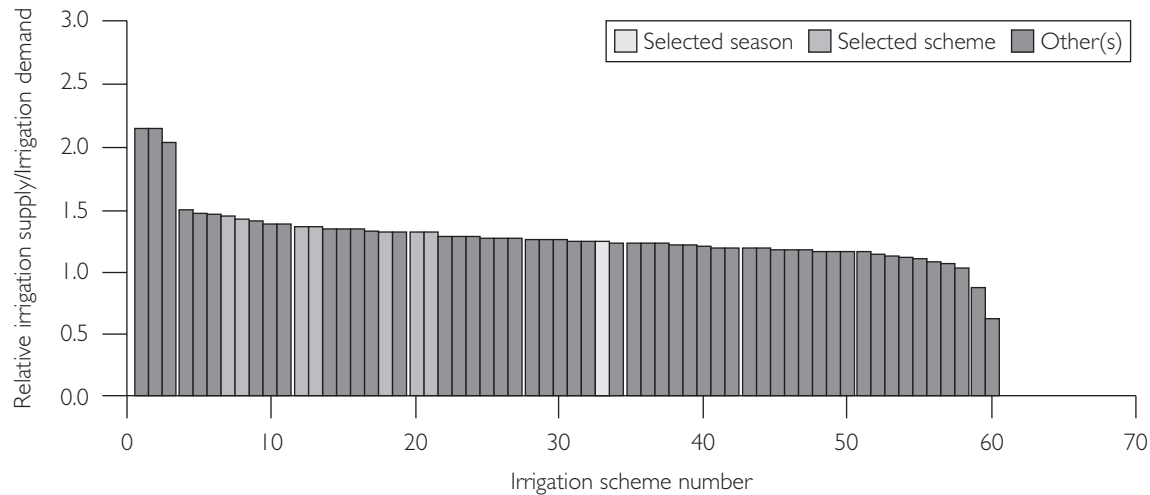
total annual irrigated area; water use efficiency; recovery of irrigation water charges; and crop yields. With the basic data collected, work is now underway to identify the better-performing schemes and the processes contributing to this performance.

FIGURE 9.2 REDUCTION OF MAHA SEASON WATER ISSUES THROUGH BENCHMARKING



Source: Jayatillake 2003.

FIGURE 9.3 PLOT OF COMPARATIVE ANALYSIS USING THE ONLINE IRRIGATION BENCHMARKING SERVICE



Source: OIBS 2003.

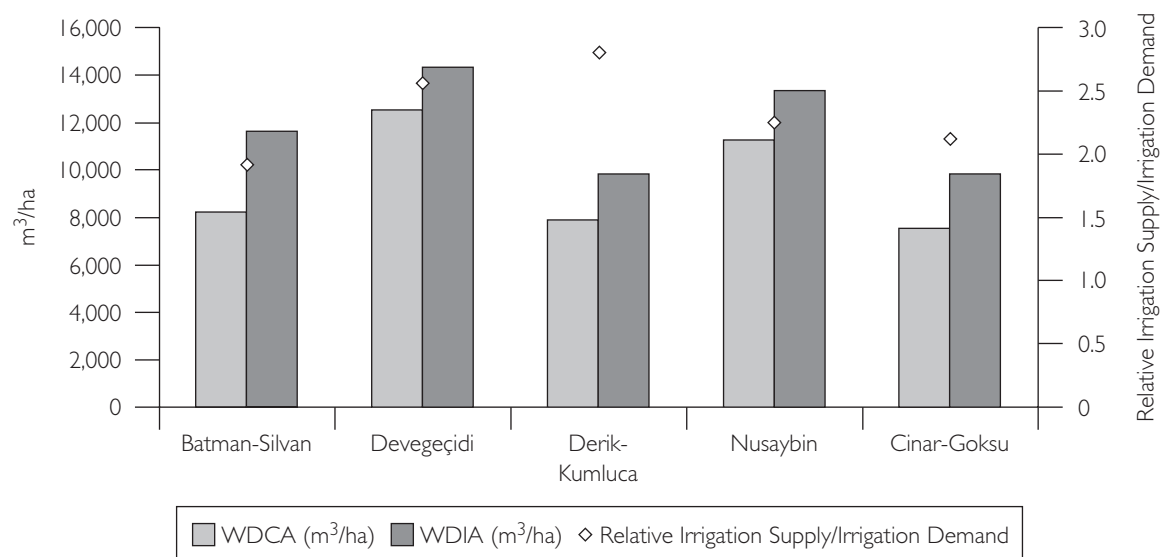
In Turkey, Cakmak et al. (2003) applied the preliminary set of indicators presented by Malano and Burton (2001) to five schemes, identifying noteworthy differences in water delivery performance (figure 9.4). From this study, the better-performing schemes were identified, one difficulty encountered being that different schemes performed best according to different indicators. This emphasizes the need to be clear at the outset on identifying the key objectives of

a scheme (such as maximization of crop production, or protection of livelihoods), and selecting key performance indicators accordingly.

ISSUES FOR WIDER APPLICABILITY

Benchmarking is a means to understanding current relative performance of irrigation and drainage schemes in a growing number of countries. Most schemes in the initiative supported by

FIGURE 9.4 COMPARATIVE PERFORMANCE OF WATER DELIVERY IN FIVE TURKISH SCHEMES



Source: Cakmak et al. 2003.

Note: m³/ha = cubic meter per hectare.

the World Bank, the International Commission on Irrigation and Drainage (ICID), the Food and Agriculture Organization (FAO), and IWMI are in stages 1, 2, and 3, although some reports have been received that management changes have been made based on benchmarking results. To some extent, the first two stages are the easy part. More difficult is the identification of the reason(s) for performance gaps between different schemes and the action needed to raise the performance of the less well-performing schemes. The true impact of the benchmarking initiative will be felt when reports are received detailing action in stages 4 and 5.

As with any change-management process, key factors in ensuring success in stages 4 and 5 are strong leadership, communication, and gaining ownership. Strong leadership is needed to create the future vision, to develop strategies, and to make the change happen. Communication is needed with stakeholders to provide information gained from the gap analysis and to clearly identify the benefits to be derived from changing the way things are done. This should be supported by measures to gain ownership of the proposed changes such as meetings with stakeholders to discuss and debate the proposed changes.

World Bank staff can make a difference in promoting benchmarking by using such an assessment as part of project preparation. The current version of the Project Appraisal Document (PAD) includes a section for key performance indicators to enable M&E. The choice of such indicators is generally made on an ad hoc basis, and the resulting list does not facilitate any comparison between similar projects. Hence, applying the proposed stepwise methodology would enable management to implement M&E based on more meaningful and comparable indicators.

For schemes in the public sector, benchmarking is a political issue, assuming a genuine desire and rewards for improving performance. Governments and reform advocates may use benchmarking to put reform of irrigation management on the national agenda. Public scorecards may prompt environmental groups and

other nonirrigation stakeholders to demand improvements and an end to wasteful use of land and water resources, as has happened in the state of Victoria, Australia. Better performance is about better resource use, more productive agriculture, and enhanced livelihoods, particularly for those with limited access to water within irrigation and drainage systems.

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This Profile was prepared by Martin Burton of ITAD~Water Ltd, Hector Malano of University of Melbourne, Australia, and Ian Makin of IWMI. It was reviewed by Maria Saleth.

INNOVATION PROFILE 9.5

APPLYING ENVIRONMENTAL AND SOCIAL SAFEGUARD POLICIES TO AGRICULTURAL WATER OPERATIONS AND MONITORING THEM DURING THE PROJECT CYCLE

What is new? The Bank's Environmental and Social Safeguard Policies ("Safeguards") are mandated instruments to help integrate environmental and social considerations in the planning and implementation stages of the project cycle. This Innovation Profile reviews adverse environmental and social impacts associated with agricultural water operations, steps needed to mitigate such impacts in the sector policies and the project cycle, and problems observed and lessons learned in the design and implementation stages of past projects. The importance of evaluating institutional arrangements and ensuring monitoring of agreed mitigation measures is stressed.

OBJECTIVES AND DESCRIPTION

This Innovation Profile elaborates on IP 9.2, which provides guidance on the incorporation of the Bank's Safeguards into agricultural water operations such as irrigation and drainage, water logging and salinity control, groundwater abstraction, and water reuse and conservation at sectoral and project levels. It is designed for those in agriculture and water sector agencies specifically concerned with the planning and management of investment operations, including preparation and implementation of environmental and social assessments, supervision of tender contracts, and monitoring and evaluation of mitigation measures.¹ It may also prove useful to government environmental agencies and other relevant organizations responsible for assisting the agricultural sector in the application of Safeguards, as well as to NGOs and the public.

This Innovation Profile identifies significant potential environmental and social impacts (direct and indirect) normally associated with

agricultural water operations. It demonstrates how, for effective and sustained application of Safeguards, mitigation measures may be integrated into the project cycle to ensure timely management and coordination within and across the agriculture sector. The need for prior review of the relevant policies, legislation, and regulations and the importance of appraising agriculture and water sector administrative/institutional arrangements and capacity are stressed. Finally, this Innovation Profile cites issues that the Bank and the borrower need to recognize as particular challenges to mainstreaming environmental and social safeguards at project design and implementation stages.

POTENTIAL ENVIRONMENTAL AND SOCIAL IMPACTS OF AGRICULTURAL WATER PROJECTS

The potential environmental impacts of projects may be direct, indirect, or cumulative. Direct environmental impacts (also known as primary impacts) are caused mainly by such development actions as water abstraction, diversion or impoundment, and land grading, and include loss of habitat as well as modifications to the hydrology of watersheds and to the water and salt content of soils. Direct impacts also involve the human environment, especially displacement of indigenous peoples or rural settlements or disruption of their lifestyles, as well as increased incidence of water-borne diseases, particularly when reusing irrigated wastewater. Unless appropriately mitigated, other factors such as constraints on access to water, land, and vegetation may result in significant loss or reduction of incomes of landowners, tenants, and sharecroppers. Extensive ditching and related excavations associated with a major drainage project may potentially intersect sites of local or national cultural significance.

Indirect impacts (also known as secondary impacts) may sometimes have more profound consequences than do direct impacts. They may affect larger geographic areas of the environment than anticipated and continue well after project completion. Examples include gradual degradation of vulnerable ecosystems such as wetlands, seawater intrusion into downstream

freshwater systems, and overpumping of groundwaters. Other common indirect impacts associated with new or rehabilitated projects involve increased deforestation, influx of settlers, deterioration of surface water quality through erosion of land cleared or modified for construction to enhance agricultural productivity, and the application of agricultural chemicals. Downstream indirect impacts may be in the form of reduced agricultural productivity and incomes due to change in water levels and the like.

Cumulative impacts can generate additive or synergistic impacts and result in damage to the functions of neighboring ecosystems. This is particularly the case with investments involving multiple subprojects, for example the impacts of the creation of access roads for transporting produce to markets or the establishment of small check dams in a concentrated area. Other cumulative impacts involve modifications to river or stream flows and maintenance of water-dependent ecological functions and services in a catchment area. (See box 9.13.)

Virtually all undesirable impacts may be avoided or controlled by the adoption of mitigation measures. This may be attained by the formulation of environmentally and socially sound designs and appropriate institutional arrangements for implementation, the implementation of contract clauses by the contractor to ensure environmentally and socially sound construction and work practices, and diligent monitoring and supervision.

INTEGRATING ENVIRONMENTAL ASSESSMENT AND OTHER SAFEGUARDS INTO INVESTMENT OPERATIONS

The integration of Safeguards into investment operations consists of several steps:

Review of relevant policies, laws, and regulations for water sector operations

The first step involves a broad review of the country's current policies and legislative and regulatory practices relevant to the application of the Bank's Safeguards and determining levels

Box 9.13 Tanzania: Social Action Fund Project

The importance of maintaining river flows has been demonstrated in several subcomponents supported under this project. Completed irrigation works abstract water from neighboring rivers that, in some cases, have resulted in denying any downstream flow during the dry season. Downstream users have been marginally affected but the impact on river ecology has been substantial and is under investigation by the Department of Environment.

Increasing realization that flows are critical to maintaining ecosystems has generated moves to understand and describe links between flows and ecosystem functioning so that "environmental flows" can be specified and thus minimize the loss of valued ecosystem features. This realization may be mobilized to describe flows for a river that will (1) minimize or mitigate the impacts of new water resources development, (2) rehabilitate systems impacted by past developments, and (3) allow calculation of the costs of compensating people for such impacts.

Source: Author.

of complementarity and departure. Most countries have enacted environmental laws constituting the legislative and regulatory basis for conducting an environmental assessment (EA)—which includes an assessment of social dimensions—as part of project development and implementation; articles and regulations may also list project categories subject to EA and, by inference, social assessment (SA), and other Safeguards. They may also have sector guidelines covering safeguards and these should be consulted during the review.

Invariably, regulations require a clear definition of the rights and obligations of the investing party (government authorities and/or the private sector) and the general public. Consequently, before initiating any activity, there should be a clear understanding of all Safeguard procedures to follow and authorities and other stakeholders (including the public) to be engaged and consulted. In particular, all parties should know the required EA/SA procedures to follow; the assigned responsibilities to prepare and approve the EA, Environmental Management Plan (EMP), and/or the SA—and, as required, a Pest Management Plan (PMP) and other appropriate mitigation plans; and, arrangements to monitor and evaluate the application of the relevant Safeguards. Such

parties should also know what sanctions might be imposed in cases of noncompliance.

Many countries have signed several international conventions and agreements that serve as guidelines for environmental protection in agriculture and water resources projects. These target biodiversity conservation, wetlands of international importance, world cultural and natural heritage, migratory species, climate change, desertification, and hazardous wastes. The advice of the environment authority or equivalent organization should be sought concerning the conventions' and agreements' application to agricultural water projects.

REVIEW OF SECTOR-SPECIFIC POLICIES, REGULATIONS, AND PROCEDURES

A parallel analysis should be undertaken of existing sector-specific policies, responsibilities, and regulations (along with a review of the sector investment planning process for review and approval of investment projects) to determine whether environmental and social Safeguard issues are covered adequately in the processing of both sectorwide and project-specific investments. This includes appraisal of in-country capacity for the effective application of Safeguards and, as appropriate, recommending means to strengthen relevant institutions for effective execution of investments. This is especially critical for sectorwide investments.

It is important to ensure that government and private sector units responsible for contract management, quality control, and monitoring at regional and district levels have clear objectives and procedures, including those for reporting the effective application of all Safeguards during implementation.

In keeping with the requirements of the Environmental Assessment Safeguard Policy (OP/BP 4.01), a review should be conducted of public consultation/participation and grievance redress mechanisms and practices. In addition, the borrower should make the draft EA (for category A projects) or any separate EA report (for category B projects)

available in-country in a local language and at a public place accessible to project-affected groups and local NGOs prior to appraisal. (See table 9.2 for the classification of EA categories.) It is good practice to disclose the draft EA report through the information-sharing agencies, such as the InfoShop of the World Bank.

Review of Bank and other donor Safeguard requirements

The Bank's Safeguard policies should be reviewed with the borrower during the initial stages of project preparation. For the most part, Bank and borrower EA policies will be complementary, though differences sometimes occur over project classification, public consultation, or disclosure. Such differences should be resolved as early as possible. Other Safeguards may not be as well accommodated and require special attention and defining arrangements for their effective implementation with the borrower. If the project involves other donors, steps should be taken to ensure complementarity and consistency in the application of all relevant Safeguards. Where necessary, an environmental and social management framework should be developed to fill any gaps that may exist between local laws and regulations and international best practice.

Review of the project cycle

The EA Safeguard policy is specifically designed to integrate EA and other Safeguard requirements with the project cycle. This integration is essential to providing timely environmental and social information for decision making at key stages in the project cycle—when findings may indicate practical siting and design changes—to avoid or minimize adverse impacts or better capture the project's benefits. Sector agencies and other parties have the opportunity to review and comment on a project as it is formulated and, where necessary, require changes to avoid or reduce adverse impacts *before* irrevocable project decisions are made. Likewise, all parties can monitor the mitigation measures to ensure their implementation to a satisfactory standard.

The Bank's increasing use of programmatic, sector-based loans and time-slice investments involving multiple subprojects has stimulated the use of the Sectoral Environmental Assessment (SEA). The assessment undertakes a sectorwide environmental and social analysis of policies and investment strategies *before* major decisions are determined and supports the integration of Safeguard concerns into long-term development and investment planning. SEAs are also suitable for analysis of institutional, legal, and regulatory aspects related to the sector and for making recommendations on Safeguard standards, guidelines, law enforcement, and training, thus reducing the need for similar analysis in downstream EA work. Details on further advantages and use of SEAs may be found in World Bank (1993).

For EA and other Safeguards to be incorporated into sectorwide and project-specific activities, it is essential to understand the project and the relationships within and between the sector and its partners, including the private sector. This will help determine the particular Safeguard activities to be synchronized with each stage of the project cycle and identify the parties responsible for these actions.

A summary of the triggers and mechanisms for achieving policy objectives of each Safeguard is provided in table 9.2.

The application of Safeguards within the project cycle involves several stages:

STAGE I: SCREENING (CLASSIFICATION) OF PROJECTS

Screening serves two major purposes: to determine if proposed projects require an EA or the application of other Safeguards, and to indicate actions to ensure compliance with the relevant Safeguards.

OP/BP 4.01 (Environmental assessment) classifies the proposed project into one of four categories (A, B, C, or FI) depending on the type, location, sensitivity, and scale of the project and the nature and magnitude of its potential environmental impacts. Consequently, the Task Team needs to determine classification of the

proposed project with the borrower, the need for an EA, and the likely level of environmental planning and management. Depending on the country, an SA may be required as a separate document. However, the Bank and the borrower should ensure the integration of environmental and social concerns and their mitigation for final decision making.

STAGE II: PREPARATION OF THE EA/SA (SCOPING)

Scoping involves identifying and narrowing down potential environmental and social impacts of the project (including alternatives) so that efforts focus solely on those likely to be of significance. For a project to be properly scoped, a site visit and preliminary consultations with relevant stakeholders must be included. It is important not only to cover all environmental and social issues known at inception of the project (and identified during screening), but also to allow breadth and flexibility so that unanticipated impacts may be identified and, if significant, addressed at any time during the project cycle.

Alternatives to a proposed project are a major requirement of the Safeguard on EA and should be explored at this stage. They may include improving the efficiency of existing projects, such as the adoption of integrated pest management (IPM), and locating an irrigation or drainage project where adverse environmental and social impacts may be minimized. The different impacts described should indicate which are reversible or unavoidable and which may be mitigated. The analysis should address the costs and benefits of each alternative and incorporate the estimated costs of any associated mitigation measures. The alternative of maintaining the current status should be included for comparison.

It is also essential at this stage to prepare Terms of Reference (TORs) for the EA/SA and obtain the necessary expertise to conduct the assessments. Special studies such as those on resettlement and pest management and the necessary specialists to conduct them should be noted. The Bank and the borrower should subject the TORs to review and approval by the relevant Bank specialist(s) and the borrower's environmental regulation agency.

Table 9.2 Policy Triggers and Mechanisms

Policy	Triggers	Mechanisms for achieving policy objectives
OP/BP 4.01 Environmental assessment	When a project is likely to have potential (adverse) environmental risks and impacts in its area of influence.	Classification of the project as Category A, B, C, or FI according to the nature and magnitude of potential environmental impacts. For Category A and B projects, the borrower prepares an EA report. Depending on the project and the nature of the impacts, a range of instruments can be used: Environmental Impact Assessment, Environmental Audit, Hazard or Risk Assessment, and EMP. A sectoral or regional EA is required when the project is likely to have sectoral or regional impacts.
OP/BP 4.04 Natural habitats	When a project has the potential to cause significant conversion (loss) or degradation of natural habitats.	The environmental assessment should identify any critical natural habitats within a proposed project's area of influence. Bank-supported projects must avoid significant conversion or degradation of any critical natural habitats. If significant conversion or degradation of noncritical habitat is needed, the project must include mitigation measures acceptable to the Bank.
OP 4.09 Pest management	When procurement of pesticides or pesticide application equipment is envisaged or when existing pest management practices are not based on IPM.	Pest and pesticide management issues relevant to the project should be addressed in the EA. A separate PMP is prepared when there are significant pest management issues or when financing of substantial quantities of pesticides is envisaged (EP 4.01, annex C). A list of pesticides authorized for procurement under the project should be established prior to financing of pesticides and in compliance with selection criteria in OP 4.09 (pest management).
OP/BP 4.12 Involuntary resettlement	Owing to land take causing loss of shelter, assets, or livelihood and incomes with or without any physical displacement; and restriction of access to legally designated parks and protected forests causing loss of incomes.	When the policy is triggered, preparation of a Resettlement Plan (RP) is required as a condition of project appraisal; an abbreviated plan may be developed where fewer than 200 persons are affected or where the impacts are minor. Where precise impacts cannot be known at appraisal, a Resettlement Policy Framework (RPF) is prepared as a condition of the loan and detailed plans are prepared during implementation. In projects resulting in restriction of access to parks and protected forests, a process framework is required prior to appraisal.
OD 4.20 Indigenous peoples	When the project affects indigenous peoples in the project area.	Where there are adverse impacts, or where indigenous peoples are among the beneficiaries, the borrower prepares an Indigenous Peoples' Development Plan (IPDP) in consultation with the affected groups.
OP 4.36 Forestry	When forest sector activities and other Bank-funded interventions have the potential to have a significant impact on forested areas.	Bank lending in the forest sector is conditional on government commitments to undertake sustainable management and conservation-oriented forestry, including the adoption of policy and a legal institutional framework; adoption of forestry conservation and development plans; use of social, economic, and environmental assessments of commercial forests; setting aside of compensatory preservation forests; and establishment of institutional capacity to implement and enforce these commitments.

Table 9.2 Policy Triggers and Mechanisms (Continued)

Policy	Triggers	Mechanisms for achieving policy objectives
OP/BP 4.11 Physical cultural resources	Applies to all projects requiring a Category A or B environmental assessment.	The borrower assesses the project's potential impacts on physical cultural resources as an integral component of the EA, procedural steps being the same for Category A and B projects. Where the EA predicts adverse impacts, the cultural resources component of the EA also proposes a management plan.
OP/BP 4.37 Safety of dams	When the project involves a large dam (15 meters or higher) or a high hazard dam or is dependent on an existing dam.	For small dams, generic safety measures designed by qualified engineers are usually adequate. For new large dams or high dams or the rehabilitation of existing large or high hazard dams, the Bank requires reviews by an independent panel of experts throughout the project cycle; preparation and implementation of detailed plans, including an emergency preparedness plan; prequalification of bidders; and periodic safety inspection upon dam completion. For existing dams, the Bank requires the borrower to arrange for the use of one or more dam specialists.
OP/BP 7.50 Projects on international waterways	When a project involves a water body contiguous with two or more states or when any tributary or other body of surface water is a component of any applicable waterway.	The policy requires ascertaining whether riparians have entered into agreements or arrangements or have established any institutional framework for the waterway or waterways concerned. The beneficiary state must formally notify other riparians of the proposed project and its details.
OP/BP 7.60 Projects in disputed areas	When the proposed project is in a disputed area.	The Bank must be satisfied that other claimants to the disputed area have no objection to the project or special circumstances of the Bank's financial support to the project, notwithstanding any objection or lack of approval by other claimants.

Source: Author.

Decisions to undertake and mobilize resources for the preparation, assessment, and review of environmental and social Safeguards are the responsibility of the relevant sector agencies. The borrower should ensure that appropriate staff is selected to undertake the required decisions on its behalf and is responsible for contractors, consultants, and engineers from specialized government agencies or the private sector undertaking the implementation of the Safeguards.

STAGE III: MANAGING THE APPLICATION OF SAFEGUARDS

The main objective of the environmental and social assessments is to predict the potential nature and magnitude of positive and adverse impacts, evaluate their significance, and deter-

mine mitigation measures. The main tasks involve the following:

- Collecting information/data on existing conditions (baseline studies) from records, surveys, and consultation with local residents, experts, and professionals
- Characterizing the existing environmental and social conditions and predicting the significance of major impacts (including reviewing expected trends within the project's influence area)
- Developing approaches to avoid, mitigate, or compensate any adverse impacts and to resolve conflicts and enhance positive impacts

- Determining the institutional responsibilities for completing the EA and ensuring the implementation of mitigation measures and needed institutional strengthening requirements, including provisions for training
- Producing the required EA/SA reports and management plans: EMP, Resettlement Action Plan (RAP), IPDP, or PMP as required by the Safeguards policies
- Providing for the involvement of the public in the assessment and for reviewing the proposed project in an open, transparent, and participatory manner.

At all times, it is essential to ensure close consultation between the assessment and engineering design teams, especially on provisions for the reports and management plans and public consultation. The developer is ultimately responsible for ensuring compliance with statutory requirements. Components of effective participation required by the Safeguards include the following:

- Identification of groups or individuals interested in or affected by the proposed project
- Provision of accurate, understandable, pertinent, and timely information
- Dialogue between those responsible for decisions and those affected by them
- Assimilation of public views with the decision
- Feedback about actions taken and how the public influenced the decision.

It is important that implementers of this stage identify and confirm linkages to environmental legislation and regulations and Safeguards pertinent to the project, and describe proposed mitigation measures to accommodate public views derived from consultation with the public. Equally, to ensure that mitigation measures are implemented effectively and on time, clauses in contract documents should specify environmental and social practices to be adopted during construction and related activities. In turn, provisions should be made so that suitably

experienced, independent supervisors may monitor them.

STAGE IV: REVIEWING THE ADEQUACY OF THE EA/SA REPORT(S) AND MANAGEMENT PLANS

This stage of the process calls for an intensive review of the draft EA (and SA as required) and management plans by the borrower and the Bank; all parties are expected to make comments and offer recommendations for revisions as needed. The following items should be considered in determining the adequacy of the reports and plans and giving approval:

- Has the EA/SA addressed all the important issues raised in the TORs?
- Is the executive summary adequate, that is, does it highlight significant impacts and their mitigation and management sufficient for decision making? Does it cite outstanding issues?
- Are the baseline studies complete? Do they address pertinent issues? Are the methods that are used scientifically and technically sound?
- Is the section on predicted impacts and their assessment rigorous, that is, has the assessment included the environmental/social impacts or consequences of adopting alternatives (such as development schemes, management/operational practices, capital and operating costs, and costs of mitigation measures)?
- Are mitigation measures stipulated along with monitoring/supervision responsibilities, costing, and scheduling arrangements in the Environmental Management Plan (EMP), RAP, or other plans?
- Is the project in compliance with national legislation and regulations and with donor requirements (if applicable)?
- Are institutional arrangements for coordination, problem solving, reporting, and the like in place?

- Are proposals for institutional strengthening and training provided?
- Has community consultation proven effective and been adequately recorded?
- Are references given and is there a glossary of terms used?
- Are the EA/SA reports and management plans clearly and coherently organized and presented so that they may be understood, especially by the decision makers and the public?
- Do the reports provide information needed by the decision makers to assess whether or not the environmental and social consequences are acceptable?

Comments should be submitted to the EA/SA Team for discussion and review. If necessary, the Team may need to conduct more work where data are required or provide explanations to resolve apparent inconsistencies. The Team should be clear about what issues are to be addressed, when and how mitigation measures are to be applied, what agency is responsible for implementing them, and estimates of their cost.

STAGE V: MONITORING AND SUPERVISION OF SAFEGUARDS

Monitoring and supervision provides information for periodic review to ensure that anticipated impacts are maintained within the levels predicted, unanticipated impacts are suitably mitigated, and the benefits of the EA and other Safeguards are retained as the project is implemented and operated. To do this, the following should be arranged :

- Provide information for periodic review (and possible modification) of the EMP, RAP, or other plan to help optimize the application of Safeguards at all stages of the development process
- Assess performance and monitoring compliance with Safeguards and legal and regula-

tory requirements and agreed conditions specified in construction contracts and operating licenses

- Demonstrate to all parties (including the public) that the project activities comply with Safeguard requirements, including consultation and disclosure, and that mitigation measures are being implemented effectively
- Undertake regular site visits by the sector agencies and environment agency to supervise environmental and social measures and help resolve issues

Construction site supervision teams may carry out many of the monitoring and supervision activities with guidance from environment/social specialists. However, regular visits to the sites will need to be undertaken by specialists employed as part of construction supervision teams. Monitoring findings will be judged by the application of the indicators specified in the EMP or variant (such as groundwater and surface water quality) and provisions in environmental contract clauses (such as removing and retaining topsoil for subsequent rehabilitation).

STAGE VI: EVALUATING THE EFFECTIVENESS OF THE SAFEGUARDS

Evaluation of EA/SA reports and management plans involves determining whether or not Safeguard issues were anticipated and the effectiveness of mitigation measures and of institutional arrangements, including strengthening and training. Items to evaluate include the following:

- The extent to which recommendations in the EA/SA and management plans were followed
- The extent to which the EA/SA and management plans influenced decision making during project preparation, appraisal, and implementation
- Assessment of project operation and maintenance activities as they affect environmental and social considerations, such as the functioning of mitigation measures and the status of staff training programs

- Evaluation of the costs and benefits resulting from adopting Safeguard measures
- Problems areas to be considered in future application of Safeguards for the sector(s)

ISSUES FOR THE BANK AND THE BORROWER

A number of systemic problems in the effective application of environmental and social safeguards have been identified in studies of environmental and social safeguards implementation by the OED and the Quality Assurance Group (QAG). These are caused by design weaknesses at entry and deficiencies in supervision:

Problems due to design weaknesses are the following:

- Project components were sometimes overly ambitious and complex in their management of safeguards.
- Institutional arrangements were fragile, often based on an expectation that a champion (individual or technical body) was judged secure enough to sustain the functions in an unstable institutional environment.
- Analysis of institutional capability/organization was inadequate, particularly for identifying weaknesses in coordination across the sectors.
- The complexity and constraints of the legal/planning process was underappreciated; in addition, the phasing of environmental and social requirements with engineering/planning needs was frequently absent or poorly conceived, and the timeframe for their implementation was insufficient.
- The monitoring and evaluating framework was typically generalized: indicators (outputs/outcomes) lacked potency.
- There was a lack of guidance for supervision (that is, there was no supervision plan), including designated use of specialists.

- Synergy with neighboring projects (temporal and spatial domains) was not registered.
- Team members were not experienced in environmental planning and management.

Problems due to supervision weaknesses are the following:

- There was a need for earlier interventions to help restructure and modify components (especially in terms of institutional arrangements and responsibilities), for sharpening of the baseline studies, and for reordering management priorities.
- The Team was reluctant to reshape supervision requirements, including the composition of Team members.
- Supervision was inadequate at the site level.
- The preparation of supervision objectives was not coordinated with the borrower's agencies.
- There was a lack of appropriate support by the borrower and Bank management.

These issues present constant challenges and require diligence by Task Teams and Project Management Units to ensure compliance with the Safeguard policies.

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The Safeguard Policies are available from the World Bank’s Safeguard Web site at <http://www.worldbank.org/safeguards>.

Advice on the application of Safeguards may be obtained from the Safeguard Units in the regional vice presidencies and the Quality Assurance and Compliance Unit (QACU). Refer to <http://www.worldbank.org/safeguards>.

ENDNOTES

1. For large dams, the reader should refer to Annex B for the BP section of OP/BP 4.01 (Environmental assessment).
2. Annex A to OP/BP 4.04 provides detail on the definition of significant critical areas.
3. It is sometimes asserted that, in cost-benefit analysis, “Shadow prices that include carefully traced indirect changes in value added include the multiplier effects while

minimizing the danger of double counting.” And “...most of the multiplier effect is accounted for if we shadow-price at opportunity cost” (Gittinger 1982, 61). However, in practice, when cost-benefit analysis is performed for large water projects, shadow prices are not estimated in a regional framework and the use of shadow prices may not include multiplier effects.

4. Some of the impacts on the poor in other regions are not captured by the multiplier analysis carried out for a particular region. For example, in India, the urban poor have also benefited from surplus foodgrains from Bhakra distributed all over the country through fairprice shops. Bhakra Dam contributed 30 million tons, 60 percent of total foodgrains procured by public distribution agencies during 2000–1. Remittances (around Rs 3548 million or US\$75 million during 1995–6) sent by migrant laborers working in the Bhakra command have benefited millions of poor in the villages in Bihar and Uttar Pradesh, with resulting multiplier and downstream effects.

This Profile was prepared by Colin Rees and reviewed by L. Panneer Selvam and Pramod Agrawal.

INDEX

- Tables, figures, and boxes are indicated by *t*, *f*, and *b* respectively.
- Adaptable Program Loan (APL), 14, 15t, 262, 277
- Adjustable Program Loan (APL), 170
- Adjustment loans, 292
- Adverse climate impacts, 272–274
- Afforestation-reforestation, 235, 264
- Agricultural drought, 258
- Agricultural Growth and the Poor: An Agenda for Development*, 3
- Agricultural Investment Sourcebook (AIS)*, 3, 22, 68, 102–103, 144, 174, 206, 238, 256
- Agricultural output, 294–295
- Agricultural Sector Adjustment Loan (ASAL), 33
- Agricultural trade
- food security and, 38
 - implementation of, 40
 - investment in, 39–40, 42–43
 - lending related to, 40b
 - lessons learned from, 42
 - open, 22
 - recommendations related to, 42–43
 - reforms in, 22
 - research issues, 40–41
- Agricultural water. *See* Water management; Water use efficiency (WUE)
- Agricultural Water Management: An Agenda for Sustainable Development*, 3, 7

- Agricultural water strategy (AWS)
 - benefits of, 26
 - defined, 24
 - elements of, 24–26
 - implementation of, 26–28
 - investment in, 29
 - lessons learned from, 28–29
 - planning cycle, 25b
 - recommendations related to, 29
 - of Tanzania, 24
- Agriculture
 - chemical residues, 182
 - climate impacts on, 272–274
 - drainage impact on, 190b
 - flood recession, 265
 - investment in, 5–6
 - irrigated, 219
 - low water return in, 5
 - poverty reduction by, 7
 - rainfed, 151b
 - wastewater use in, 157
- Alley-cropping, 225
- Allocative efficiency, 53
- Alternative crop systems, 261
- Ambilivily and Ambondromifehy watersheds, 226b
- Antibiotics, 247, 248
- Aquaculture activities
 - adoption of, 248
 - benefits of, 245
 - export-focused, 247
 - implementation of, 246–247
 - introduction to, 238, 244
 - investment in, 244–245
 - lessons learned from, 247–248
 - recommendations related to, 248–249
- Aquatic vegetation, 120, 121
- Aquifers (See also Groundwater)
 - contamination, 169
 - groundwater, 150, 157, 165, 167
 - tubewells and, 152
- Area based water charges, 46t, 47
- Arid regions
 - biodrainage in, 199
 - evaporation ponds in, 196
 - waterlogging and, 177
- Armenia, 43, 47b, 52
- Artificial evaporation ponds, 197
- Asia
 - drainage development in, 177b, 179
 - pro-poor irrigation in, 115b
 - RUPES program in, 233b
 - water management in, 19t
- Asset transfer, 54
- Aswan High Dam, 178b, 295, 296b
- Australia
 - biodrainage in, 198, 199
 - drainage interventions in, 183b
 - irrigation issues in, 67, 93–95
 - technology benefits in, 125b
 - water reforms in, 80b
 - water rights in, 48b
- Australian National Committee of the International Commission on Irrigation and Drainage (ANCID), 300
- Automated weather data station network, 259, 261, 262
- Automation
 - applicability issues, 140
 - centralized, 140
 - introduction to, 139
 - objectives of, 139–140
 - prerequisites for, 140b
- Bangladesh, drainage investments in, 191b
- Bangladesh Drainage and Flood Control Project, 266, 268
- Bank Procedure (BP), 291b
- Baseline surveys, 282, 283b, 284
- Belt canal, 265
- Benchmarking
 - benefits of, 299
 - comparative assessment, 302f
 - defined, 280, 299
 - drainage schemes and, 300b
 - impact of, 300–302
 - objectives of, 299–300
 - performance indicators, 301b
 - promoting, 299, 303
 - stages in, 299f
 - water issues and, 301f
 - wider applicability, 302–303
- Beni Amir project, 135b
- Benue River, 245
- Bhakra Dam, 295b, 296b, 313
- Biodiversity loss, 227
- Biodiversity niches, 232
- Biodrainage
 - applicability issues, 199
 - in arid regions, 199

- in Australia, 198, 199
 - impact of, 198–199
 - objectives of, 198
 - purpose of, 198
- Biological concentration, 199b
- Biomass, 227, 234, 273
- Brazil
 - AWS of, 26b, 27, 28
 - crop diversification in, 111b
 - dam investments in, 296b
 - water rights in, 84b
 - World Bank projects in, 86, 113, 274
- Bunga Check Dam, 295, 296b
- Burkina Faso, 219, 220b
- California
 - groundwater management in, 164b
 - water trade in, 81
- Canals
 - drainage, 127
 - maintenance, 120
- Capacity-building programs
 - activities related, 91t
 - benefits of, 87
 - donor-recipient partnership in, 89
 - implementation of, 87
 - investment in, 87
 - irrigation and, 211, 212
 - lessons learned from, 89
 - recommendations related to, 90–91
 - soil fertility management and, 223
 - strategy, 89
 - technology and, 131
- “Cap and trade” schemes, 215
- Capture fisheries, 244, 247
- Carbon Fund, 206
- Caribbean, water management issues in, 19t
- Catchments, 232, 233b, 264, 273
- Cauca Valley (Columbia), 233b
- Cau Son-Cam Son Irrigation scheme, 135b
- Central Africa, water management in, 88b
- Central Asia. *See* Asia
- Centralized automation, 140
- Cereals production, 6
- Chalan Beel flood and drainage project, 267b
- Chile, water rights in, 83b
- China
 - CWRAS of, 60, 61
 - evapotranspiration in, 130f
 - groundwater overexploitation in, 128, 130b, 146b
 - irrigation charge system in, 48, 49b
 - Red Soils Project in, 215b
 - Sustainable Coastal Resources Development Project in, 245
 - water use efficiency in, 56
 - World Bank projects in, 215b, 217, 231, 271, 274
- Climate impacts, fighting
 - impact of, 273
 - introduction to, 272
 - objectives of, 272–273
 - wider applicability, 273–274
- Climate change, 6–7, 234, 255–256, 264, 272, 306
- Climate indexes, 259
- Climatic conditions, 255–256
- Coalition Building for Reform of the Office du Niger, 94b
- Colorado, groundwater management in, 165b
- Comite Tecnico de Aguas Subterraneas-COTAS, 163b
- Community-based fish culture, 246b
- Community-based soil conservation projects. *See* Soil conservation projects
- Community-driven development (CDD)
 - approaches, 11
 - benefits of, 240–241
 - government and, 239
 - implementation of, 241
 - introduction to, 237–238
 - investment in, 239–240
 - lessons learned from, 241–242
 - participatory approaches and, 277
 - recommendations related to, 242–243
 - requirements for using, 242b
 - watershed management and, 240b
- Computable general equilibrium (CGE)
 - models, 294, 295, 296, 297
- Computerized gate movement, 140
- Conetoe Creek project (North Carolina), 193b
- Conjunctive water use
 - benefits of, 158–159
 - defined, 144
 - in India, 156b, 157b, 158b
 - institutional issues, 159–160
 - introduction to, 156
 - investment in, 144, 156–158, 160–161
 - lessons learned from, 160

- in Mexico, 159b
 - recommendations related to, 160
- Contour bunding, 264
- Controlled drainage
 - applicability issues, 194
 - benefits of, 193–194
 - defined, 193
 - drainage systems and, 202, 203
 - in Egypt, 194b
 - objectives of, 193
- Controlled impact evaluations, 282
- Conveyance efficiency, 53
- “Core welfare” indicators, 282, 283
- Cost-benefit analysis, 313
- Cost recovery issues
 - irrigation charges and, 48, 49
 - soil conservation projects and, 228
 - watershed project and, 231
 - water supply and, 252
- Council of Australian Governments (COAG)
 - Water Reform Framework, 80
- Country Assistance Strategy (CAS), 14, 26, 243
- Country Water Assistance Strategies, 187
- Country Water Resources Assistance Strategy (CWRAS)
 - assessment of, 60
 - description of, 59–60
- equation, 59
 - impact of, 60
 - introduction to, 59
 - lessons learned from, 61
 - objectives of, 59
 - of Philippines, 60b
 - poverty reduction and, 60t
 - purpose of, 14, 23
 - World Bank projects and, 61
- Credit systems, 223, 227
- Croatia, biodrainage in, 199
- Crop(s)
 - breeding, 40
 - cultivation, 230
 - restrictions, 188
 - varieties, 275
 - water charges and, 46t, 47
 - water productivity, 128b
- Crop diversification
 - benefits of, 111
 - effective O&M and, 125
 - implementation of, 111–112
 - introduction to, 110
 - investment in, 110–111, 112
 - lessons learned from, 112
 - recommendations related to, 112
 - tubewell irrigation and, 145
- Crop pattern
 - conjunctive management and, 159
 - controlled drainage and, 194
 - water rights and, 128–129, 131b
- Crop yield
 - controlled drainage and, 193
 - irrigation and, 135b, 152
 - soil salinity and, 286, 287b
 - technology and, 129b
 - watershed project and, 230
- Cultivated land, 230
- Cultivation techniques, 261
- Cultural values, wastewater reuse and, 187
- Dam investments
 - impact of, 296–297
 - in India and Brazil, 296b
 - introduction to, 294
 - objectives of, 294–296
 - wider applicability, 297
- Dams, safety of, 309t
- Deep tubewell irrigation
 - benefits of, 152
 - implementation of, 152–153
 - introduction to, 150
 - investment in, 150–151, 153–154
 - lessons learned from, 153, 154b
 - recommendations related to, 153
- Deforestation, 227
- Demand management
 - AWS and, 28
 - irrigation charges and, 48
 - water management project and, 170
- Developing countries
 - drainage systems in, 176, 178
 - water management and, 91
- Development Policy Lending (DPL)
 - benefits of, 33–34
 - effectiveness of, 33
 - features of, 31–33
 - implementation of, 34
 - as a lending instrument, 14, 15t
 - lessons learned from, 35
 - purpose of, 31
 - recommendations related to, 35–36
 - water projects and, 290

- Diesel pumpsets, 114
- Direct seeding, 227
- Disaster preparedness, 268, 272t
- Disclosure Policy, 290, 293
- Disputed areas projects, 309t
- Dissemination plans, 29
- Distributor modules, 139
- “Dog-eat-dog” attitude, 166
- Downstream ecosystems, 290
- Drainage
 - canals, 127
 - climate issues and, 272t
 - crop diversification and, 112
 - in humid tropics, 177b
 - impact of, 190b
 - networks, 110
 - on-farm, 110
 - rehabilitation, 179
 - schemes, 300b, 301, 302
 - technology, 174, 176
 - water, 246b
- Drainage Integrated Analytical Framework (DRAINFRAME). *See* DRAINFRAME
- Drainage investments
 - applicability issues, 191
 - assessing benefits of, 286–289
 - decline in, 5–6
 - DRAINFRAME and, 192b
 - in Egypt, 191b
 - impact of, 191
 - introduction to, 190
 - objectives of, 190
- Drainage Master Plan (Pakistan), 191b
- Drainage projects
 - flood management and, 266
 - operation and maintenance of, 123–125
 - planning of, 123, 126b
 - technology for, 127–132
- Drainage systems
 - benefits of, 176–177
 - ditch-type, 198
 - flood management and, 264
 - implementation of, 177–178
 - introduction to, 176
 - investment in, 176, 179
 - lessons learned from, 178–179
 - recommendations related to, 179
 - rehabilitation of, 286, 288
 - subsurface, 196
- Drainage systems O&M
 - applicability issues, 203
 - design process and, 202f
 - in Egypt, 201–203
 - impact of, 202–203
 - objectives of, 201
- Drainage water reuse
 - benefits of, 182
 - in Egypt, 182b
 - implementation of, 182–183
 - introduction to, 181
 - investment in, 181
 - lessons learned from, 183
 - quality concerns related to, 182, 183
 - recommendations related to, 183–184
- DRAINFRAME
 - drainage investments and, 191, 192b
 - participatory planning and, 174, 177
 - watershed management and, 234
- Drinking water, 251–253, 272t, 277, 278
- Drip irrigation systems, 115, 117
- Drought
 - agricultural, 258
 - conjunctive management and, 158
 - defined, 258
 - early warning systems, 259
 - hydrological, 258
 - meteorological, 258, 259
 - participatory approaches and, 276
 - planning process, 259, 260b, 262
 - policy, 262
 - relief, 260
 - risk, 258
 - socioeconomic, 258
 - vulnerability to, 258–259
 - water rights and, 79
 - water supply and, 78
- Drought preparedness
 - benefits of, 259
 - implementation of, 259–260
 - introduction to, 255–256, 258
 - investment in, 258–259, 262
 - lessons learned from, 260–261
 - recommendations related to, 261–262
- Dry area ecosystems, 211
- Dublin Principle, 24, 25, 28
- East Asia. *See* Asia
- East Slovak Lowlands, 287, 288
- Economic incentives
 - benefits of, 55

- features of, 57b
- implementation of, 56
- investment opportunities and, 53–55, 57
- lessons learned from, 56–57
- recommendations related to, 57
- water management project and, 171
- water-saving technologies and, 106
- in water use, 22, 53
- World Bank projects and, 54b
- Economic rates of return (ERRs), 190
- Economic Sector Work, 292
- Ecosystem services, 232, 233b, 235, 292
- Egypt
 - controlled drainage in, 194b
 - dam investments in, 296b
 - drainage systems in, 178b, 191b, 201–203
 - DRAINFRAME applications in, 192b
 - fish farming in, 246b
 - irrigation project in, 132b
 - water reuse in, 182b, 183
 - World Bank projects in, 52, 184, 192
- EIER-ETSHER Group, 88b
- Electromechanical automatic gates, 140
- El Fadly Water Board (Egypt), 201
- Emergency Recovery Loan (ERL), 14, 15t, 262
- Endemism rate index, 227
- Engineers. *See* Planners and engineers
- Environmental assessment (EA) policies, 305–308, 310–311
- Environmental Assessment Safeguard Policy, 306
- Environmental concerns, 248
- Environmental management, 170
- Environmental Management Plan (EMP), 305
- Environmental Protection Agency (EPA), 233b
- Environmental regulations, 246, 249
- Environmental services
 - benefits of, 215, 216t
 - payments for, 214, 232, 233b, 234
- Environmental sustainability, 7
- Environment Strategy, 3
- Erosion mitigation, 226
- Europe
 - drainage development in, 178b
 - water management in, 19t
- Evaporation ponds
 - applicability issues, 196–197
 - in arid zone, 196
 - artificial, 197
 - impact of, 196
 - objectives of, 196
- Evaporation rates, 196b
- Evapotranspiration (ET)
 - biodrainage and, 199
 - in China, 130f
 - drought preparedness and, 261
 - environmental management plans and, 128, 129b
 - forests and, 233b
 - technology and, 131b
 - water resource planning and, 270–271
- “Evapotranspiration (ET) quotas”, 101, 103
- Expatriate resource persons, 36
- Extreme climatic conditions, 255–256
- Fadama User Association, 146b
- Farmer-irrigators
 - applicability issues, 98–99
 - approach, 98
 - impact of, 98
 - introduction to, 96
 - objectives of, 96–97
- Farmers
 - aquaculture activities and, 244, 246
 - CDD/SF approaches and, 242
 - controlled drainage and, 193–194
 - drainage systems and, 202
 - grants for, 223
 - groundwater development and, 241b
 - irrigation issues and, 150, 210–212
 - PIM and, 71–75
 - revenues of, 227
 - soil conservation projects and, 226
 - soil fertility management and, 219, 222
 - wastewater reuse and, 188
 - water management and, 90
 - water resource planning and, 271
 - watershed project and, 230
- Farmers-Managed Irrigation Systems (FMIS) Act, 82b
- Farming
 - fish, 246b
 - shrimp, 246
 - sustainable, 229
- Fertilizer use, 222
- Financial Intermediaries (FIs), 291, 307, 308t
- Fiscal policy, 55
- Fish farming, 246b
- Flap gate, 139
- Flood
 - damage, 266
 - disasters, 264

- embankments, 264
 - mapping, 266
 - mitigation, 266b
 - protection, 265, 266b, 267b
 - recession agriculture, 265
- Flood management
 - benefits of, 265–266
 - implementation of, 266–268
 - introduction to, 256, 264
 - investment in, 264–265, 268
 - lessons learned from, 268
 - loans for, 167b
 - recommendations related to, 268
 - strong and weak points in, 266b
 - water quality management and, 174
- Floodplain depressions, 245, 264, 265
- Flow dividers, 123
- Flow rate monitoring, 139
- Flow-through irrigation, 127
- Fodder crops, 240b
- Food and Agriculture Organization (FAO), 120, 182, 248, 303
- “Food for work”-type investment, 221
- Food-processing units, 294
- Food production, water resources and, 6–7
- Food security
 - aquaculture activities and, 245
 - investment in, 39–40
 - lessons learned from, 42
 - water scarcity and, 38
- Food Security Special Program, 90b
- Forestry Law, 214
- Forests, evapotranspiration and, 233b
- “Formosa”, 111b

- Gal Oya irrigation system, 240b
- Geographic information systems (GIS), 131, 229
- Global Environmental Facility (GEF), 15, 26
- Global Environmental Fund’s OP 15 program, 235
- Global warming, 258 (See also Climate change)
- Gohana Pilot Project, 287b, 288
- Governments
 - aquaculture activities and, 247
 - CDD/SF approaches and, 239, 240
 - conjunctive management and, 159
 - DPLs and, 35–36
 - drainage systems and, 177, 178, 191
 - drought preparedness and, 260, 261, 262
 - farmer networks and, 98
 - irrigation issues and, 93, 94, 148
 - O&M technologies and, 119
 - PIM and, 70, 74, 75
 - policy framework and, 22
 - safeguard policies and, 306
 - soil fertility management and, 222
 - tubewell irrigation and, 146
 - water entitlements and, 81
 - water investment and, 68
 - water management project and, 171
 - watershed project and, 230
 - water use efficiency and, 56–57
 - WUAs and, 73
- Groundwater (See also Aquifers)
 - abstraction, 147b, 150, 153, 270
 - aquifers, 165, 167
 - designated, 165b
 - development, 111b, 241b
 - drought preparedness and, 262
 - governance of, 162, 166
 - irrigation systems and, 120
 - legal framework for, 167
 - overdraft, 6, 12
 - overexploitation of, 130b, 146b, 162, 166, 208
 - quality of, 146, 148
 - recharge, 157, 160, 233b, 264
 - regulation of, 147b
 - saline, 157
 - tubewells and, 145
 - wells, 145b
- Groundwater irrigation
 - advantages of, 143–144, 150b, 152
 - crop yield and, 152
 - problems of, 144
 - surface water and, 144
- Groundwater management
 - benefits of, 162
 - in California, 164b
 - in Colorado, 165b
 - implementation of, 162–166
 - introduction to, 162
 - investment in, 162
 - lessons learned from, 166
 - in Mexico, 162, 163b
 - recommendations related to, 167
- Groundwater Management Advisory Team of the Bank-Netherlands Water Partnership Program (GW-MATE), 293
- Guatemala, water supply and irrigation in, 251, 252b, 253
- Gully plugging, 264

- Hadejia-Jama'are Basin, 265b
- Hai Basin Integrated Water and Environment Management project, 128, 130b
- Hai Basin project, 103, 270
- Hatcheries, 246, 247, 248
- Hazard analysis and critical control point (HACCP), 247
- Herbicides, 121
- Higher-value crops/species, 244, 281
- Human health, wastewater reuse and, 187
- Hybrid Policy and Investment Loan (HPIL), 14, 15t, 33
- Hybrid systems, 251, 253
- Hydraulic gates, 139
- Hydraulic infrastructure, 78, 156, 160
- Hydrological drought, 258
- Hydrological cycle, 182
- Hydropower projects. *See* Dam investments; Irrigation projects
- Impact evaluation, conducting, 283
- Imperial Irrigation District, 136
- Income generation, 108b
- India
 - aquaculture activities in, 244
 - benchmarking process in, 301
 - conjunctive water use in, 156b, 157b, 158b
 - crop water productivity in, 128b
 - dam investments in, 295
 - farmer networks in, 96–98
 - groundwater wells in, 145b
 - irrigation project in, 50b
 - participatory approaches in, 275–278
 - water reforms in, 82b
 - water reuse in, 183
 - watershed development in, 275, 283b, 284b
 - World Bank projects in, 52, 86
- Indian Council of Agricultural Research, 276, 284b
- Indigenous Peoples' Development Plan (IPDP), 310
- Indira Gandhi Nahar project (India), 199
- Indonesia
 - Groundwater Development Project in, 154b
 - water management in, 88b
 - WATSAL of, 32b
 - World Bank projects in, 36, 155
- Industrial output, 294
- In-field irrigation efficiency, 53
- Infrastructure. *See also* Technology
 - AWS and, 28
 - CDD/SF approaches and, 242
 - climate impacts and, 272t
 - conjunctive management and, 159
 - drought preparedness and, 262
 - evaporation ponds, 196
 - groundwater management and, 167
 - hydraulic, 78, 156, 160
 - irrigation projects and, 105, 124, 125b
 - water control, 223
- Inland areas, 246
- Innovations grants, 223
- Input management, 247
- Input/output (I/O) tables, 295
- Institutional development, 170
- Institutional innovations, 16
- Institutional reforms, 72
- Institutional Revolutionary Party (PRI), 94b
- Integrated Irrigation Improvement Management project (Egypt), 191
- Integrated Wasteland Development Program, 276
- Integrated water and soil fertility management (IWSFM), 220b
- Integrated Water Resources Management (IWRM), 28
- Integrated Watershed Development project, 275, 278
- International Bank for Reconstruction and Development (IBRD), 41
- International Commission on Irrigation and Drainage (ICID), 120, 303
- International Development Association (IDA), 108b, 216, 229
- International Finance Corporation (IFC), 23
- International Food Policy Research Institute (IFPRI), 284b
- International Fund for Agricultural Development (IFAD), 15
- International Institute for Land Reclamation and Improvement (ILRI), 90
- International Monetary Fund (IMF), 31
- International Network on Participatory Irrigation Management, 97
- International Programme for Technology & Research in Irrigation and Drainage (IPTRID), 120, 179
- International Waterlogging and Salinity Research Institute (IWASRI), 90
- International Water Management Institute (IWMI), 120, 127, 301

- International waterways projects, 309t
- Investment opportunities
 - in aquaculture activities, 244–245
 - AWS and, 24–26, 29
 - in capacity building, 90–91
 - in conjunctive water use, 144, 156–158, 160–161
 - in crop diversification, 110–111, 112
 - in drought preparedness, 258–259, 262
 - economic incentives and, 53–55
 - in flood management, 264–265, 268
 - in food security, 39–40
 - in groundwater management, 162
 - in irrigation, 114, 150–151, 153–154, 208–209, 212
 - ISCs and, 45–49
 - in land drainage, 176, 179
 - in monitoring and evaluating, 281–283
 - in O&M technologies, 119–121
 - PIM-related, 70–71, 73–76
 - in RAP, 134–135
 - in remote-sensing technologies, 127–128
 - in soil fertility management, 219, 223
 - in wastewater use/reuse, 185–186
 - in water management, 87, 90, 219, 223
 - in water-saving technologies, 105, 106, 107, 109
 - in water scarcity, 39–40
 - in watershed management, 214–215, 217
 - World Bank, 16, 17t
- Investment returns, 10
- Involuntary resettlement, 308t
- Iraq, 209–210
- Irrigation. *See also* Agricultural water strategy (AWS)
 - advisory services, 107b
 - climate impact on, 272t
 - costs, 71
 - development policy, 55
 - efficiency, 129b
 - Environment Strategy and, 3
 - equipment, 63–65
 - flow-through, 127
 - furrow, 121
 - gender-sensitive, 75
 - investment in, 5–6, 10, 105b
 - low water return and, 5
 - management transfer, 67
 - with mine water, 158b
 - modernization, 101, 102
 - O&M technologies, 119–122
 - on-demand, 152
 - on-farm, 110
 - pro-poor, 115b
 - RDS objectives and, 2
 - schemes, 300b, 301, 302
 - subsidies and, 9–10
 - wastewater reuse and, 187
 - water management and, 4–5
 - water supply and, 251–253
 - WRSS and, 2–3
- Irrigation and drainage (I&D) sector, 31
- Irrigation and Training Research Center (ITRC), 135b
- Irrigation projects
 - in Armenia, 47b, 52
 - funding issues, 45
 - in India, 50
 - investment in, 78
 - modernization of, 135, 136, 139–140
 - operation and maintenance of, 123–125
 - planning of, 123, 126b
 - technology for, 127–132
 - wider applicability, 297
- Irrigation reforms
 - applicability issues, 94–95
 - in Australia, 93
 - crop diversification and, 112
 - farmer networks and, 96–98
 - impact of, 93–94
 - introduction to, 93
 - in Mali and Mexico, 51b, 94b, 95b
 - objectives of, 93
- Irrigation service charges (ISCs)
 - benefits of, 49
 - implementation of, 49
 - introduction to, 45
 - investment opportunities and, 45–49, 51
 - lessons learned from, 50
 - in Morocco, 48b
 - recommendations related to, 50–51
 - water use efficiency and, 22
- Irrigation systems
 - automation of, 139–140
 - challenges facing, 127
 - in China, 48, 49b
 - drip, 115
 - in Egypt, 132b
 - flood management and, 265
 - government-owned, 105, 107, 134

- groundwater and, 120
 - in Guatemala, 252b
 - low-energy, 212
 - modernization of, 135, 136
 - on-demand, 132b
 - piped, 105, 106b
 - sedimentation of, 226
- Jala Spandana*, 97
- Jordan
- water use efficiency in, 55b, 56b
 - World Bank projects in, 36–37
- Karnataka State Agriculturalist Society, 96
- Kenya, soil fertility management in, 220b, 222
- Kesterson Reservoir, 197b
- Kotri Left Bank, 192b
- Kyoto Protocol, 206, 235
- Labor supply, smallholder irrigation and, 116
- Lake Karoon (Egypt), 197
- Lam Pao Scheme, 111b
- Land
- consolidation, 110–111
 - contracts, 230
 - management, 273
 - reclamation, 128–129, 131b
 - tilting, 216b, 225
- Land and Water Conservation project, 108
- Land drainage
- benefits of, 176–177
 - impact of, 287–288
 - implementation of, 177
 - introduction to, 174, 176
 - investment in, 176, 179
 - lessons learned from, 178–179
 - objectives of, 286–287
 - poverty reduction and, 286
 - recommendations related to, 179
 - wider applicability, 288–289
- Land Management II-Santa Catarina Project, 272–273
- Land tenure systems
- irrigation and, 116
 - soil conservation projects and, 225, 227
 - watershed management and, 216, 230
- Large-scale irrigation (LSI), 239, 240b
- Latin America, water management in, 19t
- Learning and Innovation Loan (LIL), 15t, 277
- Left Bank Outfall Drain (LBOD), 192b, 196
- Lending instruments/program
- drought preparedness and, 262
 - for flood management, 267b
 - for irrigation technology, 223
 - rapid appraisal method for, 134–138
 - reorienting, 16, 17t, 18
 - for water-saving technologies, 105–109
 - of World Bank, 15t
- Lerma Chapala Basin, 159b
- Letter of Developmental Policy (LoDP), 31, 32
- Limarí Basin, 83b
- Lined canals, 124, 125, 135, 136
- Loess Plateau Watershed Rehabilitation project
- impact of, 229–230
 - introduction to, 229
 - lessons learned from, 230–231
 - objectives of, 229
- Los Angeles County Flood Control District, 164b
- Madagascar Environment Program, 225, 226b
- Maharashtra Water Resources Regulatory Authority (MWRRA) Act, 82b
- Maha season, 301
- Mahaweli Restructuring and Rehabilitation project (MRRP), 73b
- Main San Gabriel River Basin, 164b
- Making Sustainable Commitments: An Environment Strategy for the World Bank*, 3
- Mali
- irrigation reforms in, 94b
 - mango exporting project in, 41b
- Market-based incentive systems, 232
- Market conditions, 116
- Market opportunities, 228
- Mauritania, 43–44
- Mechanized technologies, 114, 117
- Medium-scale irrigation, 239, 240
- Mekong Delta Water Resources Project, 251
- Meteorological drought, 258, 259
- Mexico
- conjunctive management in, 159b
 - groundwater management in, 162, 163b
 - irrigation issues in, 51b, 95b
 - RAP outcome in, 137b
 - water rights program in, 79b
 - World Bank projects in, 86, 140
- Micro-irrigation installations, 101, 102, 103, 105, 121
- Middle East

- crop diversification in, 112b
 - water management in, 19t
- Millennium Development Goal (MDG), 7
- Mine wastewater, 158b
- Modeling techniques, 184
- Modernization of irrigation projects, 135, 136, 139–140
- Monitoring and evaluation (M&E) systems
 - benchmarking process and, 300
 - benefits of, 283
 - implementation of, 283
 - introduction to, 279
 - investment in, 281–283
 - planning for, 282
 - purpose of, 281
 - recommendations related to, 284
 - resource requirements for, 282–283
- “More crop per drop” criteria, 30, 87, 152, 193
- Morocco
 - irrigation charges in, 48b
 - Rainfall-Based Contract in, 39b
 - RAP in, 135b
 - watershed management in, 240b, 241
 - water use efficiency in, 55b, 56
- Multiplier analysis, 297, 313
- Multiplier impacts/values/effects
 - of dams, 296b
 - defined, 294
 - how to conduct, 295
- Murray Darling Basin, 48b, 183b
- MWRI programs, 201

- Napier grass, 275
- National Agriculture Technology Project (NATP), 278
- National Association of Environmental Action (ANAE), 225b
- National Drainage Project (Egypt), 190b
- National Drainage Project (Pakistan), 191b, 196
- National Water Law, 79b
- Natural habitats, 308t
- Natural resources management, 241, 242
- Natural salt lakes, 196
- Nepal
 - groundwater development in, 241b
 - soil fertility management in, 222
- Netherlands, The, 199
- Network of Aquaculture Centers in Asia-Pacific, 248
- Neyrtec float gates, 139

- Nigeria
 - flood management in, 265b
 - irrigation in, 146b
- Nile Delta, 182b, 183, 190b, 196
- Nile River Basin, 178b
- Nitrate, phosphorous, and potassium (NPK) fertilizer, 221
- Nondesignated groundwater entitlements, 165b
- Nongovernmental organizations (NGOs)
 - aquaculture activities and, 247
 - DPLs and, 34
 - drought preparedness and, 260
 - farmer networks and, 98
 - participatory approaches and, 276
 - safeguard policies and, 306
 - soil conservation projects and, 226
- Nonirrigation inputs, 116
- Nonpaddy crops, 110
- Nonpoint source pollution, 193, 214
- Nontributary aquifers, 163, 164
- North America
 - controlled drainage in, 193b
 - drainage development in, 178b

- Ogallala aquifer, 165b
- On-farm surface drainage systems, 176b, 177b
- On-farm water-saving technologies. *See* Water-saving technologies
- Online Irrigation Benchmarking Service (OIBS), 301
- Operational Policy/Bank Procedure (OP/BP) 8.60, 31, 37
- Operation and maintenance (O&M)
 - of drainage systems, 123–126, 177b, 178, 201–203
 - of irrigation projects, 31, 123–126, 154b
 - participatory approaches and, 278
 - water charges and, 46, 47b, 78
 - water loss and, 276
 - water reforms and, 82b
 - water-saving technologies and, 106b, 107
- Operation and maintenance (O&M) technologies
 - benefits of, 121
 - implementation of, 121–122
 - introduction to, 119
 - investment in, 119–121
 - lessons learned from, 122
 - recommendations related to, 122
 - selection of, 119

- Operations Evaluation Department (OED), 11, 311
- Orissa Disaster Management Project, 265b
- Overabstraction, 153
- Paddy crops, 110
- Pakistan
 - crop water productivity in, 128b
 - DRAINFRAME applications in, 192b
 - evaporation ponds in, 197
 - World Bank projects in, 192
- Participatory approaches
 - impact of, 276–277
 - introduction to, 275
 - lessons learned from, 277–278
 - objectives of, 275–276
- Participatory irrigation management (PIM)
 - benefits of, 71
 - implementation of, 71–72
 - introduction to, 68, 70
 - investment in, 70–71, 73–76
 - lessons learned from, 74
 - recommendations related to, 74–75
 - risks of, 71b
- Periurban agriculture, 157
- Peru, water management in, 89b
- Peruvian Social Fund project FONCODES, 282b
- Pest Management Plan (PMP), 305, 308t
- Philippines, CWRAS of, 60b, 61b
- Physical culture resources, 309t
- Piloting approach, 16
- Piped irrigation systems, 105, 106b
- Planners and engineers
 - for drainage systems, 202, 203
 - for irrigation projects, 135, 136
 - remote-sensing technology and, 130
- Policy-based loans, 68
- Policy framework/reforms
 - agricultural trade and, 38–43
 - AWS and, 24–29
 - DPL and, 31–37
 - governments' role in, 22
 - overview of, 8–9, 21
- Polluter pays principle, 178, 187
- Pollution, 183, 193, 214, 215
- Polychlorinated biphenyls (PCBs), 248
- Polyphagous organism, 121
- Poor-quality water
 - conjunctive use with, 157, 158b, 160
 - reuse of, 174
 - wastewater reuse and, 186
- Poverty maps, 282b
- Poverty reduction
 - by agriculture, 7
 - aquaculture activities and, 247
 - CDD/SF approaches and, 242
 - climatic conditions and, 256
 - CWRAS and, 60t
 - dam investments and, 296b
 - irrigation projects and, 11–12
 - soil stabilization and, 215b
 - Tanzania's water policy and, 24b
 - water projects and, 281–284
 - watershed project and, 229, 230
 - water supply and, 252
- Poverty Reduction Strategy Paper (PRSP), 16, 26, 243
- Pragathi, 96, 97b
- Precipitation deficiencies. *See* Drought
- Pre-tubewell conditions, 151b
- Private agencies, 119
- Private sector units, 306
- Programa de Modernización del Manejo de Agua* (PROMMA), 163b
- Programmatic Development Policy Lending (PDPL), 15t, 32, 35
- Programmatic economic and sector work (PSEW), 14
- Programme National de Gestion des Terroirs*, 221
- Project Appraisal Document (PAD), 303
- Project multiplier value, 295b
- “Pro-poor agreement”, 38
- Pro-poor interventions, 244
- Pro-poor investments, 239, 279
- Public health, 272t
- Public investment/sector
 - in agriculture, 5–6
 - in aquaculture activities, 245b, 247, 248
 - benchmarking process and, 303
- Punjab Private Sector Groundwater Development project, 147b
- PVC pipes, 108b, 115b
- Qat chewing, 170
- Quality Assurance Group (QAG), 311
- Quality Assurance and Compliance Unit (QACU), 313
- Quasi-experimental designs, 283
- Rainfall-Based Contract, 39b

- Rainfed crops
 - biodrainage and, 199
 - climate impact and, 272
 - irrigation and, 208
 - water management and, 219, 221
- Rapid appraisal procedure (RAP)
 - benefits of, 135
 - implementation of, 136
 - indicators used in, 134b
 - introduction to, 134
 - investment in, 134–135
 - lessons learned from, 136
 - in Morocco, 135b
 - outcomes of, 137b
 - recommendations related to, 136, 138
 - in Vietnam, 135b
 - watershed management and, 217
- Raymond Basin, 164b
- Reaching the Rural Poor: A Renewed Strategy for Rural Development (RDS)*, 2
- Red Soils II Area Development Project (China), 215b, 216
- Rehabilitation Investment Loan (RIL), 37
- Remote monitoring, 139
- Remote-sensing technologies
 - applications, 129b
 - benefits of, 128
 - conjunctive management and, 160
 - implementation of, 128–130
 - introduction to, 127
 - investment in, 127–128, 131–132
 - lessons learned from, 130
 - outcomes of, 127b
 - poverty maps and, 282b
 - recommendations related to, 130–131
- Renewable energy, 272t
- Republic of Yemen
 - AWS of, 27b, 28
 - CWRAS of, 60, 61b
 - groundwater management in, 162
 - water conservation in, 108
 - World Bank projects in, 30
- Research and development (R&D) projects
 - irrigation and, 210
 - water management and, 88, 90
- Reservoir fisheries, 245
- Resettlement Action Plan/Resettlement Plan (RAP/RP), 310, 311
- Resettlement Policy Framework (RPF), 308t
- Resource sharing, 234
- Rice-fish systems, 246b
- Risk-Management Instruments, 39b
- River-basin level, 159
- River flows, maintaining, 305b
- Rock phosphates, 221
- RUPES program, 233b
- Rural development, 177b
- Rural Development Strategy (RDS), 2, 3
- Rural water supply and irrigation. *See* Water supply and irrigation
- Rural water supply and sanitation (RWSS), 251, 252
- Safeguard policies
 - application of, 309–310
 - EA/SA reports and, 310–311
 - effectiveness of, 311–312
 - impact of, 290–292
 - list of, 291b
 - monitoring of, 311
 - objectives of, 290, 304
 - policy triggers and, 308t–309t
 - problems related to, 312
 - purpose of, 280, 290
 - review of, 306
 - sector-specific, 306–307
 - wider applicability, 292–293
- Sahayoga, 96
- Saline drainage water, 197, 199b
- Salinity, 215, 276
- Salinity Control and Reclamation project, 159
- Salinization
 - crop diversification and, 110
 - drainage systems and, 176, 178, 198–199
 - impact of, 2, 7
 - land drainage and, 286
 - tubewells and, 145, 147, 152
 - water quality management and, 173
 - water-saving technologies and, 106–107, 110
- Salt deposition, 197
- Salt lakes, 196
- Sana'a Basin Water Management project
 - applicability issues, 171
 - benefits of, 171
 - components of, 170
 - hydrological facts about, 169–170
 - impact of, 170
 - introduction to, 169
 - lessons learned from, 171
 - objectives of, 170

- risks of, 171
- Sanitary-phytosanitary standards (SPS), 247
- Sanitation, 252, 272t
- San Joaquin Valley (California), 199b
- Satellites. *See* Remote-sensing technologies
- Seasonal climate forecasts, 262
- Seasonal floodplains, 246b
- Secretariat of Water Resources (SRH), 84
- Sector Adjustment Loans/Credits (SECALs/SECACs), 37
- Sectoral Environmental Assessment (SEA), 307
- Sedimentation, 226, 232, 233b
- Seepage problems, 197b
- Semi-arid regions
 - irrigation technologies and, 105, 107
 - soil fertility management in, 220b, 222
 - tubewells and, 145
 - waterlogging and, 177
- Semi-input/output (S-I/O) model, 295
- Sfax Flood Protection project, 265
- Shadow prices, 313
- Shallow tubewells irrigation. *See also* Ground-water
 - benefits of, 145–146
 - implementation of, 146–147
 - introduction to, 145
 - investment in, 145, 148
 - lessons learned from, 147
 - in Nigeria, 146b
 - pre-tubewell conditions and, 151b
 - recommendations related to, 148
- Shanxi Poverty Alleviation project, 245
- “Show and tell” approach, 275
- Shrimp farming, 246
- Silt deposition, 124, 214, 226
- Slope erosion, 124
- Smallholder farmers
 - PIM and, 71
 - ZATAC and, 63–64
- Smallholder irrigation
 - benefits of, 114–115
 - implementation of, 116
 - introduction to, 114
 - investment in, 114
 - lessons learned from, 116–117
 - recommendations related to, 117
 - technology financing issues, 117
 - in West Africa, 115b
- Small Scale Drainage and Flood Control Project, 267
- Small scale irrigation
 - CDD/SF approaches for, 239–243
 - tubewells for, 145–148
- Sobradinho Dam, 296b
- Social accounting matrix (SAM) databases, 294, 295, 296, 297
- Social action fund project, 305b
- Social assessment (SA) policies, 305, 307, 310–311
- Social fund (SFs) approaches
 - benefits of, 240–241
 - implementation of, 241
 - introduction to, 239
 - investment in, 239–240
 - lessons learned from, 241–242
 - recommendations related to, 242–243
- Society for Water Resource Development, 96
- Socioeconomic drought, 258
- Sodic soils, 276, 278
- Soil
 - degradation, 225b
 - erosion, 226, 230, 233b
 - management, 110
 - stabilization, 215b
- Soil conservation projects
 - applicability issues, 227–228
 - impact of, 226–227
 - introduction to, 225
 - objectives of, 225–226
 - participatory approaches for, 275–278
 - watershed project and, 230
- Soil fertility management
 - benefits of, 219–221
 - flood management and, 264
 - implementation of, 221
 - introduction to, 206
 - investment in, 219, 223
 - lessons learned from, 221–222
 - recommendations related to, 222–223
- Soil salinity
 - classification of, 287b
 - conjunctive management and, 159
 - land drainage and, 286
 - remote-sensing technology and, 129b
 - waterlogging and, 287b
- South Africa
 - conjunctive water use in, 158b
 - drought preparedness in, 260
- South America, drainage development in, 179
- South Asia. *See* Asia

- South-Asian Rice-Wheat Consortium, 219, 220
- Southeast Asia. *See* Asia
- South India Farmers Organization for Water Management, 97
- Specific Investment Loan (SIL), 15t, 32–33, 262
- Spot market, 83b
- Sri Lanka
 - benchmarking process in, 301
 - World Bank projects in, 76
 - WUAs and, 72, 73b
- Stakeholder participation
 - in AWS, 26, 27t, 28
 - benchmarking process and, 299, 300, 303
 - DPL and, 33
 - drainage investments and, 190, 191b
 - irrigation issues and, 95, 239
 - participatory approaches and, 276, 277
 - technology and, 130
 - watershed management and, 217
- Sub-Saharan Africa
 - irrigation in, 210b
 - water management issues in, 19t
- Subsidies
 - irrigation and, 9–10, 147
 - participatory approaches and, 277
 - water efficiency issues and, 53–55
 - water-saving technologies and, 106, 107b
- Subsurface drainage systems, 196, 286–289
- Sujala Watershed project, 283b
- Supplemental irrigation (SI), 206
 - benefits of, 209–210
 - implementation of, 210–212
 - investment in, 208–209, 212
 - issues related to, 208
 - lessons learned from, 212
 - purpose of, 208
 - recommendations related to, 212
 - in Sub-Saharan Africa, 210b
 - in Turkey, 210
- Supply chain development, 116–117
- Supply management, 170
- Surface drainage, 286–289
- Surface irrigation methods/projects
 - drought preparedness and, 261
 - groundwater irrigation and, 111, 150, 157, 163, 164
 - lessons learned from, 160
 - pre-tubewell conditions and, 151b
 - reconfiguring, 156–157
 - wastewater reuse and, 185
 - water-saving technologies and, 105
- Sustainable farming, 229, 246
- Syria, 209b
- Tanzania
 - AWS of, 24b, 27
 - social action fund project in, 305b
 - World Bank projects in, 30
- Tarim Basin projects, 128, 129, 131b, 273
- Technical assistance
 - climatic conditions and, 256–257
 - drought preparedness and, 261
 - economic incentives and, 57
 - effective O&M and, 126b
 - institutional reforms and, 69
 - irrigation issues and, 104, 144, 207
 - water quality management and, 175
 - water resources assessment and, 23
 - water reuse and, 181
 - watershed management and, 207
 - ZATAC and, 64
- Technical Assistance Loan, 36
- Technology. *See also* Remote-sensing technologies
 - adoption of, 227, 228
 - drainage, 174, 176
 - irrigation issues and, 107, 108, 117, 223
 - making use of, 10–11
 - O&M, 119–122
 - RAP and, 138
 - soil fertility management and, 222
 - water control, 125
 - water resources and, 6–7
- Terms of Reference (TORs), 307
- Thailand
 - crop diversification in, 111b
 - World Bank projects in, 113
- Trade facilitation
 - agricultural trade and, 41–42
 - recommendations related to, 43
 - water scarcity and, 40
- Trade policy framework, 55
- Trade reforms, 22
- Transboundary groundwater resources, 292
- Treadle pumps
 - cost issues, 64, 103
 - irrigation and, 114, 115b, 117
- Treated wastewater reuse. *See* Wastewater use/reuse
- Tree plantation

- biodrainage and, 198
- watershed project and, 229, 231
- Tubewells. *See* Shallow tubewells irrigation
- Tunisia
 - water management in, 88b
 - water reuse in, 186b
- Turkey
 - benchmarking process in, 302
 - irrigation in, 210
- United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP), 266
- Unlined irrigation canal, 120, 124
- Upper levels associations (ULAs), 82b
- Upstream-downstream resources management, 232
- Upstream populations, 206
- Urbanization, 157
- Urban wastewater, 157
- User operation and maintenance. *See* Operation and maintenance (O&M)
- Uttar Pradesh Sodic Lands Reclamation Project, 276, 278, 283b
- Vetiver grass, 215, 275, 277
- Vietnam
 - RAP in, 135b
 - Water Resources Assistance project in, 293b
 - World Bank projects in, 253
- Village development committees (VDCs), 275–277
- Virtual water concept, 38b, 40
- “Virtuous circle”, 102
- Volumetric entitlements, 79, 80, 81
- Volumetric water devices, 46t, 47
- Voluntary resettlement, 292
- Warping dams, 229
- Wastewater disposal, 158b
- Wastewater use/reuse
 - in agriculture, 157
 - benefits of, 186
 - drought preparedness and, 261
 - implementation of, 186–187
 - investment in, 185–186, 188
 - lessons learned from, 187–188
 - private participation in, 187b
 - recommendations related to, 188
 - in Tunisia, 186b
 - water quality management and, 174, 175
- Water
 - boards, 201, 202, 203
 - control, 223
 - delivery system, 212, 302f
 - harvesting, 234, 264
 - pollution, 214
 - productivity, 211b, 270
 - resources, 6–7, 80–81
 - retention, 264, 266b, 268
 - supply, 78
 - trade, 81
- Water and Land Management Institute, 96
- Water charges
 - allocation methods, 46t
 - water pricing and, 54, 56
- Water conservation
 - drought preparedness and, 261, 262
 - participatory approaches for, 275–278
 - in Republic of Yemen, 108b
 - watershed project and, 230
- Water entitlements. *See* Water rights
- Waterlogging
 - conjunctive management and, 159
 - drainage systems and, 110, 176, 177b
 - irrigation projects and, 124
 - salinization and, 7, 107
 - soil salinity and, 287b
 - technology and, 129b
 - tree plantation and, 198
 - water quality management and, 173
 - water tables and, 286
- Water management. *See also* Policy framework/reforms; Soil fertility management
 - benefits of, 40, 87, 219–221
 - capacity building and, 69, 73, 74
 - CDD/SF approaches and, 239–243
 - challenges facing, 4–7
 - changing emphasis of, 8t
 - climatic conditions and, 256
 - defined, 2
 - development policy for, 7–8
 - in different regions, 16, 18, 19t
 - donor-recipient partnership in, 89
 - drought preparedness and, 262
 - governance for, 9
 - government’s role in, 107b
 - implementation of, 87, 221
 - integrated approaches to, 11

- introduction to, 1, 219
- investment in, 87, 90, 219, 223
- knowledge transfer for, 88
- lessons learned from, 89, 221–222
- in Peru, 89b
- rained crops and, 219, 221
- RAP and, 138
- RDS objectives and, 2
- recommendations related to, 90–91, 222–223
- for sustainability, 12
- watershed management and, 232–235
- WRSS and, 2–3
- in Zambia, 89b
- Water markets (See also Water rights)
 - advantages of, 79
 - water allocation and, 80, 81
 - water rights and, 51, 54, 78–84
- Water projects
 - categories of, 291
 - EA and safeguards integration into, 305–306
 - impact of, 290–291, 304–305
 - policies related to, 291b
 - poverty reduction and, 281–284
 - screening of, 307
- Water quality
 - drought preparedness and, 262
 - irrigation issues and, 116
 - wastewater reuse and, 185
 - wastewater treatment and, 187
 - waterlogging and, 173
 - water projects and, 305
- Water productivity 39–40, 45, 68, 70–75, 90, 105, 127–132, 173, 265, 270, 273
- Water reforms
 - in Australia, 80b
 - farmer networks and, 98
 - in India, 82b
 - introduction to, 67–68
- Water resource planning
 - applicability issues, 271
 - impact of, 271
 - introduction to, 270
 - objectives of, 270–271
- Water Resources Action Program (WRAP), 63
- Water Resources Assistance project, 293b
- Water resources management
 - drainage investments and, 190–192
 - implementation of, 41
 - investment in, 39
 - recommendations related to, 43
 - reforms, 159
 - water management project and, 171
 - water reuse and, 185
- Water Resources Management Group (WRMG), 59
- Water Resources Sector Adjustment Loan (WAT-SAL), 32b, 33, 34
- Water Resources Sector Strategy (WRSS), 2–3
- Water reuse. *See* Wastewater use/reuse
- Water rights
 - assessment of, 79
 - assignment of, 54
 - in Australia, 48b
 - benefits of, 78–79
 - in Brazil, 84b
 - cropping pattern adjustment and, 128–129
 - droughts and, 79
 - formalization of, 51
 - implementation of, 79–81, 82
 - investment in, 69, 84–85
 - irrigation issues and, 120, 153
 - ISCs and, 50
 - land reclamation and, 128–129
 - legal framework, 82, 84b
 - lessons learned from, 81–83
 - market-based, 83b
 - recommendations related to, 83–84
 - tradable, 48b, 50
 - training farmers for, 90
 - water management project and, 171
- Water Rights Adjustment Program (WRAP), 79
- Water-saving technologies
 - adoption of, 103, 105
 - benefits of, 106–107
 - in group context, 108b
 - implementation of, 106–107
 - introduction to, 101–103
 - investment in, 105, 106, 107, 109
 - lessons learned from, 107
 - recommendations related to, 107–109
- Water scarcity
 - drainage water reuse and, 181–184
 - food security and, 38
 - groundwater management and, 166
 - investment in, 39–40
 - ISCs and, 45
 - water resource planning and, 270–271
- Water sector
 - lending instruments for, 15t
 - reforms, 67–68

- Watershed management
 - benefits of, 215
 - CDD/SF approaches and, 240
 - climate impact on, 272t
 - community-based, 225–228
 - implementation of, 215–216
 - introduction to, 214
 - investment in, 206, 214–215, 217
 - lessons learned from, 216
 - in Loess Plateau, 229–231
 - recommendations related to, 217
 - water management and, 232–235
- Watersheds
 - development, 275, 276
 - flood management and, 264
 - projects, 283b, 284b
 - services, 232
- Water supply and irrigation
 - impact of, 252
 - introduction to, 251
 - objectives of, 251–252
 - wider applicability, 252–253
- Water tables (See also Groundwater, Aquifer)
 - controlling, 176b
 - drainage systems and, 179, 193, 194
 - rise in, 174, 177
 - tree plantation and, 198, 199
 - waterlogging and, 286
- Water treatment
 - gaps, 186b
 - hybrid systems and, 253
 - investments in, 233b
- Water use efficiency (WUE). *See also* Economic incentives
 - improving, 53
 - irrigation service charges and, 22
 - water projects and, 290
- Water user associations (WUAs), 25
 - controlled drainage and, 194
 - farmer-irrigators and, 96, 98
 - irrigation issues and, 147, 151, 154, 212
 - O&M technologies and, 119
 - PIM and, 70–71, 74
 - water investment and, 68
 - water management and, 88, 89b
 - water reuse and, 183
 - water rights and, 80, 83b
 - water-saving technologies and, 106
 - water use efficiency and, 54
- Weather data station network, 259, 261, 262
- Weed infestation, 124
- West Africa, irrigation issues in, 115b
- Wetlands, 290
- “With/without” design, 282
- Wivenhoe Dam, 215
- Women
 - aquaculture activities and, 245, 248
 - irrigation issues and, 211
 - PIM and, 71, 72b, 75
 - water management and, 88–89
- Women Irrigation Network (WIN), 89b
- World Bank
 - lending instruments of, 15t
 - safeguard policies, 290–293
 - strategies, 2–3
- World Bank projects
 - in Armenia, 43, 52
 - in Brazil, 86, 113, 274
 - in China, 215b, 217, 231, 271, 274
 - climate-related components in, 273b
 - CWRAS and, 59–61
 - in Egypt, 52, 184, 192
 - in India, 52, 86
 - in Indonesia, 36, 155
 - in Jordan, 36–37
 - Madagascar Environment Program, 225, 226b
 - in Mauritania, 43–44
 - in Mexico, 86, 140
 - in Pakistan, 192
 - in Republic of Yemen, 30
 - in Sri Lanka, 76
 - in Tanzania, 30
 - in Thailand, 113
 - in Uzbekistan, 249
 - in Vietnam, 253
- World Commission on Dams, 294
- World Conservation Union (IUCN), 16
- World Cultural and Natural Heritage, 306
- World Wildlife Fund (WWF), 16

Yala season, 301
Yangtze and Pearl River catchments, 215b
Yaqui Irrigation project, 136
Yellow River Basin, 157, 229

Zambia, water management in, 89b
Zambia Agribusiness Technical Assistance
Center (ZATAC)
description of, 63–64
focus of, 63
impact of, 64
introduction to, 63
irrigation credit and, 64
objectives of, 63
wider applicability, 64–65
ZATAC Integrated Coffee Program, 64
Zero-tillage technique, 226

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Agricultural water management is a vital practice in ensuring food security, poverty reduction, and environmental protection. After decades of successfully expanding irrigation and improving productivity, farmers and managers face an emerging crisis in the form of poorly performing irrigation schemes, slow modernization, declining investment, constrained water availability, and environmental degradation.

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