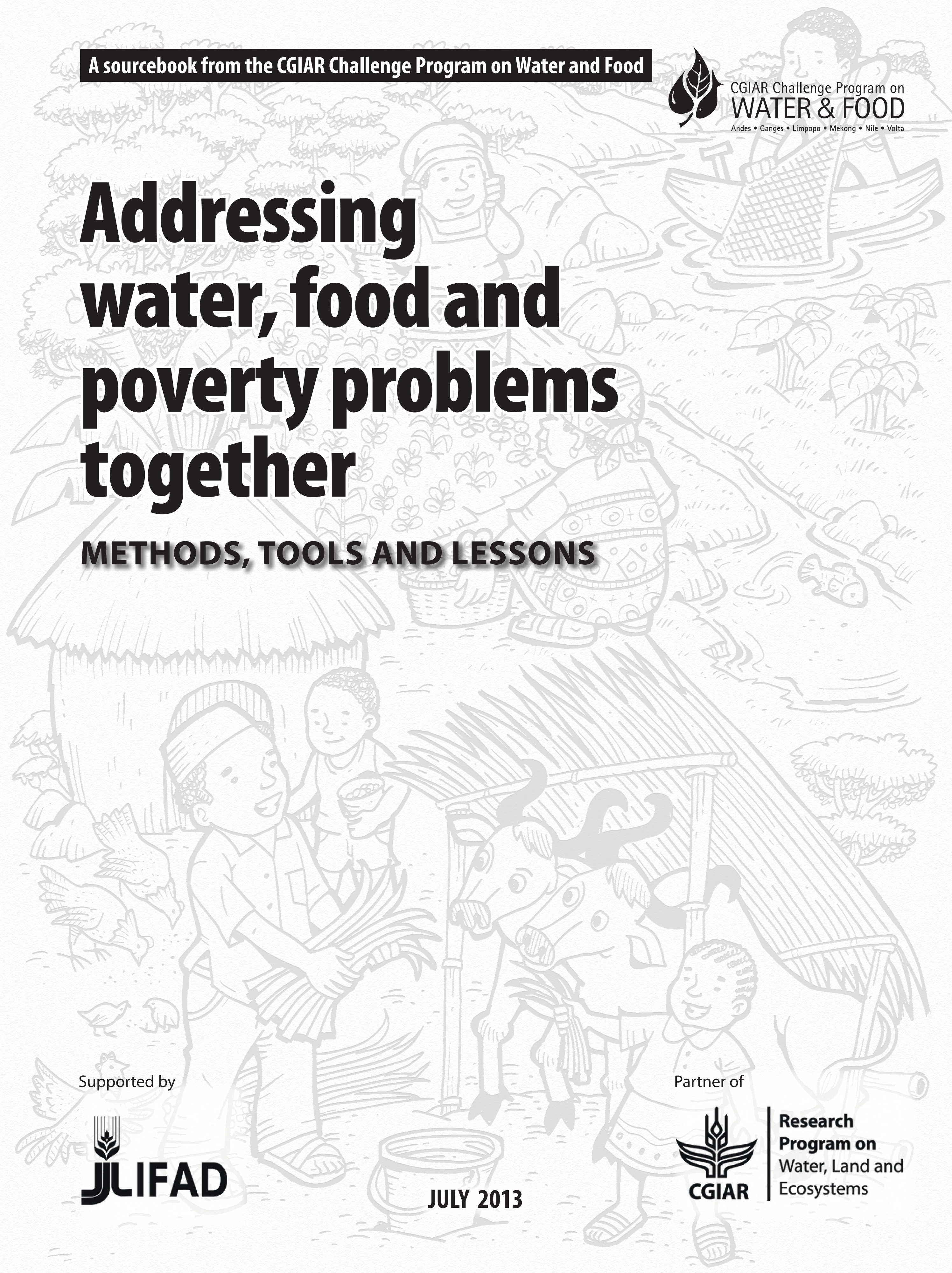
A sourcebook from the CGIAR Challenge Program on Water and Food

CGIAR Challenge Program on
WATER & FOOD
Andes • Ganges • Limpopo • Mekong • Nile • Volta

Addressing water, food and poverty problems together

METHODS, TOOLS AND LESSONS



Supported by

IFAD

Partner of

CGIAR
Research Program on Water, Land and Ecosystems

JULY 2013

Donors that support CGIAR Challenge Program on Water and Food Phase 1 (2003-2009) include:

Denmark
European Commission
France
Germany
Government of New Zealand
Government of the Netherlands
Norway
Sweden
Switzerland
The International Fund for Agricultural Development (IFAD)
The World Bank
UK Department of International Development
US Agency for International Development

Suggested Citation:
CGIAR Challenge Program on Water and Food (CPWF). 2013. Addressing water, food and poverty problems: methods, tools and lessons. A sourcebook from the CGIAR Challenge Program on Water and Food. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF). 144pp.

Contact Information
CGIAR Challenge Program on Water and Food
127, Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka
Mailing Address: P.O. Box 2075, Colombo, Sri Lanka
Tel: +94-11-2880000, +94-11-2784080
Fax: +94-11-2786854
Email: info@waterandfood.org
Website: www.waterandfood.org

Contents

CONTENTS

Acknowledgments

This publication of this sourcebook was carried out as part of the Mainstreaming Innovations project, with funding support from the International Fund for Agricultural Development (IFAD), and with the contributions of the following people:

Steering Committee

Larry Harrington
l.harrington@cgiar.org

Michael Victor
m.victor@cgiar.org

Tonya Schuetz
t.schuetz@cgiar.org

Martin van Brakel
m.vanbrakel@cgiar.org

Lalith Dassenaike
l.dassenaike@cgiar.org

Julian Gonsalves
juliangonsalves@yahoo.com

Production Group

Julian Gonsalves (Overall Coordinator)
juliangonsalves@yahoo.com

Ruvicyn Bayot (Review Coordinator)
ruvicyn@gmail.com

Niki West (Editing)
nvwest@gmail.com

Teresita Rola (Editing)
tessrola@yahoo.com

Noel Rajesh (Editing)
noelrajesh@gmail.com

Angelita Algo (Workshop Support)
angie.algo@gmail.com

Writers

Angelina Ibus
angieibus@yahoo.com

Bernadette Joven
bpjoven@yahoo.com

Ines Vivian Domingo
iv_sunday@yahoo.com

Josephine Bo
josephinembo@yahoo.com

Julian Gonsalves
juliangonsalves@yahoo.com

Katherine Lopez
kslopez77@yahoo.com

Kim Escobin
kim.escobin@yahoo.com.ph

Lily Ann Lando
ld_lando@yahoo.com

Lorna Calumpang
lmc3ph@yahoo.com

Ricardo Armonia
ric_armonia@yahoo.com

Ruvicyn Bayot
ruvicyn@gmail.com

Graphic Artists

Dennis Caparros
denniszcaparros@yahoo.com

Marvin Magno
zha.vhin17@yahoo.com

Ivan Caparros
cmpleguy02@yahoo.com

Lilibeth Villela
lilibeths@yahoo.com

Illustrators

Ariel Lucerna
ariel_lucerna@yahoo.com

Bernabe Remoquillo
berniemr2003@gmail.com

Contributors

Abdelbagi Ismail
a.ismail@irri.org

Alain Vidal
a.vidal@cgiar.org

Amitabha Sadangi
amitabha@ide-india.org

Contributors

Barbara van Koppen
b.vankoppen@cgiar.org

Bas A.M. Bouman
b.bouman@irri.org

Benoy Kumar Barman
b.barman@cgiar.org

Bongani Ncube
bongisto@yahoo.com

Boru Douthwaite
b.douthwaite@cgiar.org

Carmen Candelo
ccandelo@wwf.org.co

Christophe Bene
c.bene@ids.ac.uk

Don Peden
pedenonpender@shaw.ca

Douglas Merrey
dougmerrey@gmail.com

Eline Boelee
e.boelee@waterhealth.nl

Eric Kemp-Benedict
erickb@sei-us.org

Eric Ofosu
ericad200@yahoo.com

Esther van Hoeve
e.van-hoeve@cgiar.org

Eva Schiffer
eva-schiffer@web.de

Everisto Mapedza
e.mapedza@cgiar.org

Glenn Gregorio
g.gregorio@irri.org

John Dore
johndore@loxinfo.co.th

Jonathan Woolley
jonathanwoolley@gmail.com

Jorge Rubiano
jerubiano@gmail.com

Louis Lebel
llebel@loxinfo.co.th

Manuel Magombeyi
manumagomb@yahoo.com

Marc Andreini
mandreini2@nebraska.edu

Marcela Quintero
m.quintero@cgiar.org

Mark Mulligan
mark.mulligan@kcl.ac.uk

Mathias Fosu
mathiasfosu@yahoo.co.uk

Matthew McCartney
m.mccartney@cgiar.org

Max Finlayson
mfinlayson@csu.edu.au

Michael Roberts
mroberts@ide-cambodia.org

Myles Fisher
mylesjfisher@gmail.com

Nancy Johnson
n.johnson@cgiar.org

Nastaja Sheriff
nastaja.sheriff@gmail.com

Nick van de Giesen
n.c.vandegiesen@tudelft.nl

Philip Charlesworth
pcharlesworth@ide-cambodia.org

Philippe Cecchi
Philippe.Cecchi@ird.fr

Randall Ritzema
r.ritzema@cgiar.org

Robert Abaidoo
r.abaidoo@cgiar.org

Romeo Labios
r.labios@irri.org

Ruben Dario Estrada
r.estrada@cgiar.org

Sabita Thapa
sabitathapa@yahoo.com

Simon Cook
s.cook@cgiar.org

Sonali Senaratna Sellamuttu
s.senaratnasellamuttu@cgiar.org

Stephen Sherwood
ssherwood@ekorural.org

Thelma Paris
t.paris@irri.org

Preface

The Challenge Program on Water and Food (CPWF) was initiated in 2002 as a reform program of the CGIAR. It aims to increase the resilience of social and ecological systems through better water management for food production of crops, fisheries and livestock. We do this through an innovative research for development approach that brings together a broad range of scientists, development specialists, policy makers and communities, in six river basins.

CPWF places much value on the appropriate packaging and dissemination of research findings to different users of research results.

Starting in 2011, as part of an IFAD grant on "Mainstreaming Innovations for food security and livelihoods", CPWF carried out a process to repackage research materials to ensure that information is shared between agencies and institutions involved in water management, as well as uptake of promising development interventions. One output of this project is a multi-purpose resource package which includes:

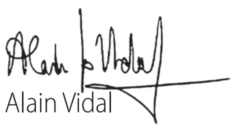
1. **Dialogue posters**. Research derived messages and statements emphasized with illustrated pictures.
2. **Outcome stories**. Stories of change in knowledge, attitudes and practices by different actors involved in CPWF activities.
3. **Sourcebook**. A compendium of best practices, research methods and tools developed.

This sourcebook format was chosen for a couple of reasons. First, there were already a number of materials that could be easily repackaged, especially in light of the documentation efforts made by CPWF staff. A sourcebook takes scientific information and packages it in a way that is accessible to different target audiences. The sourcebook does not contain information from a single source or organization, but rather a wide range of experiences that have been tested in different conditions and settings throughout the country.

It is hoped that this sourcebook will be of special reference to field workers, decision-makers, project staff, educators and others who are interested in water management for food security. We encourage readers to directly contact the authors should you need more information.

Revisions, adaptations and further translations of these are welcome and encouraged. There is intentionally no copyright and the book has been designed and formatted to ensure easy photocopy and reuse of articles. If articles are reused or adapted, please acknowledge the authors and publishers.

This sourcebook is a collaborative effort and we would like to extend our gratitude and appreciation to all those who contributed to its development. We are extremely grateful to Dr. Julian Gonsalves who went above and beyond the initial ideas to bring this sourcebook to life. We also thank all the individuals and organisations who contributed to the sourcebook. Finally, we thank IFAD for their generous contribution to make this effort a reality.



Alain Vidal
CPWF Director
September 2013

Introduction

This sourcebook entitled "***Addressing water, food and poverty problems together: Methods, tools and lessons***" is part of a wider process to capitalize on results from the Phase 1 of CPWF (2004-2008).

Phase 1 of CPWF cast its net widely. Sixty-eight individual research projects were carried out in ten river basins around the world. The learning was immense. Unfortunately, many Phase 1 lessons and experiences are locked away in people's minds or hidden in long technical and scientific reports that are difficult to access, particularly for non-researchers.

The articles in the sourcebook provide development professionals and the wider research for development community with concise information on methodologies, approaches and lessons learned on agriculture water management. The articles are not intended to provide comprehensive information on the project nor are they intended to serve as project summaries. Typically, one or more aspects of the research, usually an approach, have been highlighted in the source book article. There are some limitations to the articles themselves as the reports and journal articles are often from research that took place three to four years ago and has not been updated.

The sourcebook is divided into 12 chapters. Chapter 1 provides a short overview of the CPWF project, based on its strategic and medium term plans. Chapter 2 discusses water in the context of food production and security, information that is based on CPWF's Comprehensive Assessment of Water Management for Agriculture (2007). Chapter 3 has three articles all based on Basin Focal Point (BFP) project outputs previously published in *Water International* (Issues 35 and 36). As such, Chapter 3 provides an overview of river basin issues and discusses in some detail the connection between poverty, water and food. Chapters 4 to 12 are drawn from CPWF project level engagement in the various river basins. These chapters focus on innovative frameworks, methods, approaches and tools. Each chapter consists of a cluster of articles, each standing on its own.

Sourcebook articles were repackaged from previously written material. This means that secondary materials - primarily project reports and peer-reviewed journal articles – were used as the basis for creating these articles. Professional writers and artists were employed as part of this effort and an initial workshop was held with CPWF partners to get feedback on the initial drafts. After improvements, project leaders and external reviewers commented and approved the repackaged articles.

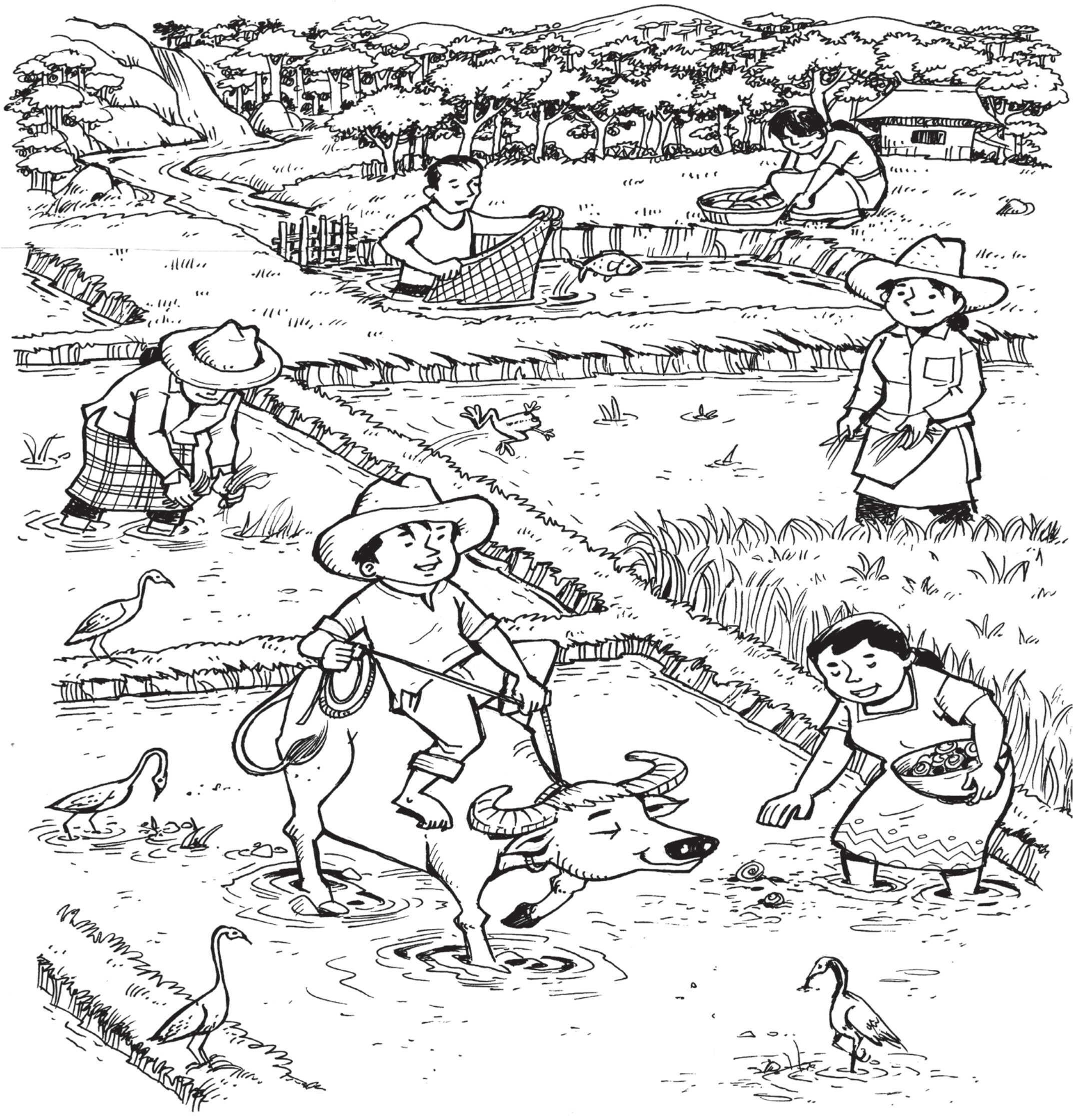
Acronyms

AfDB	African Development Bank
AEA	Agroecosystems Analysis
AguAAndes PSS	AguAAndes Policy Support System
Al	Aluminum
APHA	American Public Health Association
ARI	Advanced Research Institute
BFP	Basic Focal Project
Ca	Calcium
CA	Comprehensive Assessment
CA	Conservation Agriculture
CAC	Conversatorio de accion Ciudadana
CAEA	Commune Agroecosystems Analysis
CBFC	Community-Based Fish Culture
CBO	Community-Based Organisation
CCRP	Collaborative Crop Research Program
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Center for Tropical Agriculture
CNR	National Irrigation Commission
ComMod	Companion Modeling
CONDESAN	Consortium for the Sustainable Development of the Andean Ecoregion
CPWF	Challenge Program on Water and Food
DAE	Department of Agricultural Extension
DFID	Department for International Development
DSS	Decision Support Systems
ECOSAUT	Económica, Social y Ambiental de Usos de la Tierra (A Model for the economic, social, and environmental evaluation of land use)
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPA	Environmental Protection Agency
EPLAUA	Environmental Protection, Land Administration and Use Authority
FAO	Food and Agriculture Organization
FDP	Fertilizer Deep Placement
FFBAR	Farmer Field Based Action Research
FFS	Farmer Field Schools
FIESTA	Fog Interception for the Enhancement of Streamflow in Tropical Areas
FMC	Floodplain Management Committees
FRG	Farmer Research Groups
FRP	Fish Refuge Ponds
FS	Fecal Streptococcus
GDP	Gross Domestic Product
GIS	Geographic Information System
HDI	Human Development Index

HIAs	Health Impact Assessments
HRU	Hydrological Response Units
IARC	International Agricultural Research Centers
ICARDA	International Center for Agricultural Research in the Dry Areas
ICP-AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDE	International Development Enterprises
IEI	Institutional Environmental Index
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IF-WIAM	Integrated Framework for Wetlands Inventory, Assessment and Monitoring
IIRR	International Institute of Rural Reconstruction
ILRI	International Livestock Research Institute
INDAP	Instituto de Desarrollo Agropecuario (National Agricultural Development Institute)
INIA	Instituto de Investigaciones Agropecuarias (National Agricultural Research Institute)
INTA	National Agricultural Research Institute of Nicaragua
IPGs	International Public Goods
IRBO	International River Basin Organizations
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
K	Potassium
KAS	Knowledge, Attitude, Skills
LWP	Livestock Water Productivity
MACRENA	Red para el Manejo Comunitario de los Recursos Naturales
MAFF	Ministry of Agriculture, Forestry and Fisheries
MDG	Millennium Development Goals
Mg	Magnesium
mm	Millimeter
Mn	Manganese
MP-MAS	Mathematical Programming Based Multi Agent System
MRC	Mekong River Commission
MUS	Multiple Use Water System
Na	Sodium
NARES	National Agricultural Research and Extension Systems
NDVI	Normalised Difference Vegetation Index
Net-Map	Network Mapping
NGO	Non-Government Organization
NRSP	Natural Resources Systems Programme
PDAM	Participatory Diagnosis and Adaptive Management
PEA	Private Extension Agents
PES	Payment for Environmental Services
pH	Power of Hydrogen
PIC	Project Implementation Committees
PIPA	Participatory Impact Pathways Analysis
PN	Project Number
PRA	Participatory Rural Appraisal

PRISM	Poverty Reduction through Irrigation and Smallholder Markets
PRODINPO	Programa de Desarrollo del Norte de Potosí
PROLINNOVA	Program for Local Innovation in Sustainable Agriculture and Natural Resource Management
PSS	Policy Support System
PVS	Participatory Varietal Selection
QSMAS	Quesungual Slash and Mulch Agroforestry System
R&D	Research and Development
RBO	River Basin Organizations
RIDA	Resources Infrastructure Demand and Access
RRA	Rapid Rural Appraisal
RWH	Rainwater Harvesting
SANAA Honduras	Servicio Autonomo Nacional de Acueductos y Alcantarillados
SCALES	Sustaining inclusive Collection Action that Links Economic Scales
SG	Small Grant
Si	Silicon
SLIM	Social Learning for the Integrated Management
SME	Small Area Estimation
SRP	Small Reservoirs Project
SWAT	Soil and Water Assessment Tool
TC	Total Coliforms
TTC	Thermotolerant Coliforms
UBN	Unsatisfied Basic Needs
USD	US Dollar
VCM	Voluntary Contribution Mechanism
WASIM-ETH	Water Flow and Balance Simulation Model
WBAAM	Water Body Attribute Analysis Matrix
WEAP	Water Evaluation and Planning
WHO	World Health Organization
WIAM	Wetland Inventory, Assessment and Monitoring
WN	World Neighbors
WP	Work Packages

General Overview of the CPWF Phase 1 (2003-2008)



The CGIAR Challenge Program on Water and Food (CPWF) is an international, multi-disciplinary research for development program that was conceived to identify, create and support partnerships between research and development institutions to address water, food, environment challenges, and to help alleviate poverty. It emphasizes south-south and north-south cooperation and knowledge exchange. The program was successful in bringing together over

Growing more food with less water is a key challenge in the fight against poverty, hunger, and environmental degradation (CPWF 2002)

200 institutions including International Agricultural Research Centers (IARCs), Advanced Research Institutes (ARIs), National Agricultural Research and Extension Systems (NARES), Non-Government Organizations (NGOs), and International River

Basin Organizations (IRBOs) (Fig. 1). Operating across multiple levels, partnerships and knowledge sharing mechanisms were used to carry out innovative ranging from functional genomics to global change research.

At the core of the program was the goal of improving water productivity at different scales, in a way that is environmentally sustainable and socially acceptable. The approach to the improvement ofwater productivity focused on increasing food production and natural resources management. This goal interlocked with the following UN Millennium Development Goals: (1) to eradicate extreme poverty and hunger; (2) to promote gender equality and empower women; (3) to combat HIV/AIDS, malaria and other diseases; (4) to ensure environmental sustainability; and (5) to develop a global partnership for development. The program monitored its progress towards four related targets: (1) food security for all at the household level; (2) poverty alleviation through increased sustainable livelihoods in rural and peri-urban areas; (3) improved health through

The overarching goal is to contribute to the efforts by the global community to increase food production to achieve internationally adopted food security and poverty eradication targets by 2015; while simultaneously ensuring that the global diversions to agriculture are maintained at the level of the year 2000.

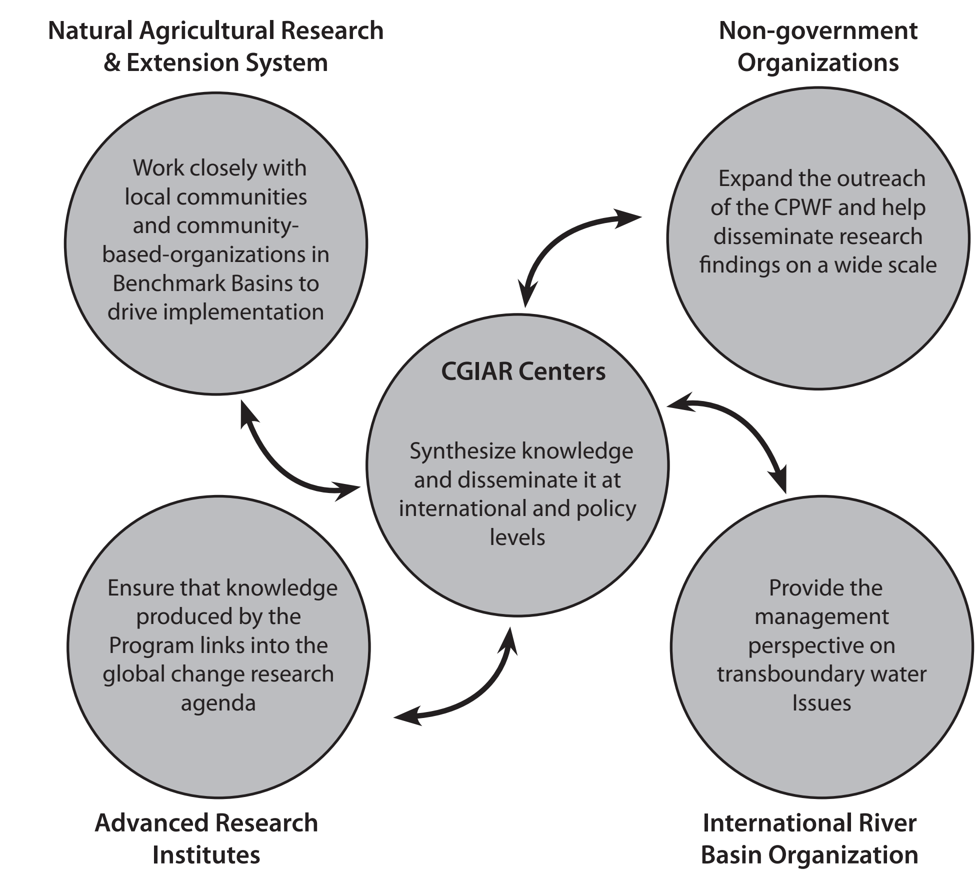


Figure 1. Roles and functions of CPWF partners

better nutrition, lower agriculture-related pollution and reduced water-related diseases; and (4) environmental security through improved water quality as well as the maintenance of water-related ecosystem services, including biodiversity.

A total of 68 research projects were implemented from 2004 to 2008 to address this goal. Projects were selected largely through an open competition. Concept notes were screened based on scientific merit (25%), quality and institutional mix of research team/ stakeholder participation (25%), strategic relevance to CPWF research agenda and priorities (20%), likely impact on beneficiaries (20%), and value for money (10%) The data on type of participating institutions show an average of five institutions per concept note of which one-third are members of the CPWF Consortium. NARES participation is above the minimum of two required. Other institutions who participated in the first open call were CGIAR Centers, Advanced Research Institutes, NGOs, consultancy companies, other international organizations and international projects. Projects were assigned to themes and basins.

Themes

Five interrelated research themes (Fig 2) provided the breadth of scope of the program:

Theme 1: Crop water productivity improvement
Enhancing food and livelihood security through a 'more crop per drop' approach.

This theme viewed water productivity through technological and managerial innovation at the farm level. It endeavored plant breeding solutions for agriculture in areas affected by abiotic

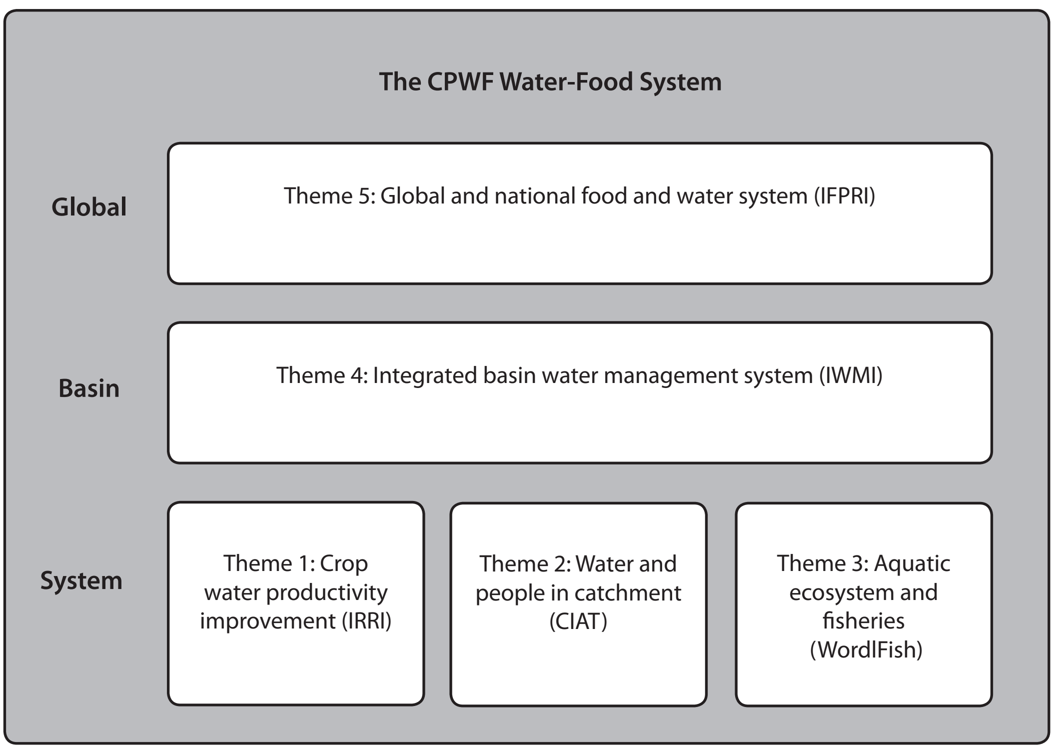


Figure 2. Roles and functions of CPWF partners

stresses. It studied integrated natural resources management and crop production at field, farm and agro-ecosystems level. Moreover, this theme promoted policy and institutional mechanisms to facilitate adoption of crop water productivity improvements.

Theme 2: Water and people in catchments
Improving water management in upper catchment areas.

This theme focused on water, poverty and risks in the upper catchments. It provided innovations in improved water management to enable people to benefit from improved management of land and water resources.

Theme 3: Aquatic ecosystems and fisheries
Protecting aquatic ecosystems and fisheries for more secure livelihoods and biodiversity.

Aquatic environments are a key source of nutrition for many of the world's poor – often, they are the sole source of protein for these communities. Research under this theme investigated environmental water requirements; carried out valuation of ecosystem goods and services; and improved the productivity of aquatic ecosystems through influencing policies, institutions and governance.

Theme 4: Integrated basin water management systems
Managing river basin in a holistic, integrated way Increasingly, integrated water resources management (IWRM) is viewed as a promising strategy for managing water resources.

This theme identified appropriate technologies and management practices to enable integrated water resources management (IWRM). It provided innovative institutional arrangements and decision support tools and information to effectively manage water resources.

Theme 5: Global and national food and water systems
Evaluating water resources and food production in the global and national food and water system.

This theme was about water management and use at the broadest possible scale. Globalization, trade, macroeconomic, and sectoral policies have an important bearing on water, how it is used, and its productivity. It identified the kinds of investments and financing for agricultural water development and water supply that may improve or hinder water productivity improvement. It also recognized the complexity of water resources management at international levels, and formulated appropriate policy and institutional mechanisms to deal with it. In addition, it tackled the changes in the global water cycle.

Basin

The program used an integrated river basin management approach, ranging from the community and field, irrigation and farming systems, to catchment and river basin levels. The scope encompassed agriculture, fisheries, human health, environment and governance.

The research activities were implemented in nine benchmark river basins (Fig. 3) selected across Africa (Limpopo, Nile and Volta), Asia (Indo Gangetic, Karkheh, Mekong and Yellow River) and South America (Andean System of Basins and Sao Francisco). This approach ensured that regional priorities were addressed, that relevant stakeholders were involved, and that the program produce direct measurable impacts on the quality of life in poor communities.

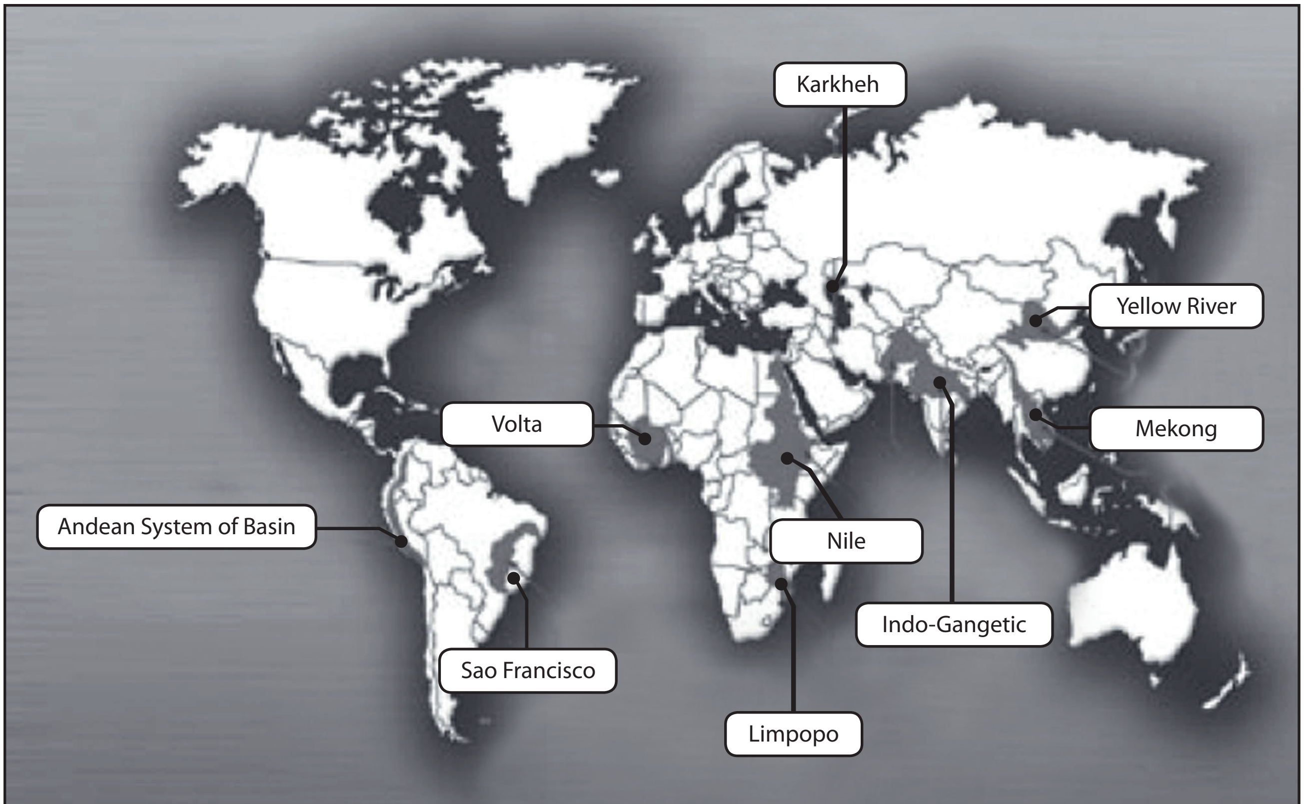


Figure 3. CPWF Benchmark Basins

The significant diversity within and between basin research and development priorities prompted CPWF to identify priority research issues for each of the benchmark basins. This was to ensure direct contribution to the thematic orientation of CPWF (Table 1).

Table 1. Concordance between Themes and Basins in Phase 1

Themes and priority areas	Methods and Approaches								
	Andes	Sao Francisco	Volta	Nile	Limpopo	Karkheh	Indo-Gangetic	Mekong	Yellow
Crop water productivity improvement (Theme 1)									
Developing water-efficient and stress-tolerant crop			■	■			■	■	■
Developing water-saving farm practices			■		■	■	■	▒	
Quantifying needs-based water supply			■	■	■		■	■	
Developing institutional mechanisms and enhancing strategies for adoption				■	■	■	■	■	
Water and people in catchment (Theme 2)									
Examining water and poverty in upper catchments	■					■	■		
Identifying the potential for improving land and water management					■	■			
Enabling people to benefit from improved land and water management	■		■	■	■		■	■	
Generating knowledge	■		■	■	■		■	■	
Aquatic ecosystems and fisheries (Theme 3)									
Improving water productivity of aquatic ecosystems		■	■				■	■	
Valuing ecosystem goods and services	■		■	■	■		■		
Developing institutional mechanism			■	■			■	■	■
Integrated basin water management systems (Theme 4)									
Developing integrated decision support systems	■	■	■	■		■	■		
Developing innovative technologies and management strategies			■	■	■				
Developing institutional mechanism and polices	■		■	■	■		■	■	
The global and national food and water systems (Theme 5)									
Assessing the effects of globalization, trade, and macro-economic and sectoral policies			■		■				
Identifying incentives, options for investments and financing							■		
Developing transboundry water policy and institutions			■	■	■			■	
Adapting to changes in the global water cycle				■	■		■		

Small Grants Program

In 2006, the CPWF contracted 14 "small grants for impact" that operated for periods of 12 to 18 months. For a total investment of under US$1 million – less than the equivalent of a typical three to five-year CPWF research for development project in Phase 1—the small grant projects made significant contributions to: identifying water and food technology for specific end-users (thus showing the potential of CPWF research in general); understanding technology adoption better; stimulating research by NGOs; and to better linking CPWF research to the development process. The CPWF proved that call for small grant proposals are an effective way of obtaining local impact and of connecting a wide range of relevant institutions to the efforts of a network such as CPWF.

Basin Focal Projects

CPWF's integrated approach at the basin level added value to individual research project outputs, and produced knowledge about water productivity at the basin level. Basin focal projects were developed to deliver this added value to various thematic research projects. A basin focal project was carried out in each of CPWF's benchmark basin to assess water poverty and water productivity in terms of methodological developments, decision support information, and knowledge management. The basin focal projects developed a scientific framework for evaluation and outreach of interventions to evaluate their potential impact within and across basins. This strategic research at the basin level increased the innovativeness of the CPWF and helped generate international public goods.

Research Outputs

CPWF's research outputs comprise agricultural, environmental, institutional, and/or policy innovations to address the needs of the rural poor through increased water productivity. Increased basin-level water productivity contributed toward the livelihood improvement of the poor through:

- economic solutions by generating higher income for each cubic meter of water utilized;
- social solutions by creating more jobs and higher food security for each cubic meter of water used;
- environmental solutions by obtaining greater resilience of vital ecosystems for each cubic meter of water.

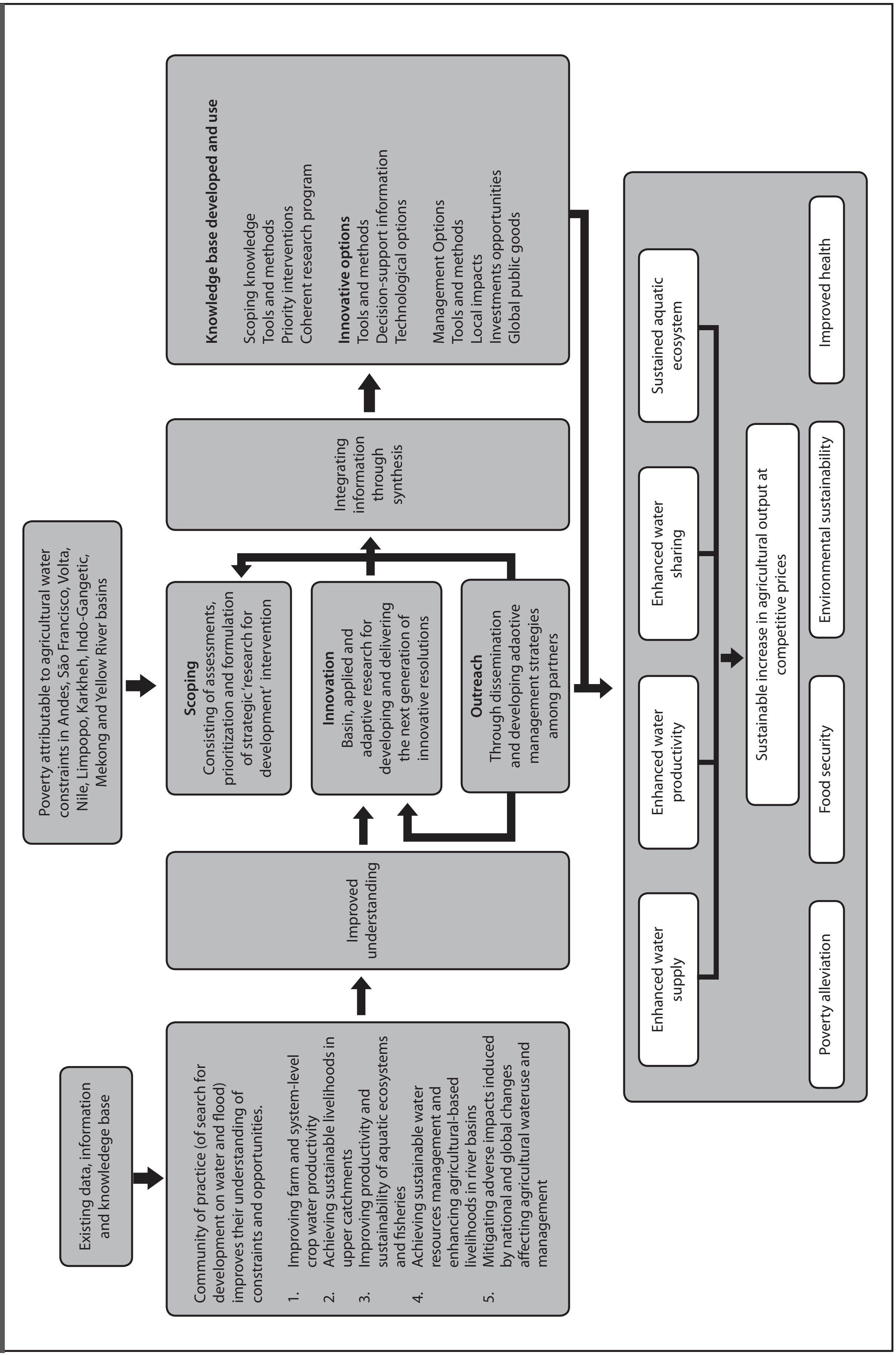
These outputs present the kind of innovation the CPWF provided (Fig. 4).

CPWF products are international public goods (IPGs). These provide information and knowledge that can be applied in several parts of the world, and that are made accessible for public use without restriction. IPGs are available free and are characterized by the fact that they are not depleted by use.

Lessons Learned

- Working with more and different partners in the CPWF has contributed to the achievement of science and outcomes that are different from the 'business as usual' research approaches. CPWF widened the geographical reach of institutions through its basin-scale perspective and approach. By "casting the net widely" and seeking innovative projects with innovative partnerships, we achieved unexpected breakthroughs,

Figure 4. Overview of CPWF process, outputs and outcomes



such as: understanding a range of water-related problems and challenges and how these relate to livelihoods and food security; understanding the performance of some water-related technical and institutional innovations; and learning about the importance of engagement with a wide range of stakeholders and partners as a means of achieving outcomes. Moreover, increased partnerships increased access of participating institutions to data, literature, technical pieces, and high quality science.

- Phase 1 also had direct application in the design of Phase 2, in that basin programs were in part built around interesting and successful phase 1 projects.

Summary

CPWF is a global program that was designed to develop research-based solutions to water and food issues, specifically in developing countries. At the core of these issues are questions on how to sustainably improve water productivity, and create positive impacts on the health and livelihood of the affected communities. The program invested in viable partnerships between research and development institutions across scales, culture, and disciplines to address these questions on water productivity improvement.
CPWF research was defined thematically and spatially through its Themes and Benchmark Basins. It also introduced a set of basin focal projects to provide methodologies and information for the assessment of water productivity and water poverty at the basin level.

The CPWF project outputs are international public goods.

Contact Person

Alain Vidal (a.vidal@cgiar.org)

Key References

CPWF 2005. *CGIAR Challenge Program on Water and Food Research Strategy 2005–2008*.Colombo, Sri Lanka: CPWF.

CPWF 2007. CGIAR *Challenge Program on Water and Food Medium Term Plan 2008-2010*. Colombo, Sri Lanka: CPWF.

Water for Food – Water for Life[1]

Food and feed crop demands will nearly double in the coming 50 years. The two main factors driving how much food we will need are population growth and dietary change. With rising incomes and continuing urbanization, food habits change toward more nutritious and more varied diets—not only toward increasing consumption patterns among cereal crops but also to a shift in consumption from cereals to livestock, fish products and high-value crops.

Producing meat, milk, sugar, oils and vegetables typically requires more water than producing cereals – and a different style of water management. Increasing livestock production requires even more grain for feed, leading to a 25% increase in grains. Thus, diets are a significant factor in determining water demand. While feed-based meat production may be water costly, grazing systems behave quite differently. From a water perspective, grazing is probably the best option for large land areas, but better grazing and watering practices are needed.

Without further improvements in water productivity or major shifts in production patterns, the amount of water consumed by evapotranspiration in agriculture will grow from 70% to 90% by 2050. The total amount of water evaporated in crop production would amount to 12,000-13,000 cubic kilometers, almost doubling the 7,130 cubic kilometers of today. This corresponds to an average annual increase of 100-130 cubic kilometers, almost three times the volume of water supplied to Egypt through the High Aswan Dam every year.
On top of this is the amount of water needed to produce fiber and biomass for energy. Cotton

[1] *Source: Comprehensive Assessment of Water Management in Agriculture. 2007. Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London: Earthscan, and Colombo: International Water Management Institute*

demand is projected to grow by 1.5% annually, and demand for energy seems insatiable. By 2030, world energy demand will rise by 60%, two-thirds of the increase from developing countries, some from bioenergy.

Fortunately, water productivity in agriculture has steadily increased in the past decades, in large part due to increases in crop yields, and will continue to do so. The pace of this increase can vary substantially according to the type of policies and investments put in place, with substantial variation in impacts on the environment and the livelihoods of agricultural populations.

The last 50 years have seen remarkable developments in water resources and in agriculture. Massive developments in irrigation infrastructure have put water at the service of people, while the world population grew from 2.5 billion in 1950 to 6.5 billion today. The irrigated area doubled, and water withdrawals tripled.

Agricultural productivity grew with the development of new crop varieties and introduction of fertilizers and irrigation. Global food prices declined remarkably (Figure 1), and the greater use of water for irrigated agriculture benefited farmers and poor people, propelling economies, improving livelihoods and fighting hunger.

In spite of these developments, in 2003, 850 million people in the world were food insecure, 60% of them living in South Asia and Sub-Saharan Africa, and 70% of the poor live in rural areas. In Sub-Saharan Africa, the number of food-insecure people rose from 125 million in 1980 to 200 million in 2000. Also, the last 50 years have witnessed changes in ecosystems, with many negative consequences.

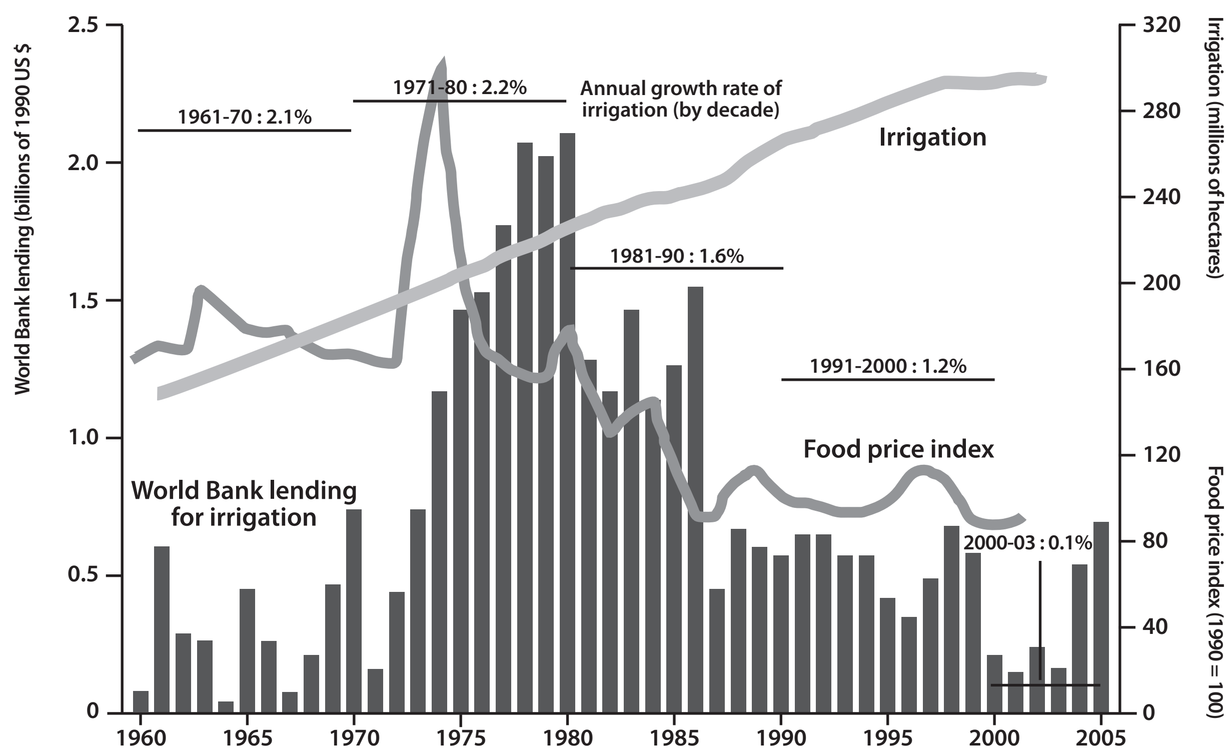


Figure 1. Irrigation expanding, food prices falling

Source: Based on World Bank and Food and Agriculture Organization data

The Millennium Ecosystem Assessment pointed out that growth in agriculture has been responsible for much of this change. Agricultural practices have contributed primarily to the loss of regulating ecosystem services – such as pollination, biological pest control, flood retention capacity, and changes in microclimate regulation – and to the loss of biodiversity and habitats. Our message: better water management can mitigate many of the negative consequences.

"Growth in agriculture has been responsible for much of the loss of biodiversity and habitats and of regulating ecosystem services. Better water management can mitigate many of the negative consequences."

Upgrading rainfed agriculture to meet future food demand

Today, 55% of the gross value of our food is produced under rainfed conditions on nearly 72% of the world's harvested cropland. In the past, many countries focused their 'water attention' and resources on irrigation development. The future food production that should come from rainfed or irrigated agriculture is the subject of intense debate, and the policy options have implications that go beyond national boundaries.

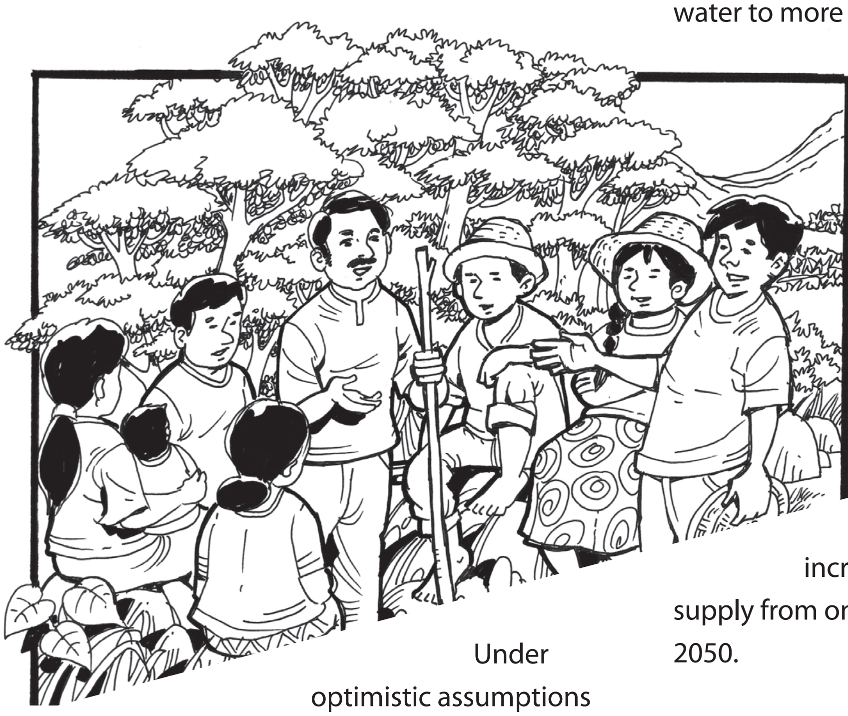
An important option is to upgrade rainfed agriculture through better water management practices. Better soil and land management practices can increase water productivity; an example is adding a component of irrigation water through smaller scale interventions such as rainwater harvesting. Integrating livestock in a balanced way to increase the productivity of livestock water is important in rainfed areas.

At the global level, the potential of rainfed agriculture is large enough to meet present and future food demand through increased productivity. An optimistic rainfed scenario assumes significant progress in upgrading rainfed systems, while relying on minimal increases in irrigated production, by reaching 80% of the maximum obtainable yield. This leads to an average increase of yields from 2.7 metric tons per hectare in 2000 to 4.5 in 2050 (1% annual growth). With no expansion of irrigated area, the total cropped area would have to increase by only 7%, compared with 24% from 1961 to 2000, to keep pace with rising demand for agricultural commodities.

But focusing only on rainfed areas carries considerable risks. If adoption rates of improved technologies are low and rainfed yield improvements do not materialize, the expansion in rainfed cropped area required to meet rising food demand would be around 53% by 2050. Globally, the land for this is available, but agriculture would then encroach on marginally suitable lands and add to environmental degradation, with more natural ecosystems converted to agriculture.

"A growing population is a major factor behind today's water scarcity, but the main reasons for water problems are lack of commitment and targeted investment, insufficient human capacity, ineffective institutions, and poor governance."

Potential of improving irrigated agriculture



Under optimistic assumptions about water productivity gains, three-quarters of the additional food demand can be met by improving water productivity on existing irrigated lands. In South Asia—where more than 50% of the cropped area is irrigated and productivity is low—additional food demand can be met by improving water productivity in irrigated agriculture, rather than by expanding the area under production. But, in parts of China and Egypt and in developed countries, yields and water productivity are already quite high, and the scope for further improvements is limited. In many rice-growing areas, water savings during the wet season make little sense because they will not be easily available for other uses.

An alternative strategy is to continue expansion of irrigated land because it provides access to water to more people and can provide a more secure food future. Irrigation could contribute 55% of the total value of food supply by 2050. But that expansion would require 40% more withdrawals of water for agriculture, surely a threat to aquatic ecosystems and capture fisheries in many areas. In Sub-Saharan Africa there is very little irrigation, and expansion seems warranted. Doubling the irrigated area in Sub-Saharan Africa would increase irrigation's contribution to food supply from only 5% now, to an optimistic 11% by 2050.

Potential of trade to release pressure on freshwater resources

By importing agricultural commodities, a nation "saves" the amount of water it would have required to produce those commodities domestically. Egypt, a highly water-stressed country, imported 8 million metric tons of grain from the United States in 2000. To produce this amount of grain Egypt would have needed about 8.5 km^3 of irrigation water (Egypt's annual supply from Lake Nasser is 55.6 km^3). Japan, a land-scarce country and the world's biggest grain, importer, would require an additional 30 billion cubic meters of crop water consumption to grow the food it imports. Cereal trade has a moderating impact on the demand for irrigation water because the major grain exporters–the United States, Canada, France, Australia, and Argentina–produce grain in highly productive rainfed conditions.

A strategic increase in international food trade could thus mitigate water scarcity and reduce environmental degradation. Instead of striving for food self-sufficiency, water-short countries would import food from water-abundant countries. But poor countries depend, to a large extent, on their national agriculture sector, and the purchasing power required to cover food needs from the world market is often low. Struggling with food security, these countries remain wary of depending on imports to satisfy basic food needs. A degree of food self-sufficiency is still an important policy goal. And despite emerging water problems, many countries view the development of water resources as a more secure option to achieving food supply goals and promoting income growth, particularly in poor rural communities. The implication is that under the present global and national geopolitical and economic situation, it is unlikely that food trade will solve water scarcity problems in the near term.

"But even in an optimistic investment scenario, by 2050, the cropped area will increase by 9% and water withdrawals for agriculture will increase by 13%".

What Policy Actions are Needed?

Policy action 1. **Change the way we think about water and agriculture.**

Thinking differently about water is essential for achieving our triple goal of ensuring food security, reducing poverty, and conserving ecosystems. Instead of a narrow focus on rivers and groundwater, view rain as the ultimate source of water that can be managed. Instead of blueprint designs, craft institutions while recognizing the politically contentious nature of the reform process. And instead of isolating agriculture as a production system, view it as an integrated multiple-use system and as an agroecosystem, providing services and interacting with other ecosystems.

Policy action 2.
Fight poverty by improving access to agricultural water and its use.

Target livelihood gains of smallholder farmers by securing water access through water rights and investments in water storage and delivery infrastructure where needed, improving value obtained by water use through pro-poor technologies and investing in roads and markets. Multiple-use systems, operated for domestic use, crop production, aquaculture, agroforestry and livestock can improve water productivity and reduce poverty.

> **"A wider policy and investment arena needs to be opened by breaking down the divides between rainfed and irrigated agriculture and by better linking fishery and livestock practices to water management".**

Policy action 3.
Manage agriculture to enhance ecosystem services.

Good agricultural practice can enhance other ecosystem services. In agroecosystems, there is scope to promote services beyond the production of food, fiber and animal protein. Agricultural production does not have to be at the expense of other services that water provides in rivers and wetlands. But because of increased water and land use, and intensification, some ecosystem change is unavoidable, and difficult choices are necessary.

Policy action 4.
Increase the productivity of water.

Gaining more yield and value from less water can reduce future demand for water, limiting environmental degradation and easing competition for water. A 35% increase in water productivity could reduce additional crop water consumption from 80% to 20%. More food can be produced per unit of water in all types of farming systems, with livestock systems deserving attention. But this optimism should be met with caution because in areas of high productivity only small gains are possible. Larger potential exists in getting more value per unit of water, especially through integrated systems and higher value production systems and through reductions in social and environmental costs. With careful targeting, the poor can benefit from water productivity gains in crop, fishery, livestock, and mixed systems.

Policy action 5.
Upgrade rainfed systems–a little water can go a long way.

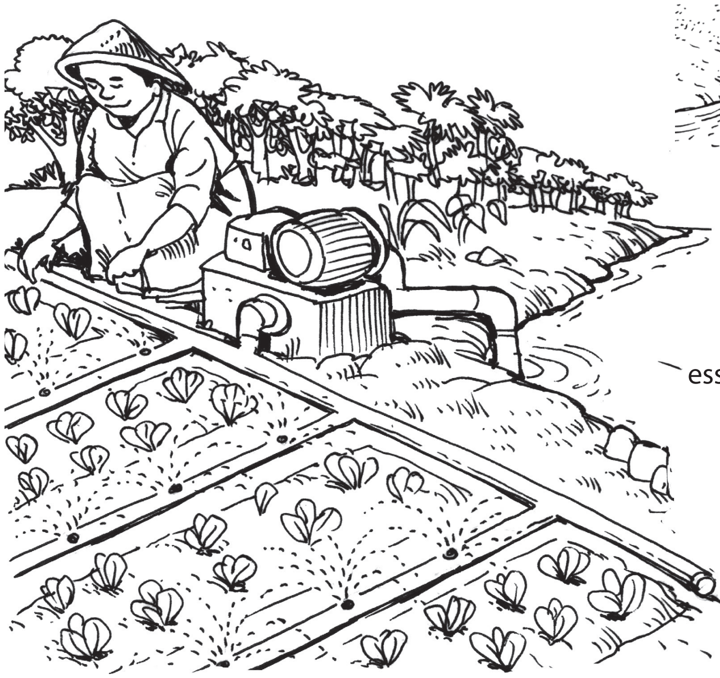
Rainfed agriculture is upgraded by improving soil moisture conservation and, where feasible, providing supplemental irrigation. These techniques hold underexploited potential for quickly lifting the greatest number of people out of poverty and for increasing water productivity, especially in Sub-Saharan Africa and parts of

Asia. Mixed crop and livestock systems hold good potential, with the increased demand for livestock products and the scope for improving the productivity of these systems.

Policy action 6.
Adapt yesterday's irrigation to tomorrow's needs.

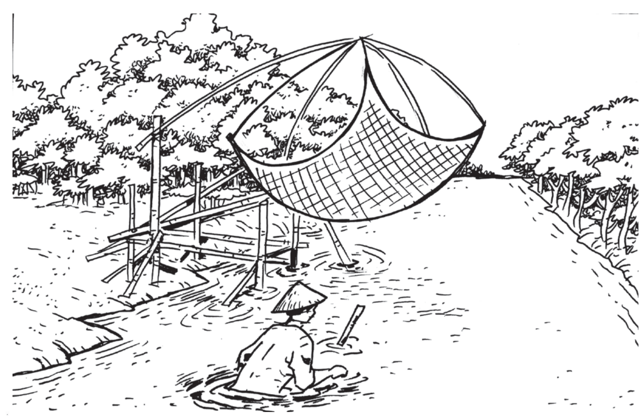
The era of rapid expansion of irrigated agriculture is over. A major new task is adapting yesterday's irrigation systems to tomorrow's needs. Modernization, a mix of technological and managerial upgrading to improve responsiveness to stakeholder needs, will enable more productive and sustainable irrigation. As part of the package, irrigation needs to be better integrated with agricultural production systems to support higher value agriculture and to integrate livestock, fisheries, and forest management.

Policy action 7.
Reform the reform process – targeting state institutions.



Following a realistic process to suit local needs, a major policy shift is required for water management investments important to irrigated and rainfed agriculture. A wider policy and investment arena needs to be opened by breaking down the divides between rainfed and irrigated agriculture and by better linking fishery and livestock practices to water management. Reform cannot follow a blueprint. It takes time. It is specific to the local institutional and political context. And it requires negotiation and coalition building. Civil society and the private sector are important actors. But the state is often the critical driver, though state water institutions are often the most in need of reform.

Policy action 8.
Deal with trade offs and make difficult choices.



Because people do not adapt quickly to changing environments, bold steps are needed to engage with stakeholders. Informed multi-stakeholder negotiations are essential to make decisions about the use and allocation of water. Reconciling competing demands for water requires transparent sharing of information. Other users–fishers, smallholders without official title, and those dependent on ecosystem services–must develop a strong collective voice.

With the inevitable increases in world food demand, agriculture will require more land and water. Part of the increase in food production can be achieved by improving crop yields and increasing crop water productivity, through appropriate investments in both irrigated and rainfed agriculture as in the Comprehensive Assessment scenario. But even in an optimistic investment scenario, by 2050 the cropped area will increase by 9% and water withdrawals for agriculture will increase by 13%, taking resources away from other ecosystems. One challenge is to manage this additional water in a way that minimizes the adverse impacts on, and where possible, enhances ecosystem services and aquatic food production, while providing the necessary gains in food production and poverty alleviation. Doing so will require a water-food-environment policy agenda suited to each country and region.

Summary notes

There is a need to invest in water, but the type of investment and how it is carried out make all the difference. The Comprehensive Assessment's view on investments is broad and considers a range of options. It includes investments in improving management, building effective institutions to meet changing demands, and increasing knowledge and human capacity. Despite good intentions, it is difficult to make meaningful investments in crafting institutions and empowering people to make better choices about water. It is often easier and politically more expedient to build large infrastructure without considering alternatives and the environmental costs. This must change.

A combination of investment, policy and research approaches will clearly be needed, and each strategy will have risks and tradeoffs. Any strategy will require a concurrent policy shift. The global policy and economic environment will provide the overall framework for local agriculture, but local conditions will dictate the choices for future water investments in agriculture.

Change does not always require governments to spend huge sums of money. Many informed investment decisions can save money – a lot of money. When the conditions are right, individuals will invest in water for their own welfare.

Contact Persons

David Molden (dmolden@icimod.org)

Key Reference

Comprehensive Assessment of Water Management in Agriculture 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. London:* Earthscan, and Colombo: International Water Management Institute.

Tag: Comprehensive Assessment on Water Management in Agriculture

Water, Food and Poverty

Water, Food and Poverty: An Overview of Issues in River Basins

The world faces emerging crises with regard to water and food. Its population is around seven billion and is forecast to be at least nine billion by 2050. The increased population will need 70% more food than it does today (Bruinsma 2009), which has major implications for the global environment that supports the food system. That goal will be a lot harder to achieve than the green revolution of last century.

Where will the water come from to produce 70% more food when agriculture already uses 70% of the world's freshwater resources? In the case of the Indus, the Yellow, and the Nile, the basins are essentially closed-that is, all the water is used. In some cases, the environmental flows essential to maintain ecosystem functions in the river estuaries have ceased or are threatened. The only solution in closed basins is to increase water productivity (WP) of crops by using the water more efficiently, what former UN Secretary General Kofi Annan called, "More crop per drop" (Annan 2000).

The Consultative Group on International Agricultural Research (CGIAR) took up this issue through its Challenge Program on Water and Food (CPWF). One of the CPWF's approaches was to examine in detail, the issues of development, poverty and water productivity in 10 river basins worldwide in the Basin Focal Projects (BFP).

The most fascinating outcome is that all the basins are different. Many of them have high levels of poverty and there are some similarities, but each presents different underlying problems, which must be addressed if the goals of increasing food production and overcoming poverty are to be met.

Water related concerns

Population growth has reduced available water in some basins below 1700 m^3/capita/yr, the level conventionally considered secure (Falkenmark 1989). Absolute water scarcity worsens when the growing population depends on unsustainable irrigation as in the Yellow, Indus, Karkheh and upstream Limpopo basins.

Apart from the need to increase WP in closed basins, populations in the sub-Sahel are doubling every 30 years, with every indication that they will continue to do so. Food production has kept pace with the increase over the last 20 years, largely by increasing the cropped area. This can continue in the short term. For the longer term, however, it is necessary to address the cause of low WP of rainfed agriculture in the sub-Sahel (the Volta and the Niger basins). WP could be increased with appropriate agronomy (high-yielding varieties and fertilizer) as demonstrated by the Millennium Villages project. As pressure on the available land increases, however, higher WP is the only solution to providing the food that will be needed.

For the rural poor in some basins, water quality is more important than quantity. Indeed water quality is a universal issue for the rural poor as in the Nile, Indus- Ganges, and Volta basins, but also in the relatively developed basins of the Andes, where mining and other uses threaten water quality. Moreover, it is difficult to provide safe water to the invariably dispersed populations of the rural poor. The success of "Thai jars" (small, artisanal, ferro-concrete water tanks) in Nepal suggests that there are feasible solutions, which could be applied more widely. Rainwater harvesting for domestic water receives little attention, but it is viable even in semi-arid countries. Rainfall collected from the roofs of dwellings and other structures was the source of domestic water for much of rural Australia during its pioneering phase, and still is in many places.

Water-related hazards of drought, flood and water-borne diseases have major impacts on development. The hazards cause more hardship where countries have little capacity to manage them, such as in the Niger, the Volta, or the Nile basins, or where the events can be extreme as in the Limpopo.

It is easy to say that poor water quality is an indicator of poverty. Yes, the poor often have bad water. But is this a cause or an effect? Certainly, poor-quality water brings with it problems like water-borne diseases and infant mortality. But if they had good water would they still be poor? Probably, but their quality of life would be improved.

Fish and the commons

Fish in general are a common resource and at least in the case of maritime fisheries have been plundered to the point of collapse with the advent of industrial fishing in the last century. Will the Mekong suffer a similar fate? There is evidence that the total catch has remained static for the last 10 years, so that per capita consumption has fallen as the population has increased. The productivity of the Tonle Sap fishery in Cambodia, which provides livelihoods for over one million people, depends on the seasonal ebb and flow of the Mekong. Will hydropower dams impact the fish catch by smoothing out this seasonality and cause wrenching social change? Will economic development based on hydropower provide compensation for the population that now depends on fishing? If there is a parallel between possible loss of the commons of the fish in the Mekong and the misery and migration caused by the enclosure of the commons in the United Kingdom 250 years ago, there is little cause for optimism.

Legal duality

Legal duality of institutions leads to the inability of herders, migrants and fishers to get access to land and water resources in West Africa (see the Niger and the Volta papers). Central governments have been unable to insist that rights to land and water should be by means of formal land title. The breakdown of traditional cattle herders' access to forage and water is having a profound effect on their livelihoods in West Africa.

Transboundary issues

Transboundary institutional weakness is a common theme, identified in all but the Karkheh, which is entirely within one country. Boundaries do not have to be international to be problematic; provinces in China and states in federal systems such as India are quite proprietary over the waters within their borders.

One reviewer of the Limpopo paper commented that the river is notable for not having a large dam that would encourage transnational co-operation. There is no large dam on the lower Limpopo because there is no suitable dam site. But it begs the question of whether large dams do indeed encourage transnational co-operation. Giordano et al. (2005) show that despite tensions, transboundary rivers encourage more cooperation than conflict.

Salman (2010) describes how upstream riparian countries can be "harmed by downstream [riparian countries] through foreclosure of their future uses [of water]". He concludes that co-operation amongst riparian countries is the cardinal principle of the law of international waters, and that the interests and concerns of both upstream and downstream riparian countries need to be considered by all parties. It is hard to argue against that conclusion, but implementing it requires good will on all sides, which is difficult to achieve if all parties continue to pursue their own narrow interests, as they often seem to do.

Transboundary institutions

Most of the transnational rivers do have a statutory institution, nominally with a coordinating role, but the participating countries in general have not ceded any useful authority to the institutions they have created. They remain bodies that support dissemination of research, and convene conferences and meetings, but they do little to influence political outcomes, which can only be arrived at by consensus of the constituent countries. The Nile River Commission is dominated by the downstream countries, Egypt and Sudan, who insist on adherence to the arrangements made in colonial times, which did not consider upstream countries. Indeed, Egypt threatens to go to war with any country that presumes to reduce downstream flows of the Nile.

The Volta River Commission does achieve some useful collaboration between Ghana and Burkina Faso, which together occupy 84% of the basin. In contrast, each of the members of the Mekong River Commission (MRC), Cambodia, Lao PDR, Thailand and Vietnam, insist on their right to do whatever is in their own best interests. China's participation in the MRC is limited to observer status, and although it appears to be increasingly willing to co-operate, there is little reason to expect that it will be any less protective of its interests than other Mekong Basin states. Even though the number of nations involved is fewer, conflict in the Ganges is more intense. The Farakka Barrage in India, 10 km upstream from the border with Bangladesh, controls the Ganges by diverting it to the Hooghly River from its course through Bangladesh. India closes it during the dry season, but opens it when the Ganges floods so that Bangladesh gets no Ganges water in the dry season, but is inundated when the river floods. Repeated efforts to resolve the issue have not been successful.

Climate change

The threat of climate change hangs over all. The global circulation models forecast that temperatures will rise by 2°-3°C by 2050, which will increase water lost to evaporation. The effect of the higher temperatures on crop yield is harder to predict, but there are some indications with maize and rice that higher temperatures will reduce yields. Precipitation is not so clear-cut, but most basins are likely to decrease somewhat, which when coupled with higher temperatures, will cause more water stress on crops. Moreover, with less snow and ice to spread river flows, timing of flow peaks will change and there will be more floods. In some places, there will be plant-breeding solutions, such as crops that flower earlier in the day to avoid the heat, but these are possibilities rather than off-the-shelf solutions. There are also agronomic solutions, such as later planting to avoid high rates of evaporation during the very hot weather that precedes the monsoon to reduce the demand on groundwater in the Indian Punjab.

Basin summaries

The outstanding features of each basin are summarized below:

Andes

The Andes are a complex system of independent basins in which biophysical and developmental diversity are confronting change. The economies of the Andean countries are developing, although there are still large populations who do not share the benefits. The pressing issue the countries confront is how to share the benefits of development more equitably.

Ganges

The Ganges Basin is under extreme population pressure. Low WP downstream contrasts with high WP upstream but unsustainable groundwater use. There were great benefits from the green revolution in the western states, but much less in the eastern states. The Farakka Barrage is a transnational issue, which forced Bangladeshi farmers to adapt to less water by changing from flooded, dry-season rice to other crops and irrigation by groundwater.

Indus

The Indus is a closed basin that is under extreme population pressure, with aging, unreliable water infrastructure, and increasing, unsustainable use of groundwater. The challenge is to upgrade the infrastructure to reduce dependence on groundwater, and to manage use of groundwater to maintain the resource.

Karkheh

The Karkheh Basin is under pressure to meet Iran's need for food self sufficiency. In general, the rural population of the basin is not the poorest in Iran. Water for the downstream Hoor-al-Azim wetlands on the border with Iraq is not a political priority.

Limpopo

The riparian countries of the Limpopo have vulnerable populations, unreliable water and low WP. Upstream is a juxtaposition of productive commercial agriculture and unproductive subsistence farming. Downstream is characterized by a poor population vulnerable to the basin's damaging floods and droughts.

Mekong

The Mekong is a diverse basin facing the tensions of development. The commons of the fishery resource on which many depend for their livelihoods is vulnerable to changed hydrology by hydropower dams. The countries as a whole may benefit, but those whose livelihoods depend on fishing likely will not. China's role remains an enigma.

Niger

Water poverty and actual poverty in the Niger are caused by illiteracy, poor-quality water and dysfunctional institutions. Planned dams upstream of the Inland Delta threaten its annual flood on which much of its productivity and the livelihoods of a million people depend.

Nile

The Nile Basin is characterized by downstream-upstream conflict and unmet agricultural potential in the upstream countries. Eighty per cent of the water that arrives at the Aswan Dam comes from Ethiopia, which wants to develop some of its irrigation potential. Egypt and Sudan want to maintain the flows agreed in colonial times.

Volta

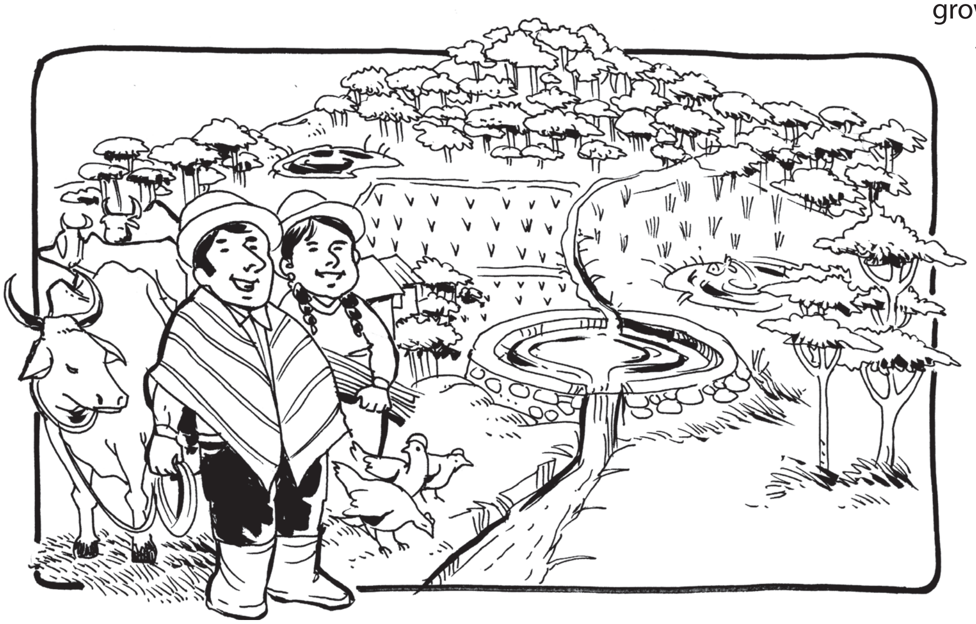
Ghana in the Volta Basin is regarded as a model in West Africa being further along the development pathway than Burkina Faso or any of the Niger countries except oil-rich Nigeria. Ghana's "rural households accounted for a large share of a steep decline in poverty induced in part by agricultural growth" (World Bank 2007), and the fertility rate is falling as a consequence. Upstream small dams will have little effect on hydropower at Akasombo.

Yellow

China's burgeoning economy puts increasing pressure on agricultural water, and in the case of the Yellow River Basin, has caused extreme basin closure and increased water scarcity. The Yellow River Basin shows that a centrally directed economy can facilitate dramatic shifts in water allocations in the absence of firm and litigable rights to water, but it is not without cost. After not reaching the sea for a number of years in the late 1990s, there is now a minimum year-round flow, but achieving it caused hardship to upstream water users.

The Role of Agriculture for Development

Ogilvie et al. conclude in their paper on the Niger that "improved agriculture and water management require technical, sociological, and regulatory changes to address the wider causes of poverty". This could be said of all basins. The tough question is how to make these changes happen. The short answer is economic development. But how can that be achieved? According to the World Bank (2007), the solution is through support of agriculture: "Agriculture has served as a basis for growth and reduced poverty in many countries, but more countries could benefit if governments and donors were to reverse years of policy neglect and remedy their underinvestment and misinvestment in agriculture" (World Bank 2007).



The World Development Report (World Bank 2007) goes on to argue that agriculture was heavily taxed to support industrialization, which, coupled with continued anemic investment in agriculture, reflects a political economy in which urban interests dominate policy that "proved lethal in Africa" (Byerlee *et al.* 2009).

In the twenty-first century, agriculture continues to be a fundamental instrument for sustainable development and poverty reduction, even while economies move beyond agriculture to more industrial economies: "The global development agenda will not be possible without explicitly focusing on the role of agriculture for development" (Byerlee *et al.* 2009).

Using agriculture as the basis for economic growth in the agriculture-based countries requires a productivity revolution in smallholder farming. To pursue agriculture-for-development agendas, local, national and global governance for agriculture need to be improved. Growth in GDP from agriculture is at least twice as effective in reducing poverty as growth in GDP in sectors outside agriculture. In the case of China, growth in agriculture reduced poverty 3.5 times more than growth outside agriculture, while in Latin America it was 2.7 times more (World Bank 2007).

Agriculture is therefore the basis for economic growth, even though development moves economies beyond it. But increased agricultural activity has major impacts on the river basin systems that support it. Furthermore, as development moves beyond agriculture, demand increases from other sectors and from the populations they sustain. Achieving processes that support balanced development of water and food systems requires detailed insight of conditions as they occur in basins, together with analysis of processes that cause them.

Contact Persons

Myles Fisher (mylesjfisher@gmail.com) and Simon Cook (s.cook@cgiar.org)

Key Reference

Fisher, M. and S. Cook. 2010. Introduction. *Water International,* **35**, 465-471.

Tag: Basin Focal Projects (BFP)

Bibliography

Annan, K. 2000. *We the peoples: the role of the United Nations in the 21st century*. New York: United Nations Department of Public Information.

Bruinsma, J. 2009. The resource outlook to 2050: by how much do land, water and crop yields need to increase by 2050? In: *How to feed the world in 2050,* FAO Expert Meeting, 24-26 June 2009. Rome: Food and Agriculture Organization (FAO) of the United Nations.

Byerlee, D., A. de Janvry and E. Sadoulet 2009. Agriculture for development: toward a new paradigm. *Annual Review of Resource Economics,* **1**, 15-31.

Falkenmark, M. 1989. The massive water scarcity now threatening Africa: why isn't it being addressed? *Ambio,* **18**, 112-118.

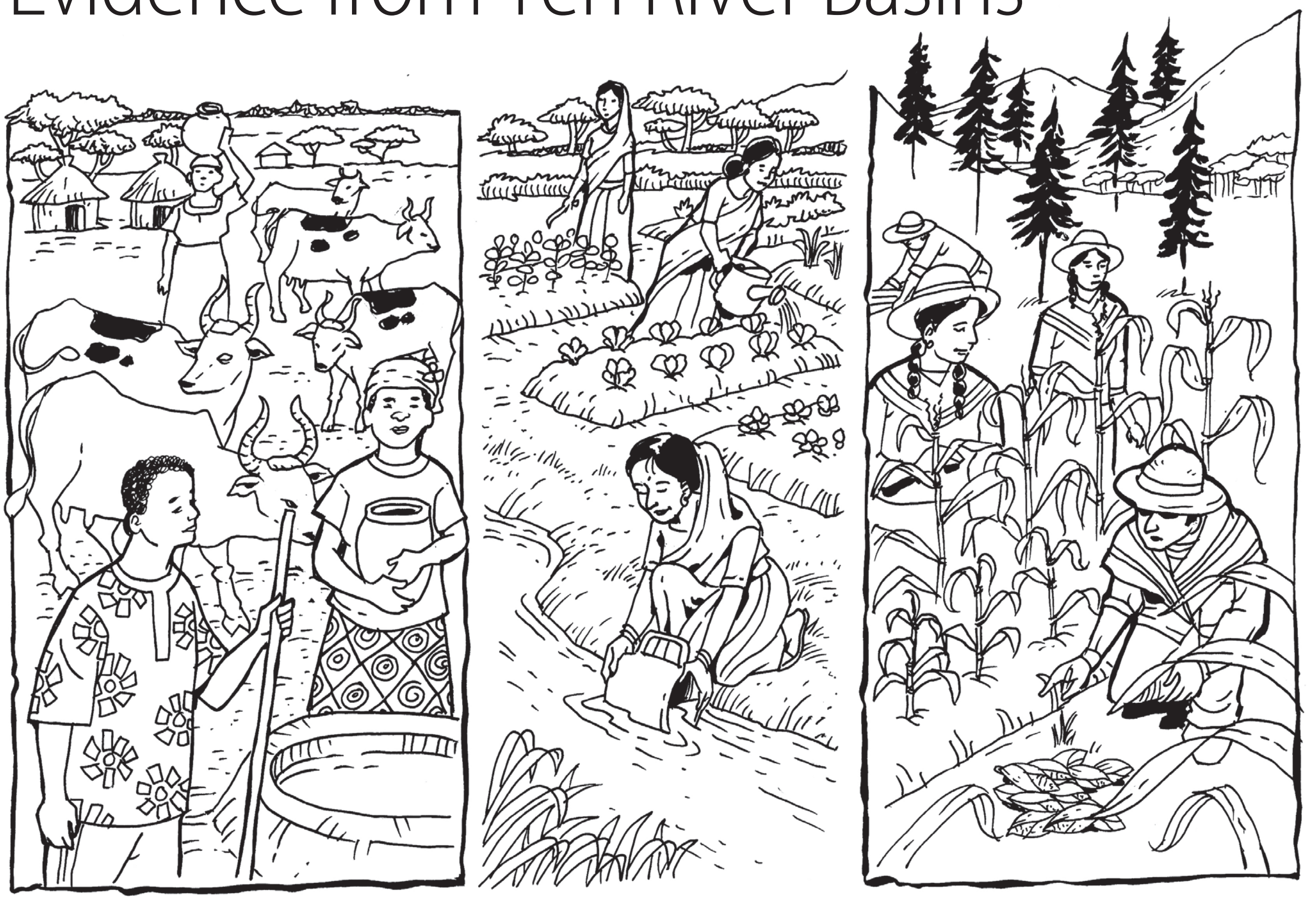
Giordano, M.F., M.A. Giordano, M.A. and A.T. Wolf 2005. International resource conflict and mitigation. *Journal of Peace Research,* **42**, 47-65.

Sachs, J. 2007. *Bursting at the seams: the BBC Reith Lectures, 2007*. London: Radio 4, British Broadcasting Corporation. Retrieved from: http://www.bbc.co.uk/radio4/reith2007

Salman, S.M.A. 2010. Upstream riparians can also be harmed by downstream riparians: the concept of foreclosure of future uses. *Water International,* 35, 350-364.

World Bank 2007. *World development report 2008: agriculture for development.* Washington D.C.: World Bank.

Connections Between Poverty, Water and Agriculture: Evidence from Ten River Basins



There are at least two ways to think about water and poverty. First, we can ask, how do water-related constraints and opportunities contribute to poverty and its alleviation? Second, we ask, what are water-specific forms of deprivation? The first framing points to links between water and poverty, where "poverty" is conceived in broad terms. The second framing leads to the concept of "water poverty." An important conclusion from the CGIAR Challenge Program on Water and Food (CPWF) Basin Focal Projects (BFP) research is that the first approach is more analytically tractable than the second; moreover, it is arguably more relevant for policy. The dominant approach within the water field, however, has been the second, the water poverty approach. Accordingly, we review those ideas briefly here.

There are multiple definitions for "water poverty" (Sullivan 2002, Black and Hall 2004, Cook and Gichuki 2006). The influential Black and Hall (2004) definition is a functional poverty definition, in that it lists observable deprivations associated with water risks and constraints. It also includes an implicit institutional context, introduced by way of explicit categorical inequalities, that is, inequalities arising from socially recognized categories, such as ethnicity, religion or gender (Tilly 1998), specifically, those affecting slum dwellers, women and girls. Cook and Gikuchi (2006) illustrate the underlying causes of agriculturally based water poverty, highlighting the role of low water productivity in the dynamics of poverty. Their framework encompasses assets and livelihood strategies by discussing the importance of livestock, crops and water infrastructure to the poor. This more expansive view is captured well by the sustainable livelihoods framework (DFID 1999) (Figure 1). Sullivan (Sullivan 2002, Sullivan and Meigh 2003) takes a functional definition of water poverty and makes it operational by constructing a water poverty index, which is a hierarchical aggregate. The water poverty index is a weighted sum of component indicators that measure water resources, water use, access to water, water-management capacity and ecosystem needs. The bottom of the hierarchy is a set of specific indicators that are aggregated to form the component indicators.

Poverty and livelihoods

For a term that has such wide currency, "poverty" is an elusive concept. In its Handbook on Poverty and Inequality, the World Bank defines poverty as "a pronounced deprivation in well-being" (Haughton and Khandker 2009), but this is rather vague and does not immediately suggest paths to identify and alleviate poverty. In practice, the World Bank uses the now-dominant approach to measurement, a consumption or income-based poverty line. Those below the line are considered to be poor and those above the line are non-poor. While a poverty line operationally defines who is poor, it is not a definition of poverty in itself. Rather, it derives from an assumption that people would obtain what they need to live if they could and if they do not, it is a symptom of their poverty. For this reason, as

with the original poverty line (Orshansky 1965), many national poverty lines are based on the cost of a minimally nutritious basket of food, on the assumption that food is the most basic necessity and hence an inability to obtain food is a good indicator of overall deprivation.

Metrics tend to create their own reality as policy increasingly seeks to change the value of the metric rather than the underlying reality it is meant to represent (Scott 1998, Molle and Mollinga 2003). This is true also of poverty lines; over time, the emerging defects of using them as guides to policy have been addressed by refining the concept (Haughton and Khandker 2009) and by exploring alternative approaches to measuring and defining poverty (Sen 1999, Carter and Barrett 2006). Here we adapt and extend the useful classification scheme of Carter and Barrett (2006) and we discuss the following poverty concepts: definitions based on static and dynamic financial flow, definitions based on static and dynamic assets, functional definitions and definitions based on capability.

Measures of poverty based on financial flow

Definitions based on financial flow focus on income or expenditure flows. Static measures of financial flow assume that people have relatively stable incomes or expenditures, which largely remain below or above a poverty line. An indicator based on this concept can be calculated using standard household surveys without the need of panel data that track individuals or households over time. But it cannot distinguish between chronic poverty, where people remain poor for many years and transitory poverty, in which a significant number of people move into and out of poverty (Carter and Barett 2006).

Measures of poverty based on assets

The argument for measures of poverty based on consumption rather than income points to an important factor, which measures of financial flows miss. People and households accumulate assets when their incomes allow them to do so and make use of those assets to meet their needs in lean times. Sufficient assets also allow them to undertake new initiatives, such as expanding a farm, digging a well or buying an animal.

Functional poverty definitions

Neither indicators based on financial flows nor on assets are direct measures of the "pronounced deprivation of well-being" that characterizes poverty. An alternative approach is to adopt a functional definition of poverty that identifies specific forms of deprivation and measures them. Most definitions of water poverty (that is, water-specific deprivation) fall into this category.

Institutional poverty analysis

One of the most creative thinkers about poverty, inequality and development is the economist

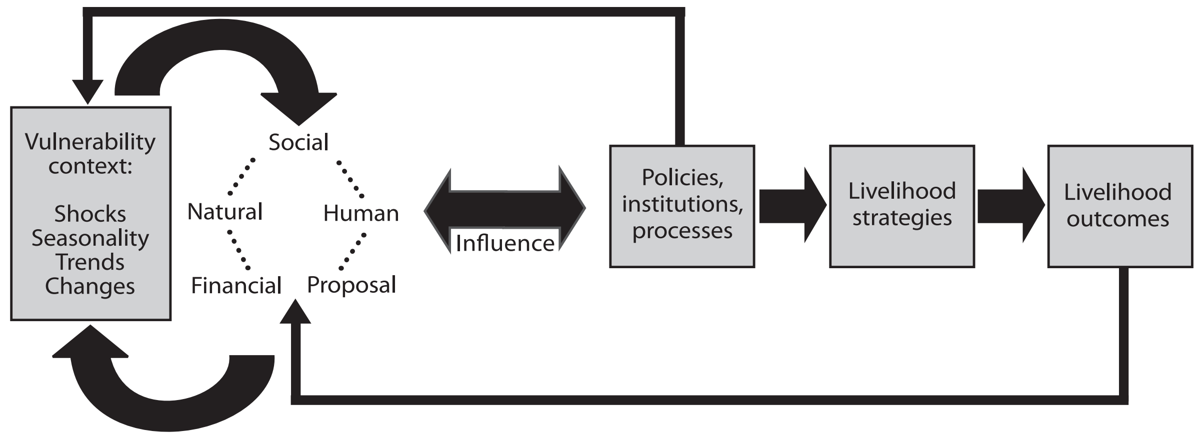


Figure 1. The DFID sustainable livelihood frameworks

Amartya Sen. He has elaborated a capability-based view of poverty, in which poverty is a reflection of the "substantive freedoms [an individual] enjoys to lead the kind of life he or she has reason to value" (Sen 1999). This notion of poverty as freedom emphasizes the impact of the institutions within which individuals and households make their decisions and pursue their livelihoods.

Livelihoods

Conceptions of poverty have evolved in tandem with concepts of development and in particular sustainable development, because poverty is expected to decrease with development. In Amartya Sen's framing, the link is explicit: development is the removal of "unfreedoms" that limit people's capabilities (Sen 1999). The asset and capabilities approaches to poverty are merged in a view of livelihoods that grew out of dissatisfaction with the views of rural livelihoods prevalent in the 1990s and that are reflected in the UK Department for International Development's (DFID) sustainable livelihoods framework (Scoones 1998, Bebbington 1999, DFID 1999). In this framework (Figure 1), households deploy their financial, physical, human, social and natural assets using livelihood strategies to meet their livelihood goals. They do this within a vulnerability context, characterized by shocks, trends and cyclical changes and moderated by the formal and informal institutions within which they operate.

The sustainable livelihoods framework is a usable way of thinking about development and poverty, including within the water resources context (Nicol 2000). It encompasses an asset-based approach to analyzing livelihoods and embeds them within an institutional context. It also draws upon resilience concepts in its focus on fluctuations in the natural, economic and social environment (Baumgartner and Högger 2004).

Review of evidence from the basins

The basin papers describe basin-specific poverty analyzes. They make clear that each of the basin teams of the BFPs followed a unique approach to understanding and analyzing water-related poverty. Techniques ranged from scoping methods with low data requirements, to intensive data analysis with significant data requirements. Regardless of the amount of data involved, the general process used in the different basins included

- choosing indicators of poverty and water poverty;
- identifying candidate causal or correlated variables;
- creating maps of variables and looking for patterns;
- carrying out statistical analysis and modeling, such as systems or hydrological models, Bayesian methods and spatial statistical techniques, to explore relationships; and,
- using models for hotspot analysis, investigating causality and scenarios.

We elaborate on these steps in the next section.

Methods

The motivation for carrying out a water and poverty analysis is to identify ways to reduce or eliminate poverty through appropriate interventions. Knowledge of where water-related poverty exists and why it is there informs the interventions. Therefore, the different BFP basins made use of either general poverty indicators or specific indicators of water and poverty. General measures of poverty included financial flow variables (such as the proportion of the population below an income or expenditure-based poverty line); asset inventories; and functional, outcome-based indicators (such as infant mortality, nutritional status, education, life expectancy and child mortality and morbidity). Water-related indicators included exposure to hazards (for example, flood risk, drought prevalence and water-borne or water-related disease), climate data (such as rainfall and remotely sensed normalized difference vegetation index, NDVI) and provision of water infrastructure (such as access to irrigation, access to safe water and sanitation and water productivity). Some basins also created summary indicators. For example, the São Francisco project constructed a novel index of water availability, while the Mekong project constructed an aggregate index for water-related poverty.

With the chosen indicators, several of the basins mapped poverty, which revealed important large-scale patterns and suggested relationships. At its most basic, poverty mapping is simply the process of putting poverty indicators on a map and looking at them, which was done at an early stage in the Volta and the Mekong to orient the study. Such analyzes can reveal compelling large-scale patterns; for example, the Volta and São Francisco basins, which run on a north-south axis, have a strong

rainfall gradient and poverty levels vary, more or less systematically, along that gradient. Similarly, the Yellow River, the Indus and the Ganges have pronounced upstream-downstream poverty gradients. Complementing this "map and look"

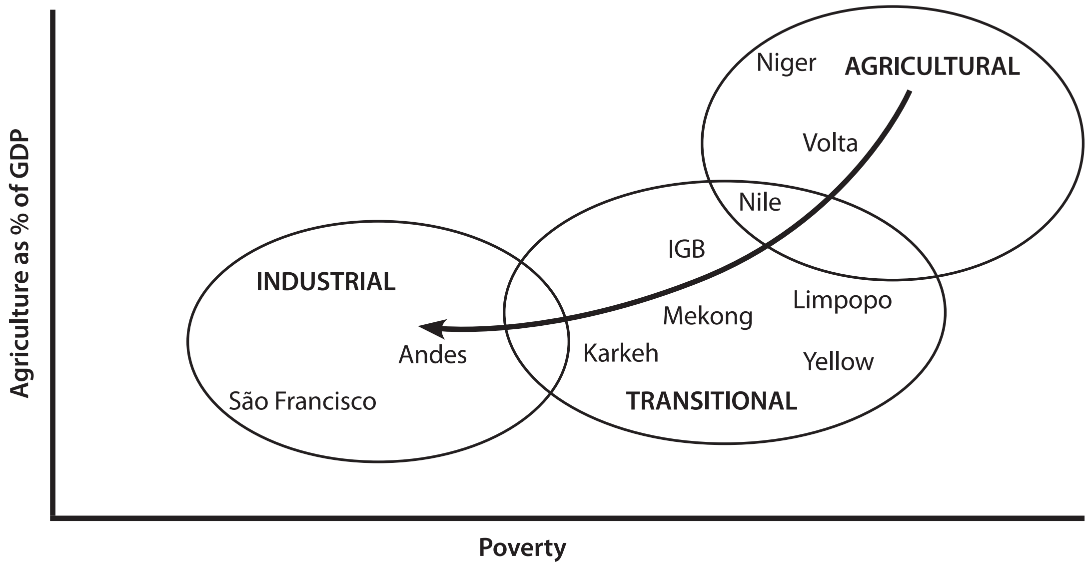


Figure 2. The basins along the development trajectory (World Bank 2007)

approach are semi-formal methods for aggregating poverty indicators into an overall poverty index (as in the Mekong) and formal methods, such as spatial statistical analysis (as in the Niger).

Most of the BFPs carried out non-spatial statistical analyzes and modeling that explored the relationships between water and poverty variables. As these constitute the bulk of the poverty discussion within the basin-specific papers, they will not be repeated here. Rather, we focus on the outcome of the analyzes, which is to reveal patterns of correlation between water-related explanatory variables and poverty variables.

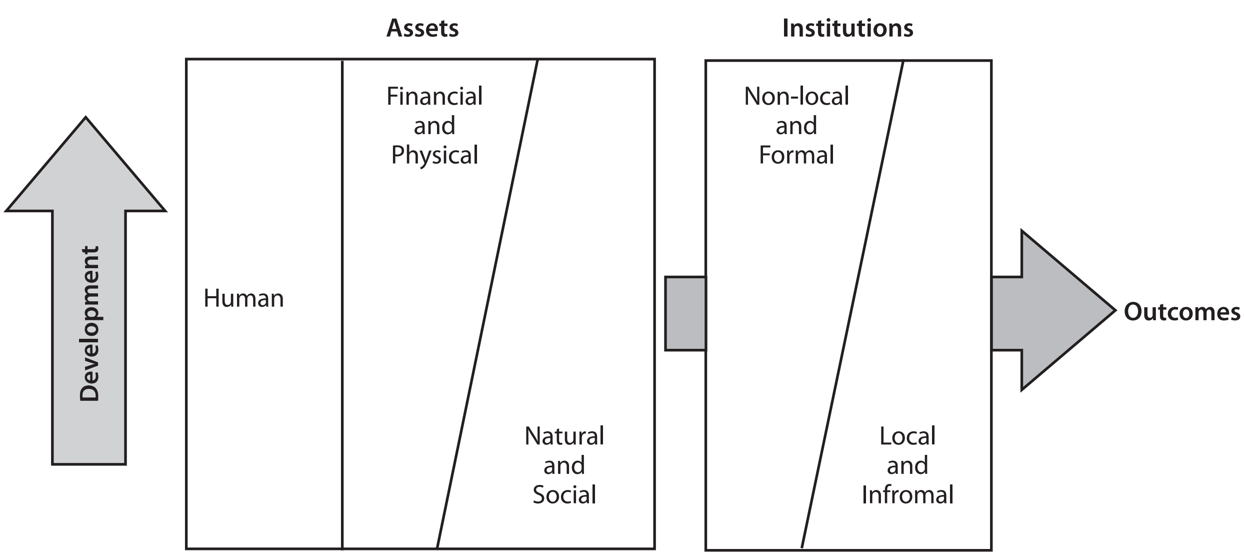


Figure 3. Assets and institutions along the development trajectory

The "development trajectory"

We have taken the current development status of the basin as an organizing principle for the framework that we have developed, since it determines the prevailing economic conditions that people are in, whether a basin is dominated by agriculture, by urbanization and industrialization or is in transition from one to the other (World Bank 2007). The locations of the 10 BFP river basins on the development trajectory are shown schematically in Figure 2. The predominantly agricultural basins Limpopo, Niger, Nile and Volta are characterized by a high contribution of agriculture to gross domestic product (GDP) and high rural poverty. The basins lying within more heavily industrialized countries, the Andes system of basins and the São Francisco, both have a low contribution of agriculture to GDP and low rural poverty. The transitional basins, Ganges, Indus, Karkeh, Mekong and Yellow, are intermediate between these extremes. As basins move along the trajectory, pervasive poverty gives way to isolated pockets of poverty within communities left behind in the overall economic development.

Poverty outcomes in the BFPs were found to depend on where each basin is located on the development trajectory, suggesting that poverty in general is a more useful analytical concept than "water poverty", that is, water-related manifestations of poverty. Moreover, as explained in the Background section, poverty is best understood within a framework that sees

Table 1. Basins at different development levels

	Agricultural	Transitional	Industrial
Exemplar basins	Limpopo, Niger, Nile, Volta	Ganges, Indus, Karkheh, Limpopo (South Africa part), Mekong, Yellow	Andes, São Francisco
Role of agriculture in the national economy	Dominant. Agricultural development in many cases a key to broader economic development. Water productivity is very low in most places.	Agriculture a mainstay to rural livelihoods but competing with urban or industrial demands for water. Water productivity is extremely high in some areas.	Agriculture declining in importance as a source of livelihood for most of the population as alternate sources of income develop. Higher water productivity is measured by monetary value (i.e., farmers may grow low-yielding but high-value crops). Rural poor tend to be "left behind" general economic growth.
Poverty incidence: Indicators of well-being	Widespread. High percentage, even if absolute numbers are low.	General, large numbers but lower percentage. Urban poverty increasing in importance.	Continued investment.
Physical infrastructure: road network, energy	Basic infrastructure is limited. A major constraint to agricultural development.	Pressure on pre-existing infrastructure. Substantial investment in infrastructure.	

	Agricultural	Transitional	Industrial
Water resource development	Very little development of irrigation. Some hydropower. Less than 70% of the rural population has access to clean water supply/ sanitation.	Extensive development of irrigation, in some cases to an unsustainable level. Hydropower or industrial users given high priority to meet demands of industrialization. Up to 80% with access to supply and sanitation.	Established. Further development of irrigation difficult due to increasing scarcity while irrigation development not often targeted to the rural poor. Institutions developing to help share resources and benefits from water resource development.
Environmental security	Ecosystem services very important to specific groups (e.g., fishers and livestock herders) but these are generally informal and not valued in markets.	Major loss of ecosystem function. Ecosystem services not valued in markets. Fishers and smallholder livestock farmer declining. Aquaculture expanding.	Increasing attention to ecosystem function with emerging opportunities for trading of ecosystem services. Aquaculture increases in importance relative to capture fisheries. Livestock dominated by large-scale enterprises.
Vulnerability to water-related hazards	Very little protection. Major impact of health on livelihoods through sickness and disease. Livelihood systems rely on risk avoidance.	Moderate protection through engineering.	Engineering and institutional protections developing.
Development of markets and financial institutions	Semi-subsistence farming dominates, although most populations are linked to markets. Local informal institutions.	Active development of markets. Financial services not available to all or for all desired investments. Diminishing importance of local institutions.	Commodity and high-value crops dominate. Widely available financial services. Relatively large role for government institutions.

households and communities making use of assets, moderated by the institutions within which they operate, to achieve livelihood goals. Figure 3 summarizes results from the BFP basin studies. As communities, households and basins move along the development trajectory in the course of national economic development, the mix of assets shifts from one in which natural and social capital are most important to one in which physical and financial capital play a larger role. At the same time, local and informal institutions decline in importance relative to formal institutions at the provincial, national and basin scales. At all levels of development, human capital is important.

The changing role and form of livelihood assets and institutions with development suggests some characteristic patterns in the 10 BFP basins. Different aspects of water-related poverty play distinct roles at different levels of development. Table 1 summarizes conditions in basins according to their classification as agricultural, transition or industrial. Some caution is needed with this classification, as within any basin, it is usually possible to find mixed classes. The specific, historically contingent, development path within a basin has a very strong influence on the conditions of the water and agricultural systems. It also influences the types of economic opportunities open to people and governments as they produce and consume, while the population and scale of economic activity within a basin strongly influences the pressures exerted on the natural environment.

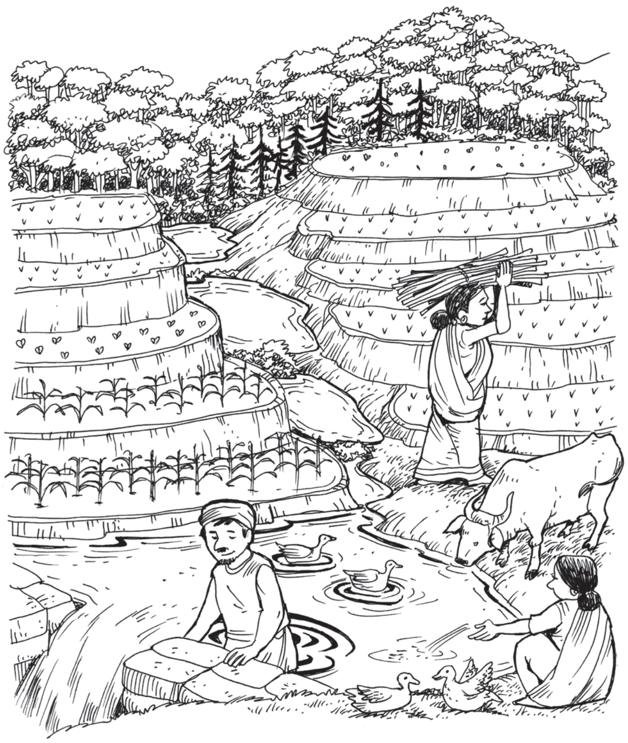
Agricultural basins

The predominantly agricultural basins of the BFP basins, the Limpopo, Niger, Nile and Volta are all in Africa. Within these basins, poverty is widespread and heavily concentrated in rural areas. People are largely unprotected from hazards, even recurring and therefore anticipated, hazards such as seasonal variations in rainfall and endemic water-related diseases.

Crop agriculture is predominantly rainfed, while livestock and fish make important contributions to household incomes and income diversification. Fish and livestock provide essential livelihoods to certain groups, such as pastoralists and freshwater fishers, who are facing increasing pressures on aquatic and land resources. Water productivity is typically very low, in part due to limited markets for outputs and inputs and in part as a result of risk management strategies that seek to maintain a minimum guaranteed output at the expense of maximizing average output.

Households derive much of their own food from subsistence agriculture and, compared with transitional and industrialized basins, operate relatively independently from state organizations. State-provided infrastructure, such as roads and irrigation and services, including education, are limited in scope. The dominance of local institutions in agricultural basins often means inconsistencies and conflicts between the plans of the state and their implementation on the ground. At the same time, local institutions ensure a minimal safety net through communal use of resources, although sharing output makes it hard for farmers to invest time and resources into improving their productivity, as the benefits are captured by everyone.

Transitional basins



The transitional basins, the Ganges, Indus, Karkeh, Mekong and Yellow, have developed substantial non-agricultural activities but agriculture remains a mainstay of rural life. These are "patchy" basins containing substantial areas that could be classified as either agricultural or industrial. These basins contain the largest populations of the BFP basins. The numbers of poor are very large, even though the proportion of poor to non-poor is substantially lower than in the agricultural basins. One of the characteristics of transitional basins is that rural development becomes a priority for governments and, in some of these basins, such as the Karkheh and the Ganges, we see considerable political pressure to stabilize the rural economy.

As illustrated in papers on the Yellow (Ringler *et al*. 2010) and Indus-Ganges (Sharma *et al*. 2010), irrigation is highly developed in the transitional basins and has enabled the populations to expand to levels that now seem, in some parts of the basins, difficult to sustain. Agriculture provides a livelihood for many and in places is at or near to its potential maximum productivity. Partially as a consequence of major expansion of agriculture, ecosystem services have been impacted considerably. Fish and livestock have declined in overall importance, although they are dominant livelihoods for some of the poorest communities and both livestock and fish continue to play a role in livelihood diversification. In the Mekong and, to a lesser degree, the Ganges Delta, fish remains a major source of livelihood support that is under increasing pressure as development massively increases the demand for hydropower and irrigation water. In the Indus and the Yellow basins, which are drier, conflicts over water use threaten continued development.

Industrialized basins

The Andes collection of basins and the São Francisco, both in Latin America, are classified as industrialized. While neither of them is dominated by industrial production, they are within countries that have significant industrial production and this affects the employment opportunities, level of infrastructure and government services available to rural populations. In both of them, agriculture accounts for less than 10% of the annual increase in gross domestic product (GDP), although in Brazil, agriculture is actually increasing in importance as a result of strong growth of commercial agriculture among which there remain large pockets of poor small-scale farmers. Rural poverty persists in these areas, but it tends to be more localized and is characterized as areas that have been "left behind" by the surrounding economic development. In the São Francisco, resource-poor smallholders do not generally benefit from the economic industrialization. They find it hard to gain entry into larger scale farming and processing operations and increasingly sophisticated agricultural markets. Moreover, they often do not have access to the resources to adapt to the major changes in the agricultural landscape.

While the poorer areas of these basins have better access to state-controlled services compared with agricultural and transitional basins, they are still marginalized in comparison with other parts of the basin. Access to water has greatly shaped agricultural development in the São Francisco Basin but concern over access to water in these basins is shared with concerns regarding access to education, markets and finance. Water-related hazards, such as flooding and drought, continue to be a problem, but institutions, financial assets and infrastructure are sufficiently well-developed that communities are able to recover from most events.

Results: A poverty and water framework

Earlier in this article, we argued that poverty is a multi-faceted phenomenon and traced a history of thinking about poverty. In reviewing evidence from the basins we also identified the critical importance of a basin's stage of development to an analysis of water and poverty links. So that we can capture the various aspects of poverty revealed in the basin studies, we combine elements of functional, asset-based and capability-based definitions of poverty to construct a poverty and water framework. We identify the following aspects of water-related poverty:

- Scarcity: where people are challenged to meet their livelihood goals as a result of water scarcity;
- Access: where people lack equitable access to water;
- Low productivity: where people acquire insufficient benefit from water use;
- Chronic vulnerability: where people are vulnerable to relatively predictable and repeated water-related hazards such as seasonal floods and droughts or endemic disease; and
- Acute vulnerability: where people suffer an impaired ability to achieve livelihood goals as a consequence of large, irregular and episodic water-related hazards.

While there are dependencies between these aspects—for example, productivity and vulnerability are both dependent to some extent on scarcity and access—to an important degree they act independently. In particular, institutions mediate the link between scarcity and vulnerability and between scarcity and access, while high productivity can lessen vulnerability in water-scarce areas. Thus, the five aspects of water-related poverty are related to the institutional, variability and asset components of the sustainable

livelihoods framework (Figure 4). Deprivation as a result of water scarcity reflects a lack of natural assets; equitable access is determined largely by institutions; vulnerability to water-related hazards is largely (although not entirely) due to variability in the natural environment; low water productivity is affected by household and community assets, such as access to markets or knowledge; and loss of livelihood due to change is a consequence of variability in the external natural, economic and social environment.

The poverty and water framework along the development trajectory

Of the different aspects of water-related poverty (Figure 4), inequitable access emerges at all levels of development. Local institutions, basin-scale institutions, geography and hydrology appear to determine whether development and poverty reduction will be broadly or narrowly based. In case studies carried out in northeast Thailand, which suffers from an extended dry season, poor groundwater quality and floods in the rainy season, local norms favor a broad distribution of benefits from improved production. Perhaps, for this reason, small-scale, local initiatives have performed better than large-scale, state-sponsored irrigation projects. In contrast, in the Niger Basin, diverse and fragmented local institutions lead to inconsistent implementation of large-scale projects. Benefits are shared inequitably, which explains the weak (or negative) relationship between water productivity and poverty that was highlighted in the Niger paper (Ogilvie *et al*. 2010). The effects of geography and hydrology can be seen in several basins: in the Andes, where water access aligns with the north-south rainfall gradient and vertical climatic gradients; in the Volta and São Francisco, where poverty follows the rainfall gradient; and in the distinct poverty trajectories of the upper and lower parts of the Ganges, Indus, Limpopo, Nile and Yellow.

Unlike access to water resources, other aspects of water-related poverty play different roles at different stages of the development trajectory. For agriculturally dominant basins, water scarcity is common, exacerbated by a lack of storage and water productivity is an effective lever for development, if the benefits are broadly shared and households suffer from chronic water-related hazards. As basins become more industrialized, water scarcity becomes less common or less severe and water productivity becomes one of many interrelated factors that impact upon poverty levels. Households and communities are more vulnerable to acute water-related hazards, that is, hazards that happen rarely but have a large impact.

Water-related interventions along the development trajectory

As shown in Figure 2, agriculture plays a smaller role in the economies of basins that are closer to the industrial end of the development trajectory and they have a lower incidence of rural poverty. Poverty reduction means, in practice, movement along the trajectory from the upper right of the figure towards the lower left. A consequence of this, as we argue below, is that water-related interventions are more or less effective, depending on where a basin lies on the trajectory. These differences can be understood from the changing mix of livelihood assets shown in Figure 3.

Within agricultural basins, development of agriculture is often a pre-requisite to other forms of development. Until recently, standard agricultural development theory argued that rising agricultural productivity was essential to raising

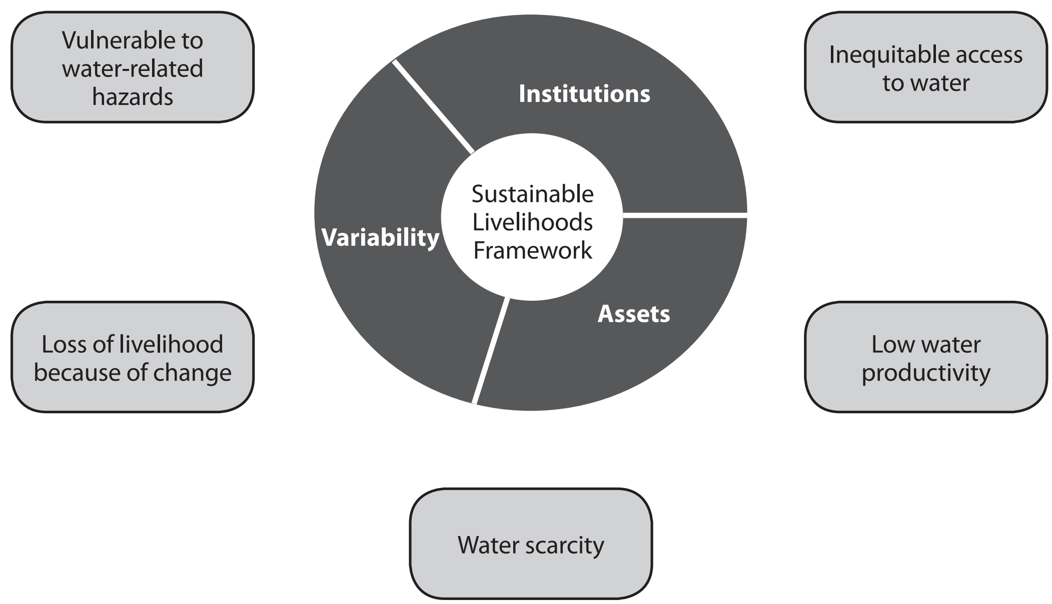


Figure 4. The poverty and water framework and its connection to the sustainable livelihoods framework.

rural incomes, as it enabled rural populations to diversify into non-agricultural activities (Timmer 1998). Following recent extensive research into rural livelihoods, the current understanding is more nuanced (FAO 1998, World Bank 2007), but rising agricultural productivity has been identified as a key factor in the transition out of rural poverty in several countries (World Bank 2007). Local activities and innovation are essential and a primary goal is to reduce barriers to effective and equitable institutions. These activities often require the development of infrastructure and services around rural populations. However, as at any stage of development, institutions are important and these interventions may be ineffective if the benefits are captured by elites.

Irrigation may have substantial impacts but only if other contributing factors are also improved, including markets and financial institutions and if local institutions are supportive. As described in the papers on the agricultural basins (the Limpopo, Sullivan and Sibanda 2010; the Niger, Ogilvie *et al*. 2010; the Nile, Awulachew *et al*. 2010; and the Volta, Lemoalle and de Condappa 2010), there is very little irrigation at present and only limited water is available to expand irrigation coverage. As smallholder production is dominated by rainfed agriculture, marginal improvements in rainfed agriculture, if they are widely shared, are likely to have a larger impact than irrigation expansion. Moreover, field-scale innovations can be carried out at relatively low collective risk and can support the development of human and social capital that make larger scale improvements more successful.

In transitional basins (the Ganges and the Indus, Sharma *et al*. 2010, Karkeh, Ahmad and Giordano 2010, the Mekong, Kirby *et al*. 2010 and the Yellow, Ringler *et al*. 2010), access to water resources or to the benefits they generate are of greater importance to the poor than water scarcity or basic

provision of infrastructure. In each of these basins, except the Mekong, the poorest areas are those without irrigation. At the same time, extensive irrigation has provided water to farmers at the cost of increasing pressure on scarce water resources. The Mekong is a wet basin and large-scale irrigation dominates only in the delta; in other parts of the basin, farmers use small-scale irrigation systems. Consequently, investments in infrastructure and development of institutional capacity to manage water resources are needed, as with the agricultural basins, but under conditions of increasing pressure. Infrastructure and institutional capacity, in turn, can help to manage chronic hazards as substantial improvements are made in water supplies and sanitation, together with flood control. Given the large numbers of people in these basins, secure provision of basic services has a significant impact on well-being and national development goals. Within existing transitional basins, there is limited scope for further development of large scale irrigation and there is already a high level of productivity in some irrigation areas (for example, in the Yellow and Ganges), suggesting that improvement of rainfed agriculture in the poorest parts of these basins may be overlooked as a source of change, while diversification through aquaculture and livestock can help to smooth variations in income.

Within industrialized basins, represented here by the Andes (Mulligan *et al*. 2010) and the São Francisco (Vosti *et al*. unpublished data), the opportunities for improvement in rural livelihoods arise less from improvements in the traditional agricultural sector than from salaried employment in the rapidly growing commercial sector or from specialization within smallholder farming to capitalize on the development of new urban markets. In these basins, except in the poorest areas, which are pockets resembling agricultural or transitional basins, increasing water productivity is less a policy lever for poverty reduction than it is a strategy for the agricultural sector to meet its own goals. These goals themselves can help reduce poverty, via employment-generation within and outside of agriculture. Water-related poverty persists, but strategies to reduce poverty, including water-related poverty, focus more on employment and market access than on water as such. In the São Francisco Basin, improved access to water may be necessary for reducing poverty in some parts of the basin, but will not be necessary in all areas and is unlikely to be sufficient in any of them.

Conclusions

Poverty is a multi-dimensional phenomenon and thinking about poverty has evolved over time as an appreciation of its complexities has grown. The links between water and poverty are also not simple and resist prescription. However, work in the BFPs revealed some common patterns and conclusions that can help to guide future policy and research. That work leads to the following conclusions concerning the nature of the relationship between water and poverty.

1. From both an analytical and policy standpoint, it is more relevant to policy makers to understand the influence of water-related variables on general poverty and livelihood measures rather than to seek the meaning of indicators of "water poverty".

2. There is no simple link between water scarcity and poverty because the nature of this relationship is strongly influenced by position along a "development trajectory." Although the development trajectory does not predict the character of water-poverty links, this condition is such a powerful factor that a first step in analyzing the water-food-poverty links within a basin should be to determine where it lies along that trajectory.

3. At any level of development, analysis of the links between water and poverty should take into account the livelihood strategies and institutional environment of the households at whom those interventions are targeted. The character of the relevant institutions and the mix of assets varies systematically with the households' and basin's development status.

Concerning interventions, we determined four different types of interventions from evidence within basins, each related to a different kind of livelihood capital.

First, interventions that seek to increase human capital are likely to be effective at any level of development, as long as they are matched to the needs and capacity of the community. Examples included improvements in human capital to support fisheries in the Volta; health and education in the upper Niger; education of farmers in the Indo-Gangetic basins in crop-specific practices; and education in the industrial Andean basins, since this was found to correlate strongly, and inversely, with poverty. Interventions such as the introduction of new management techniques, sharing knowledge about alternative crops, and individual

and community capacity building can improve livelihoods and reduce poverty throughout the development trajectory.

Second, investments in natural capital are likely to be more effective at the agricultural stage of the development trajectory since people in these conditions rely most strongly on natural capital for their livelihoods. Nevertheless, realizing the benefits of investment in natural capital is also contingent on institutional support. Interventions such as rainwater harvesting, the development and support of water-user associations and other local water institutions, and techniques to improve green water use are likely to have a significant impact in agricultural basins. Analysis from the Niger, Nile and Volta emphasized the continued role of traditional institutions and the potential gains to rural livelihoods through improvements at the field scale.

Third, investments in water-related physical capital are likely to have a greater marginal impact on poverty at the agricultural and transitional levels of development, although individual improvements are unlikely to be successful without concurrent attention to surrounding infrastructure. Small reservoirs, small-scale multiple-use water systems, local road building, tubewells, small and large-scale irrigation, and similar interventions are more likely to reduce poverty levels where physical and financial infrastructure is not already well developed. While they are also important at the industrial level of development, in these situations, they are best seen as strategic investments for regional development, rather than as mechanisms for poverty alleviation. Analysis from the Andean system of basins and the São Francisco showed that poverty in these basins is strongly affected by national and regional institutions and by access to labor and agricultural markets, as well as to markets for non-agricultural goods produced in rural areas. Fourth, at any level of development, the institutional context in which interventions are introduced is a strong influence on their success. The nature of dominant institutions varies as the basin passes through the agricultural, transitional and industrial stages of development. At the agricultural stage, the role of basin-wide institutions is less important to poverty reduction than are small-scale institutions. However, at the transitional and industrial stages, such large-scale institutions can be crucial for assisting those left in pockets of poverty as the basin experiences strong growth in population and economic activity. This was particularly apparent in the Indus, Ganges and Yellow River basins, where irrigation, which is more highly developed in some parts of the basin than in others, is strongly correlated with lower levels of poverty. In the course of development, the shift from local and informal institutions to non-local and formal ones can favor some groups and individuals at the expense of others or at the expense of the natural environment; as basins become more strongly industrialized, the economic capacity grows to invest in institutional processes to address any distortions.

Contact Persons

Eric Kemp-Benedict (erickb@sei-us.org), Simon Cook, Summer Allen, Steve Vosti, Jacques Lemoalle, Mark Giordano, John Ward, David Kaczan

Key Reference

Kemp-Benedict, E., S. Cook, S.L. Allen, S. Vosti, J. Lemoalle, M. Giordano, J. Ward and D. Kaczan 2011. Connections between poverty, water and agriculture: evidence from 10 river basins. *Water International,* **36**, 125-140.

Tag: Basin Focal Projects (BFP)

Bibliography

Ahmad, A. and M. Giordano, M., 2010. The Karkheh River basin: the food basket of Iran under pressure. Water International, 35, 522-544.

Awulachew, A. et al. 2010. The Nile basin: tapping the unmet agricultural potential of Nile waters. *Water International,* **35**, 623-654.

Baumgartner, R. and R. Högger (eds) 2004. *In search of sustainable livelihood systems: managing resources and change.* New Delhi: Sage Publications.

Bebbington, A. 1999. Capitals and capabilities: a framework for analyzing peasant viability, rural livelihoods and poverty. *World Development,* 2, 2021-2044.

Black,M. and A. Hall 2004. Pro-poor water governance. In: *Water and poverty: the themes;* 11-20. Manila: Asian Development Bank.

Carter, M.R. and C.B. Barrett 2006. The economics of poverty traps and persistent poverty: an asset-based approach. *Journal of Development Studies,* **42**, 178-199.

Cook, S. and F. Gichuki 2006. Analyzing water poverty: water, agriculture and poverty in basins. Working Paper Series.
Colombo: CGIAR Challenge Program on Water and Food.

DFID 1999. *Sustainable livelihoods guidance sheets.* London: Department for International Development (DFID).

FAO 1998. *The state of food and agriculture 1998.* Rome: Food and Agricultural Organization of the United Nations (FAO).

Haughton, J. and S.R. Khandker 2009. *Handbook on poverty and inequality.* Washington, DC: The World Bank.

Kirby, M. *et al.* 2010. The Mekong: a diverse basin facing the tensions of development. *Water International,* **35**, 573-593.

Lemoalle, J. and D. de Condappa 2010. Farming systems and food production in the Volta Basin. *Water International,* 35, 655-680.

Molden, D., ed., 2007. *Water for food, water for life: comprehensive assessment of water management in agriculture.* London: Earthscan and Colombo: International Water Management Institute.

Bibliography

Molle, F. and P. Mollinga 2003. Water poverty indicators: conceptual problems and poverty issues. *Water Policy,* **5**, 529-544.

Mulligan, M. *et al.* 2010. The Andes basins: biophysical and developmental diversity in a climate of change. *Water International*, **35**, 472-492.

Nicol, A. 2000. *Adapting a sustainable livelihoods approach to water projects: implications for policy and practice.* Working Paper 133. London: Overseas Development Institute (ODI).

Ogilvie, A. *et al.* 2010. Water agriculture and poverty in the Niger River basin. *Water International,* **35**, 594-622.

Orshansky, M. 1965. Counting the poor: another look at the poverty profile. *Social Security Bulletin,* **28**, 3-29.

Ringler, C. *et al.* 2010. Yellow River basin: living with scarcity. *Water International*, **35**, 681-701.

Scoones, I. 1998. *Sustainable rural livelihoods: a framework for analysis.* Working Paper 72. Brighton, UK: Institute of Development Studies.

Scott, J.C. 1998. *Seeing like a state: how certain schemes to improve the human condition have failed.* New Haven, CT: Yale University Press.

Sen, A. 1999. *Development as freedom*. New York: Anchor Books.

Sharma, B. *et al.* 2010. The Indus and the Ganges: river basins under extreme pressure. *Water International,* **35**, 493-521.

Sullivan, A. and M.L. Sibanda 2010. Vulnerable populations, unreliable water and low water productivity: a role for institutions in the Limpopo Basin. *Water International*, **35**, 545-572.

Sullivan, C. 2002. Calculating a water poverty index. *World Development,* **30**, 1195-1210.

Sullivan, C. and J. Meigh 2003. Considering the water poverty index in the context of poverty alleviation. *Water Policy*, **5**, 513-528.

Tilly, C. 1998. *Durable inequality.* Berkeley: University of California Press.

Timmer, C.P., 1998. The agricultural transformation. In: International agricultural development, eds. C.K. Eicher and J.M. Staatz; 113-135. Baltimore: Johns Hopkins University Press.

World Bank, 2007. *World development report 2008: agriculture for development*. Washington, DC: The World Bank.

Water, Food and Poverty: Global-and Basin-Scale Analysis

Rationale: water and food systems support development within a global environment

The global environment currently supports around seven billion people through a range of ecosystem services that include food production, water supply and sanitation. By 2050, the global population is projected to increase to over nine billion (UN 2009) with concomitant increase in the demands on the natural environment. There is evidence that, in reacting to meet some of these demands, human societies are damaging the environment's capacity to satisfy other demands. In river basins, this is manifested through the inequitable sharing of finite water and land resources.

We chose river basins as the environmental entity with which to study this problem since this is the only way to understand flows and exchanges of water. The global picture translates into very different outcomes within individual river basins. Ten river basins were chosen for study in the Basin Focal Projects (BFPs) CGIAR of the Challenge Program on Water and Food (CPWF). These 10 basins are in developing countries where the disjunct between poverty, water and food is particularly acute. Altogether, they host 1.5 billion people and half of the billion poor who leave with less than $1.25 per day.

Components of the problem: Organizing information to help explain conditions in river basins

The Food and Agriculture Organization of the United Nations (FAO) predicts that 70% more food will be required by the year 2050 (Bruinsma 2009). Due to evolving diets, especially for growing urban populations, demand for animal products is estimated to increase by 74%. FAO estimates that over 900 million people currently go hungry. Domestic and industrial demand for electric power will increase by about 50%, of which hydropower is expected to supply about one third (EIA 2010). Most of the increased food production is forecast to come from intensification of production systems, but about 15% is expected from extension of the agricultural area. Urban populations will expand from a current estimate of 3.5 billion (50%) to 6.3 billion (69%) by 2050 (UN 2010). The impacts of these changes will be compounded by other factors, in particular global climate change, which imposes major uncertainties on future water availability, environments of crop production, and disease (IPCC 2007).

The problem is made up of aspects of poverty and development: water resource management, agriculture and institutions. Poverty is described within basins according to measures of income, consumption or livelihood assets. Of course, poverty and food insecurity are related and we understand from Byerlee *et al.* (2008) that food security is a necessary if not sufficient basis for poverty alleviation.We consider poverty to be a dependent variable, which represents the degree to which people are not supported by the development of water and food systems.

A framework to analyze conditions in basins

Conventionally, analysis of development in river basins has approached the problem from the hydrologic perspective, with scant reference to the activities of the agricultural systems that operate within it. In this approach, water flow is analyzed, using water-use accounts, or "finger diagrams" to identify where water flows within basins, and to which uses. In contrast, agricultural research has focused strongly on aspects of the farming systems, with little reference to their interaction with water systems. Land productivity is the normal focus of agricultural research, with the individual aspects of agricultural systems usually studied separately. Food-systems approaches analyze the different components without accounting for water use. There is therefore a clear disconnect among the three approaches.

From the development perspective, neither the water nor the food-systems approach is sufficient to explain how either system interacts with the other to produce livelihood outcomes. Focusing only on the food system provides no insight into the implications of variations in use of a shared water resource. Focus on the water productivity of food systems takes no account that livelihood systems gain support from a wide range of support mechanisms. Water may flow through to a final benefit by many different processes, which operate in parallel or serially. Moreover, benefits may substitute one for the other, for example, people may be supported by food from irrigation, by livestock feed from rainfed grassland, by fish that live in the aquatic environment that the irrigation water might otherwise support, or by the benefits of non-farm employment enabled by hydropower. A focus only on agricultural production can therefore omit important off-farm contributions.

Molden (2007) provides the Comprehensive Assessment of Water Management in Agriculture, which was a major program of research describing a wide range of aspects of the water and food systems. The Assessment provides valuable general advice to policy makers but it does not, however, attempt to assemble these components within specific basins. The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT-Water) model of Rosegrant *et al.* (2002) and the Policy Dialogue Model (PODIUM) of de Fraiture *et al.* (2001) both assemble selected components of food systems within river basins, but these models do so at a relatively broad level of generalization at a country scale. This paper drew upon the logical structure of nine projects in river basins to provide observations according to a single analytical framework (Fisher and Cook 2010) (Figure 1).

Insights from basins

Water influences development in many different ways. It does so indirectly through its impact on irrigated or rainfed agriculture, through its support of aquatic systems, and also through the provision

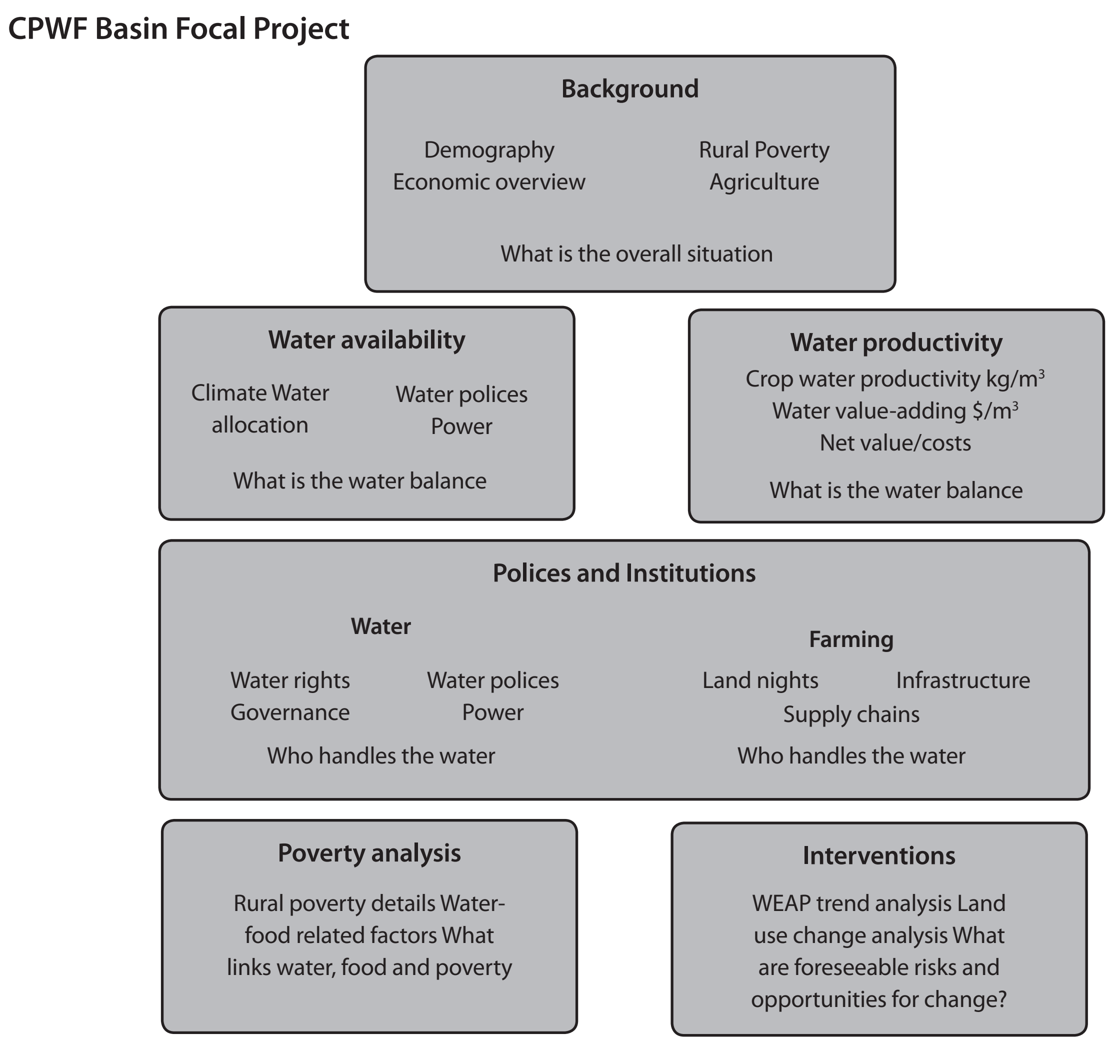


Figure 1. Analytical framework of a logical structure of observations in nine projects in river basins (WEAP = water evaluation and planning)

of urban water, power, sanitation and transport. In some basins, economic systems have responded to increasing water scarcity with no discernible impact on rate of development. In other areas, water related factors have a clear impact on rural development, which can be felt concurrently through food, income or environmental security. This can be difficult to analyze, since impacts can be interchangeable. Moreover, development of one may threaten another, such that it is the total picture that needs to be considered.

Factors that couple water to development

From observations in 10 basins, we conclude that there are four factors that link water to development.

Physical Water scarcity

Water scarcity has been described as either physical or economic (Seckler *et al.* 1998). Here we focus on physical water scarcity, as reported in the Yellow River, Karkheh, Indus and upper Limpopo basins. While the Nile as a whole is not considered water scarce, political tensions occur because Egypt and Sudan rely totally on inflows from the less developed upstream countries. Population density is low in the Limpopo where less than 1% of available water is used for irrigation. Conversely, population density in the Yellow River is extremely high and irrigation consumes 14% of average basin flow.

On average, the Niger, Nile, São Francisco and Volta Basins are moderately water scarce. Data of average water availability hides spatial variations, such that less populated parts of all are water-scarce. The Ganges, in general, is only moderately water-scarce but contains areas of extreme or increasing scarcity.

Areas of low scarcity include the Andean system and the Mekong. Nevertheless, the Andes basins are extremely diverse and contain some of the driest places on earth; average annual rainfall in Lima is less than 100 mm and the city is dependent on outside water supply. Areas of northeast Thailand, southern Laos and Cambodia in the Mekong are frequently affected by drought and seasonal water scarcity due to prolonged dry seasons of up to six months.

Evidence suggests that variation of water availability is not strongly correlated with poverty. An illustration of this apparent paradox is the comparison between the Democratic Republic of Congo (DRC) and Israel: the water-rich DRC is among the poorest in the world, while water-poor Israel ranks among the richest (Molle and Mollinga 2003). Analysis from basins suggests that water scarcity is one factor controlling development. It is undoubtedly a major concern for those agricultural economies such as Pakistan, Egypt, India and China that have developed their agriculture through intensive use of irrigation. The poorest people, however, live in areas where such development has not occurred, and where other factors therefore influence development more strongly. It is important to understand this in the light of geographical variation of development processes.

Dry areas do not support large populations without irrigation, but in some basins irrigation has supported the development of intensified agriculture using rates of abstraction that now seem unsustainable. In some cases further growth may be possible by improving water productivity. The situation becomes problematic when areas (for example, Indus and Yellow River basins) that already face moderate to severe water scarcity are squeezed by demands from non-agricultural sectors. Parts of these basins seem to have reached maximum water productivity so that the options for further growth of low value agriculture are limited. In such cases, further development depends on a move away from dependence on basic agriculture towards higher value crops or non-agricultural activities.

Economic water scarcity

Lack of access to water resources, sometimes referred to as economic water scarcity (Seckler *et al.* 1998), was reported as a widespread problem in basins and occurs even in relatively well-watered areas such as central Ghana. It occurs because either there is a lack of infrastructure development; or there are institutional constraints, which may grant access to some, but deny access to others, usually to the poorest, most disadvantaged people. The Asian basins Karkheh, Mekong, Indus, Ganges and Yellow generally have well-developed infrastructure and high levels of access to water. Gini coefficients for income are generally moderate or low, suggesting that economic benefits are relatively widely distributed. Available groundwater resources are generally exploited, with over exploitation common in some regions.

The Andes and Limpopo have high Gini coefficients implying inequitable income distribution.
Both have experienced political tensions over inequitable access to limited water resources. In the Niger, Nile, and Volta basins, infrastructure is very underdeveloped. Access to sanitation in rural areas is very poor.

In Asia, the variability in degree of development of water resources between countries is quite high, while in Africa the degree of development is low nearly everywhere. Excluding Egypt and South Africa from the data, access to water in African countries is lower than Asian countries (index of 7.3 vs. 10.8), but the standard deviation is only half of that of the Asian selection (2.38 vs. 4.38), which shows that access is uniformly low in Africa. The correlation between access and capacity for the 147 countries analyzed worldwide by Lawrence *et al.* (2002) is relatively high (r2 = 0.68). Access to water and the level of development are strongly linked.

Exposure to water related hazards of drought, flood and disease

Floods and droughts occur sporadically, but they have a disproportionately negative impact on the poor. This is because they push them into survival conditions in critical years, and overall deter critical investment that may allow them to escape from poverty. Although droughts tend to occur sporadically, in recent years, serious droughts have led to food insecurity over large parts of sub Saharan Africa and South Asia. Severe drought frequently affects the Limpopo, Nile and Niger basins, with several major events in the past decade. Though less frequent, drought has recently damaged food security in the Ganges.

Floods are generally of more limited geographic extent but – as demonstrated by the major 2010 floods in the Indus, Niger and Volta - they cause intense disruption and loss of life and property. Floods are a serious problem in the Limpopo Basin, where there are extreme year-to-year variations in flows with major floods in Mozambique in 2000 and 2008. In the Andes and upper Ganges, floods are of small magnitude but associated landslides disrupt transport infrastructure. Floods in the lower Ganges pose a serious hazard that appears to be increasing in magnitude. Devastating historic floods in the lower Yellow River are a reason for strict control of flow. In the Mekong, 90% of flow occured in three months, leading to widespread flooding in the lower basin. Contrary to being considered a hazard, however, the inundation is regarded as vital to the aquatic resource on which 65% of the basin's population depend.

Water-related diseases such as malaria, schistosomiasis, and onchocerciasis (river blindness), impose serious constraints on land use over large parts of sub-Saharan Africa. The central Volta is a hotspot for malaria, which is also an important hazard in other African basins. Together with the widespread but now controlled incidence of onchocerciasis, it is one reason for low agricultural activity of the central Volta.

Water productivity

Following Hoff and Rockström (2009), we divided water productivity into productivity of green and blue water, and restricted our comments to water productivity of crops. Blue water productivity describes the conversion of water abstracted from rivers for irrigation. Green water productivity is the conversion of precipitation in rainfed agricultural systems. Cai *et al.* (2011) provided more details on the water productivity of crops, livestock and fish. This and the basin reports (Water International, September 2010) suggest that green water use is far greater in most basins than blue water use and also that green water productivity is substantially lower than blue water productivity. This supports the conclusion of Molden et al. (2007) that improvement of rainfed agriculture presents a major opportunity to meet the demand for more food without increasing agricultural water use.

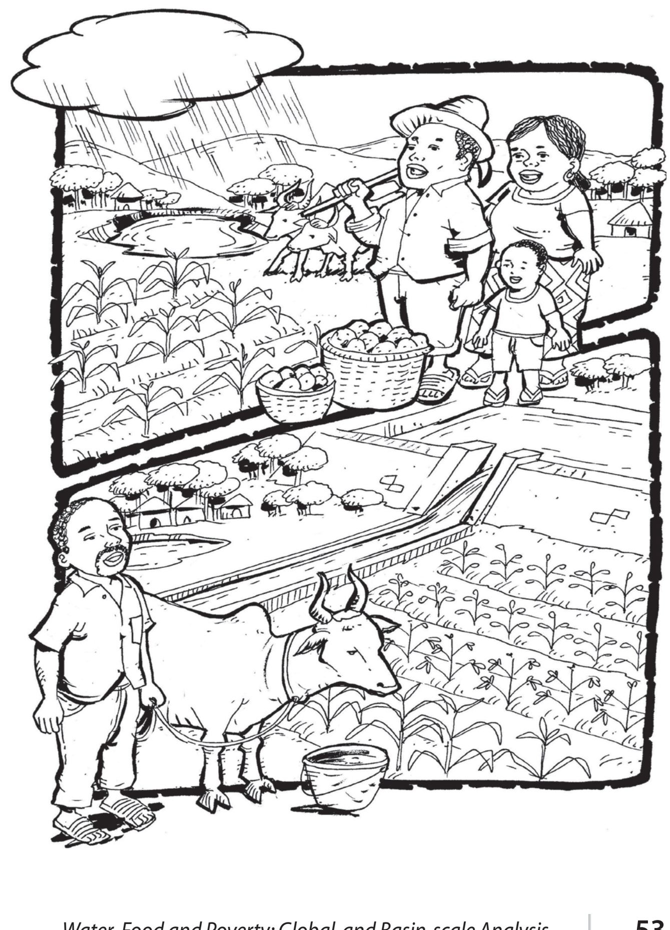
Blue water productivity

Productivity of blue water is very high for irrigated areas in the Yellow River basin. Estimates for some areas approach the likely maximum for wheat of approximately 1kg/m^3. Slightly lower estimates are recorded for irrigated areas in the upper Ganges, although they are lower in the lower Ganges and the Indus. Values from the Nile Delta have been boosted in recent years through production of high value crops, in addition to the integration of aquaculture and agriculture.

Irrigation is less widespread in the Mekong, but values of water productivity from the Delta region are also very high, and have increased over time more than keeping pace with the demand for food. In the Karkheh, water productivity of irrigated crops is much lower. With the exception of the Delta and Gezira region of the Nile, irrigation consumes less than 1% of water in the Limpopo, Niger, Nile and Volta basins and contributes little to economic activity of the basins.

Green water productivity

Overall, green water accounts for over 70% of the water flux in the 10 basins included in the BFP studies of the CPWF.
Water productivity in parts of the Yellow and



Ganges Basins are high (>0.5 kg/m^3), although less than that of irrigated areas. Elsewhere, water productivity varies between 0.1-0.5 kg/m^3, suggesting widespread low activity of the agricultural system. Water productivity of rainfed agriculture in the African basins is generally extremely low (water productivity <0.1 kg/m^3).

Low water productivity is a consequence of a wide range of limitations that collectively constrain agricultural production, and cause the widespread limit on the contribution of water and agriculture to economic development. Estimates of water productivity indicate that activity is well below potential, and taken together, low blue and green water productivity represents a systemic failure of agriculture to convert water into food or income. This is by far the most important water-related constraint to improving food, income and environmental security by consumption of water by agriculture.

Crossing from local to global scales

Coherence between different scales: global, basin and local

The linkages between the conditions that are discernible at a global scale and what happens in catchments and farming or fishing communities are complex and need clarification. Data at broad global scales indicate the emerging tension between food and water systems. Population increase and changing dietary habits are expected

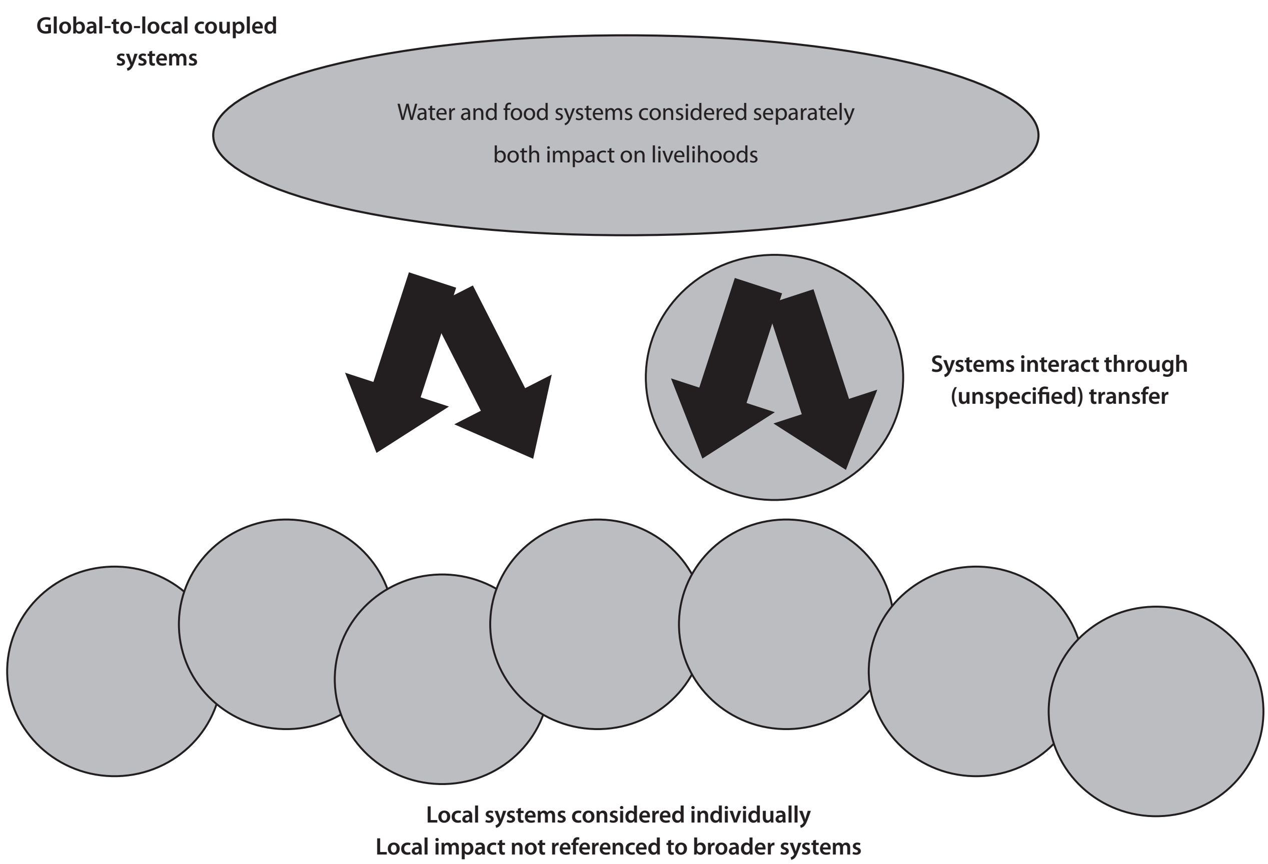


Figure 2. Food and water systems interact strongly at basin scale but linkages are difficult to see.

to double the demand for food and animal feed. Present and projected conditions are expressed very clearly in the Comprehensive Assessment of Water Management in Agriculture (Molden 2007). At a local scale, the situation can appear very different, reflecting the strong influence of local conditions on the way people manage water and food to support their livelihoods. The systems are connected within river basins through transfers of water, food or other products of agriculture (Figure 2). But how, exactly? What are the particular pressures and opportunities that occur within individual basins? How can these complex behaviors be described and analyzed, and what are their impacts on poverty locally? By adopting the basin as the prime object of analysis the BFPs connected what is happening within basins to trends and pressures that are evident globally. To move beyond analysis within individual basins towards a global view, we organize observations from basins according to the themes of the papers in this issue: water availability (Mulligan *et al.* 2011); water productivity (Cai *et al*. 2011); and poverty (Kemp- Benedict *et al.* 2011). The overall condition of economic development in river basins can be understood using the scheme of the World Development Report (Byerlee *et al.* 2009). Figure 3 shows basins arranged according to two variables: rural poverty and agriculture as a percent of GDP. The arrow tracks a generalized "development trajectory" in which agriculture is seen as a necessary, but not sufficient basis for development. The trajectory passes from strongly agricultural economies in the Niger, Volta, Nile and Limpopo,

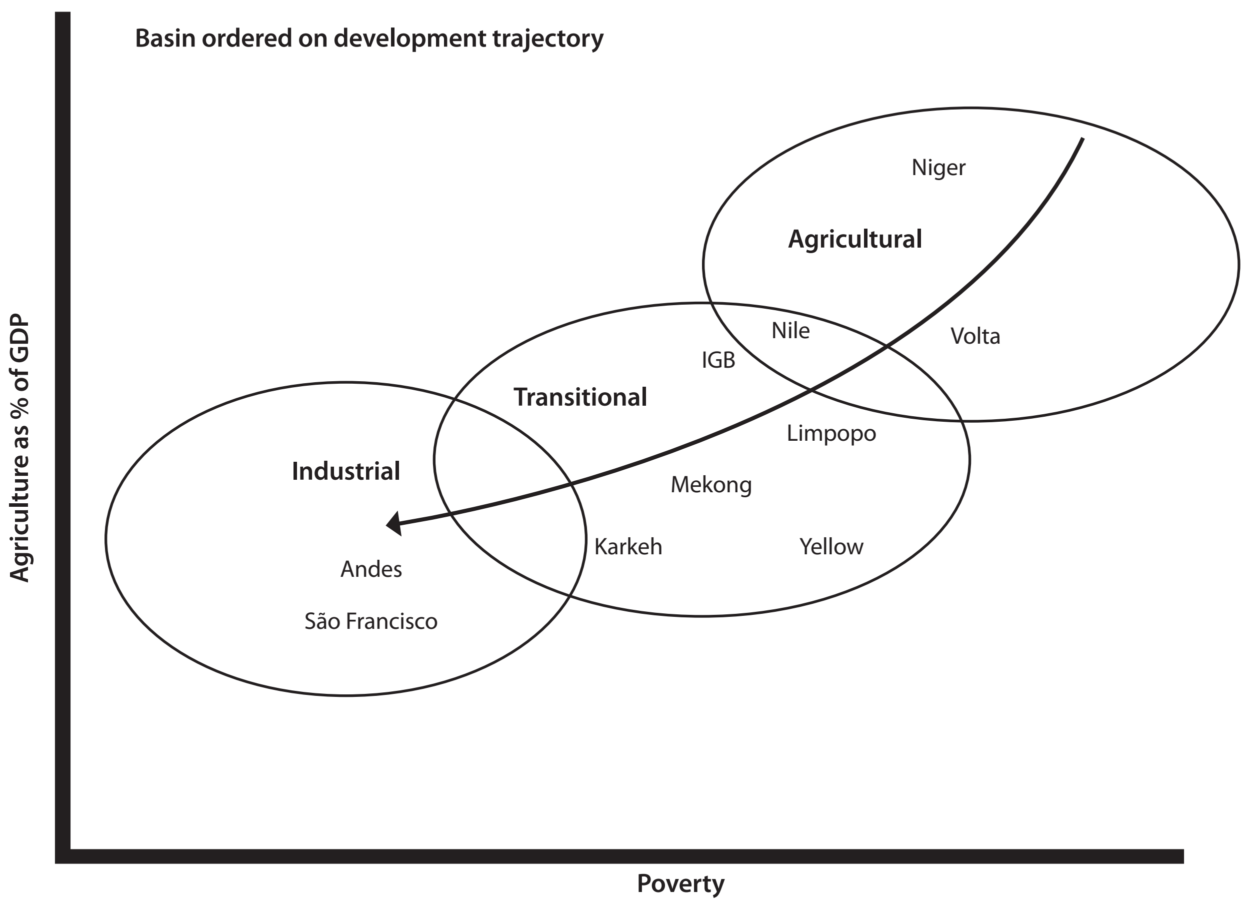


Figure 3. BFP basins ordered according to rural poverty and agricultural contribution to gross domestic product (GDP).

through those of transitional economies (Indus, Ganges, Mekong, Yellow); to basins containing industrial economies such as the Andes. It should be noted that most basins contain large variations: for example, the Mekong is transitional, but contains areas of Laos that are strongly agricultural and others in Thailand and Vietnam that are industrial.

We suggest this as a "first cut" of generalizing conditions throughout the developing world, since it is the development drivers, in conjunction with resource constraints, that determine the broad variation of constraints and opportunities (Figure 4).

Agricultural basins: Niger, Nile, Volta

Agriculture dominates activities in these basins but agricultural productivity is very low and rural poverty widespread. With the exception of mining industries in some countries, non-agricultural activities contribute little to economic activity. Water infrastructure is poorly developed, normally at 1% or less of its potential. "Non-engineered" agriculture is relatively more important than in transitional or industrial economies. In drier basins, livestock systems are very important for the poorest. In wetter areas, fish and wetlands provide vital livelihood support, on which the poorest and landless depend heavily. Demands on water resources are not fully expressed as population densities remain low, though increasing. People are exposed to water-related hazards (Figure 5).

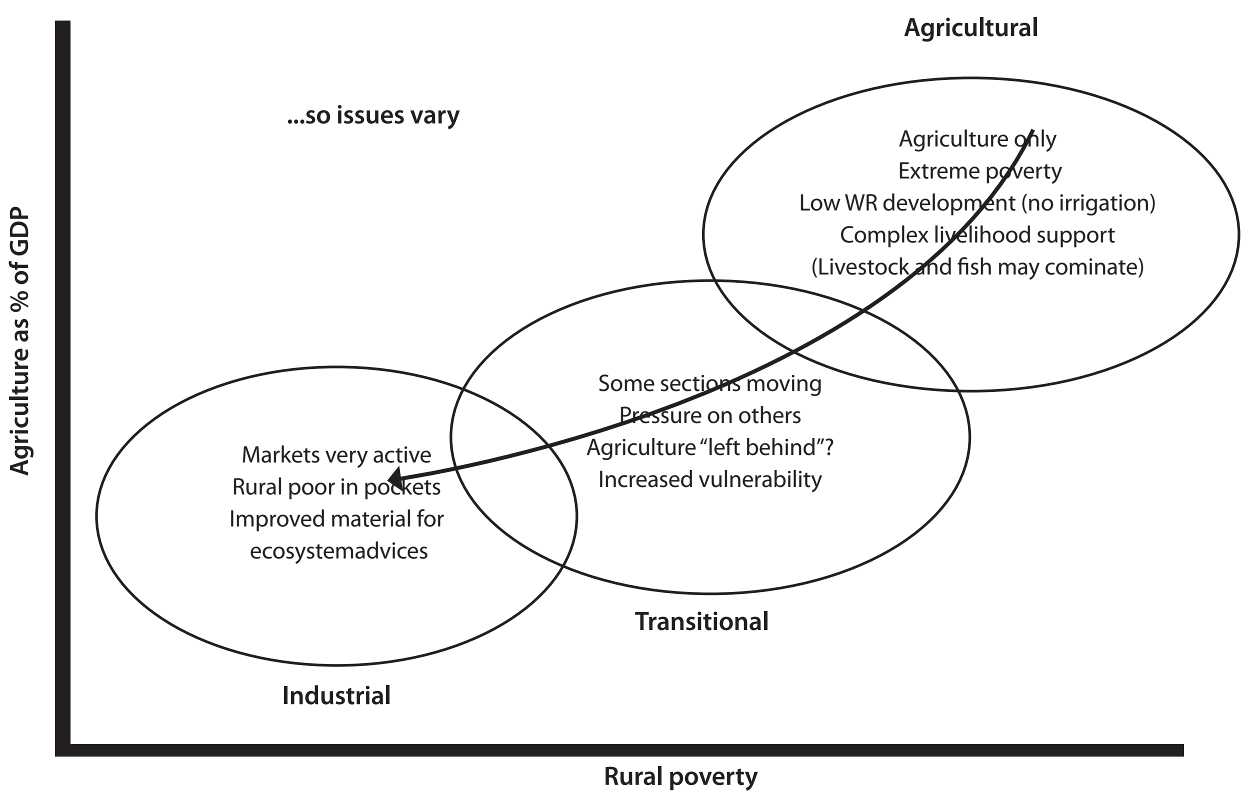


Figure 4. Prevailing conditions in three classes of basins.

Byerlee et al. (2009) show clearly that improving agricultural productivity is a necessary step to move economies along their development pathway. A prime development objective in these basins is to focus on the provision of basic needs of sanitation, healthcare, education and transport. Market development and infrastructure are key issues that are poorly developed. The major opportunity to agriculture is to support food security through rainfed agriculture without compromising livelihoods of those dependent on marginal livestock or aquatic systems. Development of water resources for irrigation may deliver local benefits, but from such a low base, this seems likely to have limited impact on rural poverty.

Transitional basins: Indus-Ganges, Limpopo, Karkheh, Mekong andYellow

In transitional economies, activities that are non-agricultural and that add higher value make increasing contributions to gross domestic product (GDP) and attract people out of agriculture. These are the areas that are expected to experience most rapid growth of economic activity and population, although the population within the Yellow River Basin is declining. It is in these regions that demand for food is expected to intensify and where water resources are generally well developed. Non-farm activities expand, and may be inter-woven with agriculture to support development. Overall, however, the process seems to be one of uneven and localized development in which many gain but some are left behind.

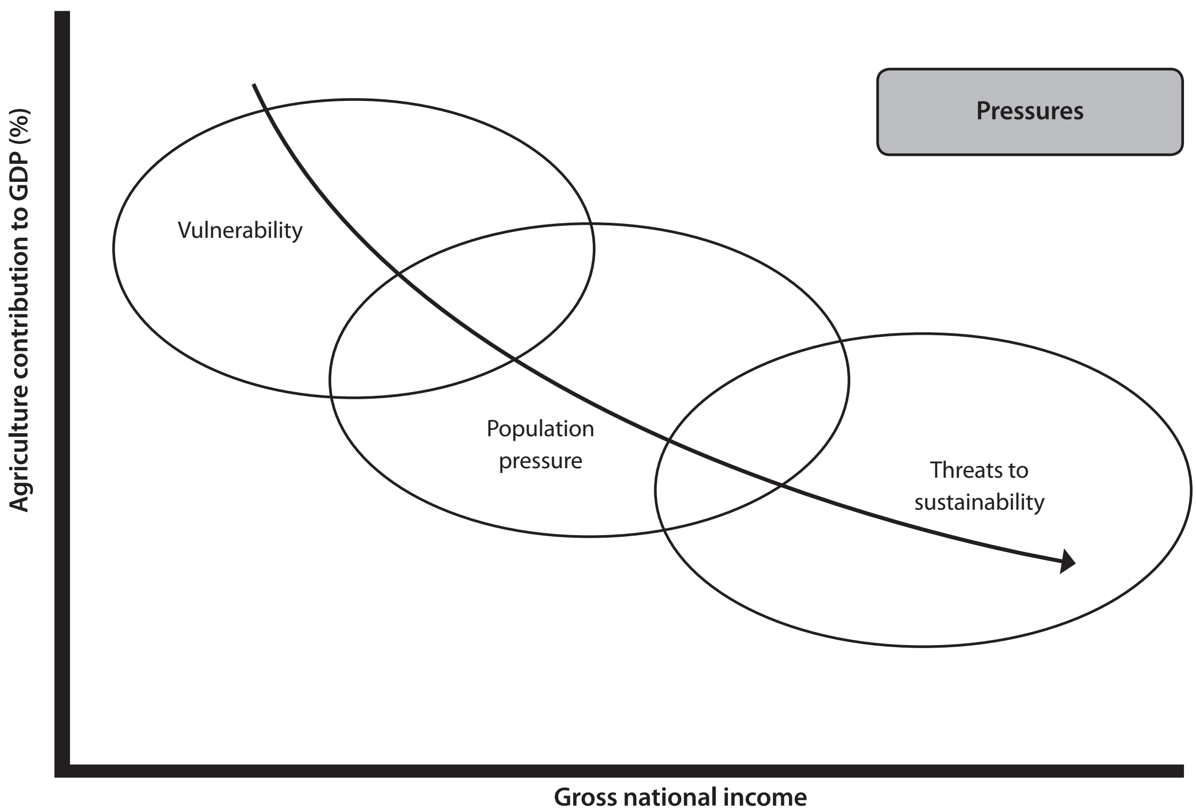


Figure 5. Pressures change with development status.

Agriculture remains important at a national level, and agricultural productivity increases in response to market demands and requirements for food security of an increasingly urban population. Agriculture may also wield considerable political power. Greatly increased agricultural activity may exert pressure on water resources and compete with expanding non-agricultural demands. Issues of water quality emerge but lack the institutional capacity for ecosystem servicing. There is only partial protection against hazards of flood, drought and water-related diseases.

The main opportunity seems to be institutional development to enable transparent, informed and broad-based processes of change, which can distribute benefits and capacity without constraining development. This can occur under a range of political environments.

Industrial basins: Andes, São Francisco

Agriculture is no longer a major economic contributor in industrial economies. Rural poverty remains in localized areas. In such conditions agriculture retains its importance as a means of reducing the risk of social unrest caused by depopulation to urban areas. Markets are highly active. Direct food security may decrease in importance as income security increases through exploitation of higher value agricultural activities. Water resources may be highly stressed, but resources may be managed intensively. Ecosystem services and benefit sharing become increasingly recognized as a means of ensuring environmental security. Greater levels of economic activity afford a high degree of protection from water-related hazards.

Food security is reasonably assured in these conditions. Income security is relatively insensitive to agricultural activity. Therefore, while agricultural activity remains supported, often for political reasons, increasing opportunities are sought for development of ecosystem services. These are required to maintain the environmental security of water supplies to urban and industrial consumers, hydropower and high-value agricultural activities. Aesthetic and cultural factors play increasingly important roles at steering development through regulation and political norms.

Developing insight to support change

Change will occur in food and water systems according to prevailing drivers in each and in how institutions respond to the drivers. Groups of people will be affected by these changes as they strive to feed themselves and maintain economic activity. In a situation of unequal power, some are likely to be left behind, or lose their livelihood support from water and other resources as they are commandeered by others.

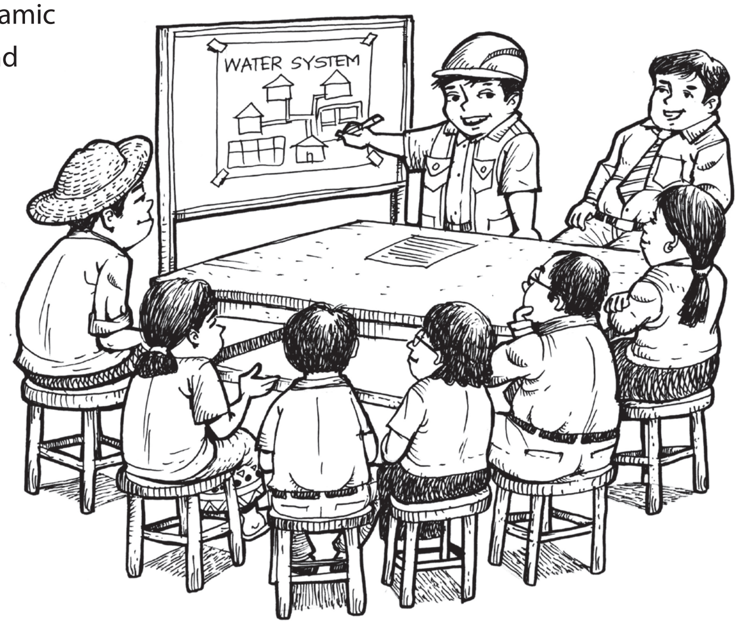
Change can occur in diverse ways but intervention can assist either by increasing the capacity of existing resources to improve productivity or by reducing the likelihood of loss of livelihood. This can only be achieved by negotiation, through the process of deliberative water politics (Dore 2007) in which people agree to adopt or accept actions based on informed and transparent debate and deliberative consideration of the options.

The relation between water and food systems and the development that they support is bi-directional. Water and food systems influence development and development influences the use of water and food resources. Societies use a range of ecosystem services as they develop, but conversely, the way these are used depends strongly on the development status of those societies, their power, their capacity to govern themselves and their capital. Consequently, while development in the Yellow River has allocated virtually all the water resources in the basin, it has also worked to increase the productivity of the system by assembling all components into a highly productive system.

Conclusions

While it is convenient to visualize a global water and food crisis in which increasing demand for food and water results in increasing poverty, food insecurity and political conflict, detailed analyzes from the BFPs show a far more nuanced reality. Analysis of conditions in basins shows a complex dynamic between development processes and the natural resources they consume. This dynamic can push river basins, or parts of them, beyond the level at which ecosystem services of water provision, food production, energy and other services can be delivered in a sustainable manner. This raises problems of potential conflict over limited resources between different communities within river basins. An alternative situation occurs when resources are effectively underdeveloped. In such cases, poverty is associated with low productivity of land and water.

The global environment supports people through the provision of ecosystem services such as food production, water supply, sanitation and hydropower. People appropriate services individually or communally, through institutions that govern sharing, production and investment. However, institutions need to evolve a holistic approach to address issues of unequal development that leads to unequal sharing



of resources and benefits. In many cases this requires a complete rethink of how departments of water resources, agriculture, mining, and health can be restructured to avoid the compartmentalized, independent institutions of the past that have proved so inadequate to confront the issues of water, food and livelihoods.

In many of the river basins studied in the BFPs, a serious problem is the underdevelopment of land and water resources as indicated by low water productivity. Lack of development is related to many factors that can be summarized collectively as a lack of coherence within farming systems, in which lack of access to resources, finance, or markets prevent farmers from developing land to its potential productivity. In the poorest areas, we attribute lack of development to water-related hazards such as drought, floods, or disease, which have a known negative impact on the investments that are essential to escape poverty. Our analysis of conditions in basins shows the need for a detailed synthesis across all the BFP basins of water availability, water productivity, institutions that underpin how people use water and food systems, and the specific consequences of these factors to livelihoods and poverty. There are problems of watwe and land resources scarcity, especially in basins characterized by transitional economics characterized by transitional economies. Our analysis further shows that a more widespread condition is low water productivity, particularly of green water. A general observation, explored in more detail in the basin reports, is that while serious problems exist at national or sub-national scale, at a global scale, the capacity exists to meet, in theory at least, future global demand for water and food. The basin reports indicate the problems of exploiting this capacity in a sustainable and equitable manner. They also point to the overriding need for institutions that will balance the demands of different groups of people within basins in addition to balancing the pressures for development and environmental protection within the environment it uses.

Contact Persons

Simon Cook (s.cook@cgiar.org), Myles Fisher, Tassilo Tiemann, Alain Vidal

Key Reference

Cook, S., M. Fisher, T. Tiemann and A. Vidal 2011. Water, food and poverty: global- and basin-scale analysis *Water International*, **36**, 1-16.

Tag: Basin Focal Projects (BFP)

Bibliography

Ahmad, M.D. and M. Giordano 2010. The Karkheh River basin: the food basket of Iran under pressure. *Water International,* **35**, 522-544.

Awulachew, A. et al. 2010. The Nile Basin: tapping the unmet agricultural potential of Nile waters. *Water International*, **35**, 623-654.

Bruinsma, J. 2009. By how much do land, water and crop yields need to increase by 2050? In: How to feed the world. Proceedings of an FAO Expert Meeting, Rome, 24-26 June, 2009. Rome: FAO.

Byerlee, D., A. de Janvry and E. Sadoulet 2009. Agriculture for development: toward a new paradigm. *Annual Review of Resource Economics*, **1**, 15-31.

Cai, X. et al. 2011. Producing more food with less water in a changing world: water productivity assessment in ten major river basins. *Water International*, **36**, 42-62.

Cohen, J., 1989. Deliberative democracy and democratic legitimacy. In: The good polity, eds., A. Hamlin and and P. Pettit; 17-34. UK: Blackwell.

Dore, J. 2007. Multi-stakeholder platforms (MSPS): unfulfilled potential. In: Democratizing water governance in the Mekong region, eds., L. Lebel *et al.*; 197-226. Chiang Mai, Thailand: Mekong Press.

De Fraiture, C. et al. 2001. PODIUM: Projecting water supply and demand for food production in 2025. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere,* **26**, 869-876.

EIA 2010. *International energy outlook 2010.* Washington, DC: US Energy Information Administration (EIA). Retrieved from: http://www.eia.doe.gov/oiaf/ieo/index.html

Falkenmark, M., J. Rockström, and L. Karlberg 009. Present and future requirements for feeding humanity. *Food Security,* **1**, 59-69.

Fisher, M. and S. Cook 2010. Introduction. *Water International,* **35**, 465-471.

Hoff, H. and J. Rockström 2009. Green and blue water in the global water system - a model synthesis. *Global Water News,* **8**, 10-12.

IPCC 2007. Climate change 2007: impacts, adaptation, and vulnerability. In: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), eds. M.L. Parry *et al.* Cambridge: Cambridge University Press.

Kemp-Benedict, E. et al. 2011. Connections between poverty, water, and agriculture: evidence from ten river basins. *Water International,* **36**, 125-140.

Kirby, M. et al. 2010. The Mekong: a diverse basin facing the tensions of development. *Water International,* **35**, 573-593.

Lawrence, P., J. Meigh and C. Sullivan 2002. The water poverty index: an international comparison. Keele Economic Research Papers.

Lemoalle, J. and D. de Condappa 2010. Farming systems and food production in the Volta Basin. *Water International,* 35, 655-680.

Molden, D. (ed.) 2007. *Water for food, water for life: a comprehensive assessment of water management in agriculture.* London: Earthscan and Colombo: InternationalWater Management Institute (IWMI).

Molle, F. and P. Mollinga 2003. Water poverty indicators: conceptual problems and policy issues. Water Policy, 5, 529-544.

Molle, F., T. Foran, and M. Käkönen (eds.) 2009. *Contested waterscapes in the Mekong Region: hydropower, livelihoods and governance.* London: Earthscan.

Mulligan, M. et al. 2010. The Andes basins: biophysical and developmental diversity in a climate of change. *Water International,* **35**, 472-492.

Mulligan, M. et al. 2011.Water availability and use across the Challenge Program on Water and Food (CPWF) basins. *Water International,* **36**, 17-41.

NWC 2009. *Australian water markets report 2008-2009*. Canberra, Australia: National Water Commission (NWC).

Ogilvie, A. et al. 2010.Water agriculture and poverty in the Niger River basin. *Water International,* **35**, 594-622.

Pearce, F. 2007. *When the rivers run dry: what happens when our water runs out?* Toronto, Canada: Key Porter Books.

Ringler, C. et al. 2010. Yellow River basin: living with scarcity. *Water International,* **35**, 681-701.

Rosegrant, M., X. Cai, and S. Cline 2002. World water and food to 2025. *Dealing with scarcity.* Washington, DC: International Food Policy Research Institute.

Seckler, D. et al. 1998. *World water demand and supply, 1990-2025: scenarios and issues.* IIWMI Report 19. Colombo: International Water Management Institute.

Sharma, B. *et al.* 2010. The Indus and the Ganges: river basins under extreme pressure. *Water International*, **35**, 493-521.

Sullivan, A. and M.L. Sibanda 2010. Vulnerable populations, unreliable water and low water productivity: a role for institutions in the Limpopo Basin. *Water International,* **35**, 545-572.

UN 2009. *World population prospects: the 2008 revision.* Population Newsletter 87, June 2009. New York: Population Division of the Department of Economic and Social Affairs of the United Nations (UN) Secretariat.

UN 2010. *World urbanization prospects: the 2009 revision.* New York: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat

WRI, 2003. *Water Resources Atlas. Watersheds of the world: global maps, 14. Degree of river fragmentation and flow regulation.* World Resources Institute (WRI), World Conservation Union (IUCN), IWMI and Ramsar Convention Bureau.

Improving Water Productivity in Crop and Livestock Systems

Aerobic Rice System for Water-Scarce Areas

Rice is the staple food in Asia but is also the single biggest user of freshwater. It is mostly grown under submerged soil conditions and requires more water compared with other crops. Asia's irrigated rice fields consume more than 40% of the world's freshwater that is used for agriculture (Bouman 2001). Tuong and Bouman (2003) estimated that, by 2025, approximately two million hectares of irrigated dry-season rice and 13 million hectares of wet-season rice will experience water scarcity. The declining availability and increasing costs of water threaten the traditional way of producing irrigated rice. Moreover, lack of rainfall is a major production constraint in rain-fed areas where many poor rice farmers live. Under these circumstances, new technologies and methods need to be developed to help farmers cope with water shortages for rice production.

Aerobic rice production is a revolutionary way of growing rice in well-drained, non-puddled, and non-saturated soils without ponded water. This system uses input-responsive specialized rice cultivars and complementary management practices to achieve at least 4-6 t/ha using only 50-70% of the water required for irrigated rice production. This is recommended in areas where water is too scarce or expensive to allow traditional irrigated rice cultivation.

The CGIAR Challenge Program on Water and Food (CPWF) Project, Developing a System of Temperate and Tropical Aerobic Rice in Asia (STAR), evaluated and selected varieties for a range of target environments, including temperate, lowland areas in China; the sub-tropical, irrigated regions in India; favorable rain-fed uplands in Laos and Thailand and tropical irrigated lowlands in the Philippines. Varietal evaluation included on-station trials on-farm trials and participatory variety selection (PVS) in farmers' fields.

Where to grow aerobic rice

Rice varieties that are suitable for aerobic production systems grow in soil with moisture content at or below field capacity. Unlike upland rice varieties, aerobic rice varieties should have yields from 4 to 6 t/ha under favorable conditions. Aerobic rice is drought-resistant like upland rice.

Favorable uplands

- Land is flat or terraced
- Rainfall or supplemental irrigation is sufficient to bring soil moisture content to or close to field capacity
- No serious soil chemical limitations (e.g., salinity)
- Farmers have access to external inputs (e.g., fertilizer)

Fields in the upper toposequence of rainfed lowlands

- Deep groundwater table
- Well-drained, coarse-textured soil so that fields are flooded only for a limited part of the growing season

Water-scarce irrigated lowlands

Areas where farmers do not have access to water to keep their fields flooded for a substantial period of time, for example:

- Tail-end part of a large-scale surface irrigation system
- Areas where groundwater has been drawn down so that cost of pumping water is high
- Areas where water for irrigation is re-directed for other uses (e.g., domestic, industries)

Aerobic rice can also be grown in non-rice-growing areas for crop diversification.

Farmers' views on aerobic rice

Favorable:
- **Contributes to food self-sufficiency**
- **Grows in water-scarce environments**
- **Can withstand both dry and flooded conditions**
- **Good alternative to other upland crops (e.g., maize) in the event of flooding**
- **Easy to establish the crop**
- **Requires less labor than lowland rice**
- **Has good eating quality**

Unfavorable:
- **Lower yield compared with lowland rice**
- **Difficult to control weeds**
- **Insufficient extension support to the farmers**
- **Difficult to market new varieties**

How to manage aerobic rice

Aerobic rice is basically managed like a wheat or maize crop. The STAR project developed management options and guidelines for crop establishment, irrigation, fertilizer management and weed management.

1. Crop establishment

Direct dry seeding

- Prepare the land by plowing and harrowing to obtain a smooth seed bed before seeding.
- Sow seeds at a depth of 1-2 cm in heavy soil (clay) and a 2-3 cm depth in light-textured soil (loam). Sowing may be done manually by dibbling seeds into slits opened by a stick or tooth harrow or mechanically using direct seeding machines. The optimum seeding rate is 70-90 kg/ha.
- Maintain 25-35 cm row spacing.

Transplanting

Note: This crop establishment method can only be done in clay soil with good water-holding capacity.

- Transplant seedlings into wet soil that is kept around saturation for a few days to ease transplanting shock.
- Let the field dry out to field capacity.

2. Irrigation

Irrigation is applied by flash flooding, furrow irrigation or sprinkler. The amount of irrigation should be enough to maintain the soil moisture condition at field capacity (30-40 kPa). Some visible signs that the soil moisture is below field capacity are hair-line cracks in the soil and rolling of the tips of leaves.

In the dry season, light irrigation (approx. 30 mm) is applied after sowing to promote emergence.

3. Fertilizer management

The site-specific nutrient management (SSNM) [http://www.knowledgebank.irri.org/rkb/ssnm] approach is recommended to determine the need for supplemental nutrients. One useful tool under SSNM is the use of the leaf color chart (LCC) to assist in the application of nitrogen (N) fertilizer. In the absence of knowledge or training on SSNM, farmers can initially apply 70-90 kg N/ha in three splits.

The first split should be applied 10-12 days after emergence to minimize N losses from leaching. The second split should be applied at active tillering and the third split at panicle initiation. Note that basal N fertilizer application promotes early weed growth.

Dry, aerobic soil can reduce the indigenous supply of phosphorus (P), hence, the application of P fertilizer is more critical for aerobic rice production than for conventional flooded rice production systems.

4. Weed management

- ◈ Use manual or mechanical weeding in the early phase of crop growth.
- ◈ Use pre- or post-emergence herbicides when weed pressure is high.

Identified aerobic rice varieties

The STAR project has identified potential aerobic rice varieties from released varieties or from breeding programs in the following countries (see table below):

Aerobic rice varieties identified in the project's target sites

Country	Variety/ Breeding line	Yield
China	Han Dai 502 Han Dao 297	6 t/ha
India	Pusa Hybrid 10 Proagro 6111 (Hybrid) Pusa 834 IR55423-01 (Apo1)	>4 t/ha
Laos	B6144F-MR-6-0-0	3.6 t/ha
Philippines	Apo (PSBRc9) UPLRi5 PSBRc80	5-6 t/ha

Key recommendations

Extensive studies on the potential and impact of aerobic rice yielded promising results. Focus should be directed at some other issues and concerns detailed in the following recommendations:

- Aerobic rice should be recognized as a special crop type (different from lowland and upland rice) and should be promoted with a complete understanding of the system.

- The technology is considered sufficiently mature in China, but more research is needed to create sustainable and high-yielding tropical aerobic rice. Further research should focus on; a) breeding and improved management (especially nutrient management to increase yield potential and attainable yield at the farm level); b) water accounting at the regional scale; c) creating an inventory of soil health issues in the target domains; d) establishing a long-term, continuous cropping experiment to address sustainability issues; e) understanding and solving the phenomenon of yield collapse and f) understanding the biophysical and socioeconomic factors that lead to the adoption of the technology by farmers. Focus should be given to setting up dedicated aerobic rice breeding programs and strengthening research and development capacity to develop sustainable production systems.

Contact Persons

Bas A.M. Bouman (b.bouman@irri.org)

Partner Organizations

Bulacan Agricultural State College, Philippines
China Agricultural University
Christian Albrechts University – Kiel, Germany
Indian Agricultural Research Institute, Water Technology Centre, India
International Rice Research Institute
National Agriculture and Forestry Research Institute, Lao PDR
National Irrigation Administration – Tarlac, Philippines
Philippine Rice Research Institute
Ubon Ratchathani Rice Research Center, Thailand

Key Reference

Bouman, B.A.M. 2008. *Developing a system of temperate and tropical aerobic rice in Asia (STAR)*. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3928

Tags: PN16; Aerobic Rice System

Bibliography

Bouman, B.A.M., Yang Xiaoguang, Wang Huaqi, Wang Zhimin, Zhao Junfang, and Chen Bin 2006. Performance of aerobic rice varieties under irrigated conditions in North China. *Field Crops Research,* **97**, 53-65.

Choudhury, B.U., B.A.M. Bouman and A.K. Singh 2007. Yield and water productivity of rice-wheat on raised beds at New Delhi, India. *Field Crops Research,* **100**, 229-239.

Ding, S., H. Wu, B.A.M. Bouman, H. Wang, S. Peng and Y. Chen 2010. Adoption and impact of aerobic rice in North Anhui. In: *Research to impact: case studies for natural resource management for irrigated rice in Asia,* eds. F.G. Palis, G. Singleton, M.C. Casimero and B. Hardy, B, 335-360. Los Baños, Philippines: International Rice Research Institute.

Fengtong Wei, Hongbin Tao, Shan Lin, B.A.M. Bouman, Limeng Zhang, Pu Wang and K. Dittert 2011. Rate and duration of grain filling of aerobic rice HD297 and their influence on grain yield under different growing conditions. *Science Asia,* **37**, 98–104.

Jing Xiang, Van Ryan Haden, Shaobing Peng, B.A.M. Bouman, R.M. Visperas, Lixiao Nie, Jianliang Huang, and Kehui Cui 2009. Improvement in nitrogen availability, nitrogen uptake and growth of aerobic rice following soil acidification. *Soil Science and Plant Nutrition,* **55**, 705–714.

Kreye, C., B.A.M. Bouman, J.E. Faronilo and L. Llorca 2009. Causes for soil sickness affecting early plant growth in aerobic rice. *Field Crops Research,* **14**, 182-187.

Lampayan, R.M., B.A.M. Bouman, J.L. de Dios, A.J. Espiritu, J.B. Soriano, A.T. Lactaoen, J.E. Faronilo and K.M. Thant 2010. Yield of aerobic rice in rainfed lowlands of the Philippines as affected by nitrogen management and row spacing. *Field Crops Research*, **116**, 165-174.

Limeng Zhang, Shan Lin, B.A.M. Bouman, Changying Xue, Fengtong Wei, Hongbin Tao, Xiaoguang Yang, Wang Huaqi, Dule Zhao and K. Dittert 2009. Response of aerobic rice growth and grain yield to N fertilizer at two contrasting sites near Beijing, China. *Field Crops Research,* **114**, 45-53.

Lixiao Nie, Jing Xiang, Shaobing Peng, B.A.M. Bouman, Jianliang Huang, Kehui Cui and R.M. Visperas 2009. Alleviating soil sickness caused by aerobic monocropping: Responses of aerobic rice to fallow, flooding and crop rotation. *Journal of Food, Agriculture & Environment,* **7**, 723-727.

Rubiano, J., and V. Soto. 2009. *Geographical Extrapolation Domain Analysis: Scaling-Up Watershed Management Research Projects, A Toolkit Guide to Implementation.* CPWF Working Paper 04. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

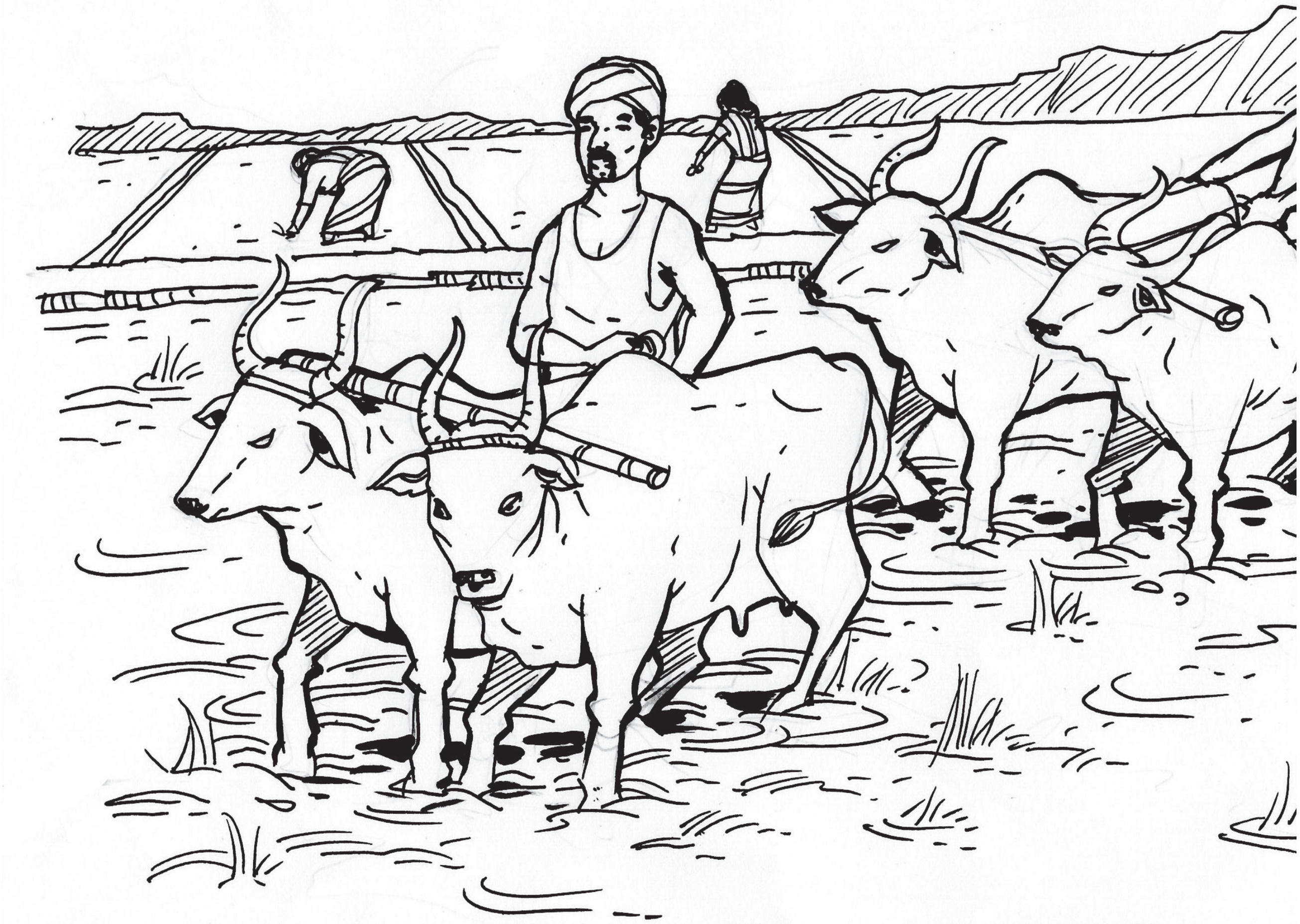
Xiao Qin Dai, Hong Yan Zhang, J.H.J. Spiertz, Jun Yu, Guang Hui Xie and B.A.M. Bouman 2010. Crop Response of Aerobic Rice and Winter Wheat to Nitrogen, Phosphorus and Potassium in a Double Cropping System. *Nutrient Cycling in Agroecosystems,* **86**, 301-315.

Xue Changying, Yang Xiaoguang, B.A.M. Bouman, Deng Wei, Zhang Qiuping, Yan Weixiong, Zhang Tianyi and Rouzi Aji 2008. Effects of irrigation and nitrogen on the performance of aerobic rice in northern China. *Journal of Integrative Plant Biology,* **50**, 1589-1600.

Xue Changying, Yang Xiaoguang, B.A.M. Bouman, Deng Wei, Zhang Qiuping, Yan Weixiong, Zhang Tianyi, Rouzi Aji, and Wang Huaqi 2008. Optimizing yield, water requirements, and water productivity of aerobic rice for the North China Plain. *Irrigation Science,* **26**, 459-474.

Yang Xiaoguang, B.A.M. Bouman, Wang Huaqi, Wang Zhimin, Zhao Junfang, and Chen Bin, 2005. Performance of temperate aerobic rice under different water regimes in North China. *Agricultural Water Management,* **74**, 107-122.

Improving Variety and Crop Management in Salt-Affected Areas



Almost 100 million hectares of coastal and inland agricultural lands are affected by soil salinity and alkalinity. Approximately 22 million hectares of saline areas are in Asia, with 11 million hectares in India alone. Low food production and poverty are high in these areas. Food production can be increased through proper technological intervention, including improvement of the condition of the soil and adapting new crop varieties for more saline soils. Because of their vast scale, a modest improvement of yields in such soils can ensure food security for millions of hungry and impoverished people.

Saline and sodic soils are different in nature (although both are caused by an excess of sodium) and require different soil management techniques. In saline soils, sodium is present as sodium chloride, or common salt, and reduces the availability of water for plants. At high enough concentrations, it can be threatening to crops. In sodic soils, much of the chloride has been washed away, leaving behind sodium ions attached to tiny clay particles in the soil. These clay particles do not stick together when wet, making soil susceptible to erosion and impermeable to both water and roots.

Planting salt-tolerant crops to adapt to soil salinization

Coastal salinity, caused by seawater intrusion and shallow saline water tables, is severe during the dry season. On the other hand, flooding in the monsoon season limits cropping to rice. Saline and sodic soils are widespread in inland areas and are progressively expanding because of improper water management. Rice is suitable for rehabilitating salt-affected soils because it can grow under flooded conditions and has a high potential for genetic improvement. Rice productivity in salt-affected areas could be increased by 1-2 t/ha, providing food for millions of the poorest people and making use of some of the least exploited land and water resources.

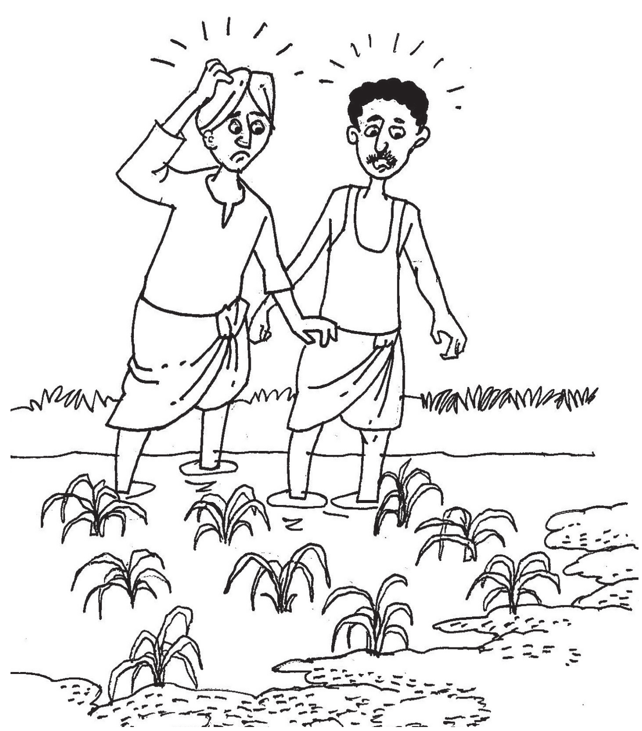
A CGIAR CPWF project on productivity of salt-affected areas attempted to enhance land and water productivity of rice-based cropping systems in salt affected areas by integrating genetic improvement and management strategies that are environmentally sustainable and socially acceptable. With 11 partners in five countries, the project made considerable contributions through its activities. This paper is limited to work done in Coastal Orissa and Faizabad, Uttar Pradesh, India. Improved salt-tolerant rice varieties, crop and natural resource management practices and rice-based cropping systems were validated through farmer participatory research.

The following key approaches were used by the project in India:

- Identification of salt-tolerant rice and other crop varieties
- Use of farmers' observations in identifying tolerant varieties and effective farming techniques
- Participatory varietal selection (PVS) for rice varietal improvement
- Participatory experiments on new farming practices, in particular water and nutrient management

Coastal Orissa, India

About half of India's salt-affected coastal lands are in Orissa and in neighboring West Bengal. In coastal Orissa, salinity is severe due to seawater intrusion and shallow saline groundwater, especially during the dry season. During the wet season, rainfall and river flow help to flush out some of the salt, making rice cropping possible, but yields remain low because of the saline conditions. Average rice production is barely enough to secure food for 4 to 9 months for a typical family, leaving farmers no choice but to purchase rice during the lean months. The recommendations from this CGIAR



CPWF research project were to 1) adopt new salt-tolerant rice varieties for the wet season and plant them earlier than traditionally done; 2) adopt the new varieties in the dry season; and 3) allocate 10% of the dry season area to non-rice crops (e.g., sunflower).

Faizabad, Uttar Pradesh, India

The important cropping seasons at Faizabad are kharif (the wet season from March to October) and rabi (the dry season from November to April). The average annual rainfall is less than 1000 mm. The major cropping patterns in the area are rice-wheat, rice-potato, rice-pea and mustard, sugarcane-wheat and rice-oilseed followed by pigeon pea. Animal production is also an integral component of the farming system.

Recommendations from the research include 1) improving production from sodic soils by using 'pressmud,' an easily accessible organic by-product of sugar factories, which is rich in sulphur and zinc; 2) planting salt-tolerant rice varieties (Usar Dhan 3 and CSR 23); and 3) propagating the legume cover crop, *Sesbania*, as a soil amendment. The third recommendation is suitable for areas with access to water from tubewells. In a span of 3 years, about 30 farmers evaluated the technology on their sodic land with a soil pH ranging from 9.2 to10.2 (moderately to highly alkaline). An average yield increase of 0.5-0.8 t/ha was noted, depending on the amount of pressmud amendment used. The benefits were greater for the more alkaline soils, where rice plants would not normally grow if there was no soil amendment. Net profits ranged from Rs 500-3500 per hectare (US$13-88) for a single rice crop, compared with land that is normally barren. Farmers preferred the medium-duration varieties, Usar Dhan 3 and CSR 23, which allowed the

cultivation of a second rabi-season crop, such as wheat, potato or pulses. However, women noted that Usar Dhan 3 was not as tasty as the other varieties. Farmers with guaranteed irrigation from tubewells used both *Sesbania* and pressmud, while farmers without irrigation adopted the pressmud technology. Farmers also obtained higher yields from the second seasonal wheat crop after applying pressmud and *Sesbania* mixtures.

Eastern Uttar Pradesh, India

In Eastern Uttar Pradesh, sodic soils are a major problem in rainfed areas. Approximately 1.3 million hectares of rice fields are affected. The problem becomes more severe during the dry season, preventing farmers from growing a second crop of rice. Aside from sodic soils, farming households also have to deal with drought and flooding. Most of the farmers are resource-poor and have marginal landholdings (less than a hectare). Few farmers have supplementary irrigation. Sodic soil reclamation with inorganic amendments, like gypsum and pyrite, are effective but these amendments are expensive for poor farmers.

The successful use of pressmud and *Sesbania* technology on the CSR 23 and Usar Dhan 3 rice varieties in Faizabad is now being promoted in Eastern Uttar Pradesh.

Women contributed almost 60% of the total labor in rice production. The project sought the participation of women in focus group discussions, surveys and participatory variety trials to get their feedback on the technology. Female informants provided more descriptive information than men, saying that the improved soil quality increased the crop yields of rice and wheat. With the excess in production, they were able to sell their crops, thereby increasing their food security. Farmers in Eastern Uttar Pradesh, who used pressmud and *Sesbania*, noted that rice and wheat yields increased by 30-50%. CSR 23 was good for sodic soils in terms of duration, plant height, threshability, milling recovery, taste and for producing puffed rice. Usar Dhan 3 was less preferred due to its inferior taste.

Southwestern Bangladesh

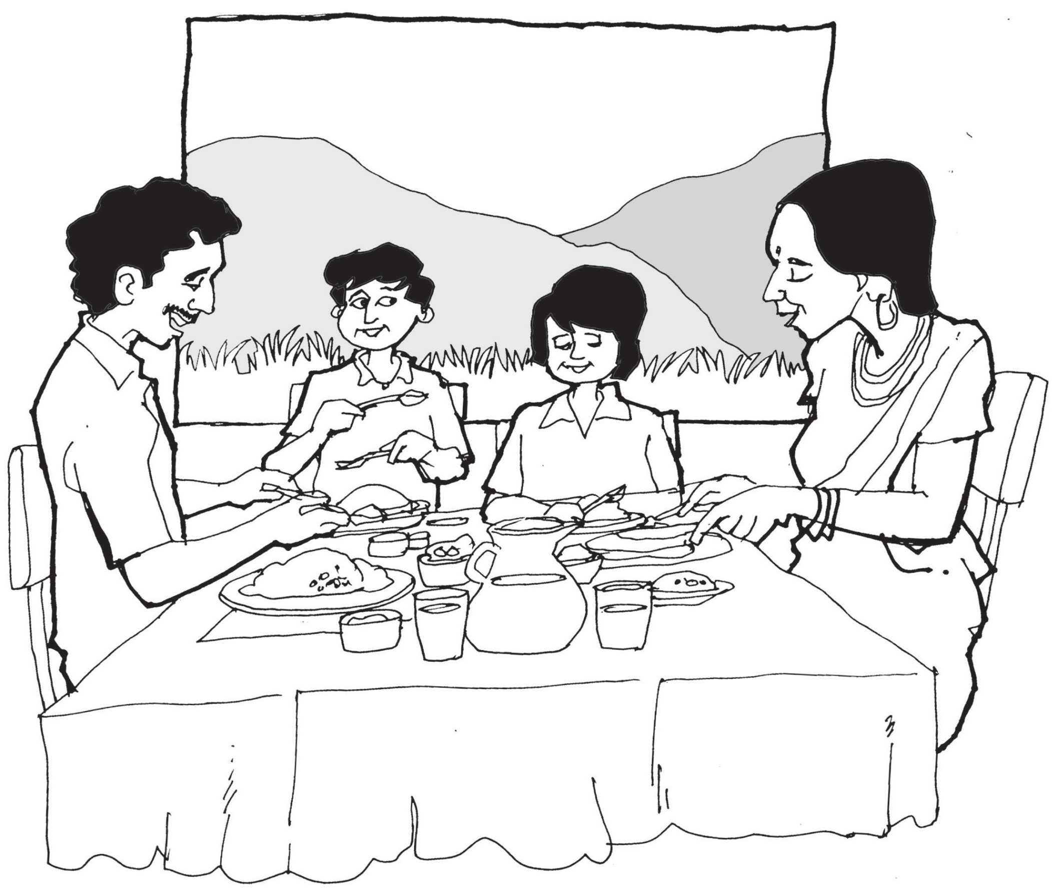
Fast-maturing rice varieties, water harvesting and proper management of irrigation water were recommended for this area. Diversification of rice-based systems doubled the cropping intensity and increased the annual grain yield. Farmers' responses to the adoption of the new multi-cropping system were positive, resulting in a rapid increase in demand for seed in the area.

Key findings

- Planting early provides farmers with at least a 30% increase in yield.
- The use of early-maturing and high-yielding salt-tolerant rice and non-rice varieties, associated nutrient management techniques and cheap soil amendments helped farmers to intensify crop production and increase yields.
- New cropping combinations, like rice-sunflower, show potential for adoption.
- The inclusion of female farmers not only helped achieve higher crop yields but also increased women's confidence in using new salt-tolerant rice varieties and nutrient management technologies. Women were recognized as legitimate farmers.

Lessons learned

- Technological improvements, including the use of new salt-tolerant varieties of rice and other crops and organic soil amendments, proved to be relatively inexpensive for farmers to adopt. Results could be observed in just 2 years.
- As farmers witness the occurrence of higher yields as a result of using the new salt-tolerant rice varieties, demand for their seeds increases. Guaranteed access to seeds becomes necessary, and this can be ensured by supporting the multiplication efforts of local farmers.
- The commercialization of new salt-tolerant rice varieties can be hastened by easing the regulations on variety release. This is necessary in countries where subsidies are only provided to farmers who grow officially released varieties.



Conclusion

With the use of simple technologies and appropriate plant varieties, farmers can grow crops in once barren saline and sodic lands. Planting salt-tolerant rice varieties, practicing multi-cropping and using soil amendments contributed to the higher yield. Using these techniques to adapt to saline and sodic soils can help improve the food security of poor households.

Contact Person

Abdelbagi M. Ismail (a.ismail@irri.org)

Partner Organizations

Bangladesh Rice Research Institute
Central Rice Research Institute, India
Central Soil Salinity Research Institute, India
Cuu Long Delta Rice Research Institute, Vietnam
International Centre for Biosaline Agriculture, UAE
International Crops Research Institute for the Semi-Arid Tropics
International Rice Research Institute
Narendra Dev University of Agriculture and Technology, India
Rice Research Institute of Iran
University of California Davis, USA

Key Reference

Ismail, A.M. 2009. *Development of technologies to harness the productivity potential of salt-affected areas of the Indo-Gangetic, Mekong, and Nile River basins*. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3785

Tags: PN7; Productivity in Salt-affected Areas

Bibliography

Woolley, J. 2011. *Legacy of PN7: Potential of salt-affected areas.* Unpublished manuscript.

Woolley, J. 2009. *Phase 1 outcomes and impacts as reported in project reports.* Unpublished manuscript.

Integrated Farming Enhances Rainwater and Soil Productivity

Food security in the entire Volta Basin is under threat. The erratic rainfall pattern and frequent periods of drought cause significant crop damage. Increasing population and livestock pressure and the growing competition over the use of water for generating hydroelectricity have aggravated water stress in the basin. Declining water quantity and quality has become a critical limiting factor for agricultural productivity. Further, inappropriate management practices (e.g., crop residue/bush burning and intensive plowing) degrade the soil and contribute to the deterioration of soil fertility, which consequently results in crop failure.

Water use efficiency holds the key to improving agricultural (Kijne *et al.* 2001) and livestock productivity in the Volta Basin. In the same way, crop yield is a function of soil fertility. Hence, improved agricultural productivity rests on how water and soil are developed and managed.

A research project of the CGIAR Challenge Program on Water and Food (CPWF), led by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), was designed to address these major constraints encountered by small-scale resource-poor farmers, who rely on rainfed agriculture for their livelihoods.

Broad stretches of the rain-starved Volta Basin could reap the benefits of an innovative land-use system, which is already helping farmers in semi-desert areas of Niger to sustain healthy soil and healthy crops, and even to diversify into higher value produce.

Named the Sahelian Eco-Farm (SEF), the system was developed by scientists and farmers at the Sahelian Center of ICRISAT in Niger. It has been shown to significantly improve the efficiency with which rainwater and soil nutrients are used by crops and retained in the soil, even in periods of extreme water scarcity.

Lessons from the past:

- **Research has shown that only 10% of rainwater is used by crops and the majority of it is lost to evaporation. International and national agricultural research institutions have developed high-yielding cereal and legume varieties that respond to different rainfall regimes.**
- **ICRISAT and its partners have developed and promoted improved varieties of sorghum, millet and groundnut, and soil management technologies adapted to the semi-arid conditions.**
- **The Center for Development Research (ZEF) and the International Water Management Institute (IWMI) are currently developing decision support tools to assist in the management of water in the Volta.**

Development and adaptation

The SEF has now been selected for further development and adaptation for this project. It is using the knowledge gained from these studies to develop 'integrated technology options—solutions that use a systems perspective for improving water and nutrient use efficiencies, while increasing crop productivity. It will also adapt the solutions as necessary for use in different locations.

The SEF was a clear choice for further development in this context. It has as its basis an integrated approach to land management in which an entire farming system is designed with a view to making the best use of the properties of local rainfall, soil and geography, together with those of selected crops and other plants. Its design was successful because it also takes into account—and optimizes—the interactions between these elements.

Package of technologies

The project evaluated and adapted, in partnership with farmers and other stakeholders, technology options that could potentially improve water and nutrient use efficiencies and increase crop productivity. From this consultation, a list of promising technologies was drawn. Four strategic research project sites were chosen along the Volta Basin, namely, Ziga and Saala in Burkina Faso (upstream) and Tamale and Navrongo in Ghana (downstream). Technologies that had shown good performance were chosen: Sahelian Eco-Farms (SEF), fertilizer microdosing, tied ridging, the zai system and stone lines. The yield of crops under these technologies has increased, in some cases by two fold, compared with the usual farmers' practices. These technologies have also brought about improvement in soil, water, nutrient and crop management.

Since the project was started in 2004, CPWF work on the SEF concept has focused on gaining greater understanding of how it works and adapting it for use elsewhere. So far, a total of 35 new SEF trials have been established in countries outside of Niger: 33 in Northern Ghana, divided between the districts of Navrongo and Tamale, and two more in Burkina Faso.

As yet, only preliminary results are available from the pilots, but for the adaptations under trial, farmers are exploring the use of common cereal crops such as millet, sorghum and maize as the base crop, to establish their suitability in various agro-ecological zones.

The Sahelian Eco-Farm concept

A typical SEF comprises a blend of traditional and introduced components selected to work in harmony. An important multi-purpose component is *Acacia colei*, an Australian species of a leguminous tree whose roots fix atmospheric nitrogen and whose leaves remain green during the dry period. Hedges of this species are planted to enrich the soil and improve its fertility and also to act as wind-breakers. Branches pruned from the hedges serve as firewood and mulch; its seeds as poultry feed.

Earth bunds are built in a half-moon shape to create micro-catchments, collecting run off water and protecting the soil against erosion. High-value trees such as the domesticated Indian variety of *Ziziphus mauritania* (or 'Pomme du Sahel') are planted inside these 'demi-lunes'. This variety produces fruit ten times bigger than that of the indigenous tree. Its leaves can be used for forage and mulch and the pruned branches for firewood.

A perennial grass, such as *Andropogon gayanus*, is planted on the earth bunds to strengthen them. Annual crops, like millet and cowpea, are each planted in half or a third of the field in rotation each year. The results are impressive and include increased water use efficiency and soil fertility, drought mitigation, reduced soil erosion, more and better animal feed during the dry season, higher incomes and more diverse sources of income and risk mitigation.

While the SEF is in many ways a self-contained concept, it has great potential for integration with other promising technologies such as conservation tillage, conservation agriculture, micro-dose fertilization (involving the application of small quantities of fertilizers at the plant base) and the Zai method of planting in water-retaining pockets.

Water harvesting (tied ridging), with or without NPK, improved maize grain yield by 20%. Nitrogen-use efficiency (NUE) increased by 45% at 54 kg/kg of nitrogen compared to the recommended rate. In Ghana cowpea and cereal rotation associated with soil and water conservation and trees increased sorghum yield by 42% compared to continuous cropping under the same conditions.

Zai and stone lines with nutrients

Zai and stone lines (water conservation structures) and nutrient source combinations were tested at Ziga and Saala in Burkina Faso. Test crops were sorghum and maize with cowpea being common in both sites.

- **In Ziga, the best yields were obtained with the recommended rate of mineral fertilizer (T2) and intensive fertilization with the addition of Burkina Phosphate (BP) (T4). However, the response of phosphorus appears slightly higher when it is associated with manure (T4).**

- **In Saala, all the technologies had a positive effect on maize yield. The grain yields of maize varied from 300 to 950 kg/ha for the control, compared with 800 to 1500 kg/ha for the improved technologies. T4 gave the best yield. The marginal product obtained from the use of intensive fertilization (T4) was three times greater than that of the simplest technology.**

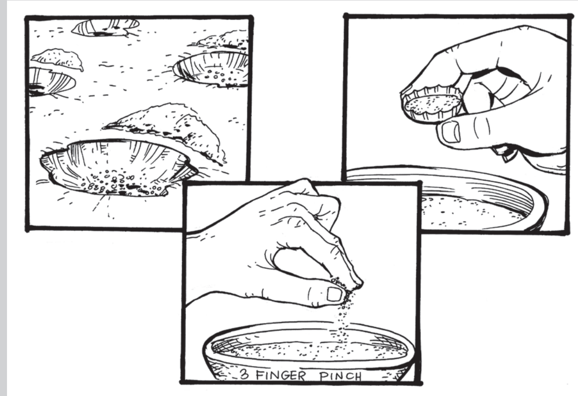
- **All of the technologies, which are a combination of organic fertilizer, mineral fertilizer and BP, produced on average 950 kg/ha of sorghum and 1500 kg/ha of maize when applied with zai and stone lines. Without such structures, the recorded yields were much lower, particularly for maize (500 kg/ha, on average). Overall, the improved technologies performed better than farmers' practices in all years.**

Common to all technologies = stone lines + Zai combined with the following:

Ziga site
T1 = 5 t ha/manure + 50 kg ha/urea
T2 = 100 kg/ha NPK (14:23:14) + 50 kg urea/ha
T3 = 5 t ha/manure + 200 kg/ha BP (26.3% P_2O_5) per + 50 kg ha/urea;
T4 = 5 t ha/manure + 100 kg/ha NPK (14:23:14) + 200 kg Burkina Phosphate/ha + 50 kg urea/ha

Saala site
T1 = 6 t ha/manure + 100 kg ha/urea
T2 = 150 kg/ha NPK (14:23:14) + 100 kg ha/urea
T3 = 6 t ha/manure + 200 kg Burkina Phosphate (BP) (26.3% P2O5) + 50 kg urea/ha
T4 = 6 t ha/manure + 150 kg/ha NPK (14:23:14) + 200 kg ha/BP + 50 kg ha/urea

Fertilizer microdosing: a complementary technology



The micro dose technique was introduced to farmers as an effective and efficient, yet less capital-intensive way of fertilizer application. This field experiment was carried out in Ghana, on-farm in Tamale and Navrongo and on-station in Navrongo.

On-station, the lowest fertilizer rate microdose (25% of recommended rate) almost doubled the yield of the control. Net returns were negative for the no fertilizer treatment and the highest nitrogen use efficiency (NUE) was obtained with the microdose treatment. The sorghum variety used responded poorly to fertilization. However, the microdose treatment out yielded the control.

On-farm, maize yield was nearly four times more than the control treatment. But, with sorghum, microdose fertilizer did not have any advantage over the control for the variety used. NUE was highest for the microdosing treatment (54 kg maize/kg N) compared with the earlier recommended rate (37 kg maize/kg N).

Field trial results: microdosing

Tamale (on-farm)	Navrongo (on-farm)	Navrongo (on-station)
(i) Improved maize variety + 4 g NPK (15-15-15)/hill (6 kg ha/N, 3 kg ha/P, 5 kg ha/K) (ii) Improved maize variety + earlier recommended fertilizer rate of 60 kg ha/N (iii) Local maize variety + earlier recommended fertilizer rate of 60 kg ha/N (iv) Local maize variety + no fertilizer The plot size was 20 x 25 m, with 80 x 40 cm plant spacing and two plants per hill.	(i) Local millet variety + 4 g NPK (15-15-15)/hill (6 kg ha/N, 3 kg ha/P, 5 kg ha/K) (ii) Local millet variety + earlier recommended fertilizer rate of 60 kg ha/N (iii) Local millet variety + no fertilizer The plot size was 20 x 25 m, with 80 x 40 cm plant spacing.	(i) Improved sorghum variety + 4 g NPK (15-15-15)/hill (ii) Improved sorghum variety + earlier recommended fertilizer rate of 60 kg ha/N (iii) Improved sorghum variety + no fertilizer The plot size was 10 x 10 m, with 80 x 40 cm plant spacing. There were three replications.

The AGRA Microdosing Project

Building on the experience of CPWF, the new Alliance for a Green Revolution in Africa (AGRA) microdosing project was aimed at a wider scaling up of the fertilizer microdosing and warrantage system in Burkina Faso, Niger and Mali. This USD 11.5 million project is targeting, on average, a 40% increase in grain yield and will reach several hundreds of households in 3 years.

However, some important research questions emerge. Due to the small amount of fertilizer applied and the increased biomass production resulting from this, a concern was raised about the sustainability of the technology with regard to soil fertility and sustained crop yield. Further work is thus needed to study crop productivity, soil water use, water and nutrient interaction and water and nutrient flows. A watershed approach could be used in such studies.

Conclusion

Though a lot has been achieved by this project, there is still work to be done in some areas. For example, the issue of water and nutrient interaction needs further study in the context of a changing climate, where water scarcity is becoming more and more apparent. In the analysis, it would be helpful to adopt a watershed management approach in addressing the problems with trying to improve the livelihoods of smallholder farmers in the basin.

The project exposed participating communities to different technology options and allowed them to learn about the importance of proper use of these technologies. Working with farmers in this harsh environment, this project showed that yields of crops can be increased through adoption of improved varieties, in-field rainfall capture and nutrient management, and availing of the productivity benefits by including a legume in the rotation.

Warrantage system

One important positive outcome of this project was the warehousing of farm products, called a warrantage or inventory credit system. This system, which is implemented during a period of four to nine months, allowed farmers to benefit from microcredits.

Upon recovery of their products, producers appreciated the warrantage system as an economically profitable operation helping them to make substantial gains and to have remaining products after settlement of their debt. The actual economic grain was 42% at Ziga and 21% at Saala in Burkina Faso compared to the product's price at harvest.

This system helped producers through pledged savings that could be used in the absence of the CPWF project, as personal contributions for future warrantage operations. In addition, they allocated part of the product for family consumption (95% for sorghum at both sites, 100% for millet at Ziga and 78% at Saala and 25% for cowpea at Ziga and 50% of rice at Saala).

Contact Persons

Mathias Fosu (mathiasfosu@yahoo.co.uk), Dougbedji Fatondji, Ramadjita Tabo, Andre Bationo, Seraphine Sawadogo

Partner Organizations

AGRA – Growing Africa's Agriculture, Ghana
Institut de l'Environnement et Recherches Agricoles, Burkina Faso
International Crop Research Institute for the Semi-arid Tropics
Savanna Agricultural Research Institute, Ghana

Key Reference

Fatondji, D., R. Tabo, A. Bationo, M. Fosu and S. Sawadogo 2011. *Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihood in the Volta Basin.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3768

Tags: PN5; Rainwater and Nutrient-use Efficiency

Other References

Fosu, M., S. Sawadogo-Kabore, A. Bationo, R. Tabo, S.S. Buah, R. Kanton, M. Bonzi, D. Fatondji, O. Hassane and A. Abdou 2008. Efficient rainwater harvesting and nutrient management for high crop productivity in Volta basin. In: *Fighting poverty through sustainable water use. Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food, Vol. 2,* Addis Ababa, Ethiopia, 10-14 November 2008, eds. E. Humphreys et al; 131-134. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Kijne, J.W. 2001. Preserving the (water) harvest: effective water use in agriculture. *Water Science & Technology,* **43**, 133-139.

Optimizing Crop Production with Drip Irrigation

A major challenge in increasing the income of resource-poor and smallholder producers is to transform them into commercially competitive farmer-entrepreneurs. This requires improvement in quantity and quality of farm yields if they are to pursue market opportunities. A key constraint here is regular availability of water for crop production, especially at times when extended dry seasons are experienced. Entering into market contracts, which require regular and timely delivery of produce, becomes problematic when water is limited. Improving on-farm water productivity to maximize yield quality, quantity and profitability is therefore important. Drip irrigation, which reduces water use by as much as 45%, shows promise in this respect. Figure 1 shows a drip irrigation setup.

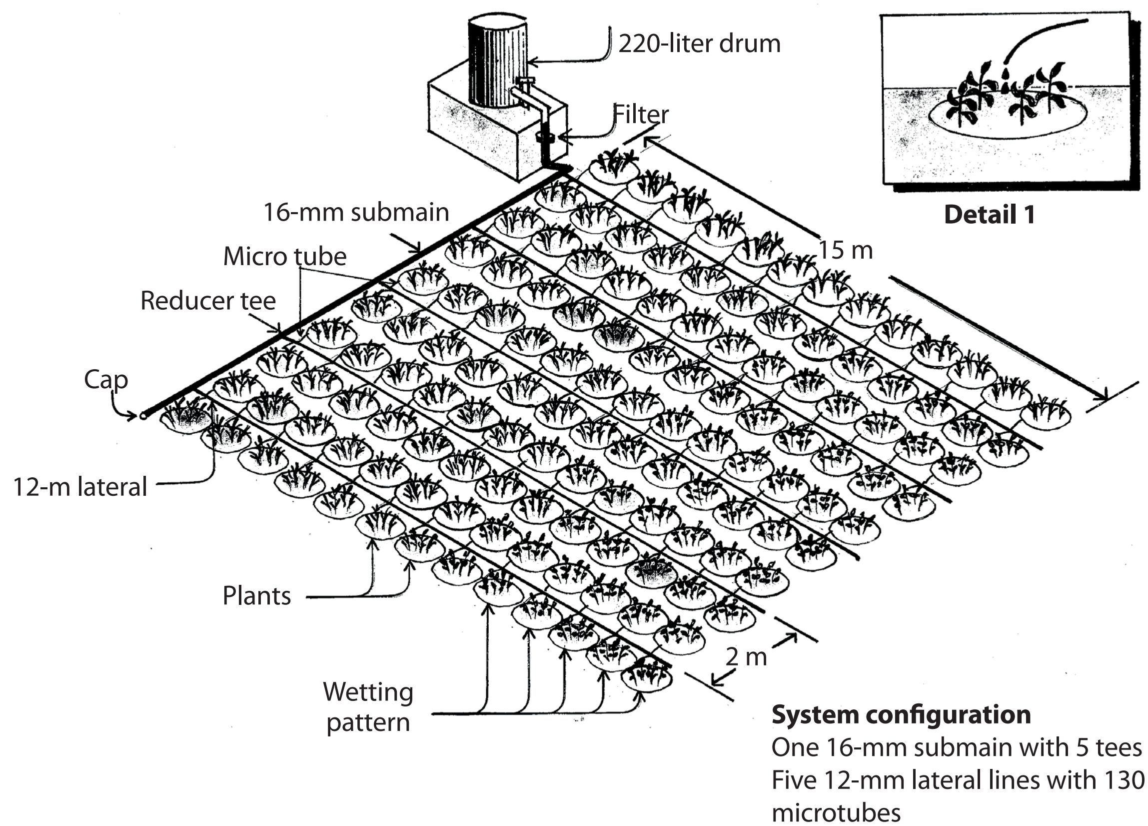


Figure 1. A Drip Irrigation Setup

Applying farmer economics to promote drip irrigation

Before the support and involvement of the CGIAR Challenge Program on Water and Food (through the Innovative Market-based Strategies project), it was assumed that the lack of reliable water was preventing farmers in Cambodia from becoming commercial producers. It was therefore believed that, by demonstrating how drip irrigation reduces water use by 45%, farmers would be willing to buy and install the system on their farms. Unexpectedly, during the actual introduction and trials, farmers valued drip irrigation more for its labor-saving benefit than for its water-saving benefit. To the farmers, the savings in labor translate into more time available for other income-generating opportunities, like having additional vegetable gardens for extra income. However, other constraints, such as low soil fertility, low market prices and a lack of technical skills, have to be addressed before farmers can invest in drip irrigation and enjoy these benefits.

Farmers place more importance on the labor-saving benefit of drip irrigation than on its water-saving benefit.

Adapting PRISM

A useful approach to ensure water productivity in smallholder farm systems is PRISM (Poverty Reduction through Irrigation and Smallholder Markets).

This is a non-prescriptive, participatory approach to help farmers adapt to the specific challenges and circumstances that they face. The approach is undertaken in five phases (see Figure 2).

1. Situational assessment of the environment where smallholder markets will be developed.

2. Assessment of agricultural markets to identify promising opportunities and constraints to smallholders and enterprises.

3. Design of interventions that will strengthen the capacity of supply and trading enterprises to deliver affordable and profitable technologies and services.

4. Implementation of approved interventions, where necessary technologies, farm inputs, agricultural knowledge and market linkages are promoted.

5. Monitoring and evaluation for feedback and adjustments in interventions as market opportunities are realized.

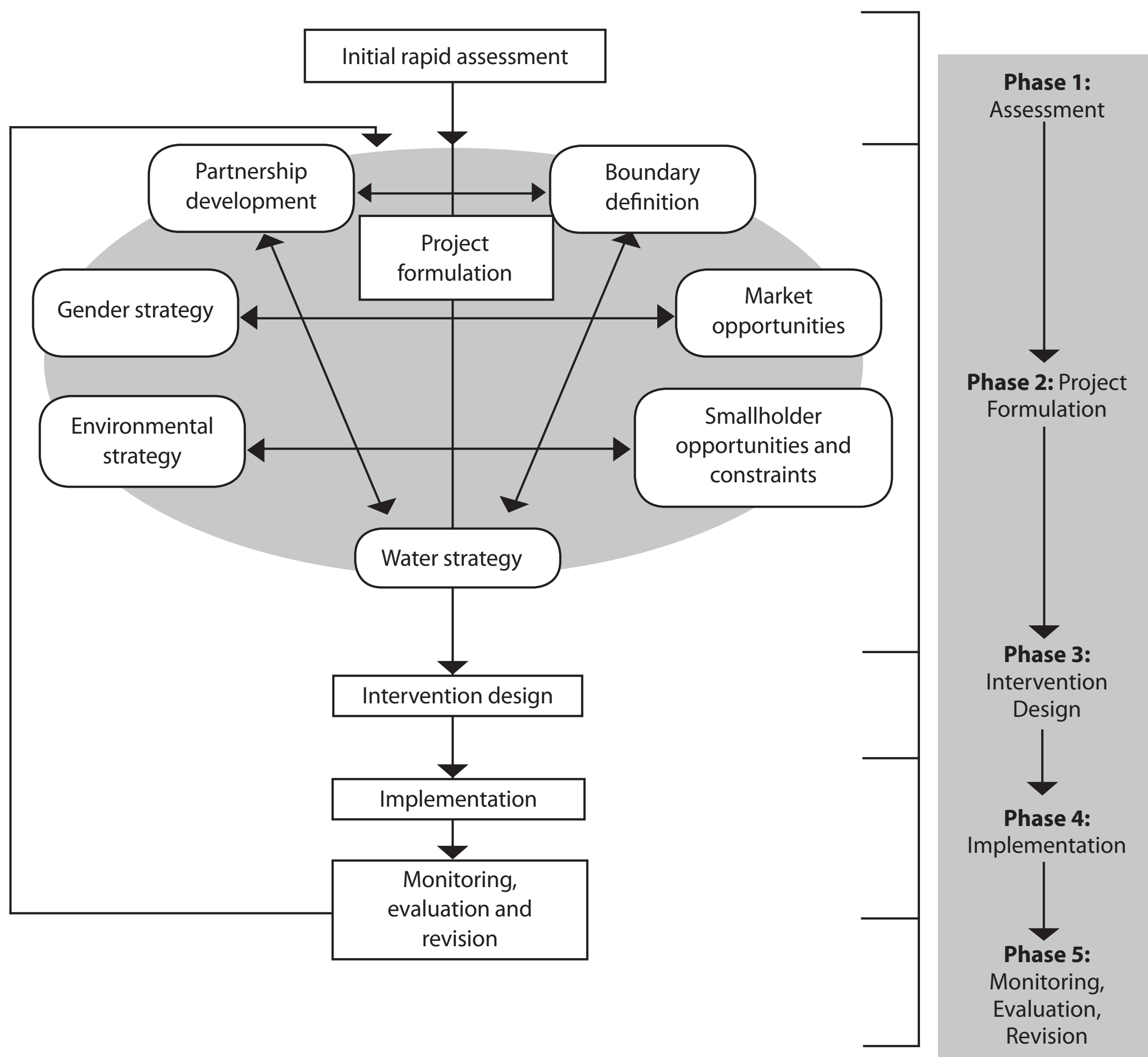


Figure 2. The PRISM Approach (International Development Enterprises 2003)

Important elements or activities of PRISM, which were adapted in the introduction and adoption of drip irrigation among vegetable growers, were:

- Selection of market clusters or geographical areas suited to production of the identified marketable crop mixes and high-value crops. This allows for crop diversification and cultivation of adequate production volumes that can be aggregated for transport to markets.

- Selection and training of farmers who will be private extension agents (PEAs). (Please refer to other articles in this sourcebook which deal with this topic in greater detail.)

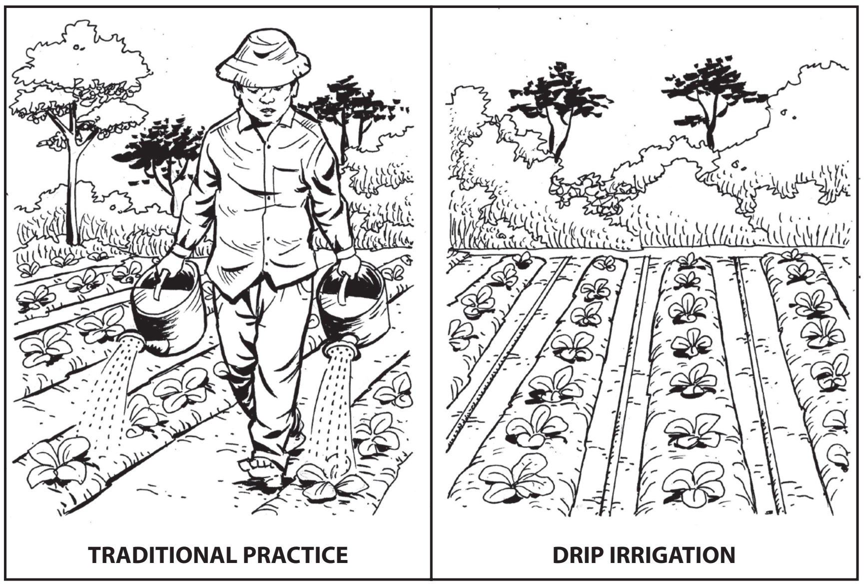
- Establishment of field demonstration trials to promote and assess the ability of each intervention (i.e., drip irrigation, fertilizer deep placement [FDP], high-value crops, PEA support) to improve farmers' access to markets.

- Facilitation of business relationships among technology manufacturers, horticultural input suppliers, marketplace retailers and PEAs.

- Strengthening of the private sectors' ability to deliver the introduced technologies and services.

What farmers say

In field trials by farmer-cooperators in Cambodia, more than 70% of them claimed savings in time, labor and water as the three major advantages of using drip irrigation. Other advantages expressed by farmers were better soil moisture and aeration, fewer weeds, easier irrigatation, healthier crops, higher yields and higher net income. Farmers who tried drip irrigation on their current crops and planting systems reported a 3% increase in net income. On the other hand, those who used drip irrigation in combination with planting of high-value crops and deep placement of fertilizers experienced a 33% increase in net income over current irrigation practices.



In separate trials, deep placement of fertilizers increased yields by 20% without improved water techniques. When combined with drip irrigation, yields increased by 73% over traditional farmer watering and fertilizer practices. However, most farmers said that they also need to have special horticultural/technical skills and knowledge on the planting and making of rows or beds when using drip irrigation systems.

Drip irrigated plot trials showed

- **43% less water used,**
- **15% higher yield, and**
- **38% less labor for irrigation used.**

Lessons learned

Farmers need assurance that they will achieve higher net incomes, not just improved water productivity by investing in drip irrigation. To accomplish this, poor soil fertility, low market prices and lack of horticultural skills should be addressed alongside drip irrigation.

- Smallholder farmers value the labor- and time-saving aspect of drip irrigation more than the reduction in water use because it allows them to engage in other income-generating activities.

- Limited water availability, soil fertility constraints, low market prices for traditionally grown vegetables and lack of horticultural skills are major limitations to commercial vegetable production.

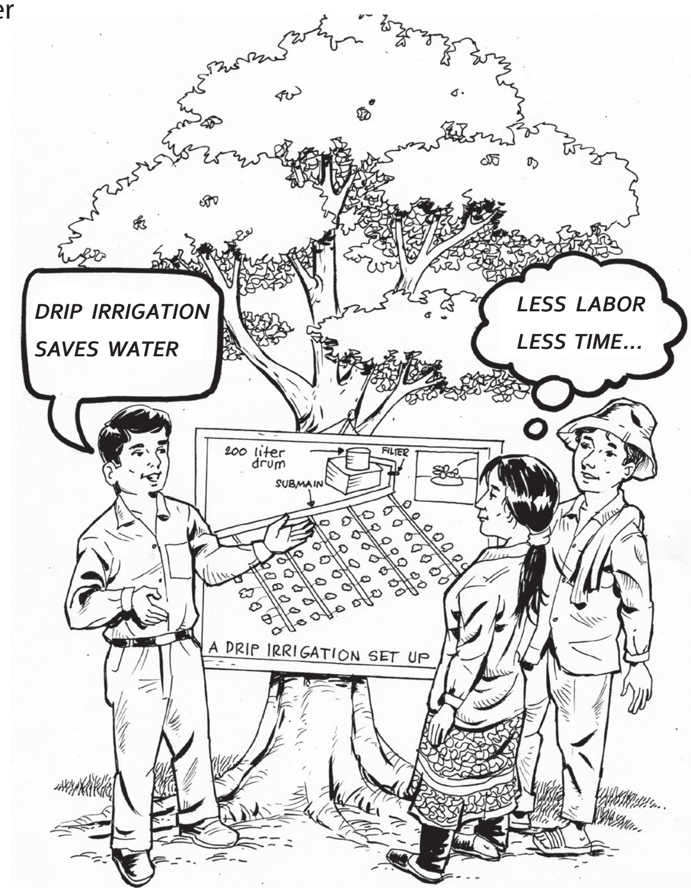
- A market-based strategy requires that farmers invest in soil fertility technologies, obtain up-to-date market information, have training in horticultural production, and know water control devices such as drip irrigation.

- Farmers need to be convinced that, by investing in drip irrigation, they will have higher net incomes.

- The introduction of high-value crops may be one approach to improve net income. These crops can be identified through market assessments.

Conclusion

Drip irrigation, in combination with appropriate crop management practices, improves water use efficiency and productivity. This may be the key to increasing farmer participation in market-oriented farming. In promoting the adoption of drip irrigation, more emphasis should be placed on its labor- and time-saving elements, along with improved access to inputs and information.



Contact Person

Michael Roberts (mroberts@ide-cambodia.org)

Partner Organizations

Canadian International Development Agency
International Center for Soil Fertility and Agricultural Development
International Development Enterprises
Provincial Department of Agriculture, Cambodia
The World Vegetable Center

Key Reference

Roberts, M. 2008. *Demonstration and documentation of innovative market-based strategies to realize agricultural income through increased on-farm water productivity and market integration.* CPWF Small Grants Final Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: SG502; Innovative Market-based Strategies

Bibliography

Baxter, N. 2007. *Market strategies for water productivity*. International Development Enterprises.

International Development Enterprises 2003. *Poverty reduction through irrigation and smallholder markets (PRISM): A manual.* Draft.

Roberts, M. and A. Long 2006. *Drip irrigation trials in Prey Veng and Svay Rieng 2005-2006*. International Development Enterprises.

Roberts, M., A. Long and N. Baxter 2008. *Provision of agricultural support services to small farmers through private-sector agents:* A review of selected field experience in Cambodia. International Development Enterprises.

Farmer-Centered Conservation Agriculture Research

A CGIAR Challenge Program on Water and Food (CPWF) project on Integrated Water Resources Management and Rural Livelihoods developed and promoted integrated water resources management (IWRM) to increase the productive use of water flows and manage the risks from drought within the Limpopo Basin. The project, covering the three countries of South Africa, Mozambique, and Zimbabwe, aimed to show that better water management can improve rural livelihoods at both the farmer and basin level.

Research was carried out in three pilot catchments using three approaches: a) farmer field-based action research (FFBAR), which involved the valuation of conservation agriculture (CA), rainwater harvesting and field-testing of different nutrient and soil salinity management regimes; b) water resources research, which modeled precipitation, surface water and groundwater flows; and c) institutional research, which developed institutional models for water governance and strengthened institutions and policies for water productivity and risk mitigation. This article focuses on the farmer-level action research in the area of CA.

Farmer-centered action research approach

This approach addresses the need to develop water management practices employing CA and supplemental irrigation (e.g., drip irrigation) technologies for adoption by smallholder farmers. Better water management is needed to reduce the effects of water scarcity on crops. Although water is limited in semi-arid to arid areas, it is often the distribution of water, rather than a lack of seasonal totals, that affects crop growth and final yields.

Challenges in the Limpopo Basin

Overall

- **Widespread poverty reflected in low income and asset base**
- **Feminization of agriculture affected by low regard for women in society**
- **Agriculture not the main source of livelihood**
- **Absence of strong institutions**
- **Lack of financial resources**

In agriculture and land management

- **Poor soil fertility**
- **Poor access to water resources**
- **Limited infrastructure development**
- **Low crop productivity**

In water resource management

- **Low, unreliable and seasonal rainfall (mean annual rainfall, 530 mm; range, 200-1200 mm)**
- **High evaporation rate, oftentimes more than the mean annual rainfall**
- **Low values of less than 0.20 on the base flow index in most sub-zones, with almost all streams flowing only during the wet season**

Crops use only 36–64% of the seasonal rainfall on average (Barron *et al*. 2003), so there is a large proportion (50%) of non-productive water flow (Nyamadzawo *et al*. 2012). Along with integrated farm system management, which addresses soil fertility and crop management issues, this approach attempts to help increase farm income and water productivity, while also incorporating gender considerations.

This approach is relevant, especially with the general consensus on increasing year-to-year variability in precipitation, due to the effects of ENSO (El Niño/southern oscillation) and climate change, which will lead to an increase in both inter- and intraseasonal drought and flood events and high uncertainty about the onset of the rainy seasons. Yields for staple cereals are predicted to fall sharply with a 1–2^{0}C change in temperature, compounded by more erratic rainfall patterns (Stige *et al*. 2006; IPCC 2007). Current dry spells lasting for more than 14 days in the basin occur every 2 years (Magombeyi and Taigbenu 2008; Mupangwa *et al*. 2011). This is likely to have an impact on the socio-economic and cultural development of poor rural communities.

Conservation agriculture

Conservation agriculture is the application of modern agricultural technologies that collect and store rainwater to improve production, while at the same time, protecting and enhancing the land resources on which production depends. Zero tillage, along with other soil conservation practices, is the cornerstone of CA (Dumanski *et al*. 2006). Positive changes in soil quality, in terms of physical structure, infiltration rates and carbon content as a result of CA, have been reported (Nyamadzawo *et al*. 2012). CA also promotes the optimization of yields and profits: labor demands typically decrease and become more flexible, while the capacity of smallholder farmers to attain family food security increases.

Specifics of CA technologies

1. **Planting basins**. Planting basins are small pits that are usually about 15 cm wide, 30-35 cm long and 15 cm deep—about the size of a man's foot. Instead of cultivating the whole field, a hoe is used to dig basins in the soil where crops are planted. The basins are dug slightly deeper than the depth at which normal hoeing is used to break through the hardpan. Basins made by hand hoes are dug with a spacing of 90 cm between rows, with each basin being 15 cm in length, width, and depth. To be more effective, a micro-fertilizer dose of 10 kg ha/N is added (IIRR and ACT 2005). This modification of CA techniques creates precision conservation agriculture (PCA). A variation of the planting basin is the zai pit.

2. **Ripping**. With stovers still on the field, a ripper is used to open up planting lines about 15 cm deep with 90 cm between rows. A ripper is a chisel-shaped implement, pulled by animals or a tractor, to break up surface crusts and open a narrow slot or furrow in the soil. Plowing is not needed. Seeds are sown along the rip lines. Crop rows are alternately planted between seasons (Mupangwa *et al.* 2007).

3. **Tied ridges**. Tied ridges have a height of 35 cm, are spaced about 75 cm to 1 m apart and are tied at 3- or 6-m intervals. Plants should be spaced every 60 cm within rows. The tie structure or the soil heaps to block the furrow should be reconstructed at weeding to continue harvesting water for the crop.

4. **Mulching**. Mulch is a protective covering, usually of organic matter such as leaves, straw or peat that is placed around plants to prevent root freezing, reduce moisture evaporation and suppress weed growth.

5. **Supplemental irrigation**. Supplemental irrigation involves the application of small amounts of water during times when rainfall fails to provide sufficient moisture for normal plant growth. The amount and timing of supplemental irrigation are adjusted to meet minimum water requirements during the critical stages of crop growth and to bridge dry spells and ensure optimal, instead of maximum, yield.

Lessons learned

Planting basins

- This technology gave the lowest seasonal run-off losses, regardless of soil type and field slope. Despite the below average rainfall of 268-353 mm during the period of study (from 2006 to 2008), planting basins consistently gave the highest soil water content, particularly during the first half of the cropping period. However, this advantage did not necessarily result in higher maize yields in farmers' fields under unevenly distributed rainfall.

- Production risk in the semi-arid conditions of southern Zimbabwe was reduced through the precise application of small doses of N-based fertilizer (10 kg/ha). Yield improvements in planting basins with this level of microdosing can be up to 78, 140 and 250% for low, normal and high rainfall regimes, respectively.

- However, during high-rainfall seasons and depending on soil type and number of days since the last rainfall event (antecedent conditions), waterlogging may occur and adversely affect crop yield under this technology. The effectiveness of this technology depends on rainfall patterns, soil type, crops and other agricultural practices such as soil fertility enhancement, planting dates and density, and mulching. There is a need to identify factors (e.g., rainfall regime, soil type and fertility level) that lead to planting basins being more beneficial and to develop associated crop management guidelines.

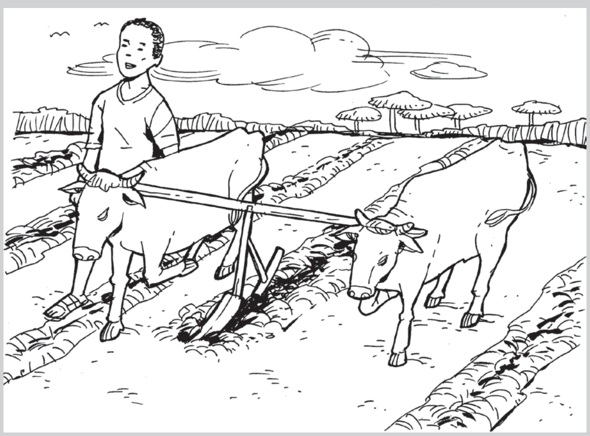
- On average, returns from labor have been higher from planting basins than from conventional practices. Although making the basins requires time and effort, once prepared, the same planting position can be used repeatedly. With each successive season, preparing the basins and weeding become easier.

Double conventional plowing

Though not a CA practice, this tillage technology, combined with the use of N fertilizer, gave better yields than did the other tillage systems, regardless of rainfall pattern during the growing season.

Thus, a majority of the farmers ranked double plowing as the most appropriate tillage system under their conditions, since farmers in the Limpopo Basin consider labor and crop yields to be major factors in the selection of technologies for adoption.

In fact, smallholder farmers who owned draft animals were prepared to continue using double plowing; however, others without similar means were not.



Ripping

- Data from various trials since the 1990s showed that mulch ripping and other minimum tillage practices that reduce draft power requirements consistently increased soil water content and crop yield by up to 50%, compared with traditional plowing.

- Mupangwa *et al*. (2007) reported a decrease of up to 50% in per-hectare yield under clean ripping compared with conventional plowing in the first year. But the yield increased in subsequent years as soil fertility improved.

- Ripping helps reduce up to 50% of sedimentation losses. However, ripping alone did not consistently give higher yields because of weed pressure, which requires timely weeding before weed seeds are spread.

Tied ridges

- Tied ridges increased yields by up to more than 50%, reduced runoff under different soil and rainfall regimes and retained more soil moisture than did conventional plowing.

Mulching

- Maize production was significantly improved by mulching (between 3-6 t/ha) in growing seasons with below average rainfall. Mulch must provide at least 30% of the soil cover. Mulch buffers the soil against extreme temperatures, reduces evaporation and surface runoff (which lead to soil loss), protects the soil from trampling, suppresses weeds through shading and improves soil fertility and biota in subsequent years as the mulch decays (Mupangwa *et al*. 2007, 2012).

Low-head drip irrigation

- Low-cost drip systems can save more than 50% of water use than surface irrigation systems, provided that farmers receive adequate training to operate and maintain the system and there is backup for servicing the drip system.

Conclusion

Access to green water in rainfed farming can be improved through a package of CA techniques. Planting basins help to concentrate rainfall in the field at the root zone and decrease runoff and soil loss. CA methods provide positive results when combined with fertility improvements, such as microdosing with N from organic and/or inorganic sources or with mulching. Supplementary irrigation, such as drip irrigation, along with appropriate water and nutrient management, can further help mitigate the effects of frequent dry spells. While yield increases under CA can be substantial, they depend on local conditions and weather, with considerable year-to-year variation in yield benefits. CA offers the promise of a locally adapted, low-external-input agricultural strategy that can be adopted by resource-constrained farming communities, as well as by those with access to different levels of mechanization and external inputs.

Microdosing in drought-prone areas

Next to drought, poor soil fertility is the single biggest cause of hunger in Africa. The International Crops Research Institute for the Semi-arid Tropics (ICRISAT) in Zimbabwe has been working for the past 10 years to encourage small-scale farmers to increase inorganic fertilizer use as the first step towards Africa's own green revolution. The program of work is founded on promoting small quantities of inorganic N fertilizer (microdosing) in drought-prone cropping regions. Results from initial on-farm trials showed that smallholder farmers could increase yield by 30–100% through application of micro-doses—as little as 10 kg/ha N. The question remained whether these results could be replicated across much larger numbers of farmers. Widespread testing of the microdosing (17 kg/ha N) concept was initiated in 2003/2004, across multiple locations in southern Zimbabwe through relief and recovery programs. Each year, more than 160,000 resource-poor households received at least 25 kg of N fertilizer, and a simple flyer explaining how to apply the fertilizer to a cereal crop. This distribution was accompanied by a series of simple paired-plot demonstrations—with or without fertiliser—hosted by farmers selected by the community, where training was carried out and detailed labor and crop records were kept. Over a 3-year period, more than 2,000 paired-plot trials were established and good-quality data collected from more than 1,200. In addition, experimentation to derive N response curves for maize (*Zea mays* L.)**, sorghum** (*Sorghum bicolor* **(L.) Moench) and pearl millet** (*Pennisetum glaucum* **(L.) R. Br.) in these environments under farmer management was conducted. The results consistently showed that microdosing (17 kg/ha N) with N fertilizer can increase grain yield by 30–50% across a broad spectrum of soil, farmer management and seasonal climatic conditions. For a household to make a profit, depending on the season, farmers need to obtain between 4 and 7 kg of grain for every kilogram of N applied. In fact, farmers commonly obtained 15–45 kg of grain per kilogram of N input. This result provides strong evidence that lack of N, rather than lack of rainfall, is the primary constraint to increasing cereal crop yields, and that microdosing has the potential for broad-scale impact on improving food security in these drought-prone regions.**

Contact Person

David Love (dlove@waternetonline.org)

Partner Organizations

Faculdade de Agronomia e Engenharia Florestal, Universidade Eduardo Mondlane, Mozambique
International Crops Research Institute for the Semi-arid Tropics
International Water Management Institute
Mzingwane Catchment Council, Zimbabwe
School of Civil and Environmental Engineering, University of Witswatersrand, South Africa
UNESCO-IHE Institute for Water Education, the Netherlands
University of Zimbabwe
Water Research Commission, South Africa
WaterNet, Zimbabwe

Key Reference

Ncube, B., E. Manzungu, D. Love, M. Magombeyi, B. Gumbo and K. Lupankwa 2010. *The challenge of integrated water resource management for improved rural livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3905

Tags: PN17; IWRM Improved Rural Livelihoods

Bibliography

Barron, B., J. Rockstrom, F. Gichuki and N. Hatibu 2003. Dry spell analysis and maize yields for two semi-arid locations in East Africa. *Agricultural and Forest Meteorology,* **117**, 23-37.

Belder, P., D. Rohrbach, S. Twomlow and A. Senzanje, A. 2007. *Can drip irrigation improve the livelihoods of smallholders? Lessons learned from Zimbabwe.* Global Theme on Agroecosystems Report No. 33. Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics.

Cox, D.M. *n.d. Designing a landscape Drip Irrigation System for Southern Nevada.* Las Vegas, Nevada: University of Nevada.

Dumanski, J., R. Peiretti, J. Benetis, D. McGarry and C. Pieri 2006. The paradigm of conservation tillage. *Proceedings of World Association of Soil and Water Conservation,* **P1**, 58-64.

Falkenmark M. and J. Rockstrom 2006. The new blue and green water paradigm: Breaking new grounds for water resource planning and management. *Journal of Water Resource Planning and Management,* 129-132.

IIRR and ACT 2005. *Conservation Agriculture: A manual for farmers and extension workers in Africa.* International Institute for Rural Reconstruction, Nairobi, Kenya; African Conservation Tillage Network, Harare, Zimbabwe.

Intergovernmental Panel on Climate Change (IPCC) 2007. *Summary for policy-makers. Climate change 2007: The physical science basis.* Working Group I contribution to IPCC 4th Assessment Report: Climate Change 2007. Geneva, Switzerland.

Bibliography

Magombeyi, M.S and E.A. Taigbenu 2008. Crop yield risk analysis and mitigation of smallholder farmers at quaternary catchment level: Case study of B72A in Olifants river basin, South Africa. *Physics and Chemistry of the Earth,* **33**, 744–756.

Marongwe, L.S., K. Kwazira, M. Jenrich, C. Thierfelder, A. Kassam and T. Friedrich 2011. An African success: the case of conservation agriculture in Zimbabwe. *International Journal of Agricultural Sustainability,* **9**, 153-161.

Mupangwa, W., S. Twomlow, S. Walker and L. Hove 2007. Effect of minimum tillage and mulching on maize (*Zea mays L.*) 3 yield and water content of clayey and sandy soils. *Physics and Chemistry of the Earth,* **32**, 1127-1134.

Mupangwa, W., S. Walker and S. Twomlow 2011. Start, end and dry spells of the growing season in semi-arid southern Zimbabwe. *Journal of Arid Environments,* **75**, 1097-1104.

Mupangwa, W., S. Twomlow and S. Walker 2012. Reduced tillage, mulching and rotational effects on maize (*Zea mays L.*), cowpea (*Vigna unguiculata* (Walp) L.) and sorghum (*Sorghum bicolor L.* (Moench)) yields under semi-arid conditions. *Field Crops Research*, **132**, 139–148.

Nyagumbo, I. 1999. Conservation Tillage for Sustainable Crop Production System: Experiences from on-station and on-farm research in Zimbabwe (1988-1997). In: *Conservation tillage with animal traction. A resource book of the Animal Traction Network for Eastern and Southern Africa (ATNESA)*, eds. P.G. Kaumbutho and T.E. Simalenga; 108-115. Harare, Zimbabwe.

Nyamadzawo, G., P. Nyamugafata, M. Wuta, J. Nyamangara and R. Chikowo 2012. Infiltration and runoff losses under fallowing and conservation agriculture practices on contrasting soils, Zimbabwe. *Water SA,* **38**, 233-240.

Rusike, J., S.J. Twomlow, H.A. Freeman and G.M. Heinrich 2006. Does farmer participatory research matter for improved soil fertility technology development and dissemination in Southern Africa?. *International Journal of Agricultural Sustainability,* **4**, 176–192.

Stige, L.C., J. Stave and K. Chan 2006. The effect of climate variation on agro-pastoral production in Africa. *Proceedings of the National Academy of Sciences,* **103**, 3049–3053.

Twomlow, S., L. Hove, W. Mupangwa, P. Masikati and N. Mashingaidze 2008. Precision conservation agriculture for vulnerable farmers in low-potential zones. In: *Increasing the productivity and sustainability of rainfed cropiing systems of poor smallholder farmers. Proceedings of the CGIAR Challenge Program on Water and Food International Workshop on Rainfed Cropping Systems,* Tamale, Ghana, 22-25 September 2008, eds. E. Humphreys and R.S. Bayot; 37-54. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Conservation Agriculture as an Alternative to Slash-and-Burn System

Agricultural areas in Central America are predominantly located on hillsides and steep slopes. This type of agricultural landscape necessitates effective and improved soil and crop management practices to maintain crop productivity, reduce land degradation and ensure water availability. Recent extreme weather variability further exposes these rainfed areas to severe water scarcity and drought, hence, a more deliberate and urgent response to management challenges is vital.

In southwest Honduras, Central America, an ancient rural village, Quesungual, was severely denuded and its soil degraded due to the traditional slash-and-burn production system. The Food and Agriculture Organization (FAO), national institutions and local farmers developed the Quesungual Slash-and-mulch Agroforestry System (QSMAS) to improve the livelihoods of the rural poor through increased water resources and food security in sub-humid hillside areas, while maintaining the soil and plant genetic resources for future generations. QSMAS has already been practiced by more than 6,000 resource-poor farmers to produce major staples (mainly maize, bean, and sorghum) in 7,000 hectares of land in southwest Honduras. This improvement led to the restoration of forest cover and the eventual improvement in crop productivity.

The use of QSMAS in Honduras was initiated by FAO, national institutions and local farmers. Building on its initial success, the CGIAR Challenge Program on Water and Food (CPWF) endeavored to scale out this system in other watersheds of Honduras, Nicaragua and Guatemala. An adoption study was then conducted to find out the factors that led to the successful uptake and scaling out of QSMAS and the related challenges and highlights are detailed in this paper.

This positive technology uptake was driven by the substantial contribution of QSMAS to food security, its remarkable resilience to natural extremes of water deficit and water excess, and its suitability to replace the slash-and-burn practice.

About QSMAS

QSMAS is a smallholder production system that combines crop planting with intense pruning of existing trees in secondary forest. This integrated land use management strategy comprises a package of technologies that allow for sustainable management of vegetation, water, soil and nutrients in drought-prone areas of hillsides in the sub-humid tropics. QSMAS is based on principles that contribute to its superior performance in terms of productivity, sustainability and biophysical resilience.

Quesungual is the name of an ancient rural village in southwest Honduras, Central America. The village's name is drawn from three indigenous words that mean soil, vegetation and a convergence of streams.

Approach

Below is a simplified presentation of the steps in establishing a slash-and-mulch agroforestry system.

Steps in establishing a slash-and-mulch agroforestry system

1. Select a well-developed (high amount and diversity of trees and shrubs) naturally regenerated secondary forest.

2. Sow, by broadcast, 'pioneer' crops such as sorghum (*Sorghum vulgare L.*) or common beans (*Phaseolus vulgaris L.*), whose seedlings are capable of emerging through the mulch. Maize (*Zea mays L.*) is not sown as a pioneer crop because too much mulch affects the emergence of seedlings. Moreover, late-season planting (August) does not provide adequate soil moisture for grain filling.

3. After planting, do selective and partial slashing and pruning of dispersed trees and shrubs in fallows. Then, remove firewood and trunks and ensure uniform distribution of the biomass (leaves and fine shoots) which results as mulch.

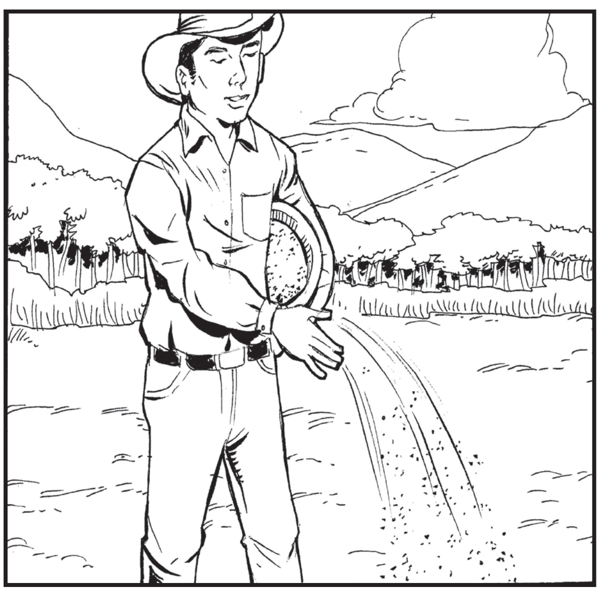
4. The result is a plot with numerous slashed trees, non-slashed high-value multipurpose timber and fruit trees, slashed shrubs (that are used for holding harvested bean plants to avoid infection of bean pods), and a dense layer of mulch.

5. After planting the pioneer crop, continue doing these QSMAS practices: annual production of maize as main crop intercropped with beans or sorghum using zero tillage; continuous slashing and pruning of trees shrubs to eliminate branches (to take out for firewood) and re-growth (to avoid shade for the crops); continuous mulching (from litterfall, slashing of trees and application of crop residues); spot fertilization technologies, and sometimes use of pre-emergence herbicides (Wélchez *et al.* 2006). Carry out these activities for at least 10 to 12 years as this is the system's productive life based on the re-growth potential of trees in the system.

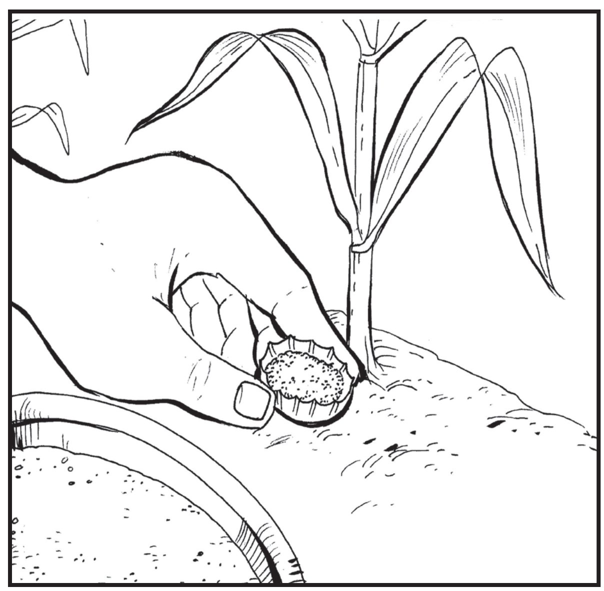
Four key principles of QSMAS

1. **No slash-and-burn:** management (partial, selective and progressive slash-and-prune) of natural vegetation

2. **Permanent soil cover:** continual deposition of biomass from trees, shrubs/weeds and crop residues



3. **Minimal disturbance of soil:** no tillage, direct seeding and reduced soil disturbance during agronomic practices



4. **Efficient use of fertilizer:** appropriate application (timing, type, amount and location) of fertilizer

Benefits of QSMAS

Changes brought about by the implementation of the Quesungual system happened gradually. In the first 3 years, farmers eliminated slash-and-burn, secondary forests and biodiversity started to recover, water became more available and food production became more resilient to extreme weather events. It took up to 7 years for the forests to become fully re-established and for the full benefits to be visible.

The reported benefits of QSMAS validated its viability as an alternative production system in southwest Honduras:

- Food security for over 6,000 small-scale farmers
- Increased productivity and profitability through crop diversification
- High degree of resilience to extreme weather events as a result of buffering provided by the forest environment and protected soil
- Maintenance and recovery of local biodiversity through the natural regeneration of around 60,000 hectares of secondary forest
- Improved environmental quality through the elimination of burning, reduction of cutting of forests and mitigation of land degradation
- Improved availability and quality of water for domestic use
- Increased average value of the maize and bean production from US$ 1,100 per hectare in the slash-and-burn system to over US$ 2,000 per hectare in QSMAS
- Sustainable supply of wood for fuel and construction

Slash-and-mulch agroforestry systems appear to respond best under the following circumstances:

1. **Sub-humid tropical conditions: enough total rainfall for re-growth of trees and/or regeneration of degraded forest, but also taking into account dry spells so that water conservation in the soil is key to production**
2. **Soils of reasonable fertility: possibility of attaining that with good management of organic matter.**
3. **Sloping but not so steep lands: caution taken to prevent agriculture from destroying their soils.**
4. **Farmer awareness: they know about land degradation, including loss of soil fertility due to erosion and lack of new land for shifting cultivation**

Scaling Out QSMAS

There were observed commonalities in land use practices and degradation in Nicaragua and Honduras. Hence, the CPWF, together with the National Agricultural Research Institute of Nicaragua (INTA), decided to expand and pilot the project to the La Danta watershed in northwestern Nicaragua. The two areas are comparable in the following aspects: similar climate and degraded secondary forest, slash-and-burn is the prevailing production system, deforestation is increasing, crop failure often occurs due to either drought or frequent torrential

The successful adoption of the improved Quesungual system within its area of origin in southern Honduras and its subsequent uptake in several other areas of the country is a compelling story for replacing the slash-and-burn practice. Slash-and-burn is traditionally used by resource-poor, small-scale farmers in the Pan tropical world.

rains and farm families do not have secure food supply and are looking for alternatives.

Arrangements were made for Nicaraguan farmers to visit and have a look at Quesungual plots for replication in their own agricultural fields. After one season, the farmers expanded their experimental farms. Other farmers in the region followed suit as a result of farmer-to-farmer information dissemination.

There were rich exchanges of experiences and lessons learned during field visits and subsequent farmers' trainings on QSMAS, workshops between farmers and researchers, and farmer-to-farmer information dissemination. During the workshop, the farmers revealed that they would willingly abandon slash-and-burn provided there is a good alternative.

The scaling out project in the La Danta watershed yielded encouraging results. About 70 of 120 farm families are now adopting the Quesungual system. About 40 others have abandoned slash-and-burn in favor of conservation methods. Only about 10 still use slash-and-burn.

Key drivers of enhanced QSMAS adoption

1. **Integration of diverse elements without losing focus**. Early on, farmers and institutions realized that, in improving their livelihoods, careful management of land and water is a must. Hence, a focused strategy on managing land and water resources is crucial as they are closely linked to food security, poverty alleviation and land degradation.

2. **Increased production and reduced labor**. With QSMAS, crop yields increased by more than 100%. Increased crop productivity allowed farmers to reduce the area devoted to traditional crops and to grow new crops with market potential. This implies that improved practices associated with QSMAS resulted in enhanced productivity and resource quality and reduced risks. Recent studies conducted by FAO show that producers using QSMAS are also trying new options in their farm areas and exploring new technologies and services. Improvements in soil fertility and water availability allowed for further intensification of the system. Also, QSMAS implied 18% reductions in land preparation and weed control and 27% in other labor requirements (Clercx and Deug 2002).

3. **Integration of local and technical knowledge**. Familiarity of producers with the main components of the system not only enabled the development of QSMAS as an existing indigenous system found in the region; this was also improved by considering local conditions.

4. **Effective participation**. Events and problems in the establishment and management of

the system were dealt with as they occurred within farmers' specific conditions, rather than being anticipated. As a result, the technological focus and general interest of farmers and communities broadened over time to include other issues such as water supply, strengthening of local organizations and health and education. Stakeholder participation in the intervention process is therefore mandatory.

Scaling up of QSMAS was made possible through the effective participation of extension agents and farmer groups as the system built on the capacity of people to use and adapt the system to their own conditions and on the use of participatory validation models. Local development committees and community leaders strongly supported the replication of QSMAS. Students in rural schools were integrated into the whole innovation process by being exposed to different technological alternatives and making them aware of the importance of integrated natural resource management.

The scaling-out process was facilitated through farmer learning tours and exchange visits across farms, communities and municipalities, with learning supplements based on farmers' experiences. Matching technology providers with the farmers' own goals was the guiding principle in the development and adoption of QSMAS. The strategic orientationof the project was complemented with an effective operational framework.

5. **Enhanced competence of farmers and communities**. More than 100 leaders were appointed by their communities to learn the main principles of QSMAS and assist other farmers in the implementation of the system. Over time, farmers' capacity to innovate and solve problems improved. This increased the

A note of caution on QSMAS adaptation and dissemination

Adaptation of QSMAS to other tropical regions may not always result in multiple benefits due to a number of preconditions:

1. **If communities are not convinced on the need to change their traditional production systems to QSMAS it may contribute to its rejection. Stakeholders must know all the key information on the system and commit to support its adaptation.**
2. **QSMAS generates benefits in the short, medium and long terms. If stakeholders expect to obtain full benefits in the short term, efforts to adapt QSMAS may be abandoned. QSMAS strategies for rural improvement must define realistic achievements according to the system's potential and the biophysical and socioeconomic contexts of each target site.**
3. **QSMAS will improve water availability to plants in sub-humid regions with a long (up to six months) dry season and when there is irregularity (dry spells) or insufficiency (shorter rainy season) of rainfall occurs. Significant increases on crop water productivity will not be achieved when water is not limiting production.**
4. **QSMAS management is based on the conversion of naturally regenerated secondary forests into productive plots. Although it is possible to establish the system while the landscape is still in the process of regeneration, the long time frame that is needed to realize benefits may cause the farmers to reject the system.**
5. **QSMAS requires efficient fertilizer applications. Smallholders practicing slash-and-burn agriculture usually do not apply fertilizers. If correction of nutritional limitations in the soil requires significant amounts of fertilizers or amendments, farmers may opt to continue using their traditional practices.**
6. **Farmers managing QSMAS plots require inputs (mainly fertilizers) and possibilities to trade expected surpluses. Lack of any of these will result in failure of the potential agronomic and economic benefits of the system and undoubtedly, to its rejection by farmers.**

spirit of experimentation with soil and water management options and other natural resource management technologies.

6. **Farmers linked to markets**. Market orientation was an important consideration after farmers produced sufficient food for household consumption. The establishment of linkages to outside markets was a key event that accelerated the integration of small farmers to markets and cross-border trade (El Salvador). This opening to new markets has been the key driver for increased crop diversification and the cornerstone for the emergence of a new agribusiness culture among rural communities.

7. **Rural financing**. Communal banks were an important financial mechanism supporting the implementation of QSMAS. Their role was not limited to credit provision. They also acted as an agency for collective action and enforcement of community control. Credit was restricted to farmers who did not burn their land. Membership in communal banks thus developed a new moral order that facilitated the subsequent adjustment of their farming systems and livelihoods.

8. **Supportive policies**. During the implementation of QSMAS, local communities became more aware of the problems associated with burning, deforestation and extensive grazing. As a result, municipal development communities and community-driven associations developed enforcement mechanisms to eliminate burning from agricultural practices. The capacity of local communities and municipalities to protect, regulate and negotiate the use of their land and water resources has been reinforced by the decentralization of power and decision-making promoted by the central government. This produced a positive impact on the scaling up and out of QSMAS.

Lessons learned

- The slash-and-mulch agroforestry system is a resilient and effective practice in tropical areas with a sub-humid climate and where there is good regeneration of secondary forest.

- The slash-and-mulch system is location-specific. Several traditional variants exist in Central America, which are dependent on local vegetation and the way vegetation growth varies on different soils and under different rainfall conditions.

- The spread of the Quesungual system in Honduras and in the pilot area in Nicaragua has shown the important role of research in taking these systems outside their traditional origin.

- The Quesungual system is valuable as a lesson of what can be achieved by conservation agriculture in general.

Conclusion

QSMAS can be a model production system for implementing conservation agriculture to achieve food security and sustainable development in drought-prone hillsides in sub-humid tropics, while providing ecosystem services in the face of land degradation and climate change.

As an adoptable alternative to the traditional slash-and-burn system, QSMAS can improve smallholder livelihoods through eco-efficient use and conservation of natural resources. Participatory validation activities suggest that the conservation agriculture principles embedded in QSMAS can be readily accepted by resource-poor farmers and local authorities in similar agro-ecosystems.

Contact Person

Aracely Castro (a.castro@cgiar.org)

Partner Organizations

Assessment, Research and Integration of Desertification Research Network Consortium, USA
Consortium for Sustainable Development of the Andean Ecoregion, Peru
Food and Agriculture Organization of the United Nations
Inter-institutional Consortium for Sustainable Agriculture in Hillsides, Colombia
Integrated Management of Soil Consortium in Central America, Colombia
National School of Forest Sciences, Honduras
National University of Agriculture, Nicaragua and Honduras
National University of Colombia
Nicaraguan Institute for Agricultural Technology, Nicaragua
Soil Management Collaborative Research Support Program, USA
Tropical Soil Biology and Fertility Institute of CIAT
University of Western Australia

Bibliography

Castro, A. *et al.* 2009. *Quesungual slash-and-mulch agroforestry system (QSMAS): Improving crop water productivity, food security and resource quality in the subhumid tropics.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

http://hdl.handle.net/10568/3906

Tags: PN15; Unraveling Mysteries Quesungual System

Other References

Clerox, L. and M. Deug 2002. *Probreza. Agricultura sostenible y servicios financieros rurales en America Latina: reflexiones sobre un studio de caso en el departamento de Lempira, Honduras.* Centro de studios para el desarrollo rural Universidad Libre de Amsterdam (CDR-ULA), Managua, Nicaragua.

Welchez, L.A., M. Ayarza, E. Amezquita, E. Barrios, M. Rondon, A. Castro, M. Rivera, O. Ferreira, J. Pavon and I. Rao 2006. Quesungual slash-and-mulch agroforestry system (QSMAS). In: *TSBF Institute Annual Report 2006,* 130-133. Cali, Colombia: Centro Internacional de Agricultural Tropical.

Woolley, J 2010. *Legacy of CPWF 1: Quesunual slash-and-mulch agroforestry program*. Unpublished manuscript.

Action Research in Support of Better Water Management in the Limpopo Basin

In the semi-arid tropics, the Limpopo basin in Southern Africa is a hotspot for poverty and water scarcity. Here, agricultural production is hampered by poor soil fertility, inadequate or unequal access to water resources and low infrastructure development, among other factors. Rainfall is unreliable, falling mainly between October and March, with frequent dry spells during the crop-growing season. Integrated water resource management (IWRM) was considered appropriate to provide ways to address the water needs of agriculture and nature. The CGIAR Challenge Program for Water and Food (CPWF) project on IWRM Improved Rural Livellihoods was designed to help smallholder farmers adopt better water management practices; develop appropriate catchment management strategies based on principles of IWRM that incorporate the sustainable use of green and blue water resources; develop institutional models for water governance and build capacity among farmers, extension officers, water managers, and researchers at local universities in the Limpopo Basin and in southern Africa. The project covered three catchment areas within the Limpopo Basin -- the Mzingwane in Zimbabwe, the Olifants in South Africa and the Chokwe in Mozambique.

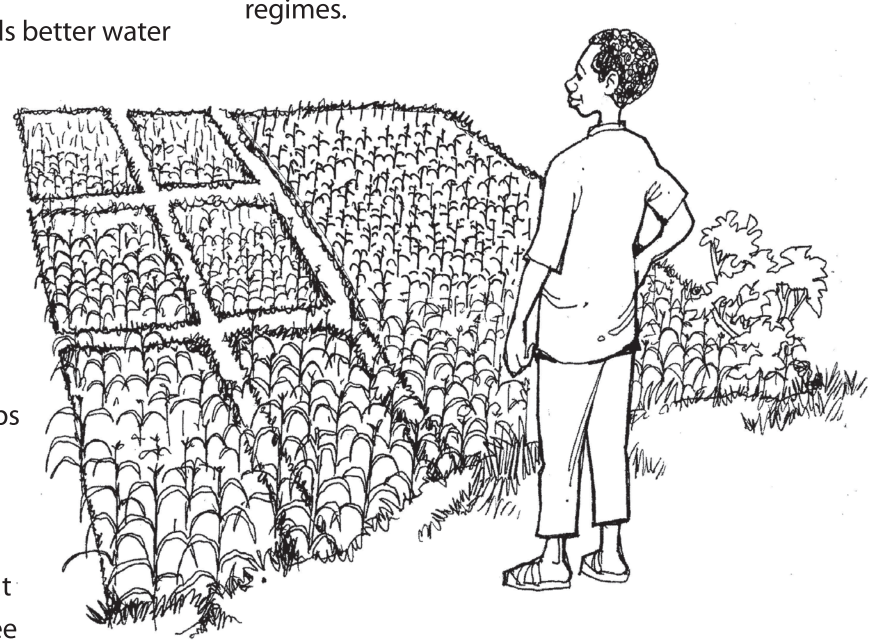
This article focuses on the experience of undertaking action research towards better water management in farmers' fields. The project started with a baseline assessment of water resources, agriculture and institutions in the basin. Issues addressed included improving crop productivity using low- input systems, such as conservation agriculture and improving water availability for crops through rainwater harvesting and supplemental irrigation.

This research project was carried out in three pilot catchments using three approaches:[1]

- Farmer field-based action research using technologies such as conservation farming and nutrient management to increase crop yield
- Water resource research where rain, surface water and groundwater flow partitioning were characterized
- Institutional research, which developed appropriate institutional models for water governance and strengthened institutions and policies for water productivity and risk mitigation

Farmer field-based action research

To identify successful innovations and improve household food security, farmers in Zimbabwe, Mozambique and South Africa were asked to evaluate conservation agriculture and rainwater harvesting and to participate in field testing of different nutrient and soil salinity management regimes.



Conservation agriculture

Conservation agriculture (no till and reduced tillage) practices help to concentrate rainfall in the root zone of plants and decrease runoff from the field. Practices include methods that simultaneously conserve soil and water resources, reduce farm energy usage and increase or stabilize crop production, such as tillage (single and double plowing), ripping, and use of planting basins or Zai pits. Studies showed that the best results are obtained when such methods are combined

[1] *This article focuses mainly on the first approach: farmer field-based action research.*

with fertility improvements (e.g., manure) or microdosing with fertilizers or mulching. Farmers in the Zhulube and Mnyabezi areas, Mzingwane in Zimbabwe, adopted some of the conservation agriculture technologies.

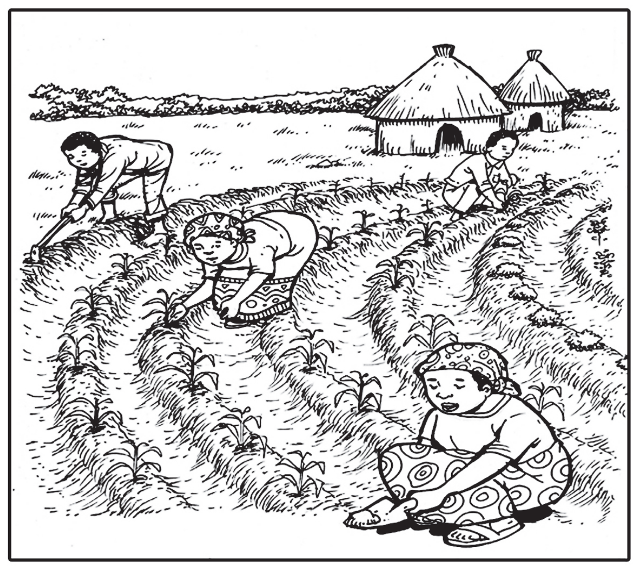
Rainwater harvesting

Rainwater harvesting (RWH), on the other hand, involves the collection and concentration of runoff for productive uses (crop, fodder, pasture or tree production, livestock and domestic water supply, etc.) either in-field (tillage techniques, pits, etc.) or off-field (micro-catchment or runoff farming and supplementary irrigation). Some of the common methods used by farmers were infiltration pits, tied furrows, dead level contours, contour ridges, potholing and fanya juus. These, and the use of plastic material to harvest rainwater in the field, were studied. Results showed that RWH improves soil moisture available to crops during the extended dry spell periods. A methodology flow chart can be used to systematically investigate the impacts of out-scaling rainwater harvesting (in-field and ex-field) techniques.

Supplemental irrigation

Supplemental irrigation involves the addition of small amounts of water to rainfed crops during times of insufficient rainfall to provide sufficient moisture for normal plant growth and to improve and stabilize yields.

Farmers practicing surface irrigation in Zimbabwe compared low-cost drip irrigation technologies with conventional surface irrigation systems in terms of water and crop productivity. NGOs were also asked to assess the impacts and sustainability of the drip irrigation program through interviews, focus group discussions and a survey.



Study results showed that low-cost drip kit programs can only be sustainable if implemented as an integral part of a development program (not short-term relief programs) and if they involve a broad range of stakeholders, including donors, implementing NGOs and beneficiaries. A first step in any such program, especially in water-scarce areas, would be to undertake a detailed analysis of the existing water resources to assess availability and potential conflicts prior to the distribution of drip kits. A protocol for the implementation of drip kit programs in the semi-arid regions was developed.

Lessons learned

- The rising frequency of mid-season dry spells suggests that there is reason for exploring rainwater management technologies and using short-season varieties to reduce the impact of dry spells on rainfed cropping systems.

- Significant opportunities exist for upgrading rainfed agriculture, thereby ensuring food security through timely and adequate supplementary irrigation to bridge and manage dry spells.

- Low-cost technologies (such as drip) rather than surface irrigation systems should be used in conjunction with good water and nutrient management if higher water and crop productivity are to be realized.
- Fertility amendments should be promoted alongside conservation tillage—microdosing is best suited to farmers' risk management needs as higher dosage levels represent a risky investment and expenditure.

- Smallholder farmer water conservation committees with women as leaders should be considered.

- Additional research at the basin scale is needed to identify the major sources of pollution in some communities. A follow-up study of cadmium (in the Limpopo Basin) is needed to determine the extent of the problem.

- Stress on water supply systems will drive the need to explore non-conventional water resources (e.g., sand dams) as potential water supplies.

- Existing geological maps can be used to predict suitable (low-seepage) areas for exploration of alluvial aquifers.

- It is important to consider the labor costs of any conservation agriculture intervention.

Conclusion

Studies among smallholder farmers in South Africa indicate a significant scope for improving water productivity in rainfed farming systems through supplementary irrigation combined with soil fertility management. Other studies show that shifting from exclusively rainfed agriculture to supplementary irrigation agriculture in the study area resulted in yield improvements due to timely application of water, reduction in water stress and greater availability of water for crops.

Contact Person

David Love (dlove@waternetonline.org)

Partner Organizations

Faculdade de Agronomia e Engenharia Florestal, Universidade Eduardo Mondlane, Mozambique
International Crops Research Institute for the Semi-arid Tropics
International Water Management Institute
Mzingwane Catchment Council, Zimbabwe
School of Civil and Environmental Engineering, University of Witswatersrand, South Africa
UNESCO-IHE Institute for Water Education, the Netherlands
University of Zimbabwe
Water Research Commission, South Africa
WaterNet

Key Reference

Ncube, B., E. Manzungu, D. Love, M. Magombeyi, B. Gumbo and K. Lupankwa 2010. *The challenge of integrated water resource management for improved rural livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3905

Tags: PN17; IWRM Improved Rural Livelihood

Bibliography

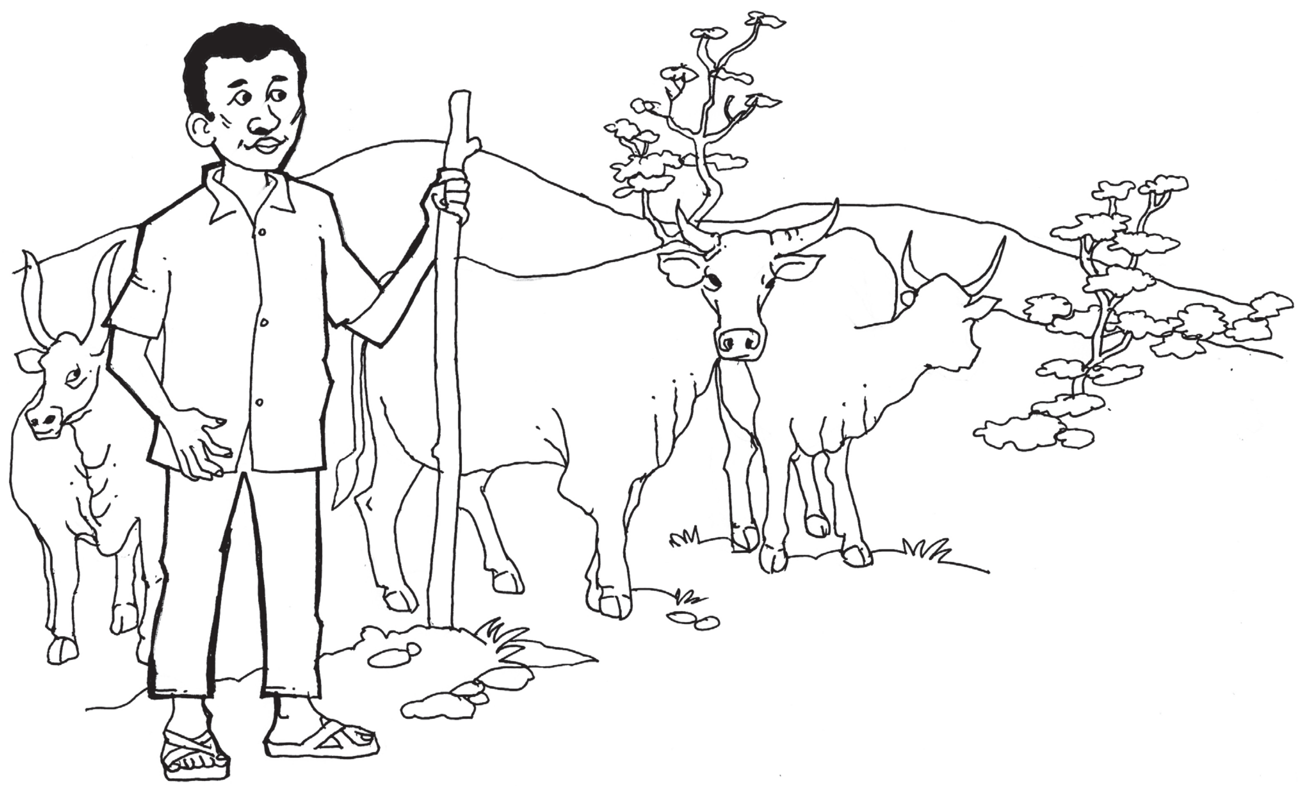
ICWE 1992. *The Dublin statement and report of the conference. International Conference of water and the environment: Development issues for the 21st century.* Dublin, Ireland, January 1992.

Savenjie, H.H.G. 2002. Why water is not an ordinary economic good, or why the girl child is special. *Physics and Chemistry of the Earth,* **27**, 741-744.

Twomlow, S., D. Love and S. Walker n.d. *The nexus between INRM and IWRM.* Retrieved from: http://www.bscw.ihe.nl/pub/bscw.cgi/d2607217/Twomlow.pdf.

Twomlow, S., D. Love and S. Walker 2008. The nexus between Integrated Natural Resources Management and Integrated Water Resources Management in Southern Africa. *Physics and Chemistry of the Earth*, **33**, 889-898.

Identifying Strategies for Increasing Livestock Water Productivity in the Blue Nile Basin



The livestock sector is socially and politically very significant in developing countries because it provides food and income for one billion of the world's poor, especially in dry areas, where livestock keeping is often the only source of livelihoods. Livestock keeping is a major component of agricultural gross domestic product (GDP), providing meat, milk, income, farm power, manure (for fuel, soil fertility replenishment and house construction), insurance, and wealth savings to hundreds of millions of people worldwide. However, livestock raising is a major consumer of water. In regions such as the Nile where water is a scarce commodity, the CGIAR Challenge Program on Water and Food (CPWF)through the Nile Basin Livestock Water Productivity project led by the International Livestock Research Institute (ILRI) saw the need to develop strategies to improve livestock water productivity (LWP). LWP is a ratio of the total net beneficial livestock-related products and services to the water depleted in producing them (Bekele Awulachew *et al* 2012). A water accounting approach was used to develop a livestock water productivity (LWP) assessment framework. This framework was then used to identify strategies for increasing LWP, assessing LWP in the Blue Nile Basin, and suggesting opportunities to improve LWP more broadly.

Livestock water productivity assessment framework

Livestock provides people, especially the poor in developing countries, with multiple benefits derived from diverse animal species and breeds. Estimating LWP requires estimates of the total value of these goods and services. Monetary units are used for benefits and LWP is expressed in units such as US$/km^3 of water. As a tool, the LWP helps stakeholders to systematically understand the livestock-water interactions in a variety of systems in the Nile basin. Beneficial outputs refer to milk, meat, hides, farm power, etc. produced from livestock. To produce these outputs, the animals, particularly cattle, need water for drinking and for producing their feed/forage. Depleted water, on the other hand, refers to the water that is lost through evaporation, transpiration (evaporation of water from the plants), and downstream discharge. Once depleted, water is no longer available and has no further value within the system. Water contamination is a depletion process that makes water less valuable to future users even though it may remain within the system.

Estimating livestock-related water inflow, depletion, and storage is a primary requirement for assessing LWP.

$$LWP = \frac{\Sigma \text{ beneficial outputs}}{\Sigma \text{ depleted water}}$$

Water Demand of Livestock

Generally, livestock production competes heavily with both humans and plants for the world's water supply. In particular, livestock in the Nile consume about 600 million cubic meters of water per year (Table 1).

Table 1. Water resources availability, loss, and use.

Crop-Livestock Production	Water Availability (est.)	Water Loss	Water Use
6 rainfed livestock-dominated and mixed crop-livestock production system	1.68 trillion m^3/year	1.27 trillion m^3/ year through evapotranspiration	
Livestock use of water for feed			0.06 trillion m^3/year or 4.7% of evapotranspiration
Livestock use of water for drinking			<600 million m^3/year

Water contamination is a depletion process that makes water less valuable to future users even though it may remain within the system. Once depleted, water is no longer available and has no further value within the system.

In assessing LWP, a basic requirement is estimating livestock-related water inflow, depletion, and storage.

Based on the assessment framework, there are four basic livestock keeping strategies that can help improve LWP. These are optimal feed sourcing, enhancing animal productivity, conserving water resources, and providing drinking water to livestock, especially cattle. These strategies involve supply-side and demand-side management of both water resources and animal products (Figure 1). The four strategies, along with the LWP assessment framework, underpin the research undertaken on a basin-wide and country-specific basis in Uganda, Sudan and Ethiopia.

The framework identified the following four strategies to increase LWP:

1. selection of feeds that require relatively little water and produce enough quality dry matter and nutrients;
2. integration of animal science knowledge (e.g. veterinary science) into water development;
3. water conservation associated with livestock keeping; and
4. optimally distributing livestock: feed and drinking water resources over large areas to maximize animal production through access tp underutilized pasture far from water while preventing overgrazing and water degradation near watering points.

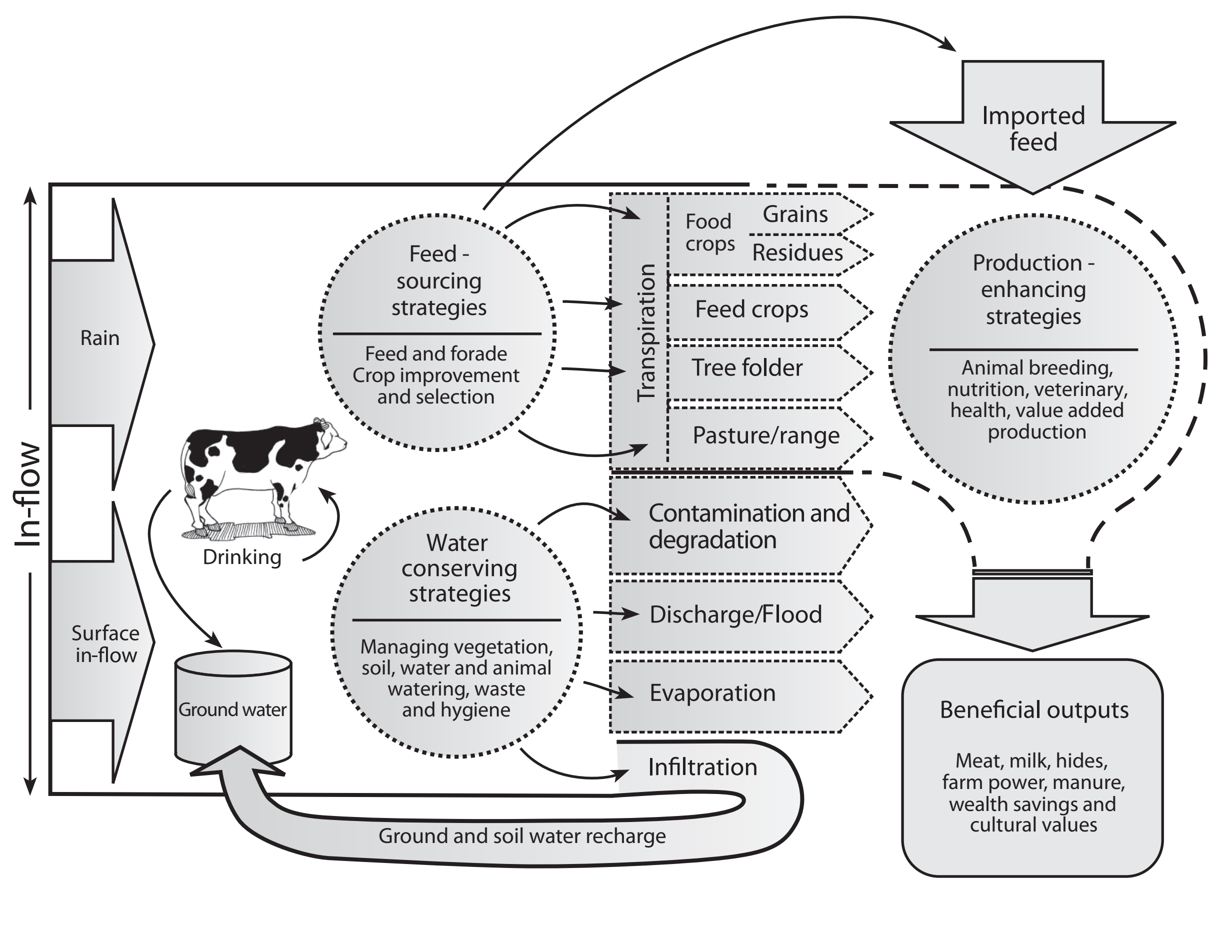


Figure 1. LWP Assessment Framework

Four basic strategies of LWP

1. Feed sourcing

One key strategy for increasing LWP lies in selecting the most water-productive feed sources that produce enough feed to meet the animals' needs. Feed water productivity estimates vary 80-fold from the most to the least efficient, due in part to biology and inconsistent methodologies.

High LWP does not necessarily mean high levels of production and livestock keepers need to maintain profitable enterprises. Thus, the approach to increase LWP through feed sourcing demands must be carefully planned.

a. Feed must meet the nutritional requirements of the animal. This includes estimating the water productivity of the feed with the ratio of metabolizable energy or protein content to actual water depleted.

b. Manure management can also have a major influence on the net benefits derived from livestock and thus on LWP. In extensive production systems, around 50% of the feeds ingested by animals are excreted as manure. Approximately, half of the depleted water supports animal maintenance and production. The other half of the depleted water supports manure production and, in well-managed rangelands, directly supports ecosystem services. Manure is highly valued and widely used for replenishing soil fertility, domestic fuel and construction of houses. However, manure can also be a major cause of environmental degradation, such as water contamination.

c. Water used to feed animals for traction is an

Best practices

In areas where livestock depend partly or entirely on crop residues and by-products, maintaining vegetative ground cover is vital.

When land is traditionally cultivated much of the year, it becomes devoid of vegetative cover. It is then made vulnerable to water loss through runoff and evaporation. The productive land often suffers from declining soil organic matter and water-holding capacity.

Since livestock keeping is highly integrated into rainfed agriculture in developing countries and feed scarcity is widespread, excessive use of crop residues for livestock and household energy aggravates the land and water resource degradation associated with cultivation.

In some cases, water harvesting and groundwater recharge techniques can capture surplus water, which is then kept in storage for dry seasons, increasing water productivity annually. Interventions, aimed at producing animal feeds utilizing crop residues and by-products, also maintain vegetative cover and soil moisture.

input into crop production. Oxen, equines, and buffaloes have traditionally provided farm power for crop production and marketing in many basins, including the communities along the Blue Nile. When the primary use of an animal is for farm power, beef production then becomes a by-product of animal production and is only "produced" when an animal is no longer capable of cultivating land.

2. Enhancing animal productivity

Increasing the ratio of feed energy for production to maintenance has high potential for increasing LWP. In Africa, feed scarcity limits intake, implying that most consumed feed is used to support maintenance, leaving little for production.

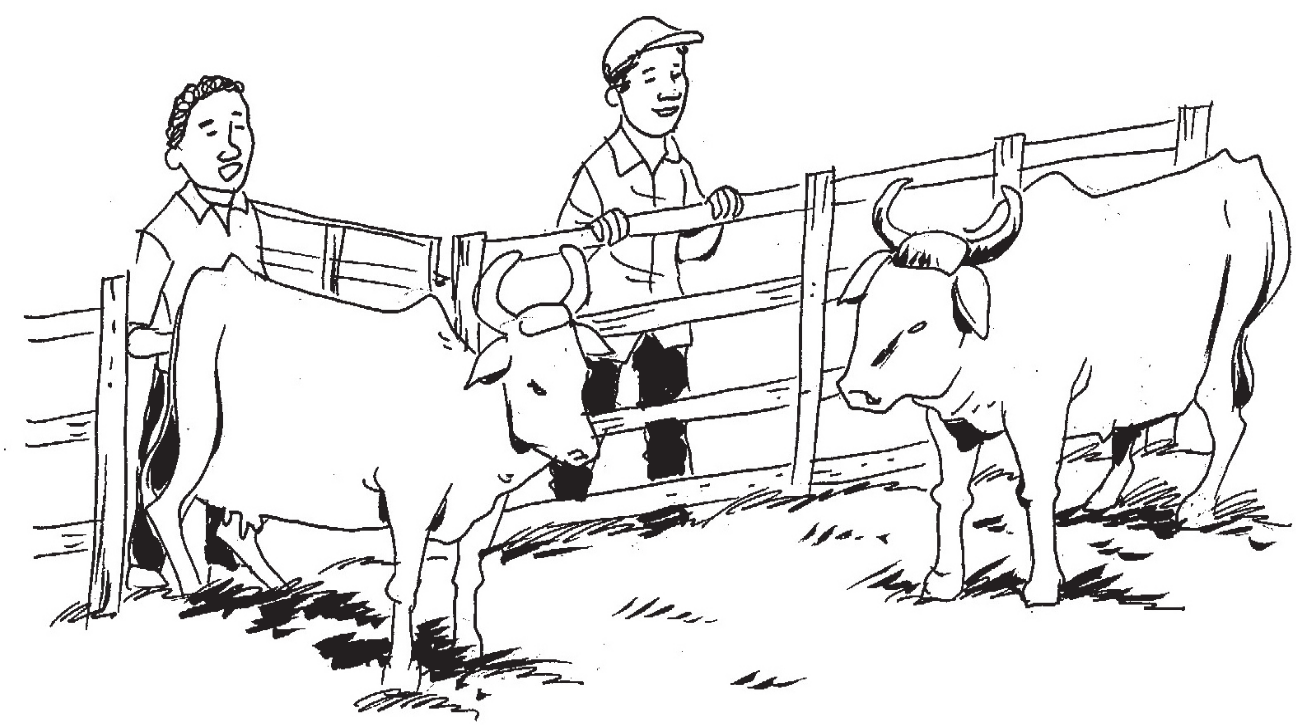
Relying only on aggregate monetary valuation of LWP does not include the disaggregation of animal products into diverse nutrients required for human nutrition. Animal food sources provide essential nutrients such as Vitamin B12 and micronutrients that are often not readily available to poor farmers producing crops on nutrient-depleted soils.

3. Conserving water resources

The primary challenge to conserving agricultural water is maintaining high levels of vegetative ground cover to promote increased transpiration, infiltration and soil water holding capacity and decreased evaporation and discharge.

GRAZING PRACTICES: We suggest limiting animal stocking rates to levels that allow moderate production and to avoid overgrazing. Overgrazing often removes excessive ground cover or shifts plant species composition from palatable to unpalatable types.

GRASSLAND: When well-managed grassland is often the best land use for capturing rainfall, encouraging storage in soil and promoting transpiration and plant production, particularly in drylands and on steep slopes.



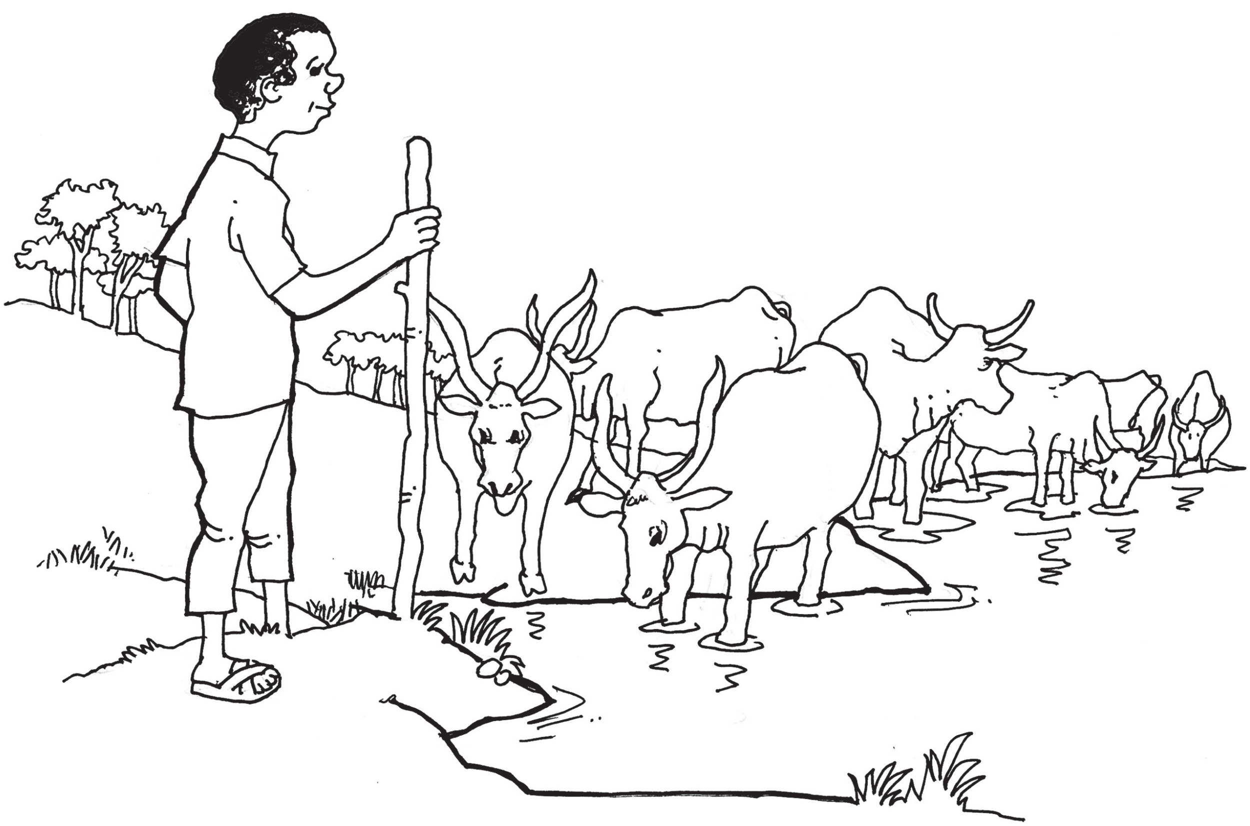
4. Providing drinking water

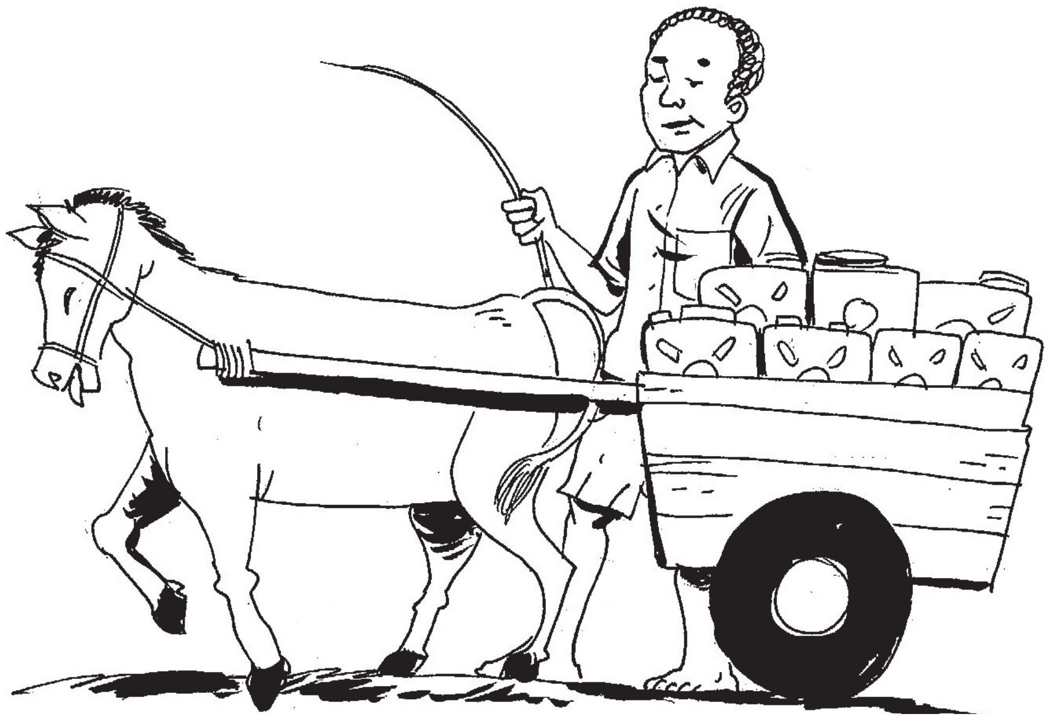
Drinking water must be of high quality and available in small but adequate quantities. Although the cost of providing a unit of drinking water may also be high, the amount of water drunk is less than 2% of that needed to produce feed. Livestock drink about 25 to 50 liters/TLU/day, with variation dependent on many factors, such as species, breed, ambient temperature, water quality, feed intake and water content of feed. More importantly, strategically allocating drinking water opportunities over time and space (seasons and landscapes) optimally distributes livestock, especially cattle, to make more effective use of forages without overgrazing the land. In Africa, livestock watering points are often inadequate in number and sub-optimally distributed and managed. During dry seasons in some areas, livestock travel for hours to reach watering points, resulting in significant loss of energy. In Sudan, achieving an optimal spatial distribution of livestock and drinking water sites can greatly increase LWP and reduce land and water degradation in large parts of the Nile Basin.

Other key issues

- The hotspots and issues identified at the Blue Nile Basin level were livestock production systems, livestock population, livestock water demand for animal feed production, LWP and livestock-induced soil erosion.

- Men tended to dominate in terms of having greater access and control over benefits from financial, social, human and natural capital as compared with women. An exception can be found in Uganda where women are actively involved in the country's cattle corridor, where they seem to have equal engagement as men in crops, goats and poultry, also having access to credit.





- Animal movement occasionally involves crossing state borders in the southern part of the country, such as the northern part of the Upper Nile, as well as with bordering countries, especially Chad and the Central African Republic. Livestock access to the Nile system in dry periods allows better utilization of the vast grazing lands that are accessible during more favorable periods in the rainy season.

Hotspots were defined as "development domains" where intervention options could improve LWP through better management of livestock and water and pasture resources and through improved marketing of livestock products. The development domains were defined on the basis of livestock distributions and densities, access to markets and human population densities.
- Peden et al. 2009

Conclusion

Where livestock are important components of farming systems, there is a need to integrate livestock management, crop management, land and water use practices and resource degradation into one integrated framework. The LWP framework is a starting point. When tested in diverse production systems, the generic framework was robust in handling conditions ranging from extensive grazing systems to intensive mixed crop-livestock systems at local, watershed and basin scales.

Contact Persons

Don Peden (pedenonpender@shaw.ca), Mengistu Alemayehu, Tilahun Amede, Seleshi Bekele Awulachew, Hamid Faki, Amare Haileslassie, Mario Herrero, Everisto Mapedza, Denis Mpairwe, Musa Tibin, Girma Taddesse, Paulo van Breugel

Partner Organizations

Addis Ababa University, Ethiopia
Agricultural Economics and Policy Research Center, Sudan
ASARECA Animal Agriculture Research Network, Kenya
Animal Resources Research Corporation, Sudan
CARE, Ethiopia
Ethiopian Institute of Agricultural Research
Ethiopian Rainwater Harvesting Association
International Livestock Research Institute
International Water Management Institute
Livestock, Environment and Development Initiative
Makerere University, Uganda
Sudan Academy of Science
Swiss College of Agriculture, Switzerland

Key Reference

Peden, D. et al. 2009. Nile basin livestock water productivity. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3927

Tags: PN37; Nile Livestock Water Productivity

Bibliography

Bekele Awulachew, S., V. Smakhtin, D. Molden and D. Peden (eds.) 2012. *The Nile River basin: Water, Agriculture, Governance and Livelihoods.* London: Routledge.

Harrington, L.W., F. Gichuki, B.A.M. Bouman, N. Johnson, C. Ringler, V. Sugunan, K. Geheb and J. Woolley 2006. *CGIAR Challenge Program on Water and Food, Changing the way we manage water for food, livelihoods, health and the environment: Synthesis 2005*. CPWF Synthesis Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Peden, D., T. Amede, A. Haileslassie and G. Taddesse 2008. Strategies for improving livestock water productivity. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food,* Vol.1, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 29-33. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

van Breugel, P., M. Herrero, J. van de Steeg and D. Peden 2010. Livestock water use and productivity in the Nile basin. *Ecosystems,* **13**, 205-221.

Community-Based Fisheries Management

Increasing the Water to Food Conversion Rate in Tropical Floodplains

The world's tropical floodplains are important resources that could be tapped for fish production to provide a rich protein source for communities. However, many of the strategies to increase food output from the world's tropical floodplains have been limited to agricultural crop cultivation and have not fully taken advantage of integrating fish culture and other aquatic resources,that will also increase the rate of water-food conversion.

The CGIAR Challenge Program on Water and Food (CPWF), through the community-based fish culture project and teams of national researchers worked together to implement a project on enhancing community-based fish production in the floodplains of Bangladesh, Cambodia, China, Mali and Vietnam.

The project aimed to scale out a successful model of floodplain aquaculture, developed through three decades of research on community-based fisheries management and floodplain aquaculture in Bangladesh. It disseminated the model to other areas in Bangladesh and to four other countries that also have extensive floodplain resources. It also developed appropriate technical and institutional options for the integration of community-based fish production into existing floodplain and irrigation systems. The project identified the most appropriate models of collective action for aquaculture under different socioecological contexts and assessed the value of these approaches to the sustainable development of floodplain resources and irrigation systems.

The project has led to a range of outcomes and variable successes in each of the project countries, delivering different levels of benefits both within and between countries. Negotiating access and managing institutions and benefit—sharing arrangements within a system where rights are dynamic, have created particular challenges to the implementation of the project. As a result, only sites in Bangladesh and China generated data over the many fish culture cycles. Substantial improvements in resource governance were, however, seen in Mali, where the intervention showed strong potential for uptake and dissemination.

The Water to Food conversion rate could increase if the world's tropical floodplains are tapped by integrating community-based fish culture with agricultural crop production.

Comparison of floodplain fishery development in five countries

The dissemination of the community-based fish culture (CBFC) model developed in Bangladesh to other countries in Asia and Africa is an important contribution to a suite of aquaculture technologies currently available to rural households across the world. Testing the CBFC model in a range of environmental, social and economic contexts has provided important insights into the conditions that support CBFC and where such an intervention is both appropriate and likely to generate benefits for rural communities (see Table 1)

Comparison of Floodplain Fisheries in Bangladesh, Vietnam, Cambodia, China and Mali.				
Country/ Description	**Methods and Approaches**	**Technical Design**	**Ownership of Floodplains and Beneficiaries**	**Fish Production and Benefit Sharing**
BANGLADESH CBFC was developed in Bangladesh. Although significantly helping floodplain communities, CBFC is said to exclude large numbers of poor people who are marginalized when benefits are captured by the local elite.	Floodplain management committees (FMC) were established to represent stakeholder groups and make decisions on fish culture activities. Project implementation committees (PIC) were tasked with advising the FMCs and coordinating project activities in CBFC.	Culture sites were delineated by flood control dikes. Bamboo fencing was installed at water inlets and outlets to permit entry of wild fish fry and prevent the escape of stocked fish. Concrete ring culverts were introduced in Kalmina Beel and water regulation using sluice gates in Beel Mail increased water retention following flood recession.	Floodplains were completely under private ownership and had the landless, fishers and landowners as beneficiaries. For publicly owned floodplains under lease agreement, fishers' groups were mostly the beneficiaries. Others were fisher-lessees and landowner-investors.	Fish production and benefit sharing varied among sites, depending on land tenure arrangements associated with the water body. Where public land was leased by a fishers' society, fishers received a larger share of the net benefits than those on privately owned sites. Benefits also depended on investments made in the lease. At all sites, the share included a revolving fund with one site achieving financial autonomy. In some sites, the landless either received 5% of the total benefit or were only allowed to catch self-recruited species.
VIETNAM Floodplain aquaculture in Vietnam has not shown significant development as the government is focused on intensifying rice culture. It has only recently begun to experiment with different types of aquaculture in flooded rice fields.	In all three sites, land ownership within the culture site was a pre-requisite for participation. At two sites, non-landowners were permitted to join, but only a few did. A leader, vice leader, secretary and accountant were elected to form the management committee.	Culture sites were delineated by dikes. Fencing to define the culture area was introduced at some sites. Fencing was installed at the top of dikes to prevent fish from escaping during high floods.	CBFC in Vietnam limited membership to households who owned land within the perimeter of the project site, although this was not intended at project inception.	When the water level became low enough to make the boundaries of individual rice fields visible, wild fish caught within the boundaries belonged to the rice field owner and were not recorded as part of the CBFC harvest.
CAMBODIA Cambodia's fresh water capture fisheries ranked 4th most productive behind China, India and Bangladesh.	Participation was open to all community members. Those interested in participating in fish culture registered during	Culture sites were located in rectangular enclosed areas made of nylon nets and supported by wooden poles within open access reservoirs or on	Selection of participants was on a voluntary basis, including landowners. At all sites, benefit sharing was done according to	Floodplain aquaculture in Cambodia did not achieve levels of production sufficient to generate benefits for project participants. Environmental factors, including flooding, late arrival of floodwaters and

Country/ Description	Methods and Approaches	Technical Design	Ownership of Floodplains and Beneficiaries	Fish Production and Benefit Sharing
	a village-level meeting.	private rice fields delineated by net fencing. Fish pathways and ditches were introduced into rice fields in some sites in the second year to facilitate fish migration.	membership and included a share of 10% for poor households of two villages in Cambodia.	reduction of the grow-out period undermined fish production. Vandalism of fish culture enclosures also led to high losses.
CHINA The CBFC model was adapted to create a system based on pooling resources (land and/or labor) by community participants.	Fish culture was managed by a caretaker household/contractor that has had experience in fish culture. All households in each of the communities received a previously agreed share of the benefit from fish culture. The local fisheries bureau supervised the project in the village.	In Jiangsu province, fish were stocked in irrigation canals. Culture sites were delineated by fencing. In Yunnan, fish were stocked in flooded rice nurseries. There was no enclosure used or modification of infrastructure.	CBFC in China did not bring about significant change in income or livelihoods. However, it did generate social benefits, such as creating additional funds for social welfare and rural development programs and decreasing the amount each household needs to contribute yearly. It has improved relationships between villagers and has increased the production of lotus in Yunnan province.	In terms of output, households in Taiping chose to eat their share of production—fish being a luxury protein source. In Jiangsu province, farmers shared the fish they got from the project with family and friends. Generally, Yunnan communities wished to continue fish culture to obtain an eco-friendly protein source at a low price.
MALI CBFC provided local communities, NGOs and the national agricultural research and extension system (NARES) with a model for increasing the productivity of *mare* (flood plain depression), which represent the primary source of income for most households during the dry season.	Fish culture was managed by a committee, composed of the village chief and representatives of main ethic groups and resource users.	Net pens were set up in one large enclosure located within *mare*.	Access to *mares* is regulated by the main families, who were descendants of the original farming-fishing settlers.	Due to persistently high water levels in the *mare* this year, the enclosures could not be harvested before the end of the project. We find that overall catch would increase over 100% but more significantly, we find that the catch per individual participating in the collective fishing event would increase roughly 500%

Impact and change

Fish culture in communities in Bangladesh, China and Mali showed potential impact in terms of food security and increased income. In Vietnam and Cambodia, research increased understanding of the conditions required for collective action, specifically for developing CBFC systems. This research will contribute directly to the development of locally appropriate and technically feasible fish culture systems in both countries. In Cambodia, the project responded to government commitments to establish community-based fish refuge ponds (FRPs) in every village in the country by providing best-practice guidelines for FRPs.

In Bangladesh, increase in fish production brought significant changes to the community, who related the story of their village in the community-produced film, 'The Island of Dreams and Success'. Moreover, prior to the intervention, households fished individually in open access waters and competed with one another for the fish catch. Since the introduction of fish culture on a community basis, households have learned to work together to manage fish culture activities and to protect the fish stock.

Beneficiaries in Bangladesh say that the overall impact has been the generation of income so that they can afford to educate their children or to purchase assets such as mobile phones and televisions—technologies that are important in providing rural households with access to information.

Although relatively modest levels of fish production were achieved in China, fish production still provided significant benefits to participating communities. In Taiping village, in particular,

beneficiary households preferred to receive their share of production in the form of fish rather than in cash. Fish production from CBFC led to a significant increase in fish consumption in Taiping. The additional fish that the project provided for home consumption was a sufficient incentive for the community to continue fish culture.

In Mali, the impacts of constructing the aquaculture enclosures in Mama Pondu *mare* go well beyond that of fish production within the enclosures. The project focused on development and management of the *mare* resources and has increased community awareness of its reliance on this common resource and its commitment to improve *mare* resource governance overall. Consequently, livestock herders have taken greater care in tending their flocks, fishers have limited their poaching during the closed season and farmers have reduced the amount of vegetation that they extract as fodder for small livestock.

At the institutional level, national agricultural research and extension system (NARES) partners also reported important changes in their working practice and research, knowledge and skills. The application of participatory rural appraisal (PRA) methods has expanded the scope of their research beyond a simple analysis of fish productivity. Consultation with farmers at the local level in order to understand their needs and preferences has also increased.

The opportunity to build international partnerships was cited as an important outcome of the project, particularly among NARES partner participants in China. The increased visibility of local departments, through connections established by the project, has led to further funding for national-level projects in areas that previously receive little attention from national agencies.

Conclusion

Floodplain aquaculture could increase water to food conversion significantly and provide much needed protein. Organizing a community to join forces in implementing floodplain aquaculture can provide multiple benefits, including food production, increased income, community empowerment and improved cooperation. It also brings about increased awareness of the importance of the environment and hygiene and of the fact that the floodplain is a common resource from which everyone should be able to benefit.

Contact Persons

Nastaja Sheriff (nastaja.sheriff@gmail.com), Olivier Joffre, Meen Chee Hong, Benoy Kumar Barman, A.B.M. Haque, Fazlur Rahman, J. Zhu, Hao van Nguyen, Aaron Russell, Martin van Brakel, Rowena Valmonte-Santos, Christine Werthmann, Amaga Kodio

Partner Organizations

Africa Rice Center
Bangladesh Agricultural Research Center
Cambodia Fisheries Administration
Freshwater Fisheries Research Center, China
International Food Policy Research Institute
Institute D'Economie Rurale, Mali
Research Institute of Agriculture 2, Vietnam

Key Reference

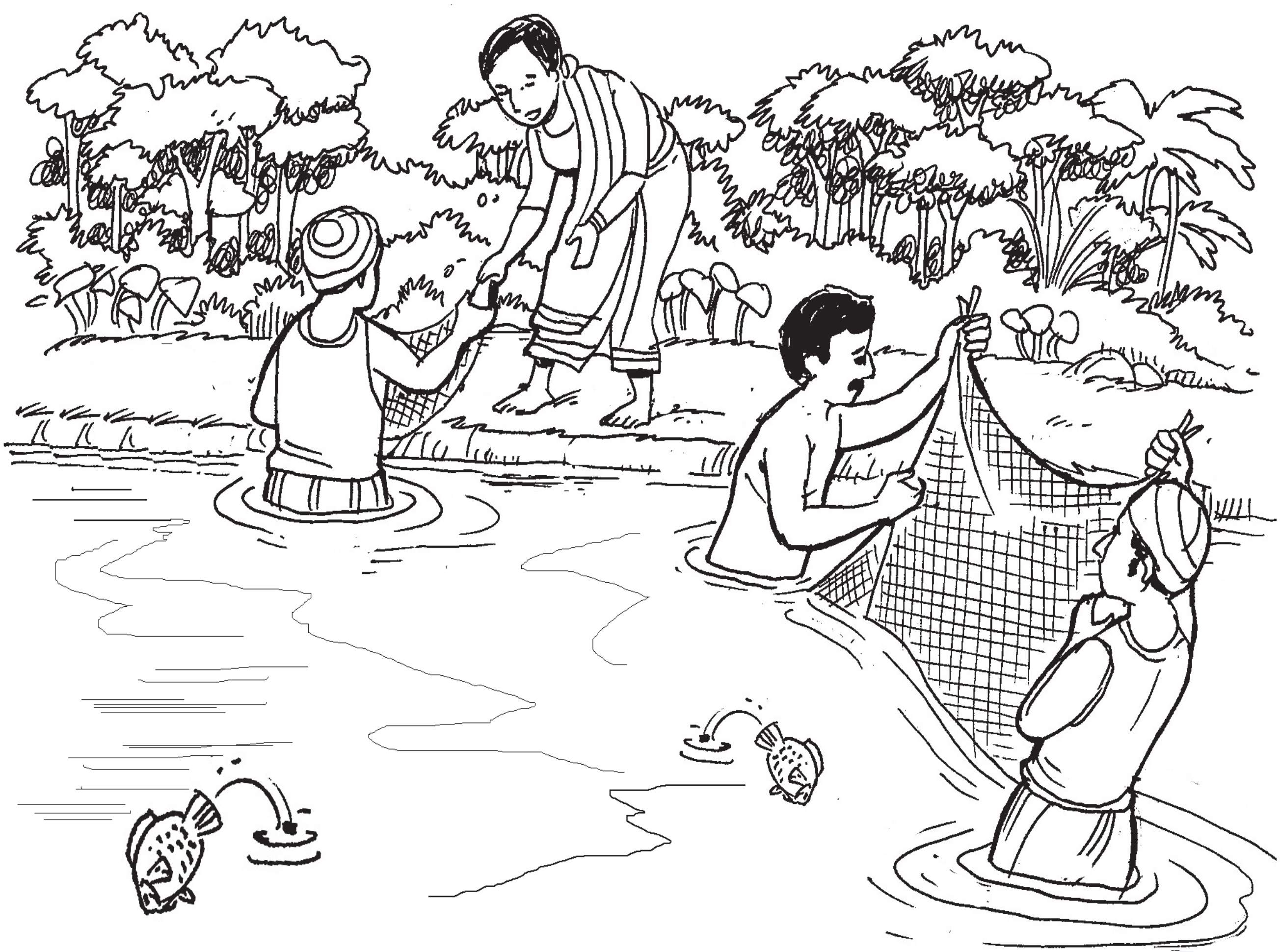
Sheriff, N. et al. 2010. *Community-based fish culture in seasonal floodplains and irrigation systems.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3924

Tags: PN35; Community-based Fish Culture

Bibliography

CPWF 2009. 2008 CPWF Annual Report: *A year of transformation and innovation.* CPWF Annual Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Collective Action in Community-Based Fish Culture in Seasonal Floodplains and Irrigation Systems



The CGIAR Challenge Program on Water and Food (CPWF) project, 'Community-based fish culture in seasonal floodplains', was a 5-year interdisciplinary action research project that aimed at enhancing fish production in seasonal floodplains to improve and sustain rural livelihoods. The research was carried out in seasonally flooded areas, where rice is cultivated on individual household plots during the dry season. During the flood season, the same land is inundated, creating an open access waterbody for capture fisheries.

The project sought to develop technologies and institutional arrangements appropriate for a variety of environmental and socio-cultural settings to support collective fish culture in the flood season. This project was implemented in five countries: Bangladesh, Cambodia, China, Mali and Vietnam.

The project focused on developing institutions for community-based management, negotiating access to floodplain resources and creating benefit-sharing arrangements. The variable success of community-based fish culture activities in the project countries led to a deeper consideration of the context and its contribution to the success or failure of collective action under differing socio-ecological conditions.

Methods

Sites were selected based on hydrological conditions (height, extent, duration of flooding), existing infrastructure (dikes, irrigation canals), willingness of local communities to participate in the project and support from local authorities.

Fish stocking was carried out at each of the project sites under the guidance of national partners with expertise in local aquaculture systems. Locally preferred species were stocked in polyculture systems, with stocking densities and proportions varying from year to year as the culture systems evolved. Similarly, enclosure designs were locally adapted and modified.

Collective approaches to aquaculture have variable success in each of the countries, with the project delivering different levels of benefits both within and between countries. Negotiating access and creating and reshaping institutions and benefit-sharing arrangements within a system where rights are dynamic were some of the key challenges experienced.

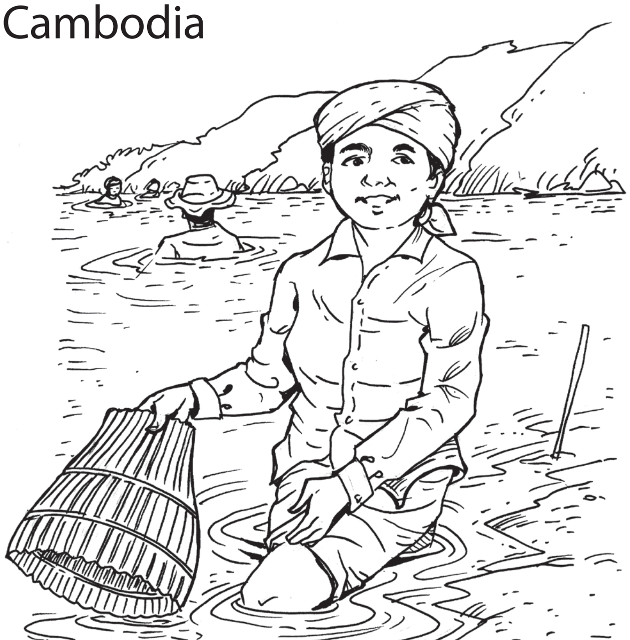
Bangladesh

Successes have been substantial in some project sites, whereas disputes, conflicts, and ultimately discontinuance have occurred at others. Building on previous community-based fisheries management experience in the country, community-based fish culture has been introduced in floodplains, subject to a complex array of administrative arrangements. The project was implemented in the floodplains under public and private ownership, in which the public portion was leased to a fishers' community, while the floodplains were completely under private ownership. In each system, enclosures were created within floodplain depressions. Fish culture was managed by a floodplain management committee, made up of representatives from all communities surrounding the floodplain, with participation of landowners and the landless. As described by Haque *et al.* (2008), however, the complexities of access and ownership to land, water and fishing rights have created serious challenges for the project. Despite these challenges, the community fishers' society at Kalmina Beel floodplain in Mymensingh (which is completely under private ownership) is still operating successfully. Fish culture is now financed by savings set aside from successful fish culture during previous years. In the Beel Mail floodplain in Rajshahi District, under public and private ownership with the support of local authorities, the fishers' society was able to extend its rights to use the floodplain for 2 more years after the project ended in 2010. However, it was recently leased to another fishers' society in the area.

Vietnam

Fish culture activities in southern Vietnam have been introduced on a collective basis in flooded rice fields of the Mekong Delta. In contrast to Bangladesh, the flooded land is entirely under private ownership, with members of the fish culture group drawn from households whose land is situated within the flooded area. Where annual flood height is low enough to permit the creation of enclosures around individual household plots, there has been a general preference towards fish culture on an individual basis or a third rice crop. There is insufficient incentive for farmers to work together collaboratively to raise fish. Consequently, there have been high levels of discontinuance of community-based fish culture in these areas. At present, however, approaches to collective fish culture are evolving among groups of households who favor fish culture in a small number of enclosed rice fields. In the provinces of the Mekong Delta that border Cambodia, floodwaters are deep, permitting only two rice crops each year. In these areas, the cost of creating individual enclosures, using fences of sufficient height to contain stocked fish is prohibitive, making collective fish culture a more viable option. Benefit-sharing arrangements, management of fish culture and leadership of community groups continue to pose challenges and need to be addressed.

Cambodia



Establishing community groups to successfully manage fish culture within flooded areas in Cambodia has been problematic. Fish culture activities have been introduced in open access reservoirs and flooded rice fields. Initially, households were keen to participate in the project. Farmers have since demonstrated a preference for fish culture on an individual basis, introducing the technology instead on their own homesteads and private plots. As in Vietnam, in some areas, there has been a move toward collective fish culture among smaller fish culture groups of 10-12 households, who practice fish culture in 3-4 enclosed rice fields. Members of these fish culture groups are currently improving the rice field environment for fish culture by creating ditches along the rice field perimeter, which act as refuges when waters are shallow. Fish culture activities have only continued in Takeo province, a fish-deficit area. The approach has met with less success in Prey Veng province. Although the reasons for this failure were not clear, it is possible that incentives to participate may have been lower due to the presence of support from numerous international organizations and NGOs. During the final phase of project development, community-based management of dry-season fish refuges was introduced.

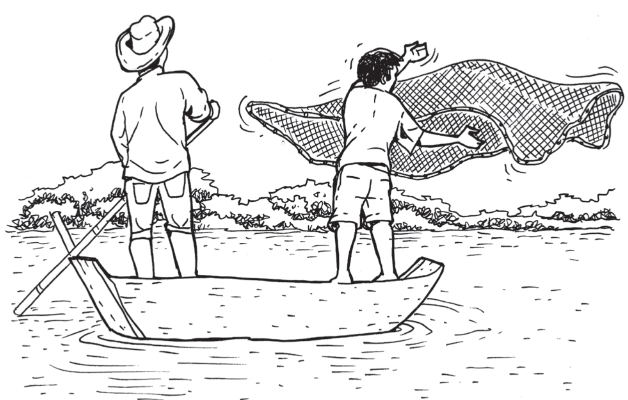
Lessons for successful collective fish culture

- **Understanding the historical context and impact of recent historical events of a country can provide insights into the likelihood of uptake by a community of fish culture on a collective basis.**
- **The presence of existing community-based institutions and evidence of collective action is a pre-condition for successful collective action.**
- **Labor is important to the success of fish culture, as protecting and harvesting the fish stock is labor-intensive.**
- **The employment opportunities provided by fish culture may provide a strong incentive for participation and cooperation, particularly where alternative occupations are limited or absent.**
- **The support of local authorities is a critical factor in the successful development of community-based fish culture.**
- **Flood management infrastructure is essential to control unpredictable flooding events and the associated damage to the fish culture system. Flood management infrastructure and fencing are strongly linked technical requirements.**
- **The presence of a market for distribution of culture products is crucial to the success of any fish culture enterprise. The cost and availability of inputs for fish culture, particularly fingerlings, were also limiting factors.**

China

Farmers in China have adopted a different approach to collective fish culture than their counterparts in other project countries. The project was implemented in two provinces, Yunnan and Jiangsu. In Jiangsu province, fish culture was introduced into irrigation canals. In Yunnan, fish were stocked in flooded rice nurseries that are also used for the production of lotus. In both cases, management of fish culture was entrusted to an individual who acts as a caretaker, feeding and guarding the stocked fish. In return, this person receives a larger proportion of the benefit from production, with the remainder distributed among project participants and local community funds.

Lessons learned



The variable success of the community-based fish culture activities in the project countries has led to a deeper consideration of context and its contribution to the success or failure of collective action under differing socio-ecological conditions, recognizing that the results of stocking are often unexpected (e.g., Lorenzen and Garaway 1998, Garaway 2006, Garaway *et al.* 2006). Socio-political history, in particular, is likely to have a strong influence on project success. For example, the suggestion that private property, although no longer recognized as privately owned during the flood season, should revert to collective management fish culture, has important implications in countries such as Cambodia and Vietnam, where collectivity is socially sensitive. At the local level, a range of factors can influence the sustainability of community-based institutions, including social context and motivation for collective action, group leadership, local markets, ecological context and the role of the implementation process itself.

The key challenges faced in collective approaches to fish culture had to do with overcoming sensitivities to collective action, negotiating benefit sharing with a range of stakeholders, ensuring equitable access to resources among multiple users and promoting participatory decision-making in the identification and implementation of technical and institutional options for fish culture. Water and the aquatic resources it supports are often subject to multiple use and overlapping access and use rights (Bene 2003, Benda-Beckmann *et al.* 1996, Meinzen-Dick and Knox 1991).

- Property rights play a significant role within the context of community-based fish culture. Dry-season private property is submerged during the flood season, creating open access water bodies available for use by multiple resource users.

- In addition to this complex set of land and water rights are the rights associated with the capture of wild fish. Despite private ownership of the flooded land, the capture of wild fish is generally not restricted, and landowners accept open access conditions on otherwise private land. Numerous overlapping rights, coupled with issues of enclosure and fisheries enhancements, introduce additional layers of interest to the management of land, water and fish resources. However, integrating aquaculture into existing water systems can change this dynamic (e.g., Lorenzen and Garaway 1998, Garaway 2006).

Conclusion and recommendation

Research results show that significant benefits can be derived from community-based fish culture, including a 10% lower cost of rice production and net returns from fish production amounting to US$220-400 per ha. Significantly, these benefits were obtained with no reduction in the wild fish catch. The returns from fish culture were distributed among the group members according to sharing arrangements pre-negotiated at the beginning of the season. This includes a share in benefits for the landless members, which is significant as they have limited income-generating opportunities.

Socio-ecological context plays a major role in the success or failure of collective action. Despite the processes of adaptation and evolution of collective fish culture systems to fit local needs, the approach appeared to have variable success within and between countries, suggesting that the conditions under which collective fish culture is appropriate must be better understood.

Community-based or co-management approaches to resource management must respond and take into consideration local complexities and acknowledge that the associated incentives to adopt collective approaches may not always be sufficient to support sustainable community-based institutions. The complexities of rights and access encountered in the floodplain context add an extra dimension to learning and experience regarding collective action. It is essential to understand the local context and evaluate the potential impacts of intervention on existing access and ownership dynamics prior to the introduction of any new technology.

Contact Persons

Nastaja Sheriff (nastaja.sheriff@gmail.com)

Partner Organization
World Fish Center

Key References

Sheriff, N. et al. 2010. *Community-based fish culture in seasonal floodplains and irrigation systems.* CPWF project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3924

Sheriff, N., R. Arthur, B. Barman and M.C. Hong 2008. Community-based fish culture in seasonal floodplains and irrigation systems. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food,* Vol.2, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 246-249. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: PN35: Community-based Fish Culture

Bibliography

Bene, C. 2003. When fishery rhymes with poverty: A first step beyond the old paradigm on poverty in small-scale fisheries. *World Development,* **31**, 949-975.

Dey, M.M. and M. Prein 2003. Participatory research at landscape level: flood-prone ecosystems in Bangladesh and Vietnam. In: *Managing natural resources for sustainable livelihoods: Uniting science and participation,* eds. B. Pound, S. Snapp, C. McDougall and A. Braun. London: Earthscan.

Garaway, C.J. 2006. Enhancement and Entitlement-the Impact of Stocking on Rural Households Command over Living Aquatic Resources: A Case Study from the Lao PDR. *Human Ecology,* **34**, 655-676.

Garaway, C.J., R.I. Arthur, B. Chamsingh, P. Homekingkeo, K. Lorenzen, B. Saengvilaikham and K. Sidavong. 2006. A social science perspective on stock enhancement outcomes: lessons learned from inland fisheries in southern Lao PDR. *Fisheries Research*, **80**, 37-45.

Haylor G., A. Lawrence and E. Meusch 1997. Identification of technical, social and economic constraints to the rearing of fish in rice fields in Lao PDR. Project Report, 3 volumes for DFID, NRSP Project R6380CB. London: DFID.

IIRR. 2000. *Rice-fish culture in deepwater rice farming system.* Report of the International Institute of Rural Reconstruction.

IIRR, IDRC, FAO, NACA, and ICLARM. 2001. *Utilising different aquatic resources for livelihoods in Asia: a resource book*. International Institute of Rural Reconstruction, International Development Research Centre, Food and Agriculture Organization of the United Nations, Network of Aquaculture Centers in Asia-Pacific, and International Center for Living Aquatic Resource Management.

Lorenzen, K. and C.J. Garaway. 1998. How predictable is the outcome of stocking? In: *Inland fishery enhancements. FAO Fisheries Technical Paper*, ed. T. Petr; 133-152. Rome: FAO.

Bibliography

Meinzen-Dick, R. and A. Knox 1991. Collective action, property rights, and devolution of natural resource management: a conceptual framework. In: *Collective action, property rights and devolution of natural resource management,* eds., Meinzen-Dick, A. Knox, and M. Di Gregorio. CGIAR.

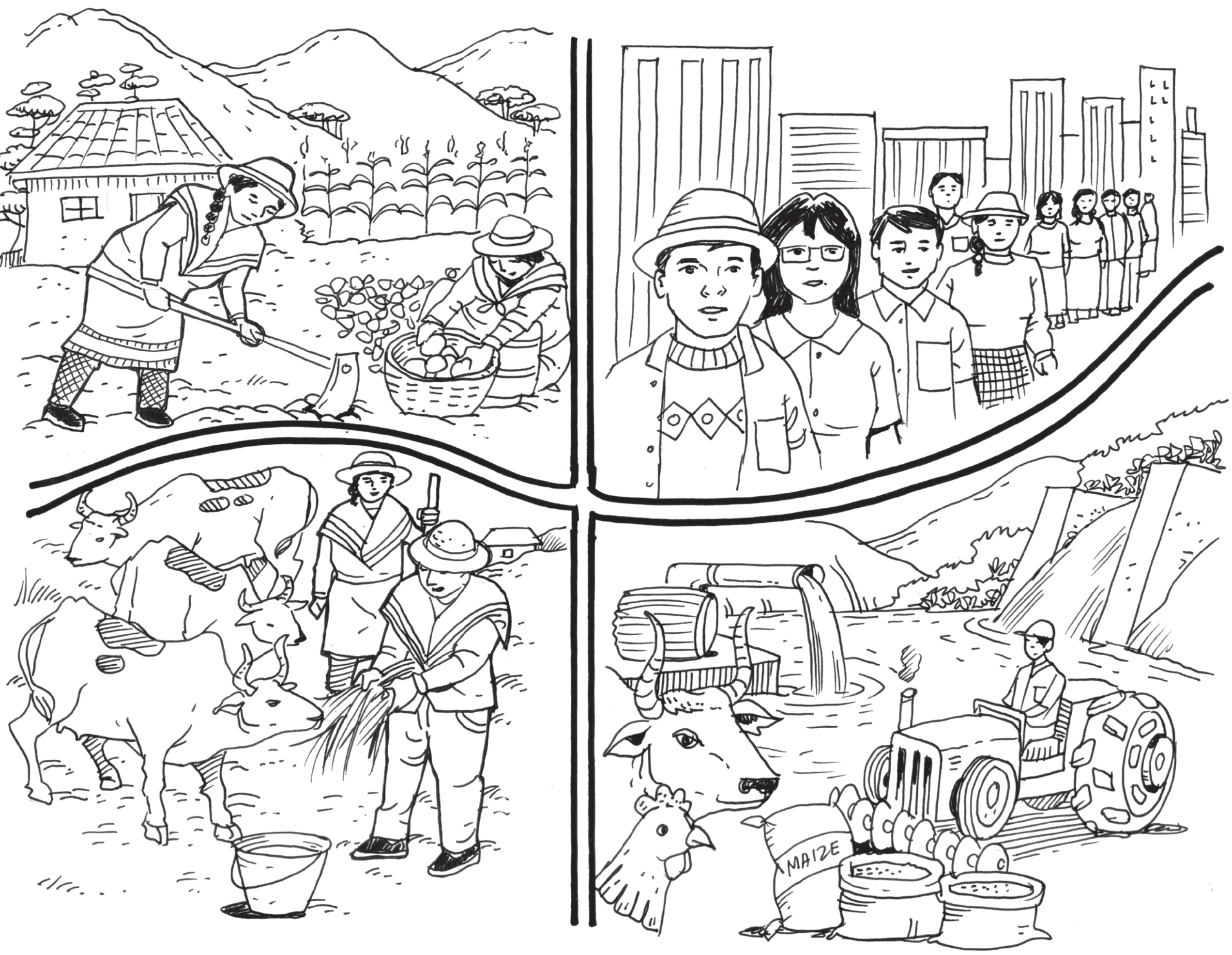
Sinhababu, D.P., B.C. Ghosh, M.M. Panda and B.B. Reddy 1984. Some preliminary observations on physicochemical characteristics of soil and water under rice-cum-fish culture. *Journal of the Inland Fisheries Society of India,* **16**, 58-61.

von Benda-Beckmann, F., K. von Benda-Beckmann and H.L.J. Spiertz 1996. Water rights and policy. In: *The role of law in natural resource management,* eds. H.L.J. Spiertz and M.G. Wiber. VUGA, the Netherlands.

WorldFish. 2002. *Increasing and sustaining the productivity of fish and rice in flood-prone ecosystems in South and Southeast Asia*. Final Report to IFAD prepared by WorldFish Center, Penang, Malaysia.

Multiple Use of Water

Multiple-Use Water Services for Poverty Reduction: A Background



Since the early 2000s, multiple-use water services has emerged as a new approach to water services in rural and peri-urban areas in low- and middle-income countries. The concept of multiple-use services (MUS) is based on the truism that people use water from multiple sources for multiple uses. People's demand is multi-purpose. Yet, water services are usually provided by 'domestic' or 'irrigation' or 'fisheries' sub-sectors for a single use only. The structuring of the public water sector according to single-use mandates leads to 'projects' that operate in parallel with each other, even when they serve the same user at the same site. MUS moves beyond these narrow sector boundaries and seeks to align water services with people's multiple needs for integrated water resources.

The challenge of bridging the gap between people's water needs and water service provision was taken up by the action research project, 'Models for implementing multiple-use water supply systems for enhanced land and water productivity, rural livelihoods and gender equity', supported by the CGIAR Challenge Program on Water and Food (CPWF). Envisaging multiple-use services as a promising new approach, the project expanded and deepened knowledge of what MUS is and could be in a range of different contexts. Its aims were twofold: identifying how MUS could best be implemented in communities and how MUS models identified in communities could be scaled up to ensure better services for, in principle, everybody.

Multiple uses from multiple sources versus single-use mandates

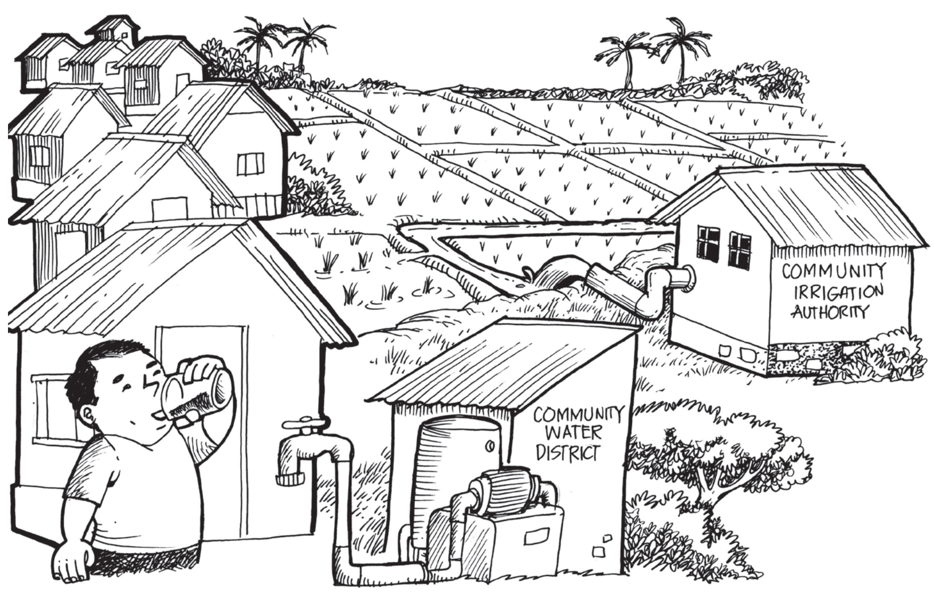
Water professionals have become increasingly aware over the past 20 years of the gap between their professional single end-use water system and the practice of communities. Their mandates to provide water services primarily for one single end use—domestic use, irrigation, livestock or fisheries—did not match the realities and water needs of their clients, who invariably used multiple water sources for multiple uses. Communities with diversified agriculture-based livelihoods depend in many ways upon water, especially in rural and peri-urban settings in low- and middle-income countries.

In contrast, water services are organized according to sub-sectors that carve out one single end use as a priority, if not an exclusive water use. This priority end use becomes the sub-sector's mandate. Mandates, in turn, greatly influence the entire structuring of the sector. This single-use view of water becomes a professional paradigm of how to perceive the world and act accordingly (Moriarty 2008).

Most notably in the domestic and irrigation sub-sectors, the single-use mandate is often linked to an assumption that there is one single site where this use takes place. Thus, the domestic sub-sector focuses on homesteads and sites as near as possible to homesteads.

The irrigation sector focuses on water end use by plants in fields. Once, these fields were assumed to be grouped into shared irrigation schemes. More recently, however, greater attention has been paid to irrigation and agricultural water management infrastructure used by individuals, including mechanized and manual groundwater pumps, water harvesting or soil moisture retention techniques. However, the question of whether these fields are near the homestead has received less attention.

Communities use water for an array of domestic and productive uses. To meet these needs, they often draw upon multiple sources of water. For them, it is obvious and normal to use water from multiple sources for multiple uses. Single uses, like rain-fed on mono-cropped fields, are the exception.



Indeed, all water sub-sectors focus on their particular end use, and no sub-sector holistically considers the entire 'water and landscape' picture in communities or sub-basins, with its spatial layout of multiple water sources, multiple users and multiple uses at various sites, the 'arenas in which humans interact with their environments on a kilometer-wide scale' (Coward 2008).

Added value of water services for domestic use and irrigation

Professionals became aware of the supply-use gap because they began to observe that systems designed for one single water use were used for multiple purposes in an unplanned way, and so became de facto multiple-use systems. 'Irrigation' systems are used for drinking, bathing, washing, cattle watering, small enterprises, fisheries or irrigation (Yoder 1983; Silliman and Lenton 1985, Meinzen-Dick 1997, Boelee *et al.* 1999, Renwick 2001).

Roads for monitoring canals became trading routes (Lee 2008). Systems planned for drinking water and other domestic uses are used for cattle watering, irrigation and a range of other small-scale productive uses (Lovell 2000, Moriarty *et al.* 2004). While some unplanned uses were absorbed by the system, others caused damage to infrastructure or deregulated planned water allocation schedules. However, measures to prevent unplanned uses, (e.g., forbidding and declaring those uses as 'illegal)', were ineffective.

Professionals started to appreciate the improvements that these unplanned uses brought to all four main water-related dimensions of livelihood well-being: freedom from drudgery, health, food production, and income. For uses that did not damage infrastructure, these livelihood benefits came at no cost other than the changing perspectives of water professionals.

Academics from both the domestic and irrigation sub-sectors corroborated the benefits of this new perspective. Various studies were undertaken to assess the 'added' value of benefits from unplanned uses (Meinzen-Dick 1997, Perez de Mendiguren 2004, Renwick *et al.* 2007). The health and hygiene benefits of using irrigation water for domestic uses received particular attention (Meinzen-Dick 1997, Van der Hoek *et al.* 2001, Boelee *et al.* 2007, Renwick *et al.* 2007).

"First you would see someone irrigating some tomatoes, and you would say that he is wasting water. Now, you see the same situation, but from the perspective of the user, and you would say that he is making good and economical use of water" (Johny Hernández, technician from Honduras).

Armed with this new understanding, the sub-sectors started proactively enhancing accessibility to water with the double aim of stimulating the livelihood benefits and avoiding damage and disturbance to the systems. They adapted their designs with 'add-ons'. Irrigation designers constructed washing steps or cattle entry points in irrigation canals. To encourage fisheries and other aquaculture, connectivity was improved and dead storage (below which water would not run off) guaranteed in reservoirs, streams and even at field level for crop-fish systems, where a crop such as rice can be grown and fin fish or prawns farmed in the same field (Nguyen-Khoa *et al.* 2005). Domestic systems were equipped with cattle troughs, washing slabs, and sometimes a communal garden. In these ways, for limited extra cost, the uses and corresponding livelihood benefits were augmented. Water services that maintain the primary mission of their own sector but accommodate uses beyond the sector's mandate are called 'irrigation-plus' or 'domestic-plus' water services (Van Koppen *et al.* 2006).

Towards multiple-use water services

Despite this trend towards recognizing the benefits from multiple use, there was hardly any cross-sectoral collaboration until the early 2000s. Each sub-sector tried to address other uses within its own domain. Gradually, realization grew that many more opportunities for better service delivery could be unlocked through a more comprehensive approach to the planning and design of new or rehabilitated infrastructure. The logical next step was taken. Practitioners and researchers from both the domestic and irrigation sub-sectors innovated and collaborated in a global endeavor to achieve 'multiple-use water services' or 'MUS'.

Understanding MUS and its emphasis on water services

MUS is a participatory, integrated and poverty-reduction-focused approach in poor rural and peri-urban areas, which takes people's multiple water needs as a starting point for providing integrated services, moving beyond the conventional sectoral barriers of the domestic and productive sectors (Van Koppen *et al.* 2006).

The 'S' in MUS stands for 'services' because the overarching goal was to unlock new potentials for better services by governmental, non-governmental and private water service providers for improved multi-faceted livelihoods in peri-urban and rural areas. MUS is about services for people rather than particular water systems. A 'water service' is defined as 'the sustainable provision of water of a given quality and quantity at a given place with predictability and reliability'. Services have hardware and software components.

Linkages to other services that enhance the benefits of water use, such as hygiene education or marketing support, are other important components. Services are not time- and location-specific 'projects' that close after an infrastructure construction or rehabilitation phase. Services are continuous and cater to post-construction technical and institutional support. Services imply accessibility to everybody, in principle; MUS should

Hardware components of water services concern infrastructure or technology–and include issues such as technology availability, spare parts, engineering skills, or water resource assessments. Software refers to all the non-hardware related issues, such as support for institution building (leadership, rule setting and enforcement), water allocation and conflict resolution.

certainly reach the poor and the marginalized. Multiple-use water 'services' refer to this sustainable holistic supportive environment to meet people's multiple water needs.

Government and NGOs in particular can invest in expensive infrastructure often with longer term benefits. They can act as a utility, facilitator, catalyst, innovator, loan provider or a combination of these. Government agencies are key for scaling up because they have a mandate to reach all citizens. Government is also in the best position to provide after-care support to ensure that projects become services. Moreover, most international water agencies and rural development organizations work through governments. While governmental line agencies tend to specialize and provide compartmentalized support, local government has the mandate to integrate services.

Conclusion

For services to be sustainable and to reach everyone, a range of stakeholders must fulfill various complementary roles. The actors in this supportive environment are the various water service provider groups: users, NGOs, domestic sub-sector, productive sub-sector, local government, and knowledge centers. Support is enhanced by searching for complementarities and synergies that lead to ever more robust networks of relationships of trust between beneficiaries or clients and service providers.

Contact Persons

Barbara van Koppen (b.vankoppen@cgiar.org), Stef Smits, Patrick Moriarty, Frits Penning de Vries, Monique Mikhail, Eline Boelee

Partner Organizations

Association for Water and Rural Development, South Africa
Catholic Relief Services, Ethiopia
Centro Andino para la Gestion y Uso de Agua, Bolivia
Instituto Cinara de la Universidad del Valle en Cali, Colombia
International Development Enterprises
International Water Management Institute
IRC International Water and Sanitation Centre, the Netherlands
Khon Kaen University, Thailand
Mekelle University, Ethiopia
Mvuramanzi Trust, Zimbabwe
The Institute for Water and Sanitation Development, Zimbabwe

Key Reference

van Koppen, B., S. Smits, P. Moriarty, F. Penning de Vries, M. Mikhailand E. Boelee 2009. *Climbing the water ladder: Multiple-use water services for poverty reduction.* TP Series No. 52. The Hague, The Netherlands, IRC International Water and Sanitation Centre and International Water Management Institute.

Tags: PN28: Multiple Water Use

Bibliography

Boelee, E.; H. Laamrani and W. Van der Hoek 2007. Multiple use of irrigation water for improved health in dry regions of Africa and South-Asia. *Irrigation and Drainage*, **56**, 43-51.

Boelee, E.; H. Laamrani, K. Khallaayoune and S. Watts 1999. Domestic water use in Morocco's Tessaout Amont irrigation system. *Waterlines,* **18**, 21-23.

Coward, Jr., E.W. 2008. *Property landscapes in motion.* Keynote address to the International Association for the Study of Common Property, 11th Biennial Global Conference, Bali, Indonesia, June 2006. Retrieved from: www.iascp.org

Lee, P. 2008. Responding to increases in food prices. 2008 World Atlas and industry guide. International Journal on Hydropower and Dams.

Lovell, C. 2000. *Productive water points in dryland areas : guidelines on integrated planning for rural water supply.* London, UK: ITDG Publishing.

Meinzen-Dick, R. 1997. Valuing the multiple uses of water. In: Water : *economics, management and demand,* eds. M. Kay, T. Franks and L. Smith; 50-58. London, UK: E&FN Spon.

Moriarty, P. 2008. Multiple use services : a new paradigm for water service provision?' In: *Multiple-use services. Proceedings of an international symposium,* Addis Ababa, Ethiopia, 4-6 Nov 2008, eds. J. Butterworth, M. Keijzer, I. Smout and F. Hagos.

Bibliography

Moriarty, P., J. Butterworth and B. van Koppen (eds). 2004. *Beyond domestic: case studies on poverty and productive uses of water at the household level.* IRC Technical Paper No. 41. Delft, the Netherlands: IRC.

Moriarty, P., C. Fonseca, S. Smits, and T. Schouten 2005. *Background paper for the symposium on learning alliances for scaling up innovative approaches in the water and sanitation sector*. Delft, the Netherlands:, IRC.

Multiple Use Water Services (MUS) Group. Retrieved from: http://www.musgroup.net/

Nguyen-Khoa, S.; L. Smith and K. Lorenzen 2005. *Impacts of irrigation on inland fisheries: appraisals in Laos and Sri Lanka.* Comprehensive Assessment Research Report 7. Colombo, Sri Lanka: Comprehensive Assessment Secretariat.

Perez de Mendiguren Castresana, J.C. 2004. Productive uses of water at the household level: evidence from Bushbuckridge, South Africa. In: Beyond domestic: case studies on poverty and productive uses of water at the household level, eds. P. Moriarty, J. Butterworth and B. van Koppen. Delft, the Netherlands: IRC.

Renwick, M. et al. 2007. *Multiple use water services for the poor: assessing the state of knowledge.* Arlington, VA, USA: Winrock International.

Renwick, M.E. 2001. Valuing water in a multiple-use irrigation system: *irrigated agriculture and reservoir fisheries. Irrigation & Drainage Systems,* 15, 149-171.

Renwick, M.E. 2001. *Valuing water in irrigated agriculture and reservoir fisheries: a multiple-use irrigation system in Sri Lanka*. IWMI Research Report 51. Colombo, Sri Lanka: International Water Management Institute. (Research Report 51).

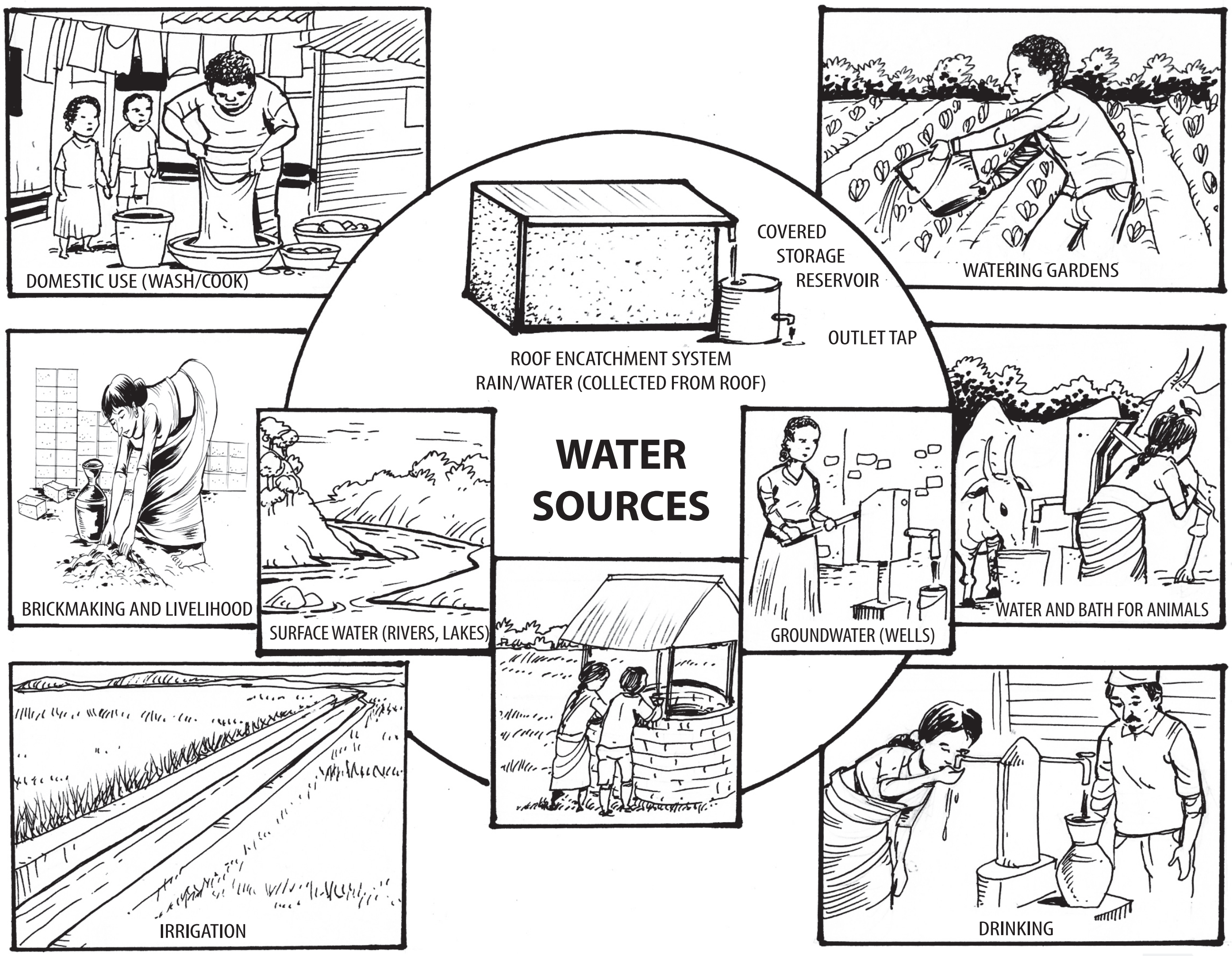
Silliman, J. and R. Lenton 1985. Irrigation and the land-poor. In: Water and water policy in world food supplies. Conference Proceedings, Texas, USA, 26-30 May 26, ed. W.R. Jordan. Texas A&M University Press.

Smit, J.; A. Ratta and J. Nasr 1996. Urban agriculture : food, jobs and sustainable cities. In: *Learning alliances : scaling up innovations in water, sanitation and hygiene,* eds. S. Smits, P. Moriarty and C. Sijbesma, C. Delft, The Netherlands, IRC.

van Koppen, B., P. Moriarty and E. Boelee 2006. *Multiple use water services to advance the Millennium Development Goals.* IWMI Research Report 98. Colombo, Sri Lanka, International Water Management Institute.

Yoder, R. 1983. *Non-agricultural uses of irrigation systems : past experience and implications for planning and design.* ODI Network Paper 7. London, UK: Overseas Development Institute.

Five Principles for Multiple-Use Services at the Household and Community Levels



People, especially families in rural and peri-urban areas, have different uses for water. Aside from domestic and irrigation purposes, they need water for their farm animals, fishponds, home gardens, off-farm livelihood/enterprises, and for ceremonies. Multiple sources of water—groundwater, surface water, wetlands, springs and rain—are tapped to meet these different needs. Adoption of multiple-use water services (MUS) can improve access to water for more users in a more sustainable manner. The approach recognizes that poor rural households use available public water infrastructure, which is often designed for single uses only, to meet all their water needs.

The services of the water sector and subsectors can be re-designed to provide for both the domestic and productive uses of water required at the homestead level. This is the experience suggested by the CGIAR Challenge Program on Water and

Food (CPWF) Multiple-Use Water Services (MUS) Project. For the domestic water use sector, this means expanding its service to include use of water for homestead-scale productive activities. For the productive use water subsector (the irrigation sector), this entails expansion of its services to include supply of water for domestic and other non-irrigation uses.

Conventional single-use systems

Planning and design of water services in rural and peri-urban areas are still not based on people's multiple needs because the water sector is organized for single-use systems. Public water services are sectoral and top-down. Water services are divided into domestic and productive sectors—e.g., irrigation, fisheries and aquaculture, and so on. Each sector adopts a "single-use planning approach" where infrastructure is designed for a particular use. Each sector also assumes that the other sectors take care of the other needs of their clients. This sectoral approach works in urban and industrialized settings but not in the case of poor rural communities. The poor use water for multiple purposes and access water from multiple sources.

Rural domestic water supply services normally provide 25 to 50 liters of clean water per capita for drinking, cooking and sanitation only. They seek to reach everybody. However, though limited, water from these supply services is also used for productive and income-generating purposes. If people can earn from using domestic water, then they may be better able to pay fees to recover costs of and sustain water system facilities designed for multiple use. On the other hand, projects on irrigation do not usually supply 100% of their coverage area and hardly target poor households. They also tend to ignore productive activities around the home. This contributes to the further marginalization of women in poor households who depend on water for both domestic and productive activities around the home.

Adoption of multiple-use water supply services is therefore urgent. It addresses the multiple water use needs of the poor and contributes to the increase of health and wealth. This may improve their willingness and ability to pay for the use and sustained operation and maintenance of the multiple-use water supply systems.

A need for a multiple-use water services approach

The MUS approach cuts across national, community and household levels. Understanding how it works at household and community levels is the focus of this article. In particular, experiences with two MUS models are presented—homestead and community scales. Homestead-scale MUS promotes access to water at and around homesteads for domestic and productive purposes to improve the health, food security and income of families. Community-scale MUS is a holistic approach that takes the community as an entry point and considers and integrates all uses, users, sites of use, water resources,

The multiple-use water services (MUS) is an approach to water services where the design starts with recognizing and planning for people's multiple water needs. It is the sum of the institutions, services, resources, and infrastructure that allows communities to effectively and inclusively manage their water resources for domestic and productive uses. MUS is one particular form of integrated water resource management.
- *Merrey* et al. *2005*

infrastructure and economies of scale in the design of water systems for multiple uses.

The five MUS principles

MUS applies for new construction and rehabilitation. For MUS to work, public service providers ensure that the following set of conditions or 'principles' is in place (Figure 1):

- water-related livelihoods as driver of services
- sustainable use of water resources
- use of appropriate technologies designed for multiple uses
- inclusive institutions that involve the poor in planning and managing the system
- adequate financing

1. **Water services should aim to achieve multi-faceted livelihood benefits from MUS.** This is the driving principle in MUS. It emphasizes the need for and the planning of services based on a thorough understanding of the multiple roles of water in people's livelihoods, especially those of the poor men and women. Improved health, income, food for the family and freedom from domestic chores are some of the benefits derived from MUS.

2. **MUS always strive for sustainable water use.** This refers to the efficient, equitable and sustainable development and management of

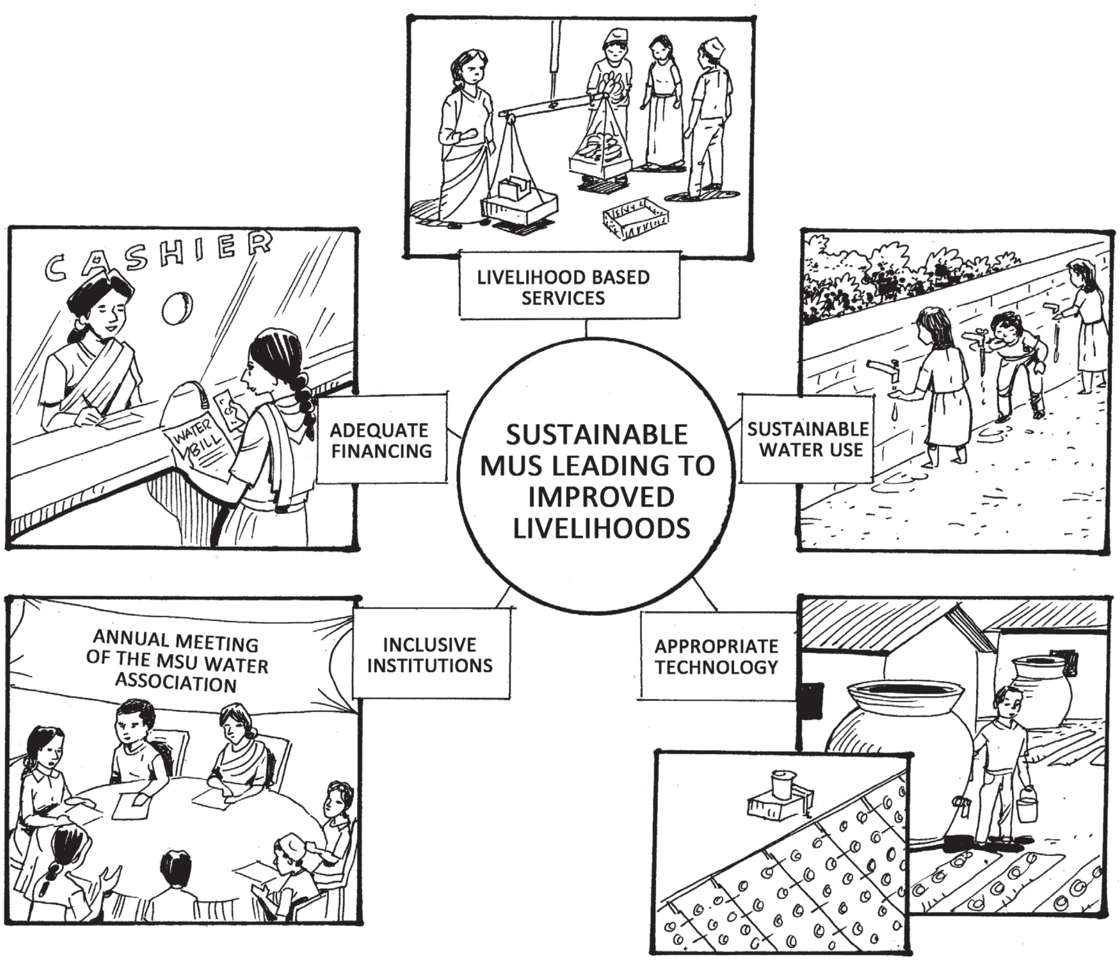


Figure 1. The five MUS principles

naturally available water resources, be it from rainfall, groundwater, surface lakes and streams, springs, wetlands or big and small reservoirs. This includes the use and re-use of water from multiple and conjunctive sources to meet multiple needs.

3. **Selection and use of technologies are based on people's needs and abilities.**
   This considers technologies to tap, store, distribute, protect and treat water for multiple uses. Among others, this involves re-assembling existing technologies to allows for multiple uses and mitigate health risks, taking into consideration users' preferences and ability and willingness to pay for the services. This also improves women's access to technologies and breaks taboos against women's control over water technologies and resources.

4. **MUS go for informed decision making and transparent management by institutions that involve the poor.**
   Under this principle, inclusive community-based water institutions are integrated and built on existing water arrangements to holistically govern conjunctive water resources. The unified water institutions may be one institution or different institutions with effective coordination mechanisms.

5. **MUS financing matches people's ability and willingness to pay.**
   Adequate financing of MUS includes enhancing its cost recovery by making end users pay including the poor. The MUS should ensure improved access to the service that is not too costly for the poor. Where appropriate, differential service levels and well-targeted subsidies are introduced.

Women and the landless poor who only have access to homestead land for their productive activities will benefit the most from homestead-scale MUS.

Types of MUS

Homestead-scale MUS. The link between the given level of water available and the uses and livelihoods that may be derived from it is described in the "multiple-use water ladder" (Figure 2). The ladder allows planners to analyze how different technology options can be used to provide a certain level of access. Studies recommend that the poor should be able to climb the water ladder—i.e., able to access 50 to 200 liters per capita per day. Of this, at least 3.5 liters should be safe for drinking and the rest for productive and other domestic uses. Research showed that homestead-scale MUS allow recovering investments within 3 years.

Community-scale MUS. This model takes the communities as the entry point for water services. Its design considers multiple water uses (domestic, irrigation for crops and trees, water for livestock, enterprises, and ceremonies) from multiple water sources (rain, surface water, wetlands and groundwater) at multiple sites (homestead, fields, open access). This is more efficient and sustainable than single-use water systems for at least four reasons:

1. More cost-effective infrastructure investments than single-use infrastructure: Small incremental investments generate substantive livelihood benefits. One multiple-use scheme is cheaper than two separate single-use ones.

2. Enhances water efficiency by combining the multiple water sources and re-use of water at different levels.

3. Improves water quality at the appropriate level, e.g., treatment for drinking water.

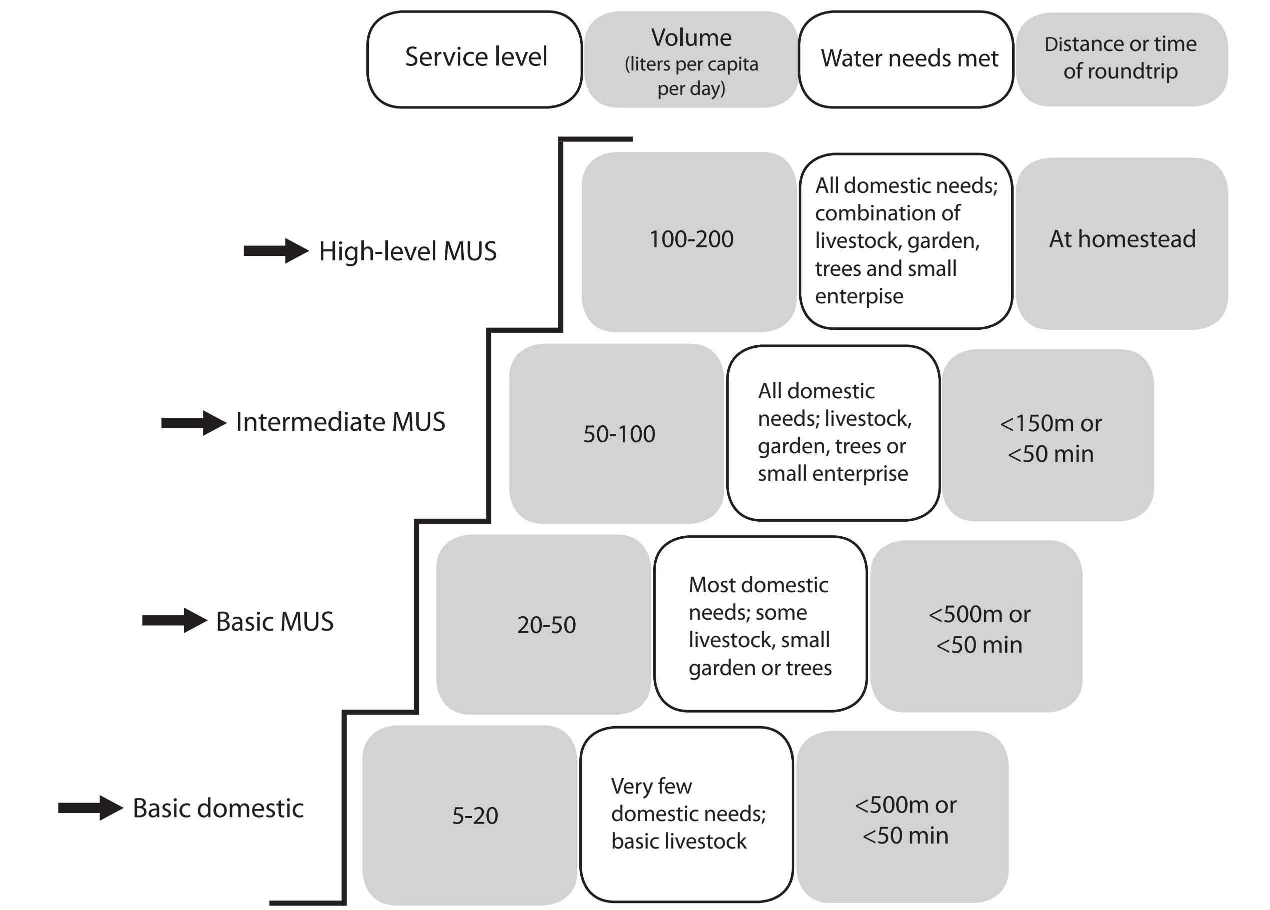


Figure 2. The Multiple-Use Water Ladder

4. Empowers communities by building on local and existing water management arrangements that are intrinsically holistic and already adopted for multiple uses.

Key findings

Regarding the five MUS principles, the following are some of the findings:

1. Water is only one of the contributing factors to livelihoods. Education training and, support for marketing are others. However, water is a very important resource that is always taken up by a significant portion of the community.

2. A key livelihood issue is intra-community allocation of public support: Whose livelihoods are to be improved? Whose preferences are followed in selecting sites of use and uses? Are there options for differential service delivery so that those who can pay do pay?

3. In planning for community-scale MUS, women, the poor and the sick are likely to prioritize homestead-scale MUS over field irrigation. Assessment tools such as Resource-Infrastructure-Demand-Access (RIDA) are important so that men and women recognize the importance of domestic water uses, besides productive uses.

4. Technologies already exist to provide different levels of access to homestead-scale MUS.

Technologies such as homestead wells, boreholes and rainwater and run-off harvesting and storage can often easily provide at least 50-100 liters per capita per day requirement at the household level.

5. The technical design from a MUS perspective becomes more efficient at the community scale. Multiple sources can be combined and economies of scale become an advantage.

6. Promoting multiple uses by multiple users and participatory process do not necessarily add to institutional complexity in managing MUS. This is because people with multiple needs have multiple interests. Single-use approaches split up people's interests. Also, *de facto* multiple uses exist. MUS becomes manageable by making existing practices transparent.

7. Investment costs for homestead-scale MUS are slightly higher than conventional domestic services. However, the potential income from productive water uses, estimated at USD 100-500 per year, implies favorable benefit-cost ratios. Investments made to climb to intermediate MUS can often be repaid within 6-36 months.

Lessons learned

Important lessons from the implementation of MUS projects occured at three levels – household, water systems and institutions. These are summarized below:

- **Productive use of water at the household level reduces poverty.** MUS cannot eliminate poverty per se. Productive use of water through MUS helps poor households diversify livelihoods, earn additional income, provide access to high-quality food and empower women.

The CGIAR Challenge Program on Water and Food Multiple-Use Water Services (MUS) project study on over 7,000 households in eight countries showed that MUS brings various benefits, including contributions to:

- **Meeting the basic needs for good health, food security and income.**
- **Adapting to the outside environment—i.e., greater resilience against shocks, extreme droughts and floods; fluctuations in food prices, market and employment opportunities.**
- **Improving household net income—Households in MUS on average earn USD100 to 500 per year higher than households with single-use water.**
- **Women's empowerment through reduction in time spent on domestic chores and increased livelihood opportunities/benefits.**

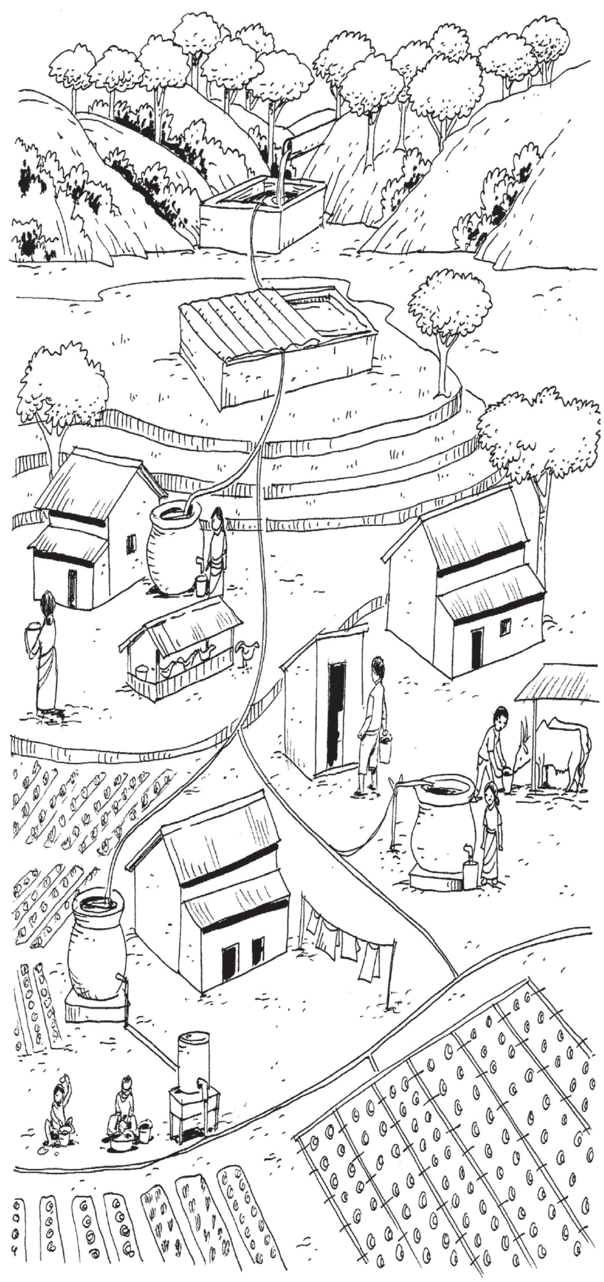
Multiple-use water services in the interest of the poor stand for: water services planning and design that take people's multiple water needs as a starting point. The challenge is how to engender the changes required in the water sector to make such multiple-use services a reality.
- van Koppen et al. 2006.

- **People require more than their domestic water needs to be productive.** Productive use of domestic water happens even when people have less than 25 liters per capita per day. However, for productive uses to take place at a significant scale, at least 40-100 liters per capita per day are needed.

- **People need local solutions and multiple sources for multiple uses.** Within the water user groups, there is considerable initiative for self-help MUS where communities seek to meet multiple needs from multiple sources. However, the poor and other marginalized groups risk being excluded from this self-initiated search for support. Collaboration with user groups to specifically target the poor and the marginalized should thus be at the heart of MUS.

- **An integrated approach is essential to achieve significant impacts on poverty.** To work in an integrated manner across sectors does not mean that the provision of MUS cannot already start from within the sectoral agencies. Of 20 irrigation systems examined in a study, 18 were already considering multiple uses of water. Integration of players from outside the water sector, such as those in marketing or hygiene education, needs attention.

- **NGOs are MUS innovators even before CPWF-MUS.** NGOs are often area-specific and have limited reach. They may depart at some stage, leaving the systems without after-care. To overcome these weaknesses, NGOs must proactively collaborate with local governments on a range of issues—e.g., ensuring long-term support after project closure and scaling up of successful innovations like MUS at the district and higher aggregate levels.



MUS in Nepal: A tank is connected to hybrid taps where domestic water is collected and a hose attached to one of the taps to fill up a drip irrigation header tank. (Mikhail and Yoder 2008.)

Contact Person

Barbara van Koppen (b.vankoppen@cgiar.org)

Partner Organizations

Association for Water and Rural Development, South Africa
Catholic Relief Services, Ethiopia
Centro Andino para la Gestion y Uso de Agua, Bolivia
Instituto Cinara de la Universidad del Valle en Cali, Colombia
International Development Enterprises
International Water Management Institute
IRC International Water and Sanitation Centre, the Netherlands
Khon Kaen University, Thailand
Mekelle University, Ethiopia
Mvuramanzi Trust, Zimbabwe
The Institute for Water and Sanitation Development, Zimbabwe

Key Reference

van Koppen, B., S. Smits, P. Moriarty, F. Penning de Vries, F., M. Mikhail and E. Boelee 2009. *The multiple-use water services (MUS) project.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3902

Tags: PN28; Multiple Water Use

Bibliography

Merrey, D.J., P. Drechsel, F.W.T. Penning de Vries and H. Sally 2005. Integrating "livelihoods" into integrated water resources management: taking the next integration paradigm to its logical next step for developing countries. *Regional Environmental Change*, **5**, 197-204.

Mikhail, M. and R. Yoder 2008. *Multiple-use water services implementation in Nepal and India: Experience and lessons for scale-up*. International Development Enterprises, CGIAR Challenge Program on Water and Food, and International Water Management Institute.

Multiple-use water services group. Retrieved from http://www.musgroup.net/page/836.

van Koppen, B., P. Moriarty and E. Boelee 2006. *Multiple-use water services to advance the Millennium Development Goals.* Research Report 98: Colombo, Sri Lanka: International Water Management Institute.

van Koppen, B., S. Smits, P. Moriarty, F. Penning de Vries, M. Mikhail and E. Boelee 2009. *Climbing the water ladder: Multiple-use water services for poverty reduction*. The Hague, the Netherlands: IRC International Water and Sanitation Centre, and International Water Management Institute.

Learning to Implement and Scale-Up Multiple-Use Water Services at the Community Level

Multiple users take water from multiple sources and use and reuse it for multiple purposes. This is the reality for rural and peri-urban water users. Moreover, infrastructure designed for single use is used for multiple purposes by communities at the local level.

At the national or basin level, water managers are aware of the integrated nature of water resources and their multiple sources, uses and users. However, this is not the case at the community and household levels. At these levels, water managers carve out a particular end-use, which becomes the mandate and structuring principle of the entire water sector. Other uses, even by the same users taking water from the same source, are ignored. In addition, existing and often informal forms of storage, conveyance and use at homesteads and at the community or sub-basin level are often overlooked in externally supported water development and storage. This is the gap that the action research project, 'Multiple-Use Water

Services (MUS),' project under the CGIAR Challenge Program on Water and Food (CPWF), addressed.

The project developed and tested homestead-scale and community-scale MUS models in 30 rural and peri-urban sites in eight countries in five basins. This approach to water services takes the water needs of rural and peri-urban communities as the starting point for planning and designing new systems or for rehabilitation of older systems. By addressing the barriers often posed by sectoral approaches, MUS brings more benefits (food, health, income, ease of drudgery) than single-use approaches.

Objectives

The objectives across all sites were

- to establish generic, field-tested and convincing models of MUS at household and community levels; and

- to widely scale up these models in order to reach, ultimately, all rural and peri-urban people with water services that meet both domestic and water needs.

Process

1. Key partners who were pioneering MUS at that time were brought together. Partners were from the four main categories of water service providers: water users with self-supply, private providers, NGOs and government. It was important to include representatives from the domestic and productive water sectors, scientists and implementers.

2. Each global partner chose their national and intermediate level partner according to the criterion of being an MUS innovator and selected sites for case studies.

3. Thirty study areas were selected, each covering either one or more communities or groups of adopters of similar technology. The three main technology groups were the following: private homestead-based technologies, communal systems with single-access points and communal systems with distribution networks to public standpipes or homesteads. This selection process ensured a wide diversity of partners and contexts that explored diverse perspectives on MUS.

4. In each country, the national MUS partner forged horizontal and vertical exchanges with other water service providers in the local study area and at the intermediate, national and global levels. These exchanges, by 'learning alliances,' were able to raise awareness about the MUS models. Through 'learning by doing,' they induced institutional changes, creating an enabling environment at the intermediate, national and global levels that responds adequately to the community's multiple water needs. This enabling environment also ensures its continuity beyond the life of the project.

Lessons learned

Models for community-level MUS

- With regard to principles of livelihood-based services and affordable technologies, a strong linkage exists between levels of people's multiple water uses for livelihoods at and around homesteads and water availability as captured, conveyed and stored through technologies. This linkage is shown in Table 1.

Table 1. Relationship between technologies and water use in selected study areas

Country	**Technology**	**Range of average daily availability of water (liters per capita per day)**	**Level**
Ethiopia	Communal piped systems with very scattered standpipes	8-17	Basic domestic
South Africa	Communal piped systems with scattered standpipes	30	Basic MUS
India	Communal piped systems with frequent standpipes	40 (design supply)	Basic MUS
Zimbabwe	a. Communal boreholes with hand pumps b. Individual shallow wells with windlass and buckets c. Individual shallow wells with rope-and-washer pumps	a. 10-15 b. 60-70 c. 80-90	a. Basic domestic b. Intermediate MUS c. Intermediate MUS
Bolivia	a. Tankers b. Piped distribution systems with household connections	a. 30-40 b. 60-80, with exceptions up to 140	
Nepal	Communal piped systems with frequent standpipes	137-225 (design supplies)	
Colombia	a. Communal piped systems with household connections (rural communities) b. Communal piped systems with household connections (peri-urban communities)	a. 190-250, with some cases much higher b. 76-118	a. High MUS b. Intermediate MUS
Thailand	Farms with ponds and other sources	80-1,000	Intermediate to high MUS

Source: CPWF Multiple-Use Water Services Project

Water-dependent productive activities that increase in number and in size with higher water availability include small and large livestock keeping; trees, crop and vegetable irrigation; craft-making and other enterprises. This confirms the project's hypothesized multiple-use water ladder.

- In terms of policy implications, the water services that aim to meet people's livelihood needs at and around homesteads should be double or triple the conventional design norms in the domestic sector [20-30 liters per capita per day (lpcd) for domestic uses only for Sub-Saharan Africa or South Asia]. Instead, 50-100 lpcd or more is required to ensure that services meet people's livelihood needs, so they can 'climb the multiple-use water ladder.'

- Increasing water availability requires incremental expansion of one type of technology or further combinations. Such incremental investments make economic sense, especially for intermediate-level MUS (50-100 lpcd).

- With regard to other principles (financing arrangements, equitable institutions and water resource availability), many challenges faced are similar to those in conventional domestic or productive water services. One unique feature of MUS, however, concerns equity notions of water sharing under scarcity. Homestead-based multiple-uses are small-scale compared with relatively few large users, most of whom use water beyond homesteads. Under scarcity, basic domestic needs should be prioritized and, after that, minimum water supplies for both domestic and small-scale productive uses should be made available. Putting in place policy and institutional and technical measures within communal systems lessens the chance that people will overuse the resource.

- When moving from homestead to community-level water development, synergies can be forged if river intakes, storage and conveyance structures are holistically designed and incrementally improved for shared water provision, whether to homesteads or fields.

Innovation and scaling up: creating a supportive environment for MUS

- At the intermediate, national and global levels, project partners initiated learning alliances that create an enabling environment for MUS.

- In all countries, the visible and documented successful performance of community-level MUS, in sufficient numbers to allow for some generic validity, appears vital for creating awareness creation.

- There are many differences between the learning alliance processes in the respective countries. The strengths and weaknesses in realizing the three principles for scaling up MUS at the intermediate level, from the perspective of each of the water service provider categories, are given in Table 2.

Conclusion and recommendation

The MUS project identified and tested new models for meeting the multiple water needs of people in rural and peri-urban areas. These multiple-use water services improve health, access to food and income more effectively than conventional single-use water development. Previously counter-productive bureaucratic water sectors started

Table 2. Strengths and weaknesses in realizing principles for scaling up MUS, by category of water service providers

Category of water service provider	Principles for scaling up at intermediate level		
	Participatory planning	**Coordinated long-term support**	**Strategic planning for scaling up**
Self-supply **Thailand** (Farmer Wisdom Network) **South Africa** (Water for Food Movement)	Multiple water needs obvious; High own contributions in cash and kind; Own experimenting, mutual learning and knowledge generation	Expansion based on mutual help with limited resources; Need-based soliciting of external support; Sustainability of movement uncertain	Strategic alliances at highest policy levels for influencing policy and support for roll-out
Private service provider **Bolivia** (Agua Tuya)	Multiple water needs obvious; Market-driven	Providing holistic support for higher sales; Private business' outlook of medium-term growth	Market-driven roll-out limited; Linking with municipality
NGOs **Ethiopia** (CRS) **Nepal** (IDE) **Zimbabwe** (various)	Responsive to multiple water needs; High own contributions to market-driven technological innovation, but otherwise limited	Poverty relief or technological innovation driving coordinated support for multiple water uses; Short-term, project-bound	Strategic alliances with local service providers and government at all levels for uptake of innovations and sustainable after-care of technologies
Government/ parastatal domestic sector **Colombia** (with university) **India** (with NGO)	Top-down, single-use and single-site planning; Unable to prevent de facto multiple-uses; Limited contributions by users	Supporting single domestic use at homesteads only; Short-term, project-bound	Lobbying at national level to increase design norms and address water quality issues; Awareness raising about livelihood benefits of de facto multiple-uses; Promoting immediate multiple-uses of domestic services planned for future expansion
Government productive sector (some Learning Alliance members)	Top-down, single-use planning biased to large-scale systems; Unable to prevent de facto multiple-uses; Limited contributions by users	Prioritizing a single productive use with add-ons for better access to other uses; Short-term, project-bound	Lobbying at national level to support small-scale productive uses at homesteads; Awareness raising about livelihood benefits of de facto multiple-uses; Promoting efficient productive water use (drip kits)

Source: CPWF Multiple-Use Water Services Project working together towards one common agenda: to plan and design new systems or rehabilitate existing ones, according to people's multiple water needs at preferred sites, providing a minimum of 50-100 lpcd to homesteads. At the level of one or more communities, communal abstraction, conveyance and storage are embedded in a holistic spatial layout.

Further research is recommended on health impacts, point-of-use water treatment, synergies and conflicts regarding specific uses of water (e.g., increasing productivity of water or market linkages). Such new research should support the common agenda of multiple water uses and not replace it by systems designed for a single end-use at one specific site.

Contact Persons

Barbara van Koppen (b.vankoppen@cgiar.org)

Partner Organization

International Water and Sanitation Centre, the Netherlands
International Water Management Institute

Key References

Koppen, B., S. van, Smits, P. Moriarty, F. Penning de Vries, M. Mikhail and E. Boelee. 2009. *The multiple-use water services (MUS) project.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3902

van Koppen, B., S. Smits, P. Moriarty and F. Penning de Vries 2008. Community-level multiple-use water services: MUS to climb the water ladder. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food,* Vol.2, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 217-221. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: PN28: Multiple Water Use

Bibliography

van Koppen, B., P. Moriarty, and E. Boelee 2006. *Multiple-use water services to advance the Millennium Development Goals.* IWMI Research Report 98. Colombo, Sri Lanka: International Water Management Institute, Challenge Program on Water and Food, and International Water and Sanitation Center (IRC).

van Koppen, B. and I.Hussain 2007. Irrigation, Gender, and Poverty: Overview of Issues and Options. *Journal of Irrigation and Drainage,* **56**, 289-298.

Renwick, M. 2007. *Multiple use water services for the poor: assessing the state of knowledge.* Winrock International, IRC Water and Sanitation Centre, International Water Management Institute www.winrockwater.org

Health and Water Quality

Simple Solutions to Reduce Health Risks from the Use of Wastewater in Urban and Peri-Urban Agriculture

Urban and peri-urban agriculture (UPA) is becoming an important means of attaining balanced diets and urban food security. Vegetables produced close to consumers will be fresher, with nutrients more intact than those stored and transported for long periods of time. This is especially important in sub-Saharan Africa, where refrigerated transport and storage are scarce. UPA also creates jobs for the poor, especially women, and is an effective way to overcome poverty (Cofie *et al.* 2003). Use of wastewater in UPA lessens the pressure on water resources and increases water productivity through the re-use of water and nutrients. However, the use of untreated wastewater raises public health concerns. The two interlinked CGIAR Challenge Program on Water and Food (CPWF) projects: "Safeguarding Public Health Concerns, Livelihoods and Productivity in Wastewater Irrigated Urban and Peri-Urban Vegetable Farming" and "The Impact of Wastewater Irrigation on Human Health and Food Safety Among Urban Communities in the Volta Basin – Opportunities and Risks" and their partners sought to balance livelihood concerns with safeguarding public health. The projects also aimed at contributing to the revision of the World Health Organization's (WHO) guidelines on wastewater irrigation, issued in 1989, especially where compliance with norms is not possible. In addition, they considered postharvest measures to reduce the health risks of diverse wastewater-irrigated crop production systems. The generic framework was robust in handling conditions ranging from extensive grazing systems to intensive mixed crop-livestock systems at local, watershed and basin scales.

Risks mount in UPA with untreated wastewater

- Untreated wastewater has high levels of pathogenic organisms. Thus, its use may adversely affect the health of consumers, farmers and the environment.
- Effective wastewater treatment can reduce pathogen levels, but, in most developing countries, it is too expensive (Keraita *et al.* 2002). Furthermore, the payback period for investing in wasterwater treatment exceeds the infrastructure's economic lifetime (Bos *et al.* 2004).
- Banning the use of polluted water in UPA threatens many livelihoods and the urban vegetable supply, which contradicts strategies to alleviate poverty.
- Inspite of its significant contributions to urban food supply, poverty alleviation, empowerment of women, and improved human nutrition, UPA has no appropriate public or institutional support in Ghana or many other West African countries. This is mainly because of the health risks posed by UPA due to high levels of fecal contamination in irrigation water.

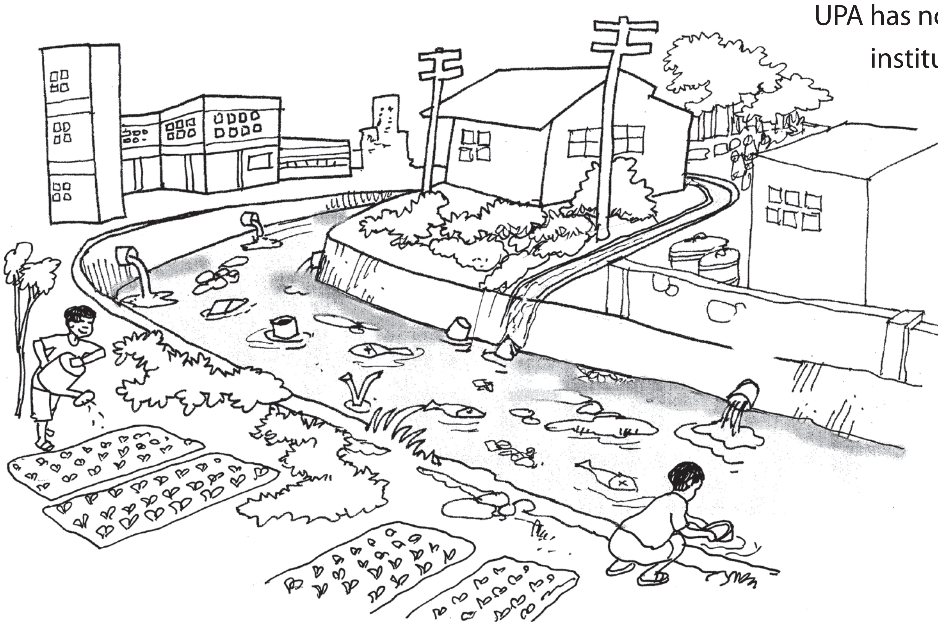
How important is peri-urban agriculture?

Urban and peri-urban agriculture (UPA) contributes about 30% of the world's food supply (UNDP 1996).

In several African cities, between 50 and 90% of the vegetables consumed are produced within or close to the cities (Cofie *et al.* 2003)

In many African countries, 65% of the people involved in UPA as farmers or traders are women.

Around Kumasi, Ghana, more than 12,000 farmers are involved in vegetable farming during the dry season and urban farmers grow 90% of the main vegetables eaten in the city (Cornish *et al.* 2001).



Realistic solutions from action research

Partners used an action research approach to systematically find solutions for safer wastewater irrigation (Figure 1).

Determine what has been done and what can be used. A literature review from related initiatives was done to find out what worked and could be adopted in the action research framework. For example, reports on low-cost farm measures and vegetable washing methods were used to develop risk reduction interventions.

Confirm and validate what is current and acceptable practice. Surveys and focus group discussions (FGDs) were done to identify current practices and situations. This was followed by interviews of individual farmers to determine the acceptability and feasibility of adopting practices to reduce health risks.

Establish the science, provide the proof. Soil, water and vegetable samples were analyzed for helminth eggs, fecal coliform bacteria, and traces of pesticides. The data from the analysis were used to assess health risks.

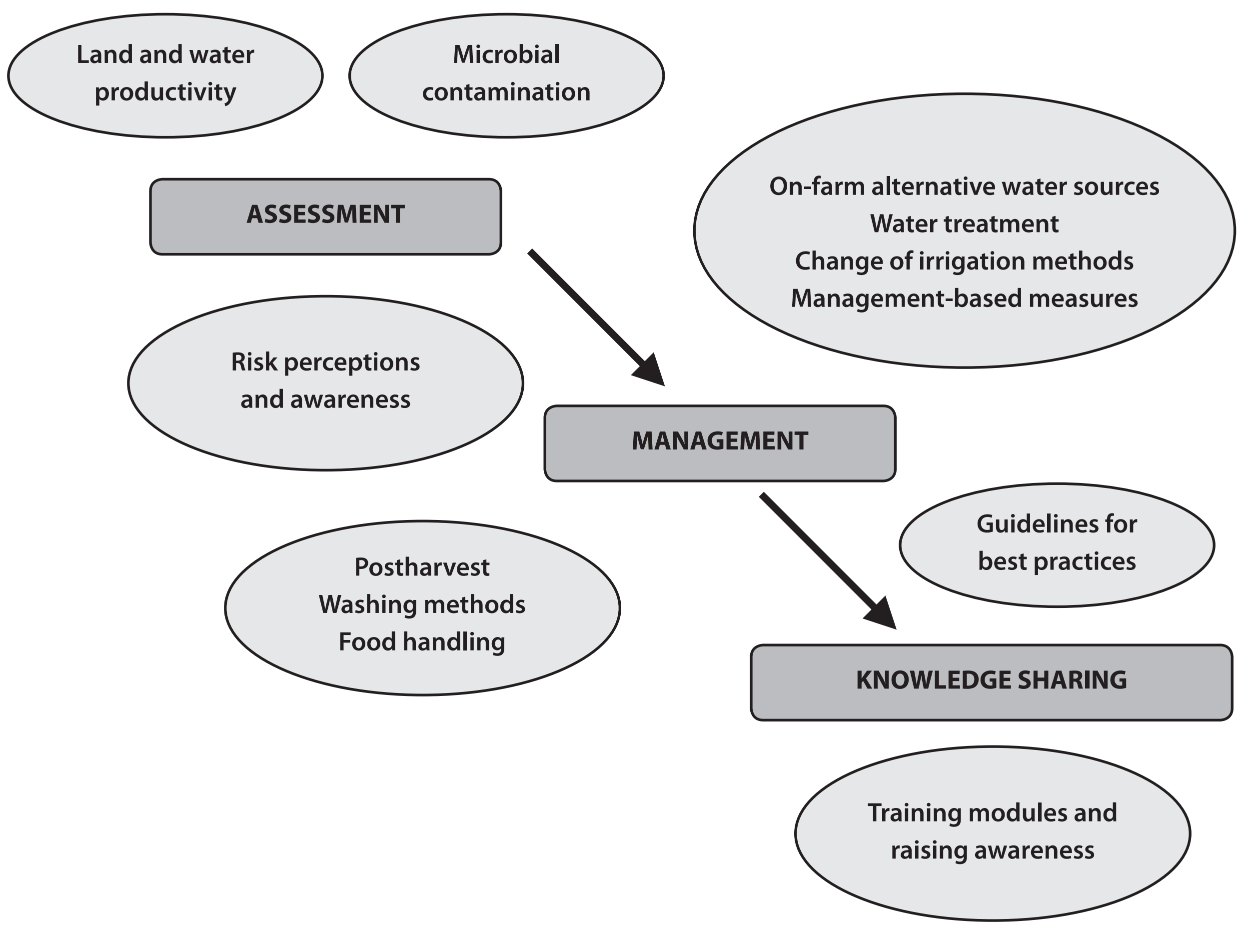


Figure 1. Action Research Approach

Confirm the effectiveness of the proposed interventions. Farmers identified and assessed the proposed interventions in their own fields (on-farm trials). Postharvest interventions, especially washing methods, were tested in the laboratory.

Develop local capacity. Relevant stakeholders participated in workshops to develop guidelines and awareness materials. They also participated in assessing the suitability of materials such as videos, flip charts and policy briefs.

Need for simple and low-cost interventions

Farmers felt that some of the risk reduction measures, including wastewater treatment as suggested in the international guidelines (WHO, 2006), were not suited to their farming practices. Farmers in Ghana preferred simple and low-cost interventions, which they could easily adopt. The projects introduced major on-farm interventions to improve water quality and reduce contamination and health risks. Sedimentation ponds and filtration techniques were assessed to improve water quality and reduce contamination of crops. Changes in water application techniques (i.e., irrigation methods and cessation of watering before harvesting) were tested. In general, there was a significant reduction in contamination using these low-cost measures. Most helminth eggs were reduced using pond and filtration systems, while bacteria loads were reduced mostly by water application techniques. For example, most helminth egg densities were reduced to less than 1 egg per liter in 3 days by ponds, while drip irrigation reduced fecal coliforms by 4 log units. Careful combination of these measures could reduce both helminth eggs and bacteria.

Farmers prefer risk reduction measures that

- **show potential for risk reduction but can achieve more when used in combination; and**
- **require little capital investment, few changes in farming practices and behavior, but need higher labor input.**

Postharvest

Washing was the main practice employed for postharvest risk reduction. Best practices varied between Ghana and its francophone neighbor countries. In the latter, the most common food disinfectants used in the middle-and upper-class homes and restaurants are bleach and potassium permanganate. These disinfectants are not commonly used in Ghana. In lower-class households in francophone countries, plain water or water with salt, soap or lemon juice is used. This is similar to Ghana, where various salt and vinegar solutions, plain water or a combination of these three are used. At both sites, however, there are no guidelines available on how to use any of the disinfectants. Respondents were unaware of international recommendations and used their own judgment on dosages and contact times.

Translating research into widespread practice

These two interlinked CPWF-funded projects significantly increased the knowledge of urban vegetable farmers and sellers regarding health risks and risk reduction measures. The projects reached out to about 60% of all vegetable farmers and sellers in the study sites—about 60 lead vegetable sellers and more than 300 street food vendors and caterers.

An increasing number of farmers have begun using sedimentation ponds and safer water application techniques; sellers are practicing safer handling practices; and food vendors are also making changes in their vegetable washing techniques.

Based on the outcomes of these projects, various kinds of awareness-raising and training materials aimed at different stakeholders were produced. The projects helped to establish strong working relationships between farmers' organizations and networks of farmers and food sellers. This led to the founding of the Ghana Environmental Health Platform, which continues the work started by local universities and CPWF partners. Project researchers were also asked to provide inputs to the WHO guidelines for wastewater use in agriculture. In close collaboration with the Resource Centre on Urban Agriculture and Food Safety (RUAF), researchers assisted in the revision of the Accra by-laws banning the use of wastewater. In 2008, a first draft of a new by-law stated that, with certain precautions, the re-use of wastewater could be beneficial. Now, Accra's urban vegetable farmers can continue to make a living, while helping to ensure the city's food security.

Conclusion

Farm-based and postharvest risk reduction interventions provide practical low-cost solutions to the health challenges in wastewater-irrigated urban and peri-urban agriculture. Though individual risk reduction measures alone may not be sufficient, they can be used in combination to lower the risks to acceptable levels.

Much headway has been made in ensuring the safety of wastewater-irrigated vegetable crops. Tested and developed in the major cities of Ghana, these measures have considerable potential to be adapted and further improved for their use in other locations. Two things remain to be done: 1) ensure the widespread application of well-tested risk reduction measures by national stakeholders, and 2) transpose them into legally enforceable national standards that can be monitored and verified.

Contact Person

Robert Abaidoo (r.abaidoo@cgiar.org)

Partner Organizations

Centre Regional pour l'Eau Potable, Burkina Faso
Faculty of Health Science, University of Copenhagen, Denmark
Kwame Nkrumah University of Science and Technology, Ghana
International Water Management Institute
University for Development Studies – Tamale, Ghana
Water Research Institute – Council for Scientific and Industrial Research, Ghana

Key Reference

Abaidoo, R.C., B. Keraita, P. Amoah, P. Drechsel, J. Bakang, G. Kranjac-Berisavljevic, F. Konradsen, W. Agyekum and A. Klutse 2009. *Safeguarding public health concerns, livelihoods and productivity in wastewater irrigated urban and periurban vegetable farming.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3925

Tags: PN38; Safer Peri-Urban Vegetable Production

Bibliography

Bos, J.J., H.B.M. Gijzen, M. Hilderink, M. Moussa, L.W. Niessen and E.D. de Ruyter van Steveninck 2004. Quick scan: health benefits and costs of water supply and sanitation. *Bilthoven: National Institute for Public Health and the Environment,* 2004374.

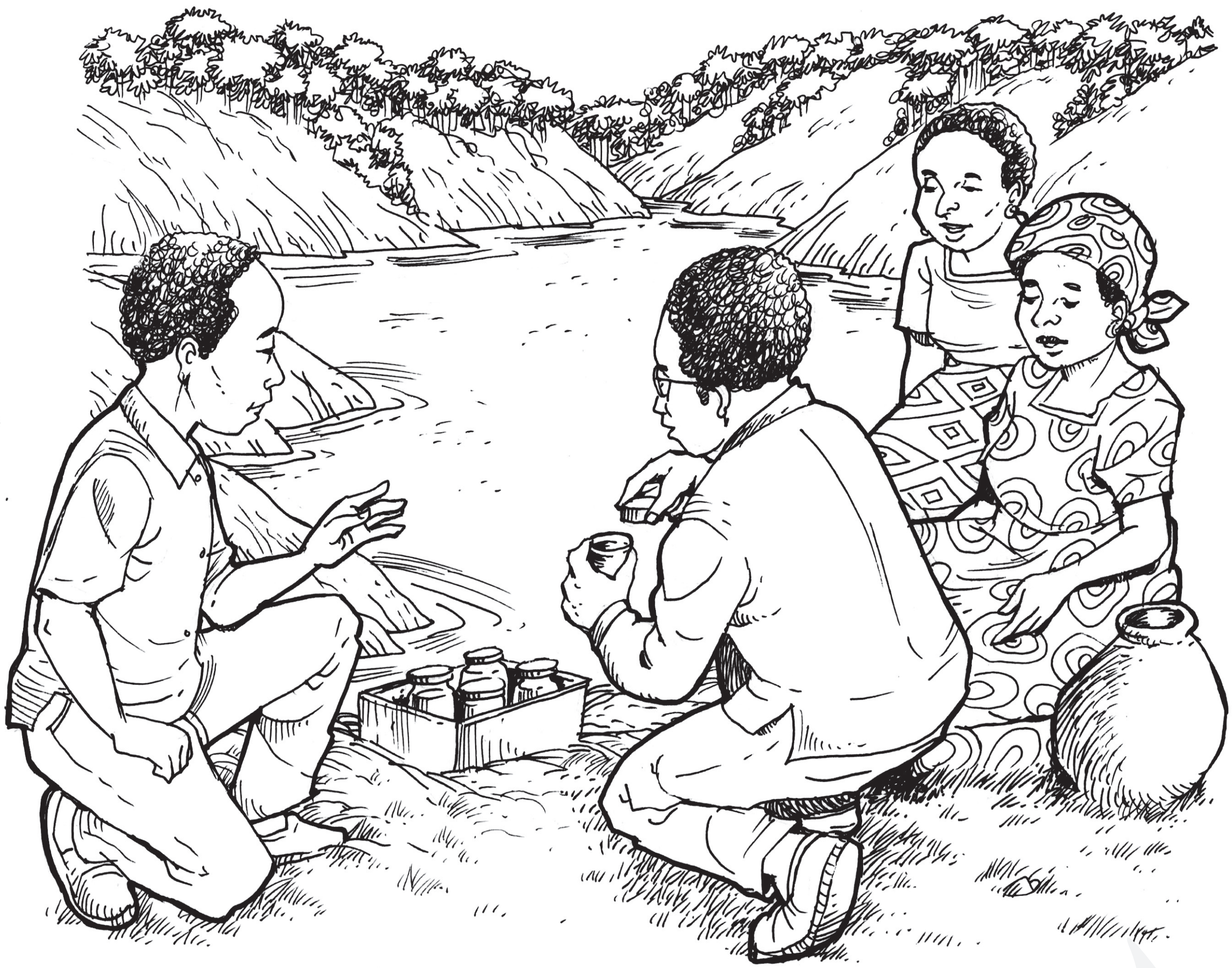
Cofie, O.O., R. van Veenhuizen and P. Drechsel 2003. Contribution of urban and peri-urban agriculture to food security in Sub-Saharan Africa. Paper presented at *The Africa Day of the 3rd WWF,* Kyoto, Japan, 17 March 2003.

Keraita, B., P. Drechsel, F. Hubers and L. Raschid-Sally 2002. Wastewater use in informal irrigation in urban and peri-urban areas of Kumasi, Ghana. Urban *Agriculture Magazine,* **8**, 11-13.

WHO 1989. *Health guidelines for the use of wastewater in agriculture and aquaculture. Report of Scientific Group*. Technical Report Series No. 778. Geneva Switzerland: World Health Organization.

WHO 2006. *WHO guidelines for the safe use of wastewater, excreta and greywater, Volume 2, Wastewater use in agriculture.* Geneva, Switzerland: World Health Organization.

Water Quality Assessment Tools for Small Reservoirs



Water reservoirs provide the basic, domestic and agricultural water needs in many rural communities. Thus, it is paramount that water quality in reservoirs is assessed every so often to determine suitability and safety for varying purposes.

Locals can assess water quality through simple and inexpensive methods such as observing color, transparency, taste and smell. More sophisticated technical methods to monitor changes in water quality include the analysis of biomedical, biological and physicochemical parameters. Some of these methods for measuring water quality are discussed here. When possible, relatively simple protocols in the field with a simple laboratory may also be used.

Before actually conducting water quality assessment, it is best to first evaluate the suitability of water based on its intended use, which may be done using the following steps:

1. Select the reservoirs for which water quality is to be monitored.
2. Identify the main water uses and determine key water quality parameters.
3. Do a qualitative survey on water quality to determine the people's perceptions. Dialogues between and among experts and community members help to identify parameters, after which systematic collection and analysis of water samples can be performed.
4. Take water samples from different water sources: reservoirs, canals, wells, water collected at the site and in the household and drains.

Biomedical parameters

Experts consider parasites to be silent epidemics as these are the main causes of chronic diseases and poor health in many people. More than 130 parasites are known to infest humans but these are often left undiagnosed. Some parasites live part of their lives in water and can be transmitted through drinking of contaminated water. The following are the steps in sampling water for parasites sampling *(Shorttet al. 2006):*

1. Collect water samples from various sources.
2. Filter the water using a hand pump with a flow rate of approximately 5 liters per minute. For each sampling, pump 49 liters of water through a single cylindrical filter, made from an inlet hose and a plastic filter holder, with a 25–cm long yarn-wound polypropylene filter.
3. Wash the filter with distilled water using a squirt bottle, then scrape it with a scalpel to obtain a concentrated specimen.
4. Preserve 200 ml of the concentrated specimen in 10% formalin for further analysis.
5. Store the concentrated specimen at room temperature until it is processed for microscopic analysis.
6. During further evaluation, centrifuge the specimen to a volume of 5 ml (containing all the sediment visually detectable in the original 200 ml). Microscope identification can be used to classify pathogens such as *Giardia* cysts and *Cryptosporidium* oocysts.

Giardia spp. **and** ***Cryptosporidium*** **spp. are common intestinal parasitic pathogens in vertebrates, including birds and mammals. Transmission of these parasites occurs by ingestion of** ***Cryptosporidium*** **oocysts or** ***Giardia*** **cysts, either by fecal-oral contact or fecal-related contamination. In humans, these parasites can cause persistent diarrhea for 2-3 weeks or longer. In some cases, infected humans and animals continue to shed these parasites asymptomatically.**

Under the microscope, ***Giardia*** **cysts appear as elongated structures with visible flagella inside. They have a mean size of 12 µm.** ***Cryptosporidium*** **oocysts, on the other hand, appear red and usually have dimensions of 5.0 µm x 4.5 µm. But prior to microscope viewing, certain preparations for identification of** ***Giardia*** **cysts and** ***Cryptosporodium*** **oocysts need to be undertaken (see Shortt** ***et al.*** **2006 for more information).**

Coliform sampling and analysis

Coliform bacteria are organisms present in the environment and in the feces of most animals and humans. These bacteria may not cause illnesses, but they indicate presence of disease-causing organisms. Sampling for coliform bacteria should be done even more frequently than for parasites (e.g., once a month for various seasons). For a given round of measurement, all selected water sites should be sampled within the 5-7 day-period so that findings can be compared. At each site, three samples should be taken.

The thermotolerant coliform analysis method can be done using the membrane filter technique as outlined by Csuros and Csuros (1999) and the American Public Health Association (1998). In this technique,

1. Filter the water samples through a membrane (0.47 µm pores) that retains thermotolerant coliform bacteria.
2. Incubate this membrane on a growth-promoting medium.
3. Count the resultant colonies of thermotolerant bacteria within 1 hour of being removed from the incubator.
4. In case of high contamination levels, prior to filtration, dilute the samples with a sterile phosphate, magnesium chloride solution. Hence, no more than 500 colonies per filter are used to calculate the concentration of colony-forming bacteria per 100 ml.

Composite sample analysis

This method can help improve precision and lower the variance of estimated average contaminant concentrations (Million 2008). Moreover, by testing for *Enterococcus* and *Streptococcus*, a distinction can be made between contamination from people and that from animals.

1. Prepare three replicate samples of 10 ml from each site.
2. Subject the samples to membrane filter analysis of total coliforms, fecal coliforms and *Enterococcus*/fecal *Streptococcus*. The latter are

important indicators of fecal contamination of animal origin.
3. Filter the composite samples under a hood using a membrane filtration apparatus with a 47 mm diameter sterile and gridded membrane, with a pore size of 0.45 mm.
4. Aseptically (pathogen-free) transfer the membranes to glass petri dishes with different media: m-Endo Agar LES for total coliforms (TC), m-FC agar with rosolic acid for thermotolerant coliforms (TTC) and m-Entrococcus agar media for fecal *Streptococcus* (FS).
5. Invert the prepared culture dishes and incubate for 24 h at 35 °C (TC), 24 hours at 44.5 °C (TTC) and for 48 h at 35 °C (FS).
6. After incubation, count the typical TC colonies (pink to dark red with sheen), TTC colonies (blue), and FS colonies (dark red) on the surface of the membrane filter, using a low-power binocular wide-field dissecting microscope, with a cool white fluorescent light source for optimal viewing sheen.
7. Rinse the funnel between each site sample filtration using buffer rinse water (APHA 1998).

8. Do verification tests by transferring growth from each colony and place growth in lauryl tryptose broth at 35±0.5 °C for 48 h. Gas formed in lauryl tryptose broth within 48 h verifies the colonies as TC. Inclusion of EC broth for 44.5±0.2 °C incubation verifies the colonies as TTC/FC.

Physicochemical parameters

Electrical conductivity

This method can measure water salinity, which can serve as an indicator of salinity-causing salts (ions), such as chlorides, sulphates, carbonates, sodium, magnesium, calcium, and potassium. Water bodies tend to have a relatively consistent range of electrical conductivity values that, once known, can be used as a baseline against which to compare regular measurements of conductivity. Significant changes in conductivity may then indicate that a discharge or some other source of contamination has entered the waterway.

Chemical characteristics

The assessment of the physical and chemical characteristics of water helps to determine its suitability for domestic, industrial and agricultural uses, as it gives a good impression of the status, productivity and sustainability of the water body. Changes in physical characteristics such as temperature, transparency, and chemical element content of water (e.g., dissolved oxygen, biochemical oxygen demand, and nitrate and phosphate content) provide valuable information on the quality of water, the sources of variations, and their impacts on functions and biodiversity of the reservoir (Mustapha 2008).

1. Collect samples for anion analysis in 100-ml polyethylene bottles. Filter the samples using 0.20-m cellulose acetate filters prior to anion analysis (Rajasooriyar 2003).
2. For cation analysis, collect samples in 200-ml polyethylene bottles and add 4% (by volume) nitric acid in the field. Before analysis, filter the samples using 0.45-m cellulose acetate filters.
3. Analyze the samples for Na, K, Mg, Ca, Mn, Al and Si by spectrometry—e.g., inductively coupled plasma atomic emission spectroscopy (ICP-AES - Varian Vista - axial system).
4. For Cl-, NO3-, SO4 2- and PO4 3- analysis, use ion chromatography,—e.g., DIONEXTM series 4000 I instrument. The total alkalinity (HCO3 -) is best determined by titration. Fluoride determinations can be made using a fluoride ion combination electrode (ORION - Model 96-09) and TISAB III buffer. Using these techniques, reproducibility for duplicate samples is less than 2%.

For indication of the (seasonal variation in) concentration of fertilizer nutrients in water of reservoirs:

1. Collect samples at least once during the rainy and dry season in reservoirs built from different parent soil materials. Collect samples from the middle of the reservoirs.
2. Determine cation and anion concentration through ion chromatography (Metrohm) in column Metrosep A Supp5 -100 e Metrosep C2. In some water bodies, the results demonstrate the influence of geology on the water quality and a low level of water contamination due to nutrients.

Biological Parameters

Cyanobacteria monitoring

Cyanobacterial proliferation, caused by blue-green algae that produce toxins (which cause water coloration that may vary from olive-green to red), also needs to be evaluated, as it has become a considerable threat in many areas. There has been a growing concern related to the development of toxic cyanobacterial populations. Twenty genera and more than 40 species of cyanobacteria are known for their potential toxicity.

A first step in monitoring can be based solely on visual information. However, visual detection often provides information after the occurrence of the phenomenon and should be considered more as an alarm than as a monitoring tool. Taxonomic composition and specific abundance of phytoplanktons can be analyzed with an inverse microscope. This standardized method, based on morphological traits of organisms, allows cyanobacteria detection before the blooms appear.

The epifluorescence microscopy developed by Andersen and Throndsen (2003) allows the detection of low concentrations (10^2 to 10^4 cells. L-1) of cyanobacteria when using fluorescent printers as orange acridin and DAPI.

An alternative method is molecular fingerprinting for identifying potentially toxic species, although it involves delays and requires adequately trained personnel and discrete sampling of water. The same limitations arise when liquid chromatography (which allows identification of a large panel of pigments) is used in conjunction with software such as CHEMTAX, so that the specific biomass of phytoplankton classes, including cyanobacteria, can be inferred.

High bloom levels can be detrimental to ecosystems and water treatment processes. If cyanobacteria reappear frequently in the same area, the following actions are recommended:

- **Avoid all direct contact with the water.**
- **Do not drink or use the water to prepare or cook food (boiling the water will not eliminate the toxins).**
- **Avoid eating fish or other aquatic species from the affected area.**
- **Do not let animals drink or bathe in the water.**
- **Do not use algicides to destroy cyanobacteria (more toxins are released when cells die).**
- **Toxins can persist after cyanobacteria have disappeared.**

Fluorescence properties of phytoplanktons are currently used as monitoring tools. Based on the optical properties of their pigments, several methods allow the determination of biomass and the distinction between different groups of organisms. The *in vivo* fluorescence characteristic of pigment-containing micro organisms, such as cyanobacteria and microalgae, thus offers attractive possibilities (Leboulanger *et al.* 2002; Gregor *et al.* 2007).

In vivo fluorescence can be measured on individual samples, with flow-through fluorometers, *in situ* or remote-sensed. Different materials and instruments are available, with huge variations in price and sensitivity. Whichever method is used, systematic taxonomic (microscopic) validations are required.

In situ multiparameter probes, including *in vivo* fluorescence, constitute the ideal compromise for rapid and efficient surveys or monitoring. However, their use requires substantial funds for field resources such as cars, boats, sampling equipment, reagents, calibration, routine maintenance, and laboratory facilities for taxonomic validations.

Conclusion

- Results from water quality analysis can be explained in terms of reservoir water-use and land management practices in reservoir watersheds. This knowledge can help water managers develop strategies to maintain satisfactory water quality.

- Water quality assessment is most accurate when all relevant parameters are analyzed. Reservoir water in areas with different kinds of landuse should be monitored to better understand the effect of landuse on water quality.

- Water in reservoirs may not be suitable for all possible uses because different levels of quality are required for different uses.

Contact Persons

Eline Boelee (e.boelee@waterhealth.nl), Philippe Cecchi, Aidan Senzanje, Muchaneta Munamati, Lucilia Parron, Lineu Rodrigues, Hammou, Laamrani, Robert Arfi, Celine Berger, Alain Coute, Muriel Gugger, Frederic Zongo

Partner Organizations

EMBRAPA, Brazil
International Development Research Centre, Egypt
International Water Management Institute
Universite Montpellier, France
University of KwaZulu-Natal, South Africa
University of Zimbabwe

Key Reference

The Small Reservoirs Toolkit. Retrieved from: www.smallreservoirs.org

Tags: PN46; Small Multi-purpose Reservoir Planning

Bibliography

Andersen P. and H. Throndsen 2003. Estimating cell numbers. In: *Manual on harmful marine microalgae*, eds. G.M. Hallegraeff, D.M. Anderson and A.D. Cembella; 99-129. Paris: UNESCO.

APHA. 2008. *Standard methods for the examination of water and wastewater,* 20th edition. Washington, USA: American Public Health Association.

Csuros, M. 1999. *Csuros C. Microbiological examination of water and wastewater.* Boca Raton, USA: CRC Press LLC.

Gregor, J., B. Marsalek and H. Sipkova 2007. Detection and estimation of potentially toxic cyanobacteria in raw water at the drinking water treatment plant by in vivo fluorescence method. *Water Research*, **41**, 228-234.

Leboulanger, C., U. Dorigo, S. Jacquet, B. Le Berre, G. Paolini and J.F. Humbert 2002. Application of a submersible spectrofluorometer for rapid monitoring of freshwater cyanobacterial blooms: a case study. *Aquatic Microbial Ecology,* **30**, 83-89.

Mustapha, M.K. 2008. Assessment of the water quality of Oyun Reservoir, Offa, Nigeria, using selected physico-chemical parameters. *Turkish Journal of Fisheries and Aquatic Sciences,* **8**, 309-319.

Million, B. 2008. *Biology Assessment of the contamination level of water at collection points and determination of the major sources of contaminants in the Central Highlands of Ethiopia (Yubdo-Legebatu PA)*. MSc Thesis, Addis Ababa University, Ethiopia.

Rajasooriyar, L. 2003. *A study of the hydrochemistry of the Uda Walawa Basin, Sri Lanka, and the factors that influence groundwater quality.* PhD Thesis, University of East Anglia, UK.

Shortt, R.L., E. Boelee, Y. Matsuno, C. Madramootoo, W. van der Hoek and G. Faubert 2006. Cryptosporidium and Giardia as determinants for selection of an appropriate source of drinking-water in Southern Sri Lanka. *Journal of Health, Population and Nutrition*, **24**, 64-70.

Approaches to Assess Health Impacts of Small Reservoirs

When small reservoirs are planned and constructed in Africa, it is not unusual for formal environmental or health impact assessments to be neglected (McCartney *et al.* 2007). But small reservoirs can have very significant local impacts on public health—impacts that conventional planning and design processes are unlikely to predict. When clusters of reservoirs are built, their cumulative impacts can be even more difficult to anticipate. Each small reservoir has its own unique set of impacts that needs to be addressed.

To understand the health effects of a reservoir in the context of local agroecosystems and agricultural and water management practices, there is no substitute for local participatory health impact assessment. Only in this way, through on-the-ground integrated assessment, can locally manageable solutions be identified and implemented. Findings from participatory health impact assessments can be quickly used to make suitable adjustments in reservoir management. By combining subjective perceptions with scientific data, participatory processes can identify locally relevant suggestions for improved reservoir operation and maintenance, as well as improved management of the wider environment. Assuming there are no major conflicts, participatory processes can enhance ownership and accelerate implementation of health risk mitigation measures.

This article discusses guidelines to reduce health risks and increase health benefits from small reservoirs, for planners, designers, builders, managers and users of these small, multipurpose reservoirs. These guidelines specifically focus on

- Major water-related diseases associated with small reservoirs in Africa
- The added value of community participation in health impact assessment
- Opportunities to mitigate risks and improve human health through better planning and operation of small reservoirs at local and cluster levels
- Improved planning of a larger number of small reservoirs and design and management options for individual small dams

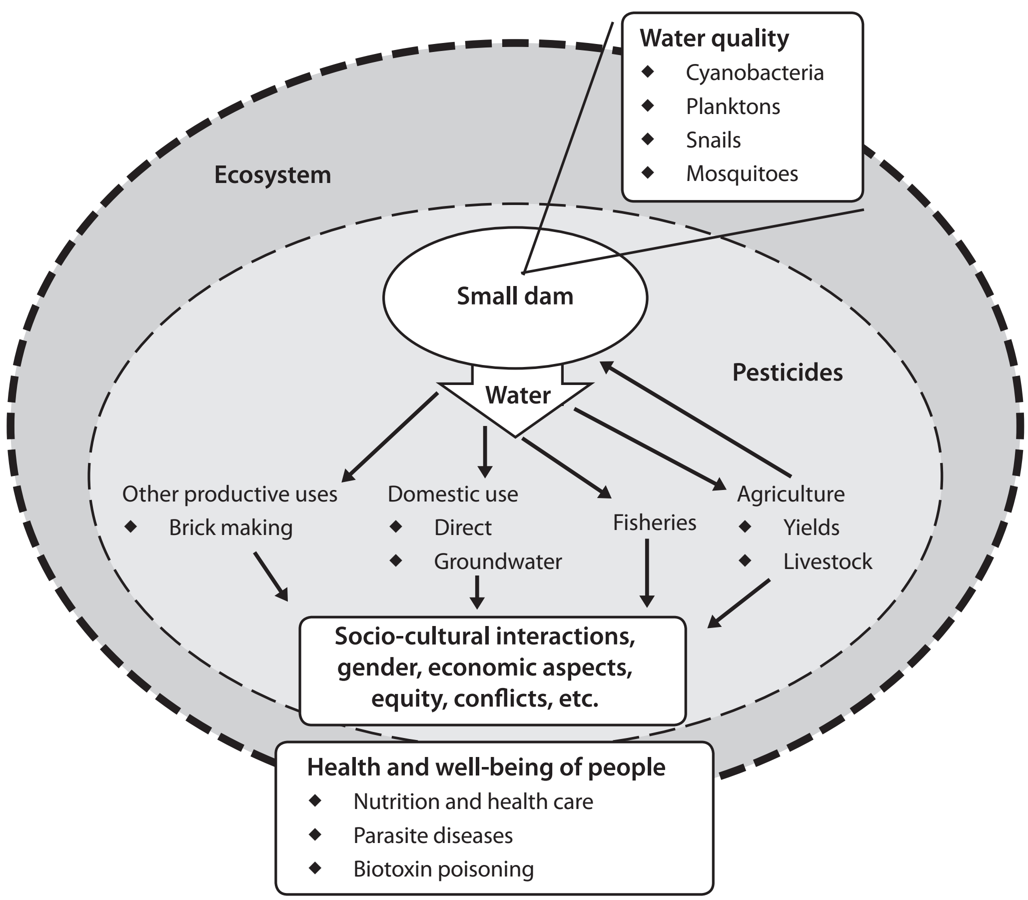


Figure 1. Conceptual model of inter-relations between small reservoirs and human health, to be used in participatory health impact assessments. Several of the aspects mentioned are addressed in other tools.

Throughout the process, various rounds of community feedback are used to clarify issues, formulate hypotheses, test recommendations and ensure that the assessment maintains a focus on the right priorities. Although steps are described as being sequential, they may sometimes overlap. Some of the methods used in different steps can take quite some time to complete.

In the final phase of intervention analysis, participatory tools are again applied. The entire process, including preparation, team building and meetings, can take as long as a year or even longer if seasonal variation needs to be captured.

Step One: Scoping

Secondary data

Secondary data from government and NGO archives can help focus research, by enabling researchers to take account of current prevalence and past incidence of different diseases. Key informants can provide complementary insights. The data to be collected are typically limited by their availability and accessibility. Data collection may also be unconsciously restricted by the interest and focus of the team. It is important to be aware of this bias and be open to other health issues that the community may bring up during the participatory steps in the approach.

In northern Ethiopia, the shading of larval breeding sites with reeds and fruit trees was one of the few malaria control measures available to communities during a period when health services were restricted because of a border conflict (Yohannes *et al.* 2005).

Stakeholders and resource people

Different stakeholders within the research team, as well as within the community, must make up the interdisciplinary team that includes professionals from the agricultural and water sectors, as well as from the health sector. Health professionals will benefit from interactions with water and agriculture professionals. In many cases, solutions to community health concerns lie outside the health sector.

Local communities, civil society representatives (NGOs and CBOs), researchers, local and regional health authorities and local development authorities all have to be involved in this investigation. A more inclusive framework typically leads to a greater sense of stakeholder ownership and increased sustainability of beneficial impacts on livelihoods from small dams. An important activity in initial stakeholder workshops is the identification of indicators (see Step Four: Synthesis).

Health issues

Many health issues can be related to small reservoirs. The impacts of a small reservoir are of an entirely different magnitude than those of a large dam or of a collection of smaller dams in the same watershed or basin. Often, the presence of new bodies of water influences peoples' mobility and, consequently, the human reservoir of pathogens. People moving into an area may bring pathogens and start a new transmission cycle. People previously unexposed to waterborne or water-related diseases (e.g., pastoralists or seasonal laborers from highland areas) may be drawn to the water, increasing their own risk of disease, in addition to raising the risk factor for others.

Assessing health benefits from small reservoirs is harder than assessing their hazards. Measurement of positive impacts usually requires longitudinal studies that compare "with" vs "without" and "before" vs "after" the implementation of a small dam. Numerous variables need to be considered, but since this kind of information is not always available, the focus may be put on overall community indicators, using experiences from clinical, socioeconomic and environmental surveys carried out in Africa.

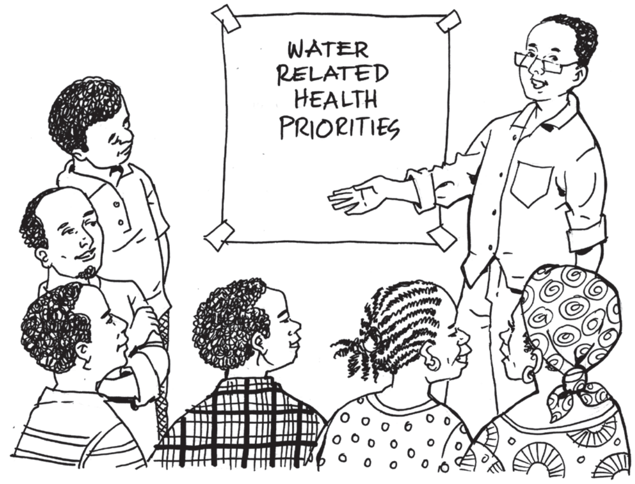
While all aspects of human health might be considered in participatory approaches, a closer focus is needed for biomedical studies: one to three key diseases should be selected. The choice of these depends on the local context, including factors such as the importance of the disease, its relation to water management and available data or expertise.

Closely related to the transmission of water-related diseases is the ecology of the small reservoir with its related environment, including upstream catchments and streams, drains and canals, and fields and seepage areas. In this integrated approach to health, the entire ecosystem is considered but water quality remains an important interface between people and pathogens. Depending on the local context, it may be necessary to do more in-depth analysis of water quality for biological indicators such as *Cryptosporidium* and fecal coliform bacteria (see Step Three: Measurements).

Step Two: Participatory Assessment

Selecting from available tools

A wealth of literature is available on participatory rapid appraisals (PRA) as well as on health impact



assessments. A good review of the literature on participatory approaches, and the merits and risks associated with different methods, is provided by Da Silva (2006). Utzinger (2004) published a similar overview for health impact assessment. Of particular interest are methods involving participatory village transects, focus group discussions, and various ways to map the health impacts of small reservoirs.

An advantage of using participatory tools is that the community shares the responsibility for identifying and solving water-related health problems. A disadvantage is that trained facilitators are needed, who can guide disciplinary professionals into a new process of listening to local perceptions.

Step Three: Measurements

Any study or assessment that looks at human health needs to speak the health sector language. Planners and managers who wish to be taken seriously in their attempts to address water-related public health issues need to collaborate with health care professionals. In many places in Africa and Asia, health information is not readily available and some primary data collection is needed. The

Epidemiology:

Depending on the key diseases that are selected, standard biomedical methodologies are available to determine infection rates. For schistosomiasis and other intestinal parasites, urine and stool samples are collected and analyzed. Normally, this is done for children under 14 years of age (often between 5 and 10 years of age) because they can easily be sampled at school. For malaria, blood smears are taken from finger pricks. If anemia is also studied, as a health outcome and indicator of heavy or chronic parasite burdens, a few drops of blood can be collected in micro-tubes for determination of hemoglobin levels.

When blood samples are collected from the children, ethical clearance is required. Usually this has to be requested from the Ministry of Health. In all parasitological surveys, it is important to provide treatment for infected people, usually free of charge and according to national or WHO guidelines. For example, in the case of urinary or intestinal schistosomiasis, praziquantel has to be given at 40 mg/kg of body weight. Albendazole is the proper treatment for soil-transmitted helminth infections, with doses dependent on species according to the World Health Organization (WHO Expert Committee 2002). For malaria, the most recent local protocols need to be followed because of fast-developing resistance.

Ecology–Vector Studies:

Around selected communities or schools, different types of water bodies (e.g. reservoirs, canals, drains, seepage areas, pits and rain puddles) are identified and mapped. After the first inventory, a sample of water bodies is monitored monthly for mosquito larvae and snails. Sampling for *Anopheles* **larvae is done with standard dippers (350 mm), with the number of dips depending on the size of the site (Amerasinghe** *et al.* **2001). Snails are sampled quantitatively using a drag scoop in deep water bodies, whereas in shallow habitats, quadrates are sampled, depending on the surface and morphological variation of the sites. Adult mosquitoes can be captured in various ways: for example, by indoor and outdoor spray catches, netting sweeps of the vegetation, human or animal bait catches or light traps. The latter methodology is standardized and the most widely accepted. In the epidemiology of schistosomiasis, in addition to snail sampling, the observation of water-use patterns is also important because this disease is contracted through water contact. Often popular water-use sites combine organic pollution with high snail densities, thus creating ideal circumstances for transmission (Boelee and Madsen 2006).**

Ecology–Water Quality:

Users of small reservoirs often have concerns about water quality, sometimes because of observed water pollution and sometimes because of widespread symptoms of disease in the community. In these cases, a selection of chemical and biological water quality measurements should be done, depending on available information and perceptions. Usually national institutes have the expertise to carry out all kinds of water quality assessments.

Source: www.smallreservoirs.org

participatory assessment conducted in step two will have narrowed the health focus and pointed at opportunities for improvement, so that more expensive biomedical studies can be well targeted.

The studies described in this section use more standard approaches, yielding the hard data required by health professionals to diagnose health care issues and to suggest interventions. It may also be necessary to collect primary information on changes in water availability and water consumption. Methods for doing this are described as separate tools.

Indicators (also available as a separate tool) http://www.smallreservoirs.org/full/toolkit/docs/111%2009%20Indicators_MLA.pdf

Step Four: Synthesis

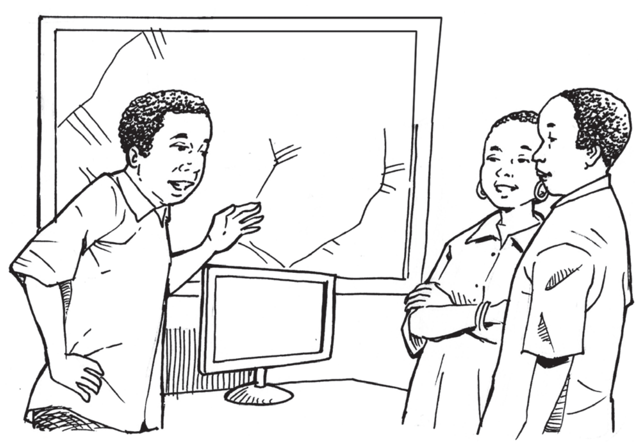
Triangulation

In the approach described in this tool, qualitative and quantitative measures are combined with participatory methods, reflecting the transformative potential of participatory health impact assessment in terms of knowledge and practices. Triangulation is used to cross-check the validity of tools and ensure the validity of results.

In discussions with the community and local experts at the beginning of the study, specific health, water quality and performance indicators were identified. These may be later complemented by standard, well-tested scientific indicators. Some of the information collected by various methodologies are best collected in a time series. It is important to align the substudies as much as possible so that data can be compared over space and time. Indicator definitions should be compatible with the literature and the field experience of those involved. Some indicators should be used in ongoing community-managed monitoring and evaluation of small reservoir health impacts.

Mapping

Existing topographic or agricultural maps, remote sensing imagery, and community-drawn maps can be entered into a single geographic information system (GIS) file. Where possible, indicators and their values (whether from secondary or primary data sources) should be geo-referenced and entered into the GIS file. GIS can help explore the possible relationships between health and water indicators, and potential explanatory factors, such as, altitude, vegetation, topography and distance from water sources. It may be possible to combine this into a formal model. Some caution should be used, however: formal modeling can be time-consuming and can lead to spurious accuracy. Model results are only as reliable as the least reliable information that is used as an input. In addition, skilled staff and adequate computing power to run models are sometimes lacking. On their own, maps can be very powerful in providing insights to local communities and decision-makers. Chambers (2006) has written a good evaluation of the combined use of community mapping and GIS.



Feedback

After the initial participatory phase, feedback sessions with the community should be conducted at each step in the assessment (Ait Lhaj and Laamrani 2007), even, for example, to present findings from the biomedical surveys. GIS maps with perceived and measured information from various disciplines are suitable for feedback sessions with communities and other stakeholders. These sessions offer interesting opportunities for early-stage brainstorming on possible interventions (mitigating measures). The authors have good experience with this in Morocco (Boelee and Laamrani 2004) and elsewhere (Laamrani *et al.* 2001).

Step Five: From Analysis to Implementation

In recent years, the authors have used the above steps in small reservoirs in Morocco, Burkina Faso

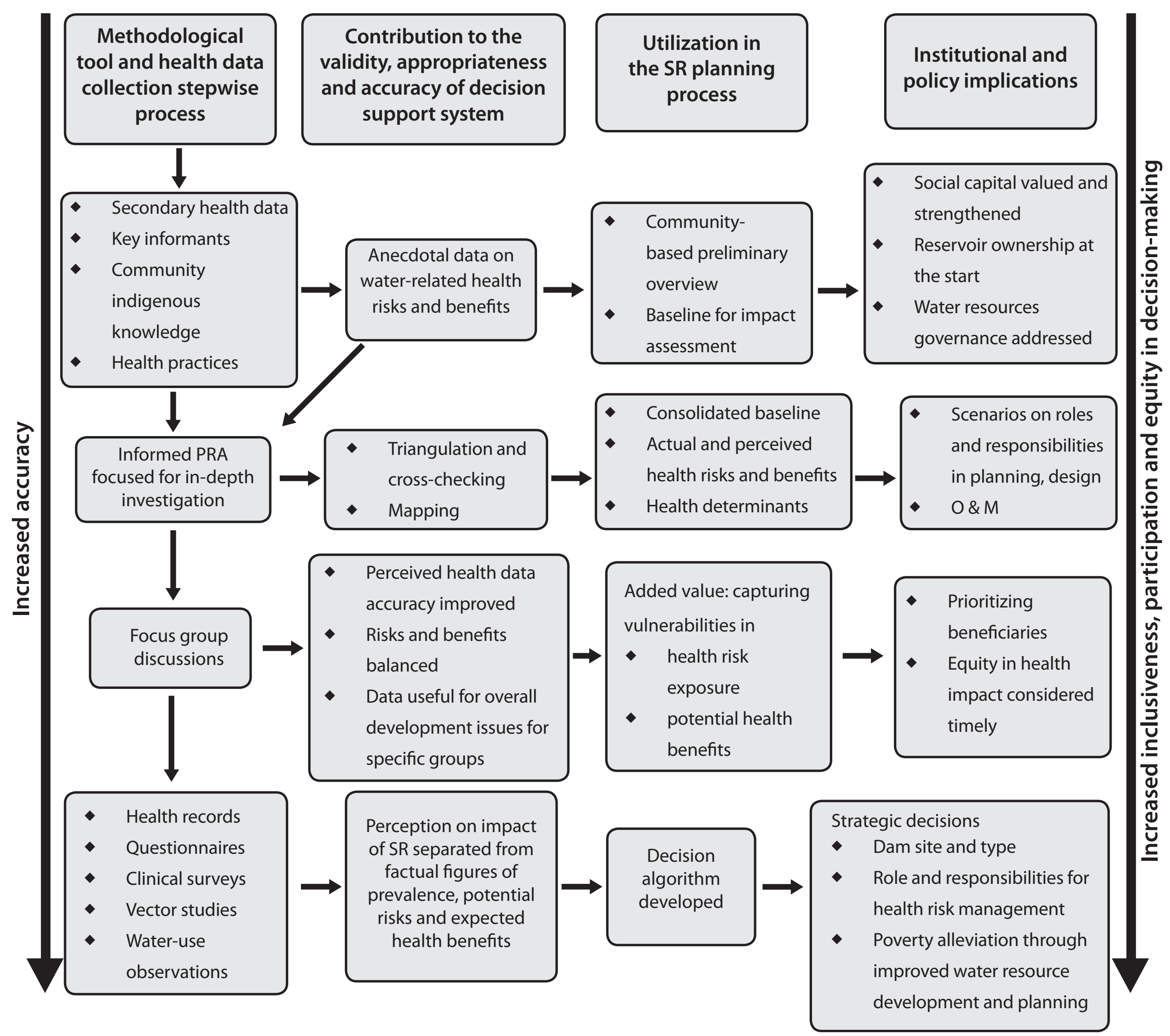
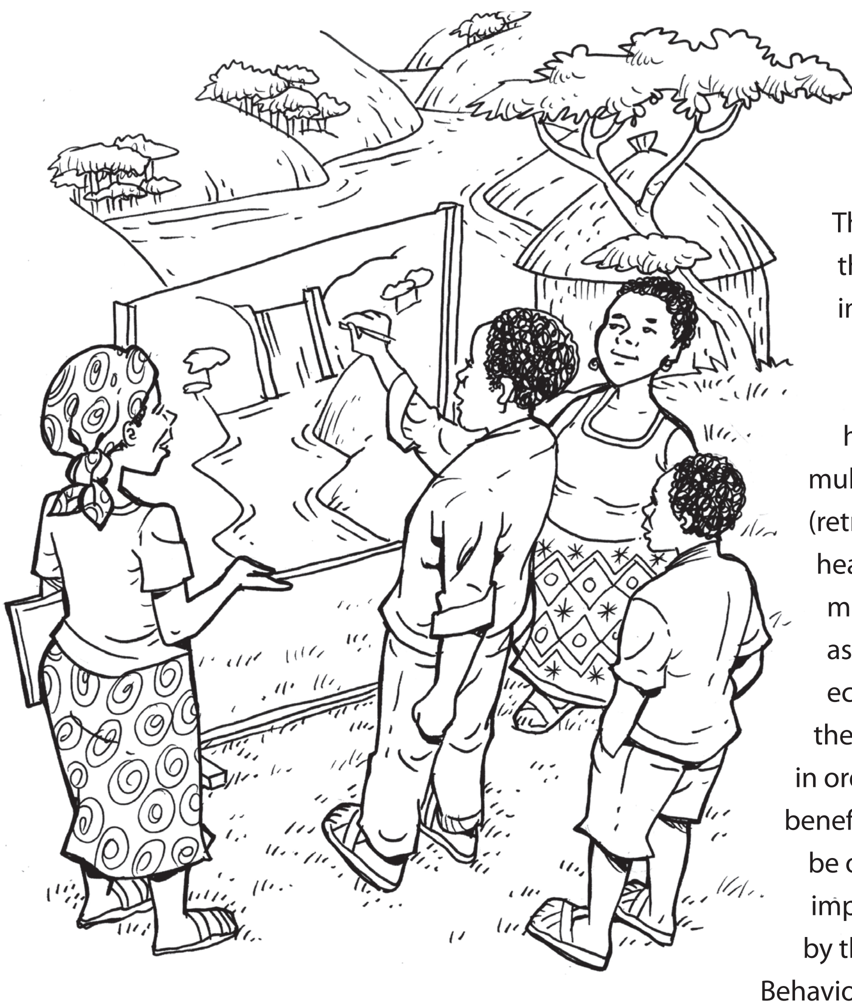


Figure 2. Diagram representing the links between various steps in participatory health impact assessment.

and Ethiopia. The most salient finding was that the methodology used in each location was dictated by local circumstances, for example, different sets of parasites, kinds of partners and political processes and relationships. The data that were collected were somewhat different in each case, and recommendations for improving the planning, design and operation of small reservoirs were different as well.

Lessons learned



- Small community reservoirs do not operate with the aid of clear policy guidance and support that is given to large dams. Hence, planning, construction, operation, and maintenance of small reservoirs do not have the same level of institutional, technical, and financial backup from government agencies. This can lead to water-related health risks, such as disease transmission. At the same time, development interventions capable of mitigating these health risks may be overlooked.

- Despite the lack of formal evaluation, according to community members across these varied agro-ecological, socioeconomic, and institutional conditions, the perceived overall health impacts of small reservoirs are positive. Generally "with and without" or "before and after" analysis based on recall of reliable informants, tends to be supportive of small reservoirs. That does not mean, of course, that their performance cannot be improved, or that water-related health risks cannot be mitigated. The approach to participatory health impact assessment combines multiple information sources (retrospective medical data, current health issues both perceived and measured, and prospective risks associated with changes in socio-ecological systems resulting from the introduction of small reservoirs) in order to better understand how benefits generated by small reservoirs can be optimized. Many interventions to improve benefits can be implemented by the communities themselves. Behavioral changes in hygiene, prophylaxis, and health seeking behavior are all dependent on awareness and require adequate health information. In as much as generic messages are not likely to lead to sustainable outcomes, the health information should be adapted to the setting, with site-specific messages related to the use and management of the small reservoirs.

- In terms of tools, there are tradeoffs with regard to available resources (both financial and time) and the accuracy, quality, and validity of the data collected. The tools used in this participatory health impact assessment have no special intrinsic value. Their value is in the way they are combined and used: mixing complementary quantitative tools (measurements) with qualitative tools, such as participatory methods, leads to a more in-depth understanding of the health issues than using only one approach in isolation.

- A combination of mapping, questionnaires and focus group discussions can produce consistent health data that can be cross-checked against clinical data records. Moreover, the combination of these tools can even shed light on community health concerns and priorities as part of overall strategies for community development.

- Stakeholders need to think about and work on small reservoirs as a cross-cutting issue that touches all sectors of rural development, including water, agriculture, environment, livestock, animal health, education and infrastructure. They should make harmonized interventions with properly coordinated tasks. For instance, site selection for the construction of dams has a technical component that requires expertise external to the community. But water allocation, use and infrastructure maintenance are all community issues that should be based upon the existing social capital. The devolution of power to local stakeholders may result in better decisions being made.

Limitations of the tool

The participatory health impact assessment proposed here should not be perceived as a stand-alone exercise. It is part of the multi-faceted small reservoirs toolkit (www.smallreservoirs.org) for better planning, implementation and management. It provides a different perspective from those offered by hydrology, remote sensing assessment, aquifer recharge and water quality risk assessment, Water Evaluation and Planning (WEAP), socioeconomics, aquatic ecosystem health and pollution/eutrophication. We believe that this approach is inclusive and provides a good entry point for community engagement in assessing benefits, risks, mitigation measures, and community preparedness.

Contact Persons

Eline Boelee (e.boelee@waterhealth.nl) and Hammou Laamrani (hlaamrani@idrc.org.eg)

Partner Organizations

International Development Research Centre, Egypt
International Water Management Institute

Key Reference

The Small Reservoirs Toolkit. Retrieved from: www.smallreservoirs.org

Tags: PN46; Small Multi-purpose Reservoir Planning

Bibliography

Ait Lhaj A. and H. Laamrani 2007. *Évaluation participative des impacts des petits barrages sur l'écosystème et la santé humaine en Afrique: formulation de recommandations pour l'amélioration de la gestion et du bien-être des communautés. Phase I: Maroc, élaboration de la méthodologie et mobilisation locale. Trois rapports pour CRDI: 1. Rapport Technique, 2. Note Méthodologique, 3.Démarche pour l'élaboration des indicateurs d'impact.* Institute National de la Recherche Agronomique (INRA), Institut National d'Hygiène (INH), International Water Management Institute.

Amerasinghe, F.P., F. Konradsen, W. van der Hoek, P.H. Amerasinghe, J.P.W. Gunawardena, K.T. Fonseka KT and G. Jayasinghe 2001. *Small irrigation tanks as a source of malaria mosquito vectors: a study in North-Central Sri Lanka. IWMI Research Report 57. Colombo, Si Lanka:* International Water Management Institute.

Boelee, E. and H. Laamrani 2004. Environmental control of schistosomiasis through community participation in a Moroccan oasis. *Tropical Medicine and International Health,* **9**, 997-1004.

Boelee, E. and H. Madsen 2006 *Irrigation and schistosomiasis in Africa: ecological aspects.* IWMI Research Report 99. Colombo, Sri Lanka: International Water Management Institute, Colombo, Sri Lanka.

Chambers, R 2006. Participatory mapping and geographic information systems: Whose map? Who is empowered and who is disempowered? Who gains and who loses? *Electronic Journal on Information Systems in Developing Countries,* **25**, 1-11.

Da Silva, J 2006. *Annotated bibliography of recent Q2 analyses of poverty.* Q-Squared Working Paper No. 30. Centre for International Studies, University of Toronto.

HIA Connect n.d. *New South Wales HIA Project.* Retrieved from: http://hiaconnect.edu.au/old/nsw_hia_project.htm

IMPACT – International Health Impact Assessment Consortium. Retrieved from: http://www.liv.ac.uk/ihia/

Laamrani, H, H. Madsen and E. Boelee 2001. Snail control in Africa: towards a community-based environmental control. In: *Proceedings of Workshop on Medical and Veterinary Malacology in Africa,* Harare, Zimbabwe, November 8–12, 1999, eds. H. Madsen, C.C. Appleton and M. Chimbari; 183-192. Danish Bilharziasis Laboratory, Charlottenlund, Denmark.

Bibliography

Lengeler, C, J. Utzinger and M. Tanner 2002. Screening for schistosomiasis with questionnaires. *Trends in Parasitology,* **18**, 375-377.

McCartney, M.P., E. Boelee, O. Cofie and C.M. Mutero 2007. *Minimizing the negative environmental and health impacts of agricultural water resources development in sub-Saharan Africa.* IWMI Working Paper 117. Colombo, Sri Lanka: International Water Management Institute.

Raso, G., J. Utzinger, K.D. Silué, M. Ouattara, A. Yapi, A. Toty, B. Matthys, P. Vounatsou, M. Tanner and E.K. N'Goran 2005. Disparities in parasitic infections, perceived ill-health and access to health care among poorer and less poor schoolchildren of rural Côte d'Ivoire. *Tropical Medicine and International Health,* **10**, 42-57.

The HIA Gateway. Retrieved from: http://www.apho.org.uk/default.aspx?RID=40141

Utzinger, J 2004. Health impact assessment: concepts, theory, techniques, and applications. *Bulletin of the World Health Organization,* **82**, 954-954.

Utzinger, J., E.K. N'Goran, Y.A. Ossey, M. Booth, M. Traoré, K.L. Lohourignon, A. Allangba, L.A. Ahiba, M. Tanner and C. Lengeler 2000. Rapid screening for Schistosoma mansoni in western Côte d'Ivoire using a simple school questionnaire. *Bulletin of the World Health Organization,* **78**, 389-398.

WHO *n.d. Health Impact Assessment*. Retrieved from: http://www.who.int/hia/en/

WHO Expert Committee 2002. *Prevention and control of schistosomiasis and soil-transmitted helminthiasis. Report of a WHO Expert Committee.* WHO Technical Report Series 912. Geneva, Switzerland: World Health Organization.

Yohannes, M., M. Haile, T.A. Ghebreyesus, K.H. Witten, A. Getachew, P. Byass and S.W. Lindsay 2005. Can source reduction of mosquito larval habitat reduce malaria transmission in Tigray, Ethiopia. *Tropical Medicine and International Health,* **10**, 1274–1285.

Understanding Communities, Social Learning and Gender Participation

Enhancing Locally-led Learning and Innovation

For rural communities, access to water and their capacity to manage it are essential to mobilizing biological resources, achieving food security and securing livelihoods. Technical barriers to localize access to water do exist, but in the semi-arid regions of the highland Andes (as exemplified by rural Ecuador and Bolivia), obstacles to innovations in water for food production were largely both conceptual and social in nature.

People and communities produce explanations of local experience and build 'truths'—explanations that may go unquestioned and become embedded in local culture. Over time, collections of such truths produce higher order explanations, leading to coherent bodies of knowledge—essentially a local science or 'people's science'. People's science or local knowledge production continues to be expressed in everyday life and emerges as diverse forms of localized change or endogenous development. It is richly expressed through the practice of agriculture. Life experiences and emergent myths in the semi-arid regions of the Andes had produced a *cultura de secano* (a dryland culture) that had effectively "blinded" the people to the water around them.

This CGIAR Challenge Program on Water and Food (CPWF) project, "Katalysis: Enabling endogenous potential for improved management and conservation of water resources in semi-arid Andean ecosystems," was undertaken in Rio Mira and Ambuqui watersheds, Chota Valley, Ecuador, and in two microwatersheds in Rio San Pedro, North Potosí, Bolivia, in South America.

The project goal was to develop effective modes for identifying local knowledge or endogenous potentials on water management as a means to improve the livelihoods of the rural people in the semi-arid Andes. It specifically aimed to

- develop farmer-led experimentation in technology development for improved water management;
- promote social learning and organization around water management concerns as a means to institutional and political advocacy for improved rural livelihoods; and
- systematize and document experiences and lessons learned as a means of influencing how farmer movements, local governments and other development agencies address water management concerns in rural Bolivia and Ecuador.

In Ecuador, the project worked with a network of farmers from the communities of La Playa, Lavanderos, San Clemente and Ambuqui, Province of Imbabura. This area is semi-arid with an average annual rainfall of 495 mm and altitudes between 1,600 and 2,400 m asl. The community-based organization EcoAmbuqui coordinated much of the local activity.

Additionally, due to interest from communities, the project conducted complementary activities in the communities of Ugsha and Rinconada in Otavalo. This area is relatively humid, with average annual rainfall of between 1,000 and 1,500 mm and altitudes between 2,700 and 3,100 m asl.

In Bolivia, the project conducted activities in the communities of Wallquiri, Logheto, Janqvillque, Wingaylla, Nununmasyani and Arampampa, which lie between the municipalities of Sacaca and San Pedro de Buenavista. The community-based organization PRODINPO supported much of the local activity. The region is very mountainous with highly variable climatic regimes. Generally, yearly rainfall averages between 300 and 600 mm and elevations are between 2,000 (near the town of San Pedro) and 4,000 m asl in the highland puna range (near the town of Sacaca).

Bringing forth water and food production

Katalysis is based on the premise that, for rural people, access to water and their individual and collective capacities to manage it are essential to mobilizing biological resources and achieving food security and livelihood ends. While certainly there are important knowledge and technical barriers to localized access to water, we hypothesize that, in semi-arid regions of the highland Andes, the central obstacles to innovation with water for food production were largely conceptual and social in nature.

In the process of socio-technical production, networks of people and communities organize to produce explanations of local experience in ways that bring forth certain realities, as they hide and conceal others (see, for example, Long and Long 1992). In such processes of 'myth construction', communities build 'truths'—explanations that may go unquestioned and become embedded in local culture. Over time, collections of such truths produce higher order explanations, leading to coherent bodies of knowledge, essentially a local science. Local knowledge production—what we refer to here as 'people's science', which is to be distinguished from more external and thus abstract forms of 'expert science' (see table below)—is continually expressed in the practice of everyday life and emerges as diverse forms of localized change or endogenous development. People's science is richly expressed through the practice of agriculture.

Comparison of Mode 1 (expert-led) and Mode 2 (laymen- or people-led) knowledge production (based on the ideas of Gibbons* et al. *2000)

Criterion	Mode 1: Knowledge produced in the context of abstraction	Mode 2: Knowledge produced in the context of application
Nature of knowledge production	Theoretical – produced from within a disciplinary community	Practical – produced from within a problem context
Bias – rules that govern conduct	Disciplinary and multi-disciplinary – single or multiple system of rules governing conduct	Transdisciplinary – dynamic, multiple systems of rules collide and collude
Problem-solving – experience and skills employed	Homogeneous – focused, well defined experience and skill set	Heterogeneous – diverse experiences and skills involved
Organization structures	Centralized and hierarchical – well-established; graded and top-down	Diverse and heterarchical – loose, flexible, and fluid structures; mixed and dissimilar constituents
Negotiation and consensus – resolution of differences	Closed and static – conditioned by pre-established norms and rules	Open and transient – conditioned by context of application and evolves with it.
Nature of knowledge	Generalizeable and cumulative	Context-specific and dependent on locality
Social accountability and reflexivity	Low – Offer-oriented, exclusive and low sensitivity to impact of outcomes; preoccupied with internal criteria and priorities	High – demand-oriented, inclusive and high sensitivity to impact of outcomes; preoccupied with relevance
Quality control – enforcement of 'good science'	Self referential – 'peer review' judgments; peers selected based on past compliance with norms; emphasizes individual creativity from within disciplinary bounds	Broadly based – composite and multidimensional, dependent on social composition of review system, emphasizes 'group think', socially extensive and accommodating
Theory of knowledge spread	Spontaneous diffusion based on merit	Repeated processes of generation

Similarly, agricultural scientists and development practitioners can be seen as members of myth-producing networks, favoring certain realities and suppressing others. For example, the science and development industry has put forward the existence of 'best practices' and the notion that 'seeing is believing.' In the process, they organize to overtake local cultures. The problem is that externally based knowledge and technology, by definition, do not 'fit' local socio-environmental circumstances, despite sometimes tremendous efforts to make them fit through 'participatory approaches'. Thus, externally based knowledge and technology tend to be rejected by local ecologies, be they social or environmental, leading to the creation of new and sometimes worse conditions (e.g., pest outbreaks or soil degradation as a result of agrochemicals) or the eventual abandonment of technologies (the famous 'white elephants' that now populate the countryside of the developing world).

Scientists and development practitioners have claimed, through their proposals and projects, that single best practices exist, and furthermore as licensed, informed and knowledgeable, they are capable of determining or devising them. They then argue that, through exposing people to best practices, for example, through demonstrations at research stations or in farmers' fields, individuals will find the 'light' and become 'developed.' Although simplistic and inconsistent with the critical literature on development, such manufactured truths nonetheless dominate the thinking of modern-day interventions.

After five decades of systematic failures in getting the rural poor to believe in externally based knowledge and technology, we committed our organization's resources to strengthening people's science and enabling community-led responses as complements to more conventional expert knowledge and technology as a means to development. Nevertheless, for farmers and development professionals alike, it is difficult to transition and see through one's mental paradigms, precisely because a paradigm defines how one sees. Agricultural practice that may seem irrational or specious to an outsider who grew up participating in a distant culture of explanation can be perfectly logical to a person emerged in a local belief system. While we may publicly question the practice of others as illogical or 'unscientific', from a social perspective, no particular science (i.e., body of explanation) is more valid than another. People's practice, be it expressed through practice of agriculture or the science and development industry, emerges from a logic embedded in culture and context.

We propose that to help rural people in semi-arid regions break through the barriers they have constructed for themselves, in this case as articulated in the *cultura de secano*, one must work from within the intimacy of the local context to co-produce new culture and knowledge, in this case around the existence of water and its utilization. In other words, we must avoid the introduction of externally based knowledge and technology and enable people and their communities to continually bring forth their own water and food production.

Key elements

To develop the project strategy, partners took a reflective "step back" to examine the deeper issues associated with socio-environmental decline in the Andes. The result of this conversation is more succinctly described in a problem tree produced during the impact pathway analysis that took place at the International Center for Tropical Agriculture (CIAT) (Figure 1). At the most general level, the project strategy centered on a "slowing down of

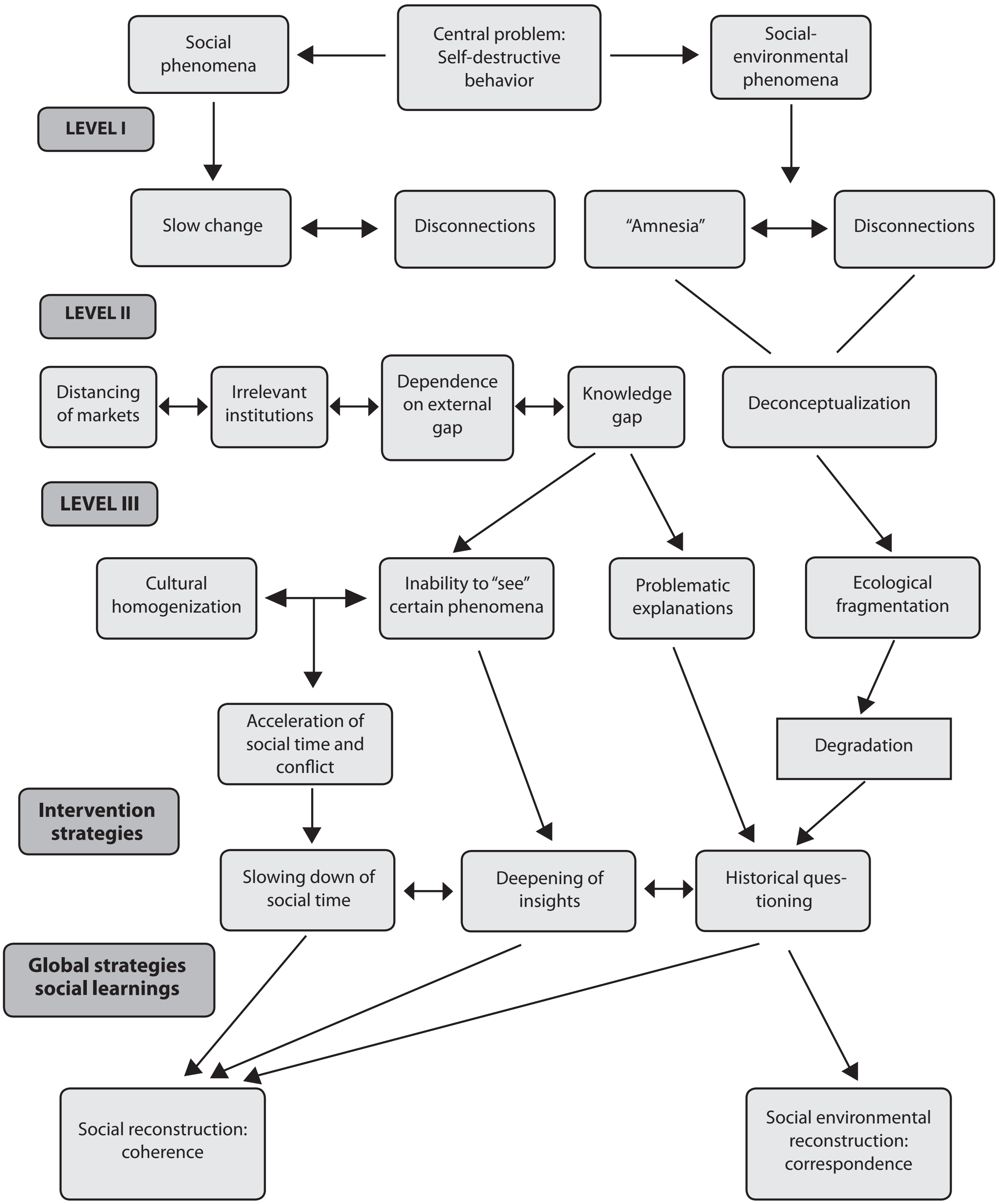


Figure 1. Deeper analysis of problems underlying ongoing socio-environmental decline

time," which involved taking people out of context so that they could begin to challenge assumptions made over water resources and food production. We generally achieved this through strategic field trips and discovery-based learning activities. This was coupled with a "deepening of insights" achieved through conceptual training on water and food closely linked with concerted action—both individual and collective—to change the situation. Drawing on the ideas of Janice Jiggins and Niels Röling (see, for example, the Social Learning for the Integrated Water Management (SLIM) website: sites.google.com/site/slimsociallearningforiwm), we describe inter-community reconstruction as a search for "coherence," in this case to stabilize and increase food production. We describe the human-environmental interface as the search for sustainability or "correspondence." The interaction between coherence and correspondence is described as "social learning." We searched for greater social learning at different levels of aggregation but, most generally, at community (i.e., geographically embedded organization, such as settlements in the micro-catchments in Chota and San Pedro) and institutional levels (broader social spaces of interaction among actors). How did these concepts translate into project activity?

Local community-level activity – The goals at this level were to break down cultural blinders and to deepen insights. We applied a social perspective to helping resource-poor farmers from semi-arid environments to overcome the conceptual and technical barriers that they had constructed for themselves around scarcity of water and limited productive potential of their land. Through helping farmers to challenge popular explanations complemented by systematic farmer-led experimentation and exchange, we sought to enable families to bring more water to bear on their agriculture and livelihoods. To achieve this, we broadly exposed farmers to new experience through field trips and then conducted future scenario workshops that led to "maps of dreams." This was followed up with capacity-building activities to enable farmers to deepen their insights on local priorities associated with water (weather patterns, rainfall, plant-water interactions). Capacity building was then organized around *mingas* (collective work parties) to help design and install individual water systems, in particular, collection tanks. Most families installed their own distribution system, though neighbors often participated in initial activities as part of capacity building. We then invested in farmer-led research on different technologies, as per local priorities (capture systems, costs of tanks, water holding under green manure, irrigation technologies). The details of this strategy are outlined in the curriculum of the generalized farmer field school curriculum that subsequently has been applied by other organizations outside the project area.

Broader institution-level activity – The goals at this level were a socialization of water harvesting and endogenous development. We aspired to insert these concepts as part of the common discourse of development actors. Drawing on the literature from socio-technical change, strategic niche management and evolutionary economics, our intention was not to create single large initiatives but rather to create multiple insertion points. The project sought to advocate for water harvesting and endogenous designs among diverse individual and organizational actors engaged in rural development at different levels of aggregation—local, national and regional levels. Rather than create new organizations, we strategically sought to insert themes and processes into multiple existing networks of actors and their initiatives, often through the strengthening of ongoing events or the creation of complementary activities to increase the profile of water harvesting and endogenous design. Once on-the-ground results were obtained, we supported continual field trips to project sites of decision-makers from farmer organizations, local governments, universities, NGOs and donor agencies. We linked the theme of water and endogenous design to the diverse agenda of partner agencies and networks. Subsequently, we documented success stories that were broadly shared through information channels, such as the CONDESAN InfoAndina (www.infoandina.org) and the different agroecology listserves and events.

Lessons learned

- **Successful examples on endogenous potential as applied to water harvesting** – Through creative utilization of new water resources combined with biological potential, project participants were able to achieve new levels of production and wealth. In the process of increasing production by factors of two to five, families supplanted a previous sense of helplessness with new hope and prosperity. One example is the story of Alfonso and Olga Juma from Lavanderos, Ambuqui, Ecuador (previously submitted to CPWF), but the project has identified another dozen outstanding cases, such as that of Don Reynaldo in Ambuqui and Teófilio in San Pedro. We are closely watching such examples and writing up brief descriptions for broader sharing (including among the CPWF community). The very process of concise story telling has caught on with World Neighbors (WN) and its partners, and we plan to update those stories over the coming years. These will include families that visited the project and later entered their own process of on-farm innovation with water harvesting and food production -- e.g., in and

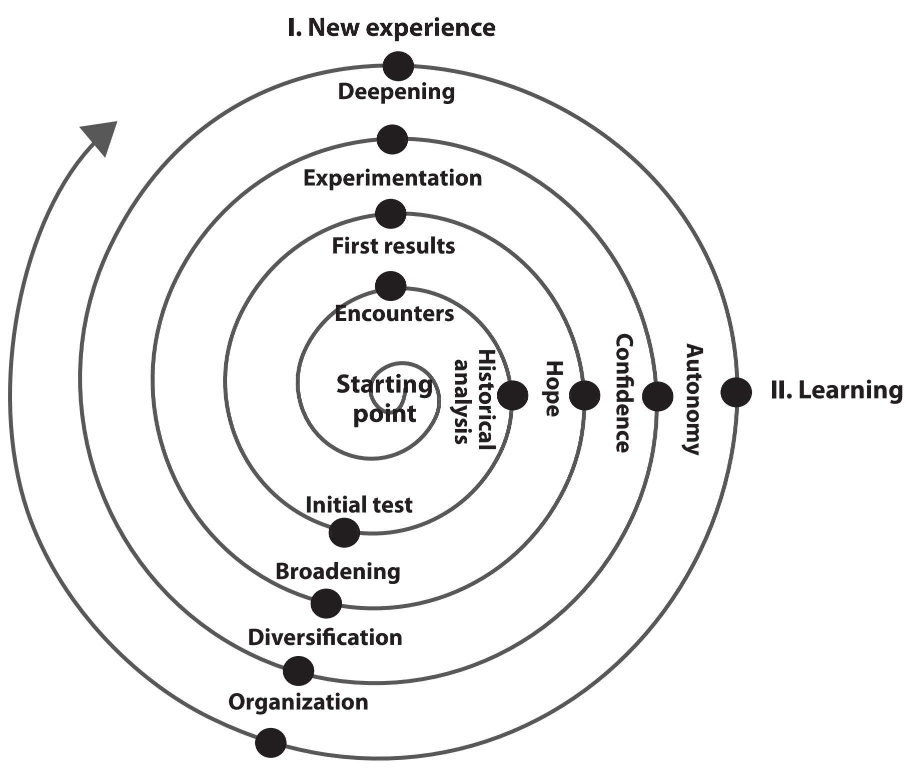


Figure 2. Stylized description of the Katalysis approach to engaging smallholder farmers in discovery learning and action on water harvesting and food production

around the Randi-Randi INNOVEG project in Ilalo in Pichincha, with little to no CPWF or WN resources. These stories include specific technological innovations, for example, with different sprinkler systems in North Potosi and alternatives to geo-membrane-lined holding tanks in Tola Chica, Ilalo. The successes and the stories they generate are a product used by farmers, their communities, development agencies and local governments to reveal other possible futures.

- **Conceptual framework for breaking through the barriers of the *cultura de secano*** – As described earlier, often, rural communities more or less know what is happening to their watershed, but they are not inspired to take action. Recently, there was some research for development experience working with farmers in interactive ways to expose the root causes of soil erosion and pest management. We did not know of any similar experience applied to water harvesting and its integration with the potential biological resources as a means to transforming the farm as a food-producing enterprise. Applying the principles of people-centered development, we engaged the network of farmer experimenters in Ambuqui in a discovery learning process, followed by systematic experimentation. After the first year, we described the emergent "Katalysis" approach based on guided experience, learning and concerted action (Figure 2). This approach included the creation of a local savings and credit scheme to help finance investments. We are now further testing and revising this approach and plan to write up results in 2008.

- **Discovery-based learning exercises and farmer field school (FFS) curriculum** – Central to the earlier mentioned methodology was the employment of new 'learning tools' or discovery-based learning exercises on water harvesting in the context of the micro-watershed of semi-arid environments. Through a process of trial and revision, over time, the project participants conceived of a large number of promising exercises. We held three 'writeshops' involving partner organizations to document these activities and expose them to the scrutiny of the broader groups through processes of presentations and critical feedback. Around 30 activities on farm, community, watershed, and broader advocacy have been tested and are being incorporated into the framework of an FFS curriculum. MACRENA and the Randi-Randi INNOVEG project tested the approach. The activities and the FFS curriculum were revised and cases were published with a description of the Katalysis approach.

- **Technical water and crop production curriculum and resource** – Early on in the project, we learned that *técnicos* (university-trained extensionists and researchers) have very limited technical skills in water. We developed and taught a 10-module course on water harvesting and crop production (available in Powerpoint presentations). We did not find a solid technical resource that was practical and accessible to these professionals in Spanish. So, in collaboration with Wageningen University and Research Centre, we translated and adapted their time-tested "AGRODOC" resource on water harvesting and soil management. Presently, partners in Meso-America are further revising the guide, and we plan to co-publish a Latin American-wide version in 2008.

- **Popularization of water harvesting and endogenous designs** – Different from those in arid and semi-arid regions of Africa and South Asia, the actors involved in agricultural development in the Andes rarely, if ever, spoke of rainwater harvesting and micro-irrigation or the use of conservation agriculture as a means to harvesting water. While countries such as Ecuador have considerable micro-irrigation experience, in large part thanks to the flower industry, this experience has made very limited contributions to resource-poor smallholder farmers. Meanwhile, the dominant development models continued to rely on questionable 'technology transfer' schemes. Through this project, we aimed to insert the themes of rainwater harvesting and endogenous development into the common discourses of rural development. Contributions perhaps were strongest in Ecuador, in large part due to the strength of the MACRENA network and close linkages with the national agroecology movement. Meanwhile, the contributions in Bolivia were limited to the municipalities and local farmer organizations in the region of North Potosi.

Summary note

Through our involvement in regional programs, such as the national agroecology movements, CCRP Community of Practice, and the Program for Local Innovation in Sustainable Agriculture and Natural Resource Management (PROLINNOVA), we found multiple opportunities to promote Katalysis. We are confident that the themes and process have been inserted as a novelty into the regional development discourse. While beyond the capabilities of an 18-month project, based on the merits of the approach and a growing concern over climate change, we feel that Katalysis could continue to grow and diversify to a point where it begins to influence how people think, organize and do with regard to rural development in the semi-arid Andean highlands.

Contact Person

Stephen Sherwood (ssherwood@ekorural.org)

Partner Organizations

Asociacion de Productores Agroecologicos EcoAmbuqui
Fundacion para Agroecologica y Turismo (AGRECO)
Pontificado Universidad Catolica de Ibarra (PUCE-Ibarra), Ecuador
Programa de Desarrollo del Norte de Potosi (PRODINPO), Bolivia
Red para el Manejo Comunitario de los Recursos Naturales (MACRENA)
World Neighbors

Key Reference

Sherwood, S. 2007. *Katalysis: enabling endogenous potential for improved management and conservation of water resources in semi-arid Andean ecosystems.* CPWF Small Grants Final Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: SG505; Improved Management and Conservation of Water Resources

Bibliography

Long, N. and A. Long (eds) 1992. *Battlefields of knowledge: the interlocking of theory and practice in social research and development.* London and New York: Routledge.

Understanding Resilience in Small-Scale Fishery Communities

In many developing countries, small-scale inland fisheries are important to the livelihoods of the poor, contributing to both income (through capture and postharvest activities) and food security (Béné *et al.* 2006). This is particularly true for river fisheries, and especially so in Africa, which has important inland and de facto unregulated open access fisheries, on which millions of poor households depend.

These inland fisheries are characterized by complex multi-species, multi-gear exploitation systems, and large numbers of fishers operating completely within the informal sector. This makes small-scale inland fisheries extremely difficult to assess and manage, thus contributing to livelihood uncertainty and vulnerability.

The CGIAR Challenge Program on Water and Food (CPWF) Improving Resilience in Small-Scale Fisheries Project introduced a range of participatory assessment and adaptive management tools which are used to develop and evaluate management interventions to reduce vulnerability to external processes and promote sound decision-making. This methodology was implemented in two pilot fishery systems in the Niger River Basin, aiming to operationalize concepts of resilience management.

In the area of water management, small-scale fisheries are significantly affected by processes outside their control. In particular, water allocation policy and investments (e.g., dams and irrigation schemes) are dominant factors driving many inland fishery dynamics. Additionally, the unpredictable institutional and policy environments, typical of many countries in Sub-Saharan Africa, is a source of great uncertainty and potential threat. Further, the uncertainty induced by climate change will in the future increase the unpredictability of fishery systems and competition for water, thereby impacting severely on the capacity of the local populations relying on those resources to sustain their livelihoods.

Faced with such constraints and multiple uncertainties, conventional management has, by and large, failed to provide a basis for sustainable development of aquatic resources. The project was designed to initiate and guide major changes in the way small-scale fisheries in sub-Saharan Africa are assessed and managed. The project, which had a strong 'action research' orientation, was aimed to strengthen the resilience of fishing communities through field-testing and application of an innovative framework for participatory diagnosis and adaptive management. Where effectively adopted, this new resilience management approach was expected to reduce the vulnerability of these fishing communities to external threats and changes, thus enhancing their capacity to contribute more actively to the process of economic development and poverty alleviation. Two pilot sites were chosen in the Niger River Basin to try this new approach, one in Mali in the Inner Delta of Niger and one in Nigeria on the shore of Lake Kainji.

A framework to manage resilience

In practical terms, the goal of resilience management is to ensure that the socio-ecological system under consideration will remain within a set of ecologically and socially desirable configurations (Carpenter *et al.* 2001). One needs therefore to identify indicators and thresholds that define these desired configurations. This is the role of the first component of the framework: the participatory diagnosis.

More formally, the objective of this participatory diagnosis is to identify key threats and resilience indicators specific to the system (in the present

The concept of resilience

In a broad sense, 'resilience' is about the capacity of systems to adapt to shocks, recognizing that disturbance and change are integral components of complex systems. More formally, resilience analysis proposes to focusing on mechanisms and processes that help systems absorb perturbations and shocks, and cope with uncertainty and risks. Defined in such a way, the concept of resilience thus appears particularly useful for the management of small-scale fisheries. While the resilience concept is appealing, particularly in the face of the failure of current management approaches, the danger is that it remains largely academic and theoretical, and not of great help in effectively improving the way natural resources are managed on the ground. The challenge, therefore, lies in a pragmatic approach to operationalizing the concept of resilience and making its implementation on the ground practical and meaningful. A framework aimed at this objective for specific context of small-scale fisheries in the Niger River Basin is proposed and discussed.

case, a fishery). This participatory diagnosis can be implemented using various techniques. In our case, we use a 360° integrated assessment map (see also Garcia *et al.,* in press). The idea of this integrated assessment tool is to 'scan', in a systematic and comprehensive manner the system in order to gain a better appreciation of the true nature of drivers and processes that affect its dynamics. Four domains are considered: (a) natural system, (b) livelihood and people, (c) institutions and governance and (d) external drivers (Figure1).

In each of these four domains, resilience indicators and the current conditions of the system assessed against those indicators are identified using a combination of quantitative variables and thresholds. One example is used here to illustrate the process. In the case of the indicator 'Asset and income poverty' in the domain 'People and livelihood', stakeholders (i.e., the fishing households) will be asked to assess their situation in terms of income by identifying two thresholds; one distinguishing what those households consider as a 'desirable' situation from an 'undesirable' one. Above, say, US$4 per household per day, the fisherfolk consider that their situation is satisfactory ('desirable'), while below that same US$4 threshold, the situation is considered as unsatisfactory ('undesirable'). Finally, under a lower threshold of US$2 per day, the households regard the situation as a 'crisis.' Over time (i.e., season, life), the households' income varies, passing above or below the thresholds. The objective of resilience management is to ensure that household's income remains in the 'desirable' zone.

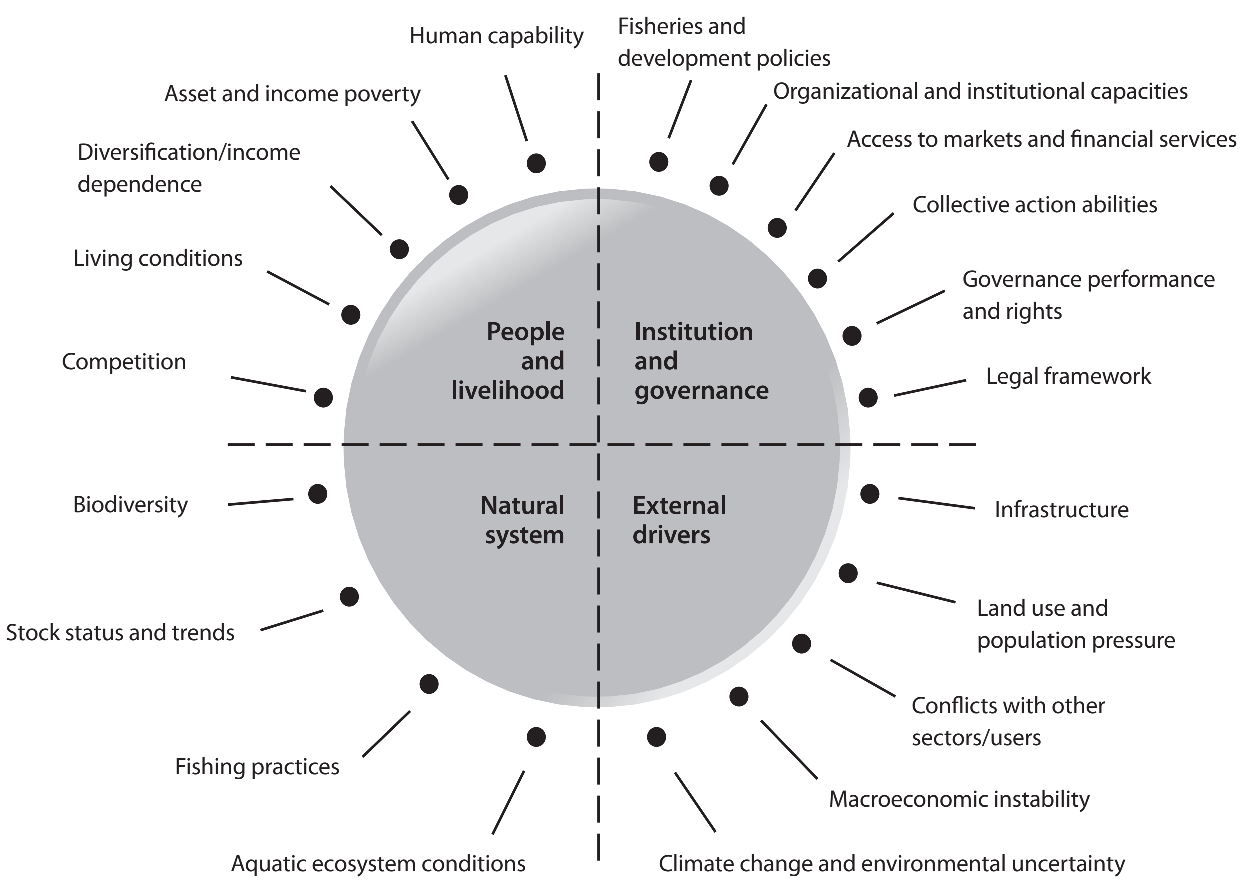


Figure 1. The 360° integrated assessment map

Applying this approach to each of the indicators is considered critical by the stakeholders. A dashboard can be constructed, which reflects, for each indicator, the perception of the stakeholders about the conditions of the system. Different stakeholders can contribute to the evaluation of different indicators (or even domains) of the system. One may, for instance, request a panel of experts to assess the situation of the system for the 'external drivers' domain, while the local community may be asked to express their views about the 'people and livelihood', or the 'natural systems' domains. An abridged example of a dashboard is given in Table, which was produced

Example of dashboard – with one indicator per domain extracted from a full dashboard completed for Lake Kainji fisheries (Nigeria).

Domain	Indicator	Justification	Variable	Thresholds	Status
Natural system	Fish biodiversity	Maintaining high and stable biodiversity is crucial to fisheries and fisheries dependent communities. The sustainability of the fishery is dependent on maintaining the ecological integrity of the natural resources.	Number of species available	◆ Desirable: > 30 species in the system ◆ Crisis: < 90 species	> 120 species (stable)
People and livelihoods	Health centers	Health facilities (e.g., hospitals, clinics, dispensaries, pharmacy) are vital to human capital and sustainabilityof livelihoods. Health has implications for household and community productivity, poverty reduction and food security.	Distance to health facilities	◆ Desirable: < 5 km to health centers ◆ Crisis: > 10 km to health centers	> 10 km to health care centers (crisis)
Institutions and governance	Accountability of traditional institutions	Accountability and responsiveness of traditional institutions are vital to providing a basis for measuring the confidence and cohesiveness of rural fishing communities.	Approval rating among community members	◆ Desirable: > 70% approval (accountable) ◆ Crisis: < 50% approval (low accountability)	> 80% (getting better)
External drivers	Infrastructure (roads)	Access roads are important for easy movement of fish and other agricultural products to market	Percentage of feeder roads in driveable condition during rainy season	◆ Desirable: > 70% in driveable condition ◆ Crisis: < 30%	< 10% (crisis)

by key stakeholders assessing the situation of the artisanal fisheries of Lake Kainji in Nigeria.

The completion of the dashboard allows the identification of site-specific indicators for which the system is considered in crisis—in the present case, the access to health services and the conditions of infrastructure—and for which immediate actions are requested. For those indicators, management actions will be identified and implemented by the stakeholders (with the support of the project), with the objective of bringing back the variables to levels considered 'acceptable'. The project was committed to help stakeholders to progressively enhance their ability to diagnose and respond to the various changes or shocks that affect the fishery. It is hoped that the improved managerial capacities resulting from this process, will lead to better informed and more appropriate decision-making processes in the fishery. In the long term this adaptive process is expected to lead in the long term to a more resilient management system and the reduction of the overall vulnerability of the households who depend on the viability of the fishery for their livelihoods.

Lessons learned

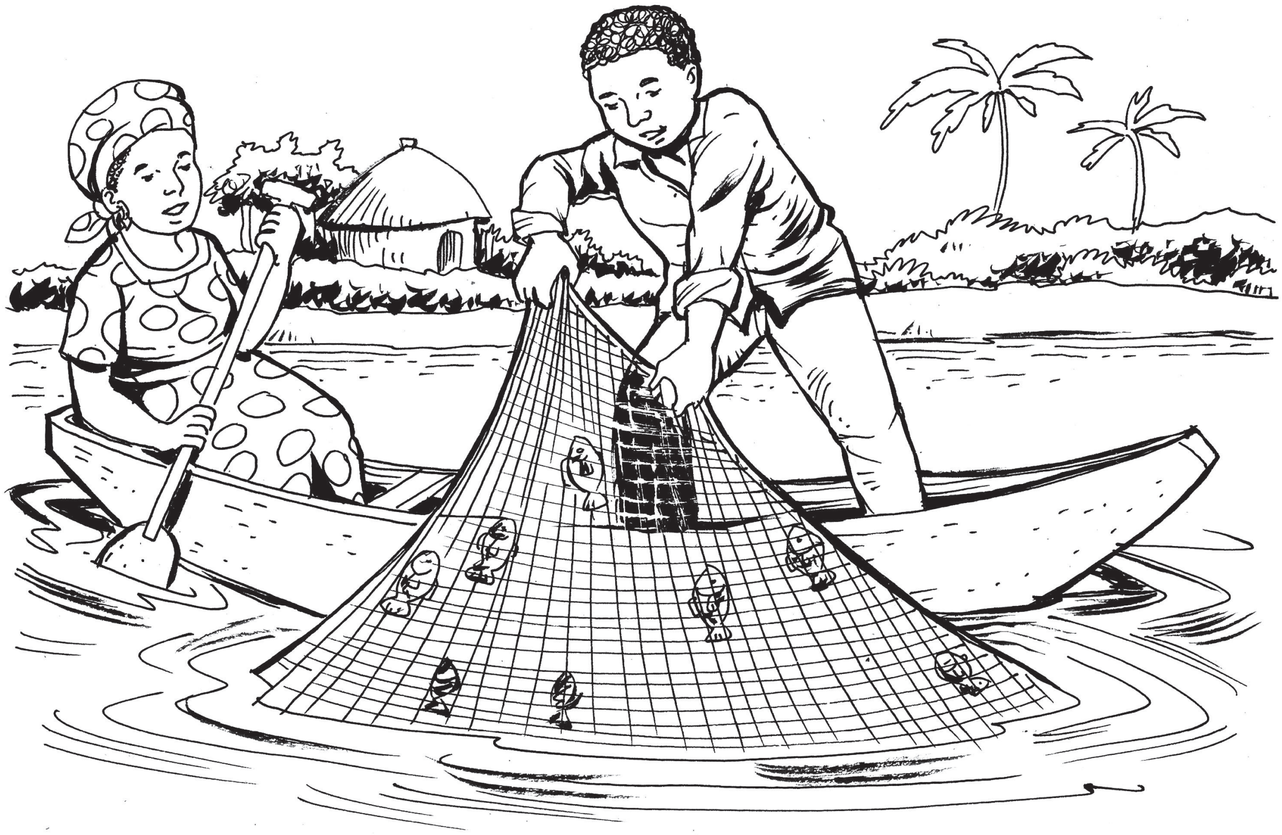
Because the dashboard allows the presentation of indicators of any nature, it provides a powerful way to integrate the combinations of economic, environmental and social dynamics that characterize the realm of fishery management. In this sense, it is an effective tool for multi-criteria assessment. The main merit of using the dashboard, however, is in its capacity to initiate and then strengthen the resilience management process. First, it helps all those involved in the process realize that there is no one unique management target. This aspect is critical in the sense that it clearly distinguishes this approach from the perceptions that the large majority of practitioners and researchers still have about fishery management.

Under the resilience approach, management is not about looking for the unique, or 'fair' solution; it is about negotiating a set of acceptable configurations and agreeing on interventions, incentives or constraints to stakeholder behaviors to ensure that the system stays within these negotiated and accepted configurations.

By so doing, the dashboard also helps stakeholders realize that the management process is bound to rely on trade-offs between ecological, social and economic indicators of management performance. A vivid example of these trade-offs could be a situation where catching 'too many' fish is a short-term objective that might be 'acceptable.' Indeed when small-scale fisheries are set within the reality of societies with great poverty, insecure food supplies and/or variable fishery resources, such levels of harvest may be necessary and unavoidable for a while as long as the overall system is not irreversibly affected.

If run through a participatory process that involves a large range of stakeholders, the dashboard assessment exercise can easily create the preliminary conditions that facilitate the adoption, comprehension and acceptance of the concept of resilience management among stakeholder groups that are not necessarily familiar with this rather abstract concept. The simplicity of the criteria ('undesirable' versus 'desirable' configurations) captures in a straightforward and clear manner the configurations of the system and management objectives.

The dashboard can facilitate communication and knowledge exchanges between the different groups of stakeholders, thus making the negotiation process easier. It also sets the stage for



rules and patterns of social interactions between stakeholders during the following adaptive learning process. In particular it can facilitate the identification of mechanisms and options that allow the fishery to move away from undesirable states. The identified resilience indicators will then be used during the implementation of the adaptive management phase to monitor the 'health' and evolution of the system under a resilience management approach.

Conclusion

The action research project described in this article tested a participatory and resilience-based approach to diagnosis and adaptive management in an acute poverty context in West Africa. Conceptualizing small-scale fishery management as being about managing a multi-dimensional system in the context of uncertainty and prioritizing stakeholder-defined variables and thresholds resulted in a comprehensive socially accepted and context-relevant outcome. Overall, however, the outcomes reflect a much more nuanced understanding of small-scale fisheries as complex systems and show promise as mechanisms of achieving food security, improved livelihoods and environmental sustainability in the long term.

Contact Persons

Christophe Bene (c.bene@cgiar.org)

Partner Organization

Institut d'Economie Rurale, Mali
Institut de Recherche pour le Developpement, France
National Institute for Freshwater Fisheries Research
UMR G Eau, France
WorldFish Center

Key References

Béné, C., A. Kodio, J. Lemoalle, D. Mills, P. Morand, S. Ovie, F. Sinaba and A. Tafida 2009. *Participatory diagnosis and adaptive management of small-scale fisheries in the Niger River Basin*. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3864

Bene, C., N. Andrew, A. Russell, F. Sinaba, S. Ovie, P. Morand and J. Lemoalle 2008. Managing resilience in West African small-scale fisheries. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food*, Vol.2, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 237-240. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: PN72: Improving Resilience in Small-scale Fisheries

Bibliography

Allison, E.H. and F. Ellis 2001. The livelihoods approach and management of small-scale fisheries. *Marine Policy,* **25**, 377-88.

Andrew N., C. Béné, S. Hall, E. Allison, S. Heck and B. Ratner 2007. Diagnosis and management of small-scale fisheries in developing countries. *Fish and Fisheries*, **8**, 227-40.

Bene, C., L. Evans, D. Mills, S. Ovie, A. Raji, A. Tafida, A. Kodio, F. Sinaba, P. Morand, J. Lemoalle and N. Andrew 2011. Testing resilience thinking in poverty context: Experience from the Niger River basin. *Global Environmental Change,* **21**, 1173-1184.

Béné C., G. Macfadyen and E. Allison 2007. *Increasing the contribution of small-scale fisheries to poverty alleviation and food security*. FAO Fisheries Technical Paper. No. 481. Rome: FAO.

Carpenter, S., B. Walker, M. Anderies and N. Abel 2001. From metaphor to measurement: Resilience of what to what?
Ecosystems, **4**, 765-781.

FAO. 1995. *Precautionary approach to fishing. Part 1. Guidelines on the precautionary approach to capture fisheries and species introductions.* FAO Technical Paper No. 250/1. Rome: FAO.

FAO. 2003. *The ecosystem approach to fisheries. FAO Technical guidelines for responsible fisheries.* Rome: FAO.

Bibliography

Folke, C. *et al. 2002. Resilience and sustainable development: Building adaptive capacity in a world of transformations.* Scientific Background Paper on Resilience for The World Summit on Sustainable Development on behalf of The Environmental Advisory Council to the Swedish Government.

Garcia S., *et al. 2008 Towards integrated assessment and advice in small-scale fisheries: principles and processes.* FAO Technical Paper FAO, Rome. 98 p.

Pomeroy, R.S. and R. Riveira-Guieb. 2006. *Fishery co-management: A practical handbook.* CABI Publishing in collaboration with IDRC (Canada).

Walker, B., et al. 2002. Resilience management in social-ecological systems: a working hypothesis for a participatory approach. *Conservation Ecology,* **6**, 14p.

Social, Cultural, and Economic Considerations in Participatory Rice Varietal Selection

Participatory varietal selection (PVS) was used in CGIAR Challenge Program on Water and Food (CPWF) work in India for selecting rice varieties for salinity affected areas. The first step in PVS is identifying farmers' needs within their agro-ecological and socio-cultural environments. In Asia, understanding the socio-cultural diversity is crucial in accelerating adoption of improved varieties in stressed environments. It is thus, important to include social considerations—i.e., ethnicity, religion, social class/caste and gender in PVS. Gender is one of the most important socio-economic factors that delineate roles, tasks, responsibilities and needs among farmers. Men and women have different roles and varying perceptions and needs. These social considerations also involve issues of equity and community empowerment. Involving women ande empowering communities are central to the PVS concept and protocol.

Factors that determine adoption

a. **Livelihood needs.** Different varieties fulfill different livelihood functions and can provide food, livestock, fodder, thatching or cash.

b. **Socio-economic status of farmers.** Farmers choose different grain types according to their socio-economic status and degree of market integration.

c. **Gender-specific roles.** Rice production involves gender-specific roles and, based on these roles, men and women have different criteria for varietal adoption.

Methods for mainstreaming socio-cultural and economic dimensions in PVS

The participatory rice varietal improvement process has several stages that involve farmers and the community (Fig. 1). Each of the methods and tools in integrating social, economic and cultural aspects of varietal selection is discussed briefly in this article.

Stage 1: Set breeding goals.

1. ***Social and gender analysis.*** Social analysis requires information on social activities and culture (way of life, which includes language, arts and sciences, thought, spirituality and interactions), while gender analysis deals with roles or domains of men and women as they interact in agricultural activities. This tool is partly incorporated in participatory rural appraisals (PRA), baseline surveys and other methods of data collection.

2. ***Participatory rural appraisal.*** This is a general methodology for development research, planning, monitoring and evaluation. It presents the link between technical (or biophysical) and socio-economic information

The following questions are central to gender analysis:

a. Who does what, when and where?
This covers crop-specific and livestock activities and operations, farm enterprises and off-farm, nonfarm and household maintenance activities that compete with or complement other tasks. Also included are crop production management and postharvest of seeds, root crops, tuber crops, other commodities, and livestock.

b. Who has access to or control over the resources? Access means that resources may be available but there are no choices related to the timing or amount of use or there are conditions attached. Control means having decision-making authority concerning a resource.

c. Who benefits from each crop enterprise? What are the incentives and disincentives for managing or for making changes to them? The question of who benefits from these is closely related to roles and responsibilities, equity, and issues of access and control.

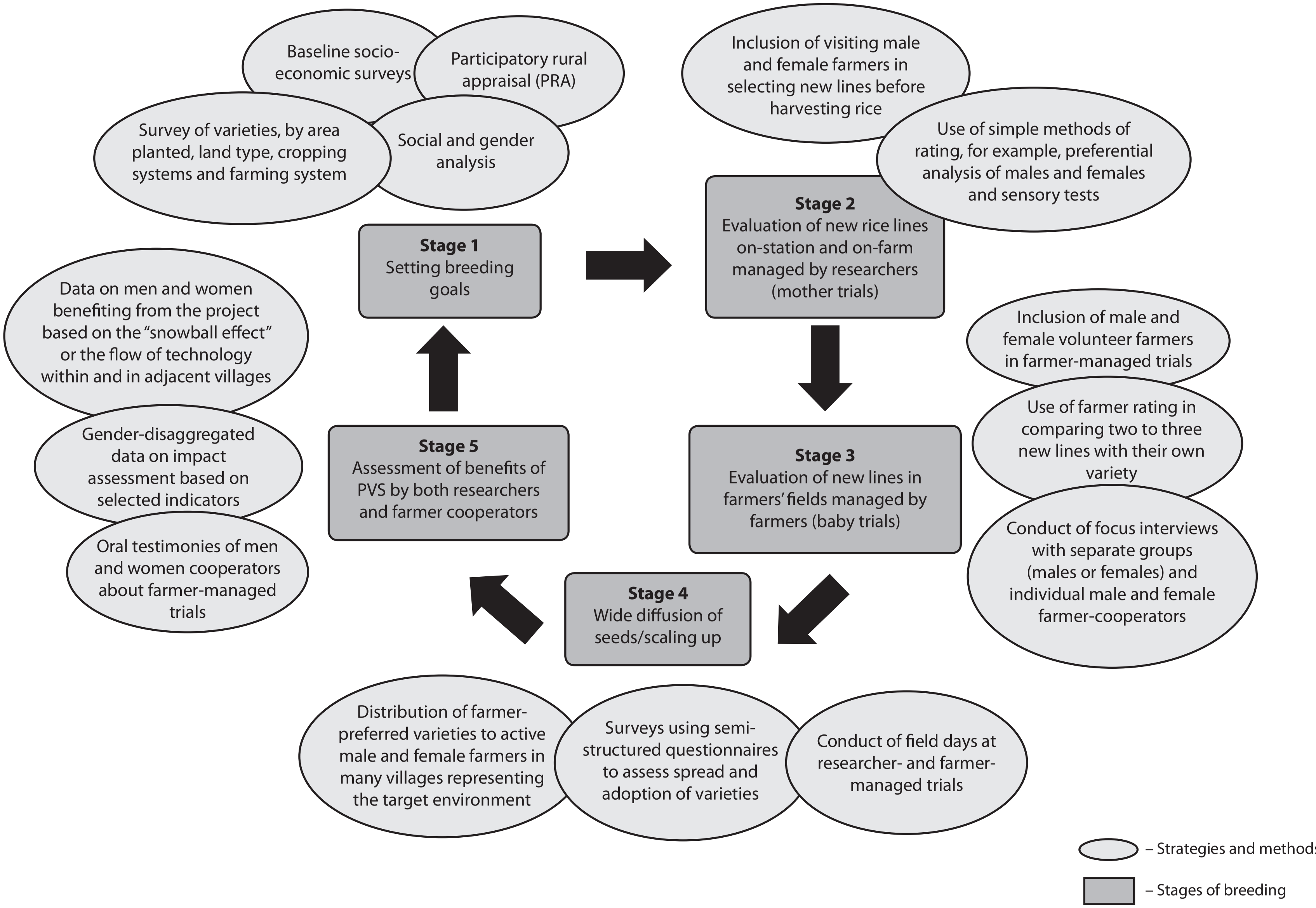


Figure 1. Tools and methods for incorporating social, cultural and economic considerations in breeding programs (Paris* et al.*).

to form the basis for the community's and the stakeholders' identification and prioritization of alternatives or courses of action.

The following PRA principles should be considered when identifying a good combination of tools and methods to use:

a. Reversal of learning by gaining physical, technical and social knowledge from rural people directly, on-site, and personally.

b. Learning rapidly and progressively with conscious exploration, flexible use of methods, iteration and cross-checking and adaptability in the learning process.

c. Offsetting biases by being relaxed, by listening and by being unimposing (instead of feeling important) and seeking out poor people and women to discuss their concerns.

d. Facilitating investigation, analysis, presentation and learning among rural people themselves so that they present, own and learn from the outcomes.

e. Self-critical awareness and responsibility, meaning that facilitators are continuously examining behavior to do better and accepting personal responsibility rather than vesting it in a manual or a rigid set of rules.

f. Sharing of information and ideas between rural people, between them and facilitators and between facilitators.

Probing questions

The following methods are used to better understand the phenomenon in an agricultural setting, particularly the social aspects for which people are the participants. The results contribute to a deeper understanding of the experience from the perspective of those concerned.

a. **Focus group discussions**. It is a rapid assessment and semi-structured data collection method in which a purposively selected set of participants or social groups gather to discuss concerns based on a list of key themes that the researcher/facilitator has drawn up.

b. **Semi-structured questionnaires**. This is a simple process of talking with individuals, families or groups to discuss a specific topic in an informal setting. The information that needs to be collected is predetermined by the team and only an interview guide is developed and not a complete questionnaire.

c. **Use of probing questions**. This means getting additional information and dealing with a topic or idea more deeply and logically, especially with complex and controversial issues that need further discussion and clarification.

d. **Use of selected PRA tools and methods.**

In characterizing the village, four additional major groups of PRA tools and methods will be used. The PVS protocol aims to (1) characterize biophysical and socio-economic conditions at target sites; (2) determine seasonality (climate, cropping pattern and calendar) and characterization of stress in rice farming (nature, timing, intensity and depth); (3) identify problems related to rice farming in target areas using a causal link approach such as the problem tree analysis; (4) analyze physical resources, human resources, institutional linkages and technology, information, and input delivery systems at target sites; and (5) integrate and analyze all the information collected as basis for identifying interventions. Table 1 shows some of the most important PRA tools and methods that can be used for Stage 1 of the PVS protocal. These are mainly used in the preparation of village descriptors and baseline information.

3. ***Baseline socio-economic survey.*** The baseline survey provides data to gain a better understanding of socio-economic conditions that affect flow of technologies and information and the driving forces behind current conditions in the community.

4. ***Key informant surveys (KIS).*** Additional information can be collected by conducting a survey with a small group of key informants. An alternative method is through focus group discussions on specific topics.

Stage 2: Researcher-managed evaluation of new rice lines on-station and on-farm (mother trials)

- **Inclusion of visiting male and female farmers in selecting new lines before harvesting of rice.** All forms or information to be collected should be gender-disaggregated to ensure that both men and women participate and are consulted when selecting new lines for the researcher-managed trials before harvest.

- **Use of simple voting methods to identify the two most preferred and two least preferred lines in the preferential analysis performed by male and female farmers**. It is suggested that at least 30% of the participants be female to allow the collection of reliable information that can be subjected to both qualitative and quantitative analysis of data and information. The design of the preferential analysis and sensory tests already incorporates the disaggregation of data for male and female cooperators/participants.

PROBING QUESTIONS

- **What qualities do consumers look for? What is the market price of this compared with a certain variety?**
- **Why do farm laborers prefer this?**
- **What is maturity period? Why do you like short/medium/long duration?**
- **Why is it easier to grow? How is it compared with that variety?**
- **How does this variety fit into the cropping system?**

Stage 3: Farmer-managed evaluation of new lines in farmers' fields (baby trials)

- **Inclusion of male and female volunteer farmers in farmer-managed trials.** The baby trials involve the participation of men and women in the growing, testing and selection of new rice lines in farmer-managed trials under their own farm conditions.

- **Use of farmer ratings in comparing two to three new lines with their own variety.** PVS makes use of farmer ratings in comparing two to three new lines with their local/traditional variety.

- **Conduct of focus interviews with separate groups (males or females) and individual male and female farmers**. The baby trials should contain a group discussion on the performance of the varieties and farmers should be asked to talk about the good and bad (positive and negative) characteristics of the varieties. These ratings and the information about trial conditions should be recorded in a form that clearly summarizes farmers' opinions and preferences. Separate focus interviews can be done for male and female farmer-cooperators.

Stage 4: Wide diffusion of seeds/scaling up

◈ **Distribution of farmer-preferred varieties to active male and female farmers in villages that represent the target environment.**

Some PRA tools and methods

Objective	Specific tools	Rationale for use	Output
1. Characterize the biophysical and socio-economic conditions of the site	a. Village transect/ transect walk	To collect information on biophysical and social conditions of farming communities and how these factors can support or constrain technology adoption	Transects that show land types, irrigation facilities and areas affected by submergence and other stresses
	b. Resource and social mapping		Resource and social maps of the village
2. Define the cropping pattern and determine the characteristics of the abiotic stress (submergence problem)	a. Seasonal calendar (climate, cropping pattern and period when rice is sufficient and scarce)	To understand the importance of rice and how this is affected by submergence and other stresses	A monthly calendar showing the cropping patterns and the nature, timing, depth, intensity, and days when submergence and other stresses occur. It shows the months when rice supply is sufficient or scarce.
	b. Trend analysis		A trend diagram showing the incidence of submergence in the last 5 years
3. Analyze the submergence problem in the farming community, its primary and secondary causes, and its effect on rice yield	Problem tree analysis-causal effect link approach	To understand farmers' perception of the problem, its causes, and effects (extent of loss) on rice yield	A diagram showing biophysical, socio-economic, and institutional causes of the submergence problem, and the effects of such stress on the various aspects of life in the community. The resulting chart will serve as a basis for identifying intervention points for research and extension.
4. Identify resources, social capital, communication, and seed delivery system (including flow of information)	a. Venn diagrams showing the relative importance and roles of each actor (relative importance reflected by size of Venn diagrams).	To understand the relative importance of each actor in the extension and communication delivery system	Schematic and Venn diagrams showing the interlinkages between actors involved in the extension and communication delivery system
	b. Schematic diagram of the seed delivery system, including the flow of information.		Schematic diagram showing the flow of seed delivery; room for improvement identified

Technology improvements should include the development of varieties based on preferences and the impacts on male and female farmers. The project should ensure that the number of women and men involved is proportional to how they are already involved in their respective activities.

- **Survey using a semistructured questionnaire for the "snowball effect" to assess the spread and adoption of varieties.** Snowball sampling uses an informant as a source for locating other people from whom data can be generated (in this case, the spread of technology or variety), who then can refer the researcher to other people, and so on.

- **Conduct of field days at researcher- and farmer-managed trials.** For both the researcher-managed PVS and the farmer-managed PVS, male and female farmers should be invited and given equal opportunity to participate, be heard, and take part in the decision-making process. This eliminates any social barriers against women and enables their interaction with male development/extension workers and other stakeholders.

Stage 5: Assessment of PVS benefits by both researchers and farmer-cooperators

- **Oral testimonies of men and women cooperators about farmer-managed trials.** It will assess initial benefits accruing to direct beneficiaries of the project, which can be gathered and presented in a simple case study, a feature article or an information clip.

- **Data on women benefiting from the project based on the "snowball effect" or the flow of technology within or in adjacent villages.** It can include the assessment of communication flow within the community that would give equal access to and control of information to both men and women.

- **Gender-disaggregated data on impact assessment based on selected indicators.** The impact assessment to be conducted should have, when possible, gender disaggregation of data and information.

Outcomes of social and gender analysis in rice varietal improvement

- Clearer understanding among plant breeders of farmers' selection criteria. These would be considered in formulating breeding objectives.

- Poor women included as visiting farmers in evaluating the performance of new lines in researcher-managed trials (mother-trial design).

- Farmers are exposed to many varieties or new lines and have many to choose from.

- Active poor women farmers included as project cooperators in farmer-managed trials.

- Both men and women farmer-cooperators able to make more objective evaluation of new genotypes using their resources.

- Farmers' rights promoted.

- Faster uptake of new varieties in rainfed areas.

- Men and women have better access to seeds and new knowledge.

- Varieties approved from PVS by formal release systems, which consider both yields and other traits for poor and subsistence farmers.

- Men and women farmers, rather than breeders, making the final decision to accept or reject new varieties.

- Women's empowerment enhanced.

Factors that influence women empowerment have considerable differences in terms of

1. economic status (poor, wealthy, small, marginal or large farming households);
2. social group (lower and upper caste);
3. ethnic group;
4. access to land (farming, landless);
5. production system (rainfed lowland, upland); and
6. type of market integration (subsistence, commercial).

Contact Persons

Thelma Paris (t.paris@irri.org), Digna Manzanilla, Gerlie Tatlonghari, Romeo Labios, Amelia Cueno, Donald Villanueva

Partner Organization

International Rice Research Institute

Key Reference

Paris, T.R., D. Manzanilla, G. Tatlonghari, R. Labios, A. Cueno and D. Villanueva 2011. Guide to participatory varietal selection for submergence-tolerance rice. Los Banos, Philippines: International Rice Research Institute.

Bibliography

Bellon, M.R. 2001. Participatory research methods for technology evaluation: a manual for scientists working with farmers. Mexico, D.F.: International Maize and Wheat Improvement Center (CIMMYT).

Chambers, R. 1994. Participatory rural appraisal - practical handbook. GOBI/UNDP/FAO Project Report 2000.

Project
Publication No. 24.

Farnworth, C.R. and J. Jiggins 2003. Participatory plant breeding and gender analysis. CGIAR Systemwide Program on Participatory Research and Gender Analysis for Technology Development and Institutional Innovation. Cali (Colombia): Centro Internacional de Agricultura Tropical (CIAT).

Horne, P. and W. Stur 2003. Developing agricultural solutions with smallholder farmers: how to get started with participatory approaches. ACIAR Monograph No. 99. Australia: Australian Centre for International Agricultural Research and Cali (Colombia): International Center for Tropical Agriculture.

International Rice Research Institute (IRRI). 2001. Farmers and scientists: building a partnership for improving rainfed rice in eastern India. Final narrative report and technical report submitted to the International Development Research Centre (IDRC), Canada, September 2001. Los Baños (Philippines): International Rice Research Institute.

Johnson, N, N. Lilja and J. Ashby 2000. Using participatory research and gender analysis in natural resource management: a preliminary analysis of the PRGA inventory. Working Document No.10. CGIAR Systemwide program on participatory research and gender analysis. Cali (Colombia): Centro Internacional de Agricultura Tropical (CIAT).

Paris, T.R., A. Singh, V.N. Singh and P.C. Ram 2008. Mainstreaming social and gender concerns in participatory rice varietal improvement for rainfed environments in eastern India. In: Participatory plant breeding and knowledge management for strengthening rural livelihoods, ed. V. Arunchalam; 102-129. Chennai (India): MSSwaminathan Research Foundation (MSSRF).

Paris, T.R.,A. Singh, J.S. Luis, M. Hossain, H.N. Singh, S.S. Singh and O.N. Singh 2001a. Incorporating gender concerns in participatory rice plant breeding and varietal selection: preliminary results from eastern India. In: Assessing the impact of participatory research and gender analysis. Participatory Research and Gender Analysis Program, eds. N. Lilja, J. Ashby and L. Sperling; 109-121. Cali (Colombia): International Center for Tropical Agriculture.

Bibliography

Paris, T.R., A. Singh and J. Luis 2001b. Listening to male and female farmers in rice varietal selection: a case in Eastern India. In: An exchange of experiences from South and Southeast Asia. Proceedings of the International Symposium on Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement, Pokhara, Nepal, 1-5 May 2000. Cali (Colombia): Centro Internacional de Agricultura Tropical.

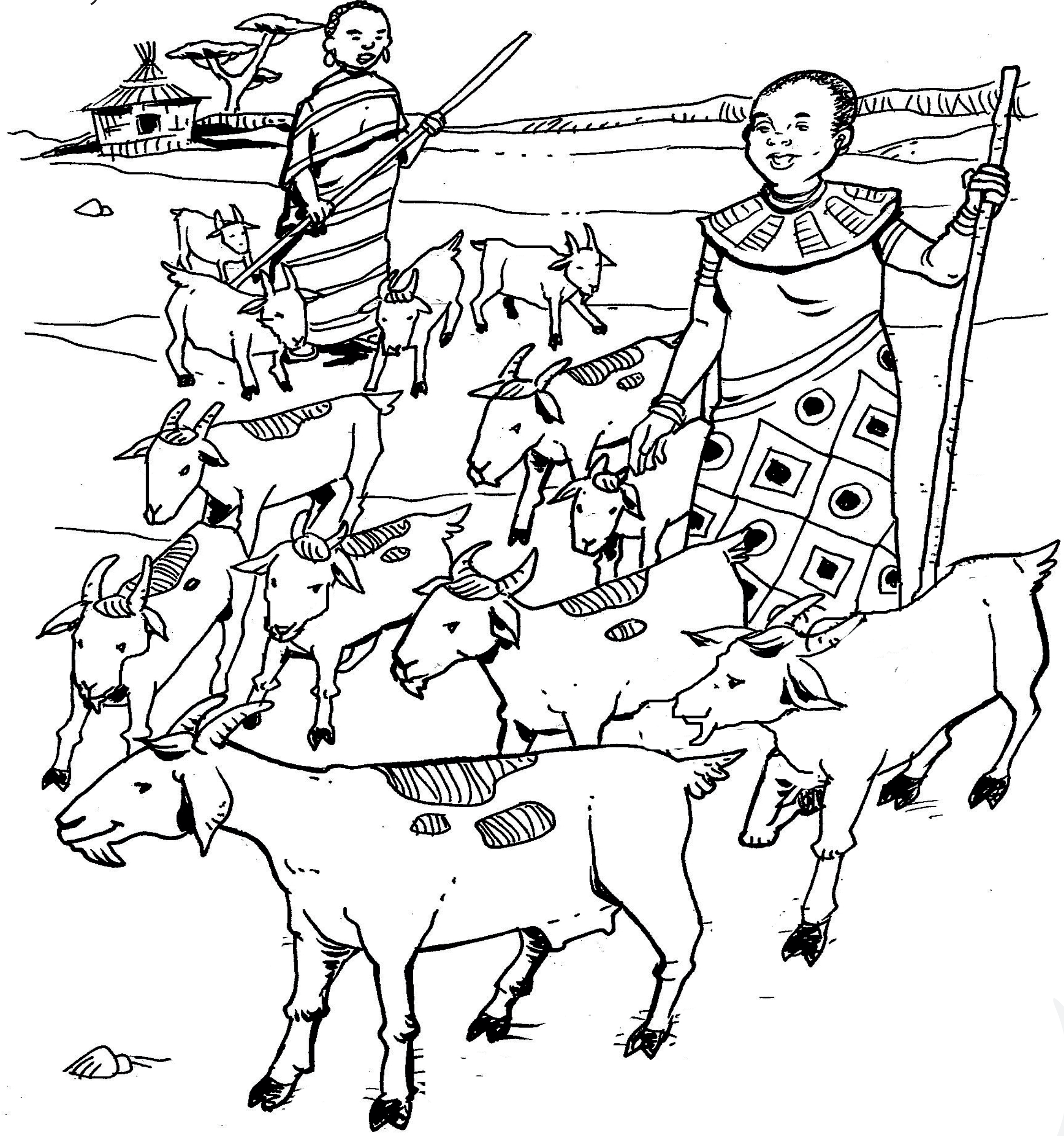
Sahu, R.K., V.N. Sahu, M.L. Sharma, T.R. Paris, K. McAllister, R.K. Singh and S. Sarkarung 2001. Understanding farmers' selection criteria for rice varieties: a case in Madhya Pradesh, Eastern India. In: An Exchange of Experiences from South and Southeast Asia. Proceedings of the International Symposium on Participatory Plant Breeding and Participatory Plant Genetic Resource Enhancement, Pokhara, Nepal, 1-5 May 2000; 343-358. Cali (Colombia): Centro Internacional de Agricultura Tropical.

Seshu, D.V. and M. Dadlani 1989. Role of women in seed management with special reference to rice. IRTP Technical Bulletin no. 5. Los Baños (Philippines): International Rice Research Institute.

Sperling, L., J. Ashby, M. Smith, E. Welzien and S. McGuire 2001. A framework for analyzing participatory plant breeding approaches and results. Euphytica, 122, 439-450.

Beyond Fetching Water for Livestock

A Gendered Sustainable Livelihood Framework to Assess Livestock Water Productivity



Livestock keeping can be a pathway out of poverty (ILRI 2002). However, livestock production systems are complex. In this system, men and women have specific roles and responsibilities and are benefiting differently. This system also varies between countries, cultures and ecosystems. To understand this diversity and the different roles of men and women in livestock production systems, a Gendered Sustainable Livelihood Framework (GSLF) is useful. The framework is based on the Sustainable Livestock Framework (SLF), and includes the assessment of livestock utilization by gender, distribution of inputs and outputs, as well as the governing arrangements for livestock production. Emphasis is put on gendered access and control over productive assets of poor livestock farmers.

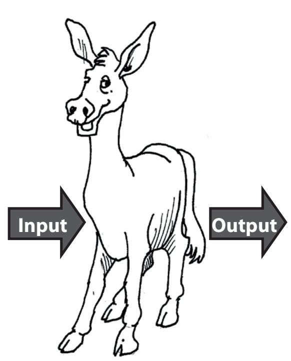
Analytical framework on gender and assets in the SLF

The SLF enables us to get a better understanding of livelihood dynamics in general and of the role of livestock within those dynamics in particular. The gender dynamics in livestock productivity as related to the roles and responsibilities of men and women, both at the household and community levels, is shown in the GSLF framework. The GSLF (Table 1) combines the SLF with the gender analysis framework developed by Feldstein and Poats (1989).

The research questions are the following:

- Labor: who does what?
- Incentives and benefits: who benefits?
- Governing arrangements: who has access and control over resources?

Table 1. The Gendered Sustainable Livelihood Framework (van Hove and van Koppen 2005).

Livelihood asset	Cost to access assets	Access/control					Livestock as an asset Keeping livestock as a strategic activity	Benefits/ outputs or outcomes	Access/control					Risks/ vulnerability contexts=shocks, trends, seasonality	Institutional contexts
		M	W	H	C	G			M	W	H	C	G		
Natural -Water -Land -Feed							Water? Feed? Land? • Where? • How much? • At what cost? (time, labor, price?) • Which mechanism helps optimize water use?	-Soil fertility -Biodiversity -Optimum water use							
Human -Labor -Knowledge -Skills								-Nutrition							
Physical -Water infrastructure -Services								-Traction -Transport -Energy/fuel							
Financial -Cash to purchase or pay for goods and services								-Income -Insurance -Coping							
Social -Resource-sharing groups -Gift bride price -Cultural festivals								-Status -Social security							

M= Men; W= Women; H= Household; C= Community, G= Government
The last two columns - Vulnerabilty and Institutional - help to show the different constraints and opportunities of livestock keeping in the context of other productive and nonproductive activities in the system.

Livestock are productive assets and the roles and responsibilities related to livestock keeping are thus valued as productive. In the GSLF, efforts made to use certain assets for livestock keeping are referred to as 'livelihood costs.' On the other hand, 'livelihood benefits' refer to outputs from livestock that provide value to men and women and their dependents. Household members also have varying degrees of entitlement and mobility, often dictated along gender lines by institutions such as marriage, inheritance and parenthood. These entitlements and mobility are largely influenced by the dynamics of incentives, allocations and benefits to men and women. These are referred to as 'structures and processes.'

The GSLF considers five livestock-related livelihood assets. These are factors required to keep livestock, improve livelihood production systems and ensure that men and women derive livestock-related benefits.

Applying the GSLF

Livelihood costs and benefits are changing due to different feeding strategies, increased need for veterinary care and other external inputs, and access to markets, credit systems and information. These changes result in a shift in roles and responsibilities at the household level. The introduction of technologies can be positive for women in terms of reduced workload. Women can then have more time to look after the children or get involved in other income-generating activities. On the other hand, the introduction of new technologies (e.g., forage technologies) could also involve extra labor for women.

The GSLF can be used for three different purposes:

1. **To assess livestock water productivity.** Identify the role of a specific animal in the livestock production system. This can offer insight into which animals are most valuable for men and women in a specific system. The information can contribute to a more holistic and meaningful assessment of livestock water productivity.
2. **To perform a gender impact assessment**. Predict what the expected impacts on the gendered costs and benefits will be when a specific technology is introduced, particularly in water scarce areas.
3. **To enhance learning.** Use the framework as a tool at different levels (community, development agent, researchers) for communities to analyze the importance of livestock, as it relates to water, in their livelihood. This is to stimulate mutual understanding about the importance and limitation of livestock rearing.

Tools for Applying GSLF

Central in the assessment of livestock-productivity is to determine what the specific values are of different animals in the livelihood systems of men and women. The assessment gives a gender specific picture of livestock productivity at the community level. This picture can be evaluated with the LWP framework.

Programs focusing on livestock - water productivity can consider the following gendered livestock information, taking the different common animal species as starting point.

1. Get a good overview of the existing livestock production system of the area. The system can be evaluated using the five capital values, to determine costs and benefits for men, women and children (see Table 2). It also explores what

benefits are more important than others, and why.

2. Identify the governing processes and structure related to livestock keeping. Discuss questions like who has access and who has control over the costs and benefits, and how flexible are these arrangements?

3. Assess how the governing arrangements enable or disable men and women to reach their specific livelihood objectives if there are opportunities for change, and how these changes would impact others (gendered SWOT assessment of governing arrangements).

The assessment used different participatory approaches (e.g., ranking, historical mapping, calendars). Information (related to LWP) from other studies can be added to the tables and maps to quantify the cost and benefits and changes over time, like for example, the amount of water consumed per year, availability of feed liters of milk produce per day etc.

Table 2. How cost and benefits can be summarized in a seasonal calendar

WOMEN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Costs												
Walk to the market to sell milk/eggs	X	X	X	X	X	X	X	X	X	X	X	X
Milking goats/ sheep/cows	X	X	X	X				X	X	X	X	
Looking after sick animals					X	X	X					X
Others												
Benefits												
Income from milk/eggs	X	X	X	X	X	X	X	X	X	X	X	X
Milk/ eggs own consumption	X	X	X			X	X	X		X	X	
Meet own consumption in household	X		X			X		X		X		
Religious celebration						X				X		
Others												

The participatory assessment of livestock productivity enhances discussions between community members. To pinpoint these discussions on LWP we can do a ranking exercise (Table 3). In this exercise, the gendered importance of livestock as decided by the local community is compared with the LWP. The ranking can be done for dry and wet years. Leading question could be: what animals are most important in a dry year and why?

Table 3. Comparing community interests with livestock water productivity (LWP)

	Ranking of livestock species by importance to community (1: least important)		**Ranking of species according to LWP**
	Men	**Women**	
Male sheep	8	5	5
Female goat	9	10	4
Female camel	7	7	10

This table can be used as a learning tool by discussing why men, women, and the 'LWP' assign ranks in this particular way. Awareness of the differences and similarities can be the starting point to explore options to improve LWP of the livestock production system. All materials derived from the participatory exercises can be used to see if proposed changes are realistic; what the impacts might be on the costs and benefits of livestock production to men and women; if governing institutions need to be adapted or strengthened; and if improving LWP contributes to poverty alleviation.

Contact Persons

Barbara van Koppen (b.vankoppen@cgiar.org), Esther van Hoeve

Partner Organization

Christian Relief Society in Dire Dawa, Ethiopia

Key Reference

Peden, D. *et al.* 2009. Nile basin livestock water productivity. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3927

Tags: PN37: Nile Livestock Water Productivity

Bibliography

Feldstein, H. and S. Poats 1989. Conceptual framework for gender analysis in farming system research and extension. In: *Working together. Gender analysis in agriculture, Volume I: Case Studies,* eds. H. Feldstein and S. Poats; 7-37. West Hartford Connecticut, USA: Kumarian Press.

ILRI 2002. *Livestock, a pathway out of poverty. ILRI strategy to 2010.* Nairobi, Kenya: International Livestock Research Institute.

Gender Issues Related to the use of Groundwater Irrigation Technologies

The Upper East Region (UER) is one of the poorest areas in Ghana. The area is semi-arid and the population mainly depends on subsistence agriculture. Increasing market demand for vegetables in the urban centers of southern Ghana, within the past 15 years, has triggered the farmer-initiated introduction of groundwater irrigation technologies, such as temporal and permanent shallow wells and riverine alluvial dugouts for dry-season irrigation. Yet, identifying the linkages between irrigation, food production and poverty alleviation for all local stakeholders requires a clear understanding of how men and women contribute to and are affected by irrigation development. The International Water Management Institute (IWMI) examined the gender dimensions of participation in the use of three groundwater irrigation technologies and in decision-making. It assessed how social relationships shape opportunities for the control of resources and investments and the sharing of costs and benefits. Important factors determining who can and who cannot participate and profit from irrigation are rights to land and water, inheritance, local leadership, intra-household relationships, credit and market conditions (INPIM 2007).

The focused on two communities where the use of groundwater for irrigation was prevalent:

1. Anateam in Bolgatanga District, where riverine alluvial dugouts (RADs) and temporal shallow wells (TSWs) are predominant.
2. Telenea in Kasena-Nankana District, where permanent shallow wells (PSWs) and TSWs are predominant.

Irrigation development in the Upper East Region

- **1950s-60s: construction of small reservoirs and dugouts**
- **1970s-80s: construction of two large reservoirs for irrigation (Vea and Tono)**
- **Early 1990s: alternative irrigation technologies, such as permanent and temporal shallow wells introduced; riverine alluvial dugouts initiated and expanded by farmers in the White Volta sub-basin to increase vegetable production; rapid development of these technologies also influenced by affordable pumping technologies from India and Pakistan in the mid-1980s (Shah 1993).**
- **Current Status: UER has 156 small reservoirs (IFAD 2005) mainly used for domestic purposes, livestock keeping and crop production; government and NGOs are developing more irrigation systems.**
- **Crops cultivated under irrigation include rice, tomato, pepper, onion, cabbage and lettuce.**

Field methodologies for data collection were as follows:

1. Focus group discussion with men and women farmer irrigators
2. Field survey with women farmers
3. Key informant interviews with village chiefs
4. Regional workshop to get feedback from stakeholders from four districts (Bolgatanga, Bongo, Kasena-Nankana and Kasena-Nankana East) in the study area, with representatives from district assemblies, the Water Resources Commission, and NGOs involved in irrigation development (e.g., Red Cross).

Gender dimensions in groundwater irrigation technologies: Some highlights

Land and water rights

There is a multitude of extremely complex land tenure and management systems in Ghana (Kasanga and Kotey 2001). There are more than 80 formal legal instruments regulating land tenure, some of which are contradictory. They co-exist with various forms of customary land tenure.
For instance, the tribes in the study areas within northern Ghana believe that land is held in sacred trust for the ancestors. To them, selling their land is a sacrilege. Farm households are allocated 'family

land.' Local farmers do not own this land from a legal perspective and cannot sell it, but they have secure usufruct rights to this land (Birner *et al*. 2005). The usufruct rights can be passed on to the descendants by inheritance so that land tenure is secure for as long as the land is cropped. When the land is fallow, the *tendana* can redistribute it. A *tendana* is an established local authority, such as a priest or a village chief, responsible for looking at land issues. A part of the farmers' harvest is given to him as rent, in recognition of his authority.

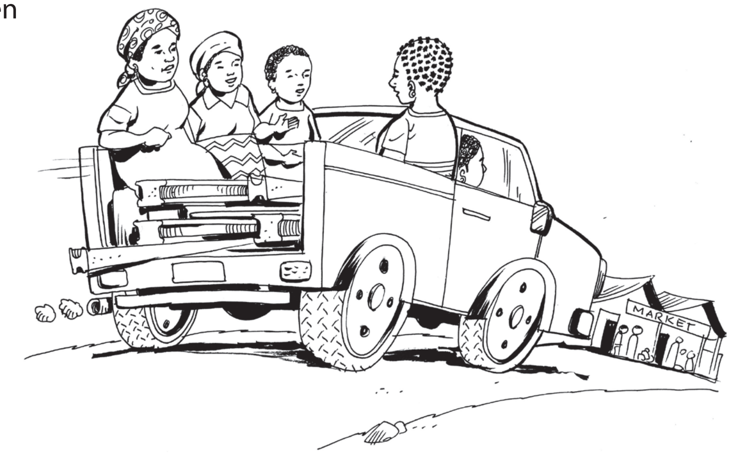
Usufruct rights have considerable social implications. Unless the occupier of the land stands in breach of the chief or the *tendana*, he cannot be deprived of his usufruct rights.

The increase in population density tends to decrease available land for the growing population. Smaller households, which do not have enough labor to cultivate their own land, can lease part of their land to their neighbors or relatives. Land security is assured for usufruct rights holders, though not for migrant farmers.

Land rights are linked to water rights. A person who holds the rights to a plot of land is allowed to tap groundwater beneath that plot of land (Lentz 2006). Surface water, however, is considered a communal resource that is freely and openly accessed, in adherence to communal water use rules (FAO 1998, Ministry of Works and Housing 1998).

Access to land and water

It is customary in the UER to consider inheritance of land as patrilineal and the traditional laws do not recognize usufruct rights for females. Women have only indirect land rights—they access land through a male member of the family. The only exception is if a household is headed by a female, in which case, they can request land from the *tendana* (Birner *et al.* 2005). Typically, women can temporarily use their husband's land. Unmarried women seldom have access to land, and widows lose access unless they have male children. Women with resources can rent land to farm. However, women are usually given small plots that are farthest from water sources or are least productive (IFAD 1998).



The table shows that RAD technology is male-dominated. The RAD technology appears unfavorable to women due to capital intensiveness, full-time demand and land tenure limits.

The ownership of PSWs is directly linked to land ownership, which is dominated by men who own the irrigated plots. Women mostly support their husbands in the watering, harvesting and selling of produce. About 15% of the males have developed separate PSWs for their wives to use for irrigation.

Traditionally, land areas along the river channel are owned by heads of families who hold it in trust for their families. Heads of families are elderly men who do not have the physical strength to do dry-season irrigated farming. Young people engage in dry-season irrigated farming, but they do not own or lease land. They can, however, rent land, although preference is given to males rather than females. People believe that men can cultivate larger areas than females can, although the

Table 1. Gender roles vis-a-vis types of groundwater technologies and management method

Management system	Practical description of gender roles	Occurrence rate per study area (% of total use per type of technology)		
		Permanent shallow Wells (PSW)	Temporal shallow wells (TSW)	Riverine alluvial dugouts (RAD)
Female	Woman decides on plot size and crop type, buys inputs, sells products and keeps all sales. She owns the technology. Men and children keep watch over crops.	About 10%	About 15%	Less than 5%
Male	Man decides on plot size and crop type, buys inputs, sells products and keeps all sales. Wives and children contribute labor. He owns the technology. Men keep watch over crops.	About 50%	About 50%	About 95%
Mixed/ separate plots	Man develops (digs wells and clears land) two separate plots, one for himself and one for the wife. Man nurses seeds for both plots and purchases farm inputs for both plots. Man refers to wife's plot as belonging to his wife, even though he invested. Individual plots managed separately, with each other providing mutual support. Man and woman each irrigates, harvests and sells his or her products separately. Man takes an amount of money from the woman's profits to buy inputs for the next season. Men keep watch over crops.	About 10%	About 15%	Not observed
Joint/ one plots	Man decides on plot size. Crop type decided by both, man buys inputs, both are responsible for watering, both harvest, both sell, woman takes a third of sales, man gets two-thirds. Woman cultivates other crops meant for domestic use. Both invest but man owns the technology. Men keep watch over the crops.	About 30%	About 10%	Not observed

women are more reliable rent payers. Women who are interested in renting land have to negotiate through their husbands, while female heads of families and unmarried women hire laborers. Some women were eligible to negotiate for engagement in dry-season farming have been successful.

Women and children learn how to irrigate and manage their own plots by working as laborers in the plots owned by their male head of household. Children take over when the women are away and assist in digging wells and watering. Enterprising women hire young men to help with the digging, irrigating and weeding.

In a mixed system, husbands support the women during land cultivation and provide protection from grazing livestock. At times, they have to depend on their neighbors, children or hired laborers to secure their crops from roaming animals.

Profits are shared between the women and their husbands in the joint system as a sharecropping arrangement—men buy inputs for the next season. Women have the ability to manage their own plots, although this is often subject to the willingness of their husbands to provide support.

Access to irrigation technology

The choice of irrigation technology depends on land ownership, water source, land size, financial capacity of the individual and social support. Those with permanent land ownership rights are able to develop permanent irrigation infrastructure such as PSWs. Those who rent land invest in temporary structures, since some technologies are capital-intensive. Moreover, access to technologies differs between men and women. Women are not able to afford PSWs, unless their husbands decide to build the wells for them. Thus, PSWs are seen to fall under male prerogative. The RAD technology is labor-intensive, and men form mutual help groups to dig each other's dugouts. Women, on the other hand, do not have the option of forming such groups since digging is done by men; they have to hire laborers.

Women tend to favor TSWs, which are suitable for relatively small plots and are less capital-intensive. They do not require hiring of labor, as much of the work is carried out by farmers and a water-lifting technology (with rope and bucket) is locally available and affordable. With TSWs, women are able to manage their plots, while performing their household duties at the same time.

Access to credit

Access to formal credit for irrigation development in the UER is poor, thus there is minimal difference in the access avail of between men versus women in terms of access to credit. Farmers try other options, such as borrowing from friends, selling their livestock or forming farmer groups to access bank loans. Here, the gender factor is evident. For instance, women are favored by banks and creditors because they are more reliable repayers of loans. Men encourage women to join cooperatives

groups to obtain access to bank loans. This advantage is also one of the reasons women are participating in irrigation. High female participation has significantly increased access to credit.

Organized women's groups

Organized women's groups are located in major markets in Accra, Kumasi and in big cities in southern Ghana. They use trucks to transport vegetables. The irrigation group leaders lead the search for these markets. The women control the distribution. The leaders ensure that group members are served first before the non-members.

Conclusion

The use of irrigation technologies such as PSW, TSW, and RAD is a promising strategy to improve the livelihoods and well-being of the people in the UER of Ghana. To ensure the success of these interventions, it is important to look at the roles of both men and women in the construction and operation of irrigation infrastructure. The role of gender must also be identified in decision-making processes, cost-benefit analyses, gaining access (to land, water and markets), and defining in the social structure.

Contact Persons

Eric Mapedza (e.mapedza@cgiar.org), Eric Antwi Ofosu, Barbara van Koppen, Pieter van Der Zaag, Regassa Namara

Partner Organization

International Water Management Institute
UNESCO-IHE, the Netherlands
University of Energy and Natural Resources, Ghana

Key Reference

Ofosu, E. A., E. Mapedza, B. van Koppen, P. van Der Zaag and R.E. Namara 2010. *Gendered access to shallow wells and riverine dugouts in the Upper East Region of Ghana*. Unpublished report.

Bibliography

Birner, R., E. Schiffer, F. Asante, G. Osman and N. McCarthy 2005. *Governance structures for water resources management in the White Volta Basin, Ghana. Integrating Governance and Modelling.*Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

FAO 1998. *Supporting aquaculture development in Africa: Reseearch Network on Integration of Aquaculture and Irrigation.* A report prepared for the Inland Water Resources and Aquaculture Service of the FAO Fisheries Department. CIFA Occasional Paper No. 23 CIFA/OP23 FAO, Accra, Ghana.

IFAD 1998. *Improving women's access to Land in the Upper East. Ghana.* Mid-Term Evaluation Report. Office of Evaluation and Studies, Rome. Retrieved from: http://www.ifad.org/gender/learning/resource/natural/40.htm

IFAD 2005. *Upper East Region Land Conservation and Smallholder Rehabilitation Appraisal.* Report No 0244-GH, Vol. II

INPIM 2007. *PIM and Gender.* Retrieved from: http://www.inpim.org/leftlinks/Topic%20Page/Topic%20Page/Gender.htm

Kasanga, K. and N.A. Kotey 2001. *Land management in Ghana: Building on tradition and modernity. Land tenure and resource access in West Africa.* International Institute for Evironment and Development. Nottingham, UK: London.Russell Press,.

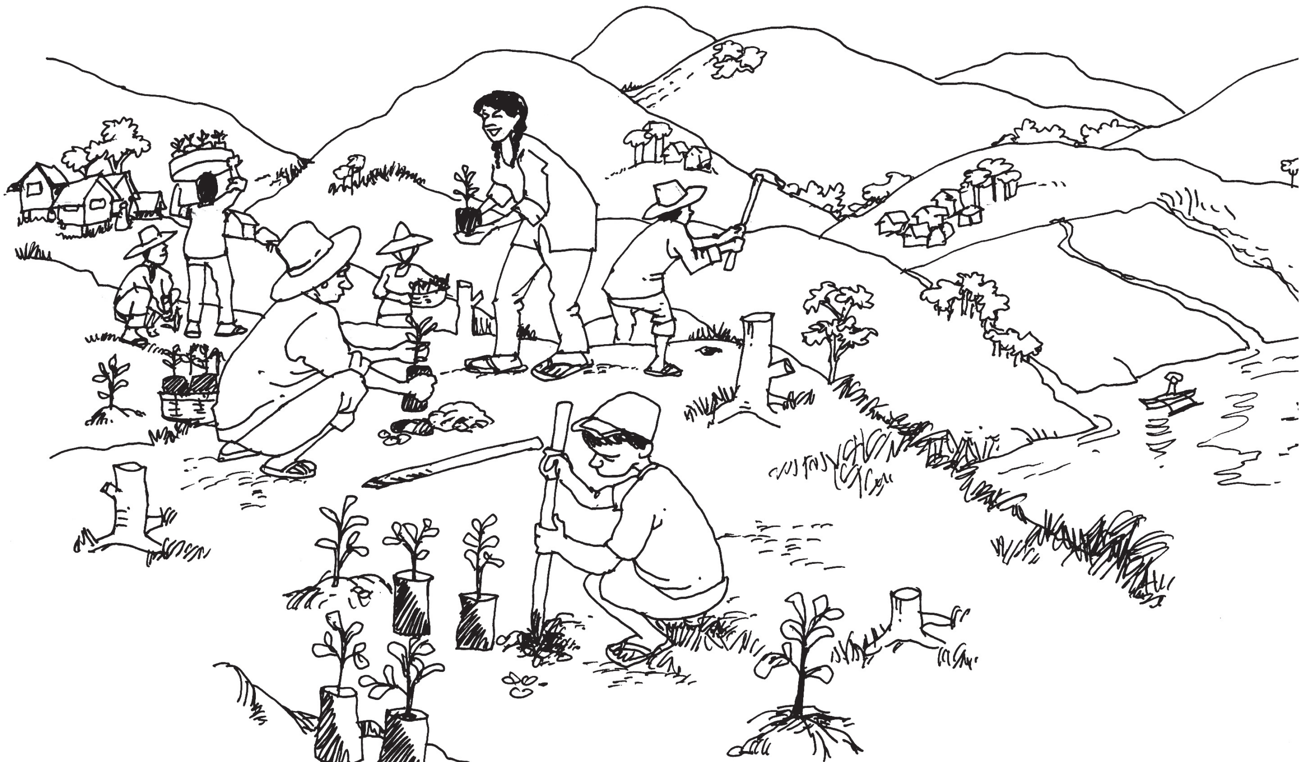
Lentz, C. 2006. Land rights and the politics of belonging in Africa: An introduction. In: *Land and the politics of belongings in West Africa,* eds. R. .Kuba and C. Lentz. Leiden and Boston: Brill.

Ministry of Works and Housing 1998. *Challenges and opportunities.* Accra, Ghana: Environmental Management Associates, Ltd.

Shah, T. 1993. *Groundwater markets and irrigation development: Political economy and practical policy.* Mumbai: Oxford University Press.

Collective Action and Poverty

A Conceptual Framework to Link Collective Action, Scale and Poverty



Watershed management is carried out on a range of scales: a group of neighbors rehabilitating a water source by planting new tree species, a women's group working with an NGO to build a potable water system that draws water from a nearby river or a producer's association in the lowlands lobbying the government to restrict land or water use in the upper catchments to ensure stable and plentiful supply of water for irrigation. These examples of collective action for natural resource management (NRM) aim to deliver benefits at the specific scale at which they are undertaken. However, whether or not these benefits actually materialize, and how substantial they are, will be affected by the actions of others. The goal of watershed management should be the equitable, efficient and sustainable use of water resources between stakeholders.

It is important not to lose sight of where the poor fit into these decentralized, collective processes. Poverty itself is a result of dynamic, multi-scale processes. Outcomes at the individual scale both influence and are influenced by what happens at the community, regional or national scale (Barrett and Swallow 2003). Projects that seek to strengthen the role of the poor in watershed management need to be aware of these issues and create spaces in which the 'action resources' of the poor have value.

The CGIAR Challenge Program on Water and Food (CPWF) project, "Sustaining Inclusive Collective Action that Links Across Economic and Ecological Scales in the Upper Watershed (SCALES)," explicitly recognizes the relationship between collective action, scale and poverty in a watershed context.

The project has developed solutions to overcome barriers and foster equitable and sustainable management of watershed resources. Tropical watersheds are typically characterized by multiple, overlapping scales. Ecological, economic, social and political asymmetries make it difficult to achieve cooperation around watershed management at anything but the very local scale. Yet, multi-scale coordination and cooperation are essential to adequately address watershed problems.

Conceptual framework linking collective action, scale and poverty

The SCALES conceptual framework explores how collective action can contribute to poverty reduction in a watershed context. Key elements of collective action in watershed management are the multiple stakeholders and multi-scale social interactions among and between community groups, neighboring groups and institutions. There are also different dimensions of poverty and human well-being, lateral flows of soil and water and multidirectional flows of economic, political and social interaction (Swallow *et al.* 2006).

1. Watershed management is inherently multi-scale, and collective action around water management occurs at multiple scales, simultaneously.

The framework (Figure 1) is a conceptual model of a watershed divided into primary physical nodes (human-dominated zones: the upland, the midland and the lowland), with secondary institutional nodes (arenas of negotiation, conflict and/or collective action among adjacent water users) and tertiary institutional nodes. Within primary nodes, local collective action can occur around the management of springs, wells, potable water systems or small-scale irrigation schemes. Upstream-downstream externalities, also termed 'water transitions' or changes in quality, quantity

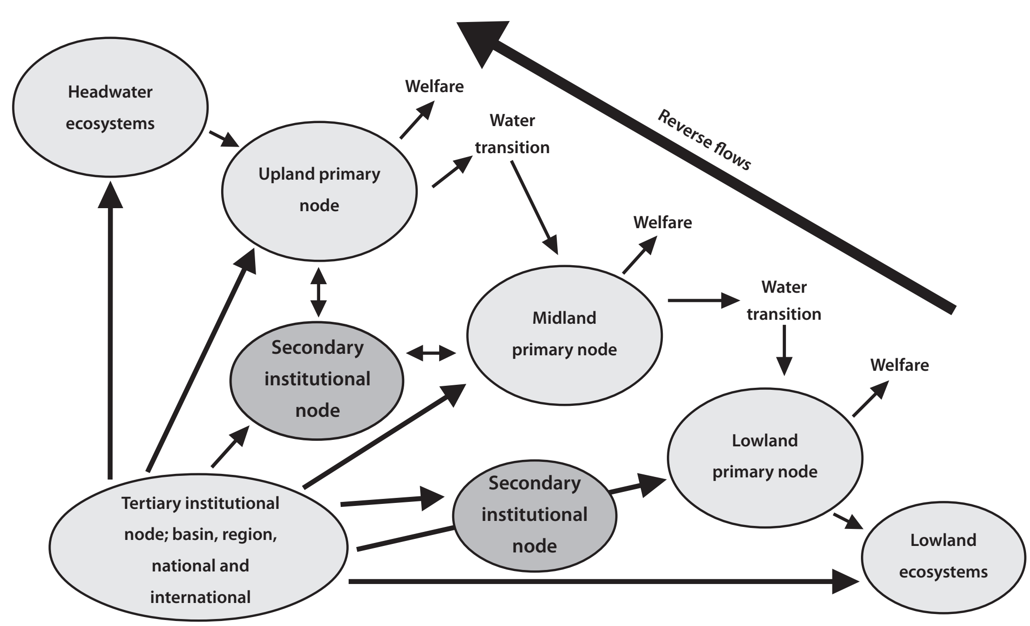


Figure 1. Conceptual framework of multi-scale collective action in watershed management

and availability of water, act between primary nodes. Such externalities are managed through secondary institutional nodes that span two primary nodes or tertiary institutional nodes that cover the watershed. Relationships are the same whether at the sub-catchment, catchment or basin scale, though with increasing complexity.

2. Lateral flows of soil and water that cause water transitions are not the only resource flows in the watershed.

Economic, social and political resources are resource flows as well, which may flow from downstream to upstream. These 'reverse flows' can be related to the magnitude and the welfare impacts of the water transitions. The form that reverse flows take, and their welfare implications, will be conditioned by the nature of social and economic relationships within catchments and institutions at primary, secondary and tertiary scales.

The framework identifies the key hydrological and socio-political relationships across scales in watersheds. This does not provide insights on how people, individually and collectively, are likely to behave in such a context. Individual and group decisions take place in an action arena: a socially defined space composed of actors, action resources, rules and actions.

The diagram (Figure 2) presents a framework for analyzing individual and group decisions that take place in an action arena adapted to the watershed context (di Gregorio *et al*. 2004, Ostrom 2005).

An example of reverse flows

Downstream water users can use political influence to push for strict regulation of land use in the upper catchments to protect downstream water supplies. This can be at the expense of upstream livelihoods. Alternatively, a payment for environmental services scheme could achieve the same environmental outcomes with more positive impacts on upstream livelihoods.

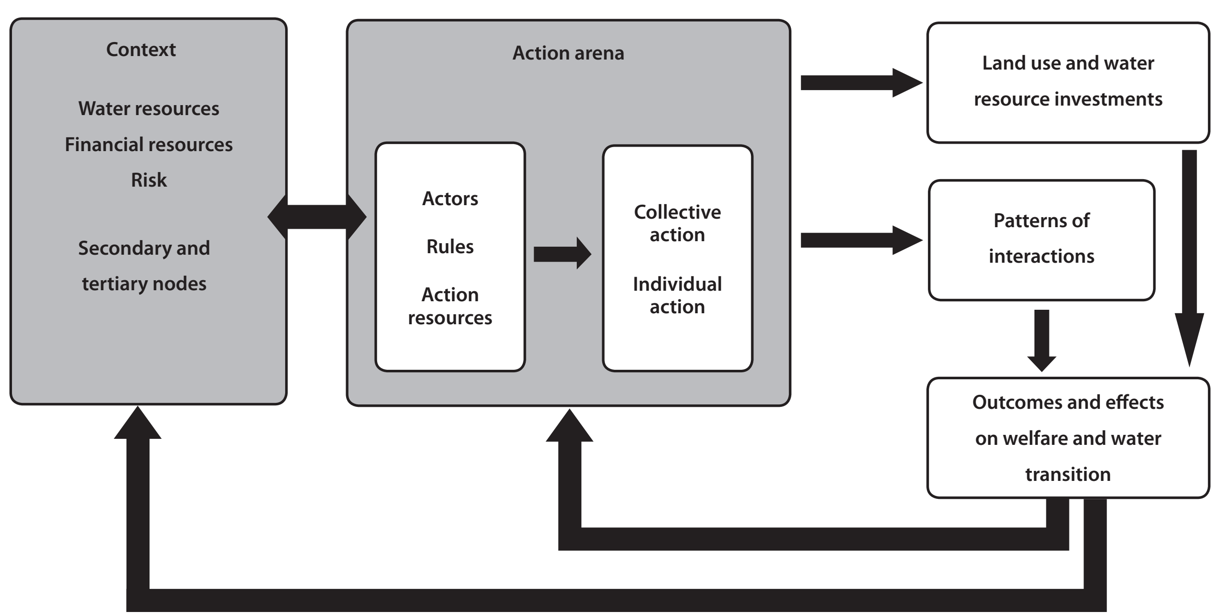


Figure 2. Actors, action resources, collective action and outcomes in a watershed unit

The rules that govern what actions are possible are embedded in institutions, which can be formal or informal, and can operate at multiple, often overlapping, scales. In a given action arena what influences an actor's ability to take action or influence others are his or her 'action resources.' These include assets, such as rights to natural, physical and financial capital, as well as the social and human capital that actors are able to draw upon. Personal characteristics such as leadership ability, charisma, ethnic origin, ideology or value systems are related to human and social capital but are worth identifying separately because they go beyond the instrumental way in which assets are normally regarded. For example, an ideology can influence one's own behavior or be used to create legitimacy or solidarity around a cause.

3. In a watershed context, decisions are made in multiple 'action arenas' at multiple and overlapping scales.

In these action arenas, both the rules and resources that have value in influencing outcomes may differ. The poor are often not without action resources, but their resources may be more useful in some arenas than in others. This is likely to be very context-specific. The better off, meanwhile, may engage in 'forum-shopping,' looking for the arena in which they are most likely to obtain a result favorable to their interest. Projects that seek to strengthen the role of the poor in watershed management need to be aware of these issues so that they can orient their work towards increasing the relevant action resources of the poor. Projects must also create spaces in which the action resources that the poor currently possess have value.

Participatory poverty analysis using the 'stages of progress' methodology

The SCALES project used the stages of progress (SOP) methodology to identify the poor and understand the role of water in their livelihoods (the next article presents this methodology in detail). SOP is a participatory methodology that relies on community definition of poverty at the household level. The methodology was developed to assess both the dynamics of poverty and the underlying causes.

The SCALES project applied the SOP methodology in the Fuquene and Coello watersheds in Colombia and in the Kapchorean and Awach basins in Kenya. Communities were purposefully selected in the upper, middle and lower parts of the watersheds

on the basis of incidence of poverty and the expected intensity of water conflicts. Interview questions focused on water use, conflicts and management at the household and community levels. In each community, quantitative and qualitative information was gathered from interviews with households and key informants and from observations by project staff in the field on movement in and out of poverty and the main causes. (Refer to other article in this source book where the SOP methodology is outlined in greater detail).

Key recommendations

Insights from the project provide important recommendations for considering poverty and collective action in watershed management.

1. Projects that seek to strengthen the role of the poor in watershed management need to be aware of the multiple and overlapping scales at which resource management decisions are made.

2. Pro-poor outcomes can be achieved by increasing the ability of the poor to influence decisions at a specific scale or in a specific forum or by shifting the scale or forum of a decision to one where the 'action resources' of the poor have more value.

3. Communication may be more effective than regulation in promoting collective management and when initiatives come from upstream rather than downstream communities.

Contact Person

Nancy Johnson (n.johnson@cgiar.org)

Partner Organizations

Centro Internacional de Agricultural Tropical
Consorcio para el Desarrollo Sostenible de la Ecoregion Andina (CONDESAN), Peru
Fundación Humedales, Colombia
International Food Policy Research Institute
Maseno University, Kenya
SANA
Semillas de Agua, Chile
Universidad de los Andes, Colombia
World Agroforestry Center
World Wildlife Fund, Colombia

Key Reference

Johnson, N. 2009. *Sustaining inclusive collective action that links across economic and ecological scales in upper watersheds.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3909

Tags: PN20: Sustaining Inclusive Collective Action

Bibliography

Barrett, C.B. and B. Swallow 2003. *Fractal poverty traps.* Working Paper. Cornell University, New York, USA.

di Gregorio, M., K. Hagedorn, M. Kirk, B. Korf, B., N. Mc Carthy, R. Meinzen-Dick, R. and B. Swallow 2004. Property rights, collective action and poverty: The role of institutions for poverty reduction. Paper presented at *Tenth Biennial Conference of the International Association for the Study of Common Property*, Oaxaca, Mexico, 9-13 August 2004.

Jensen, J. 2009. *Understanding the links between water, livelihoods and poverty in the Nyando River basin, Kenya.* MSc thesis, University of Florida, Gainesville, Forida, USA.

Johnson, N., J. García, J.E. Rubiano, M. Quintero, R.D. Estrada, E. Mwangi, A. Peralta and S. Granados 2009. Water and poverty in two Colombian watersheds. *Water Alternatives*, **2**, 34-52.

Onyango, L., B. Swallow and P. Teyie 2008. *Poverty, livelihoods and water resource interactions in the Nyando River basin*. SCALES Project Report.

Ostrom, E. 2005. The value-added of laboratory experiments for the study of institutions and common-pool resources. *Journal of Economic Behavior and Organization*, **61**, 149-163.

Swallow, B., N. Johnson, R. Meinzen-Dick and A. Know 2006. *The challenges of inclusive cross-scale collective action in watersheds. Conceptual framework of Theme 2 of the CGIAR Challenge Program on Water and Food.*

Woolley, J. 2010. Legacy of PN 20: *Collective action in (upper) watersheds.* Unpublished manuscript.

Using the Stages of Progress Methodology in Assessing Watershed Resources

Up until the 1990s, watershed management has been viewed as an engineering problem. Technical solutions for controlling erosion, reducing runoff and flooding and enhancing groundwater recharge were often designed and implemented with little regard for their impacts on livelihoods of people, farm profitability, and social equity (Pretty and Shah 1999, Johnson and Knox 2002). As a result, many programs were unsuccessful, and farmers often abandoned the technologies and practices as soon as they stopped being forced or paid to adopt them. Reviews of watershed experiences in the 1970s and 1980s identified the lack of consideration of farmer objectives and farmer knowledge as an important reason for these failures. In contrast, where user participation was encouraged, performance of the watershed projects improved (Kerr 2002).

From the lessons learned, many participatory watershed development interventions were designed and implemented with the explicit involvement of users. These interventions sought to address users' livelihood concerns, as well as environmental conservation issues. While few rigorous evaluations of these interventions exist, case studies suggest that their performance has been better—at least in terms of governance and technology adoption (Tyler 2006, Hinchcliffe *et al.* 1999 Perez and Tschinkel 2003, Grewel *et al.* 2001). Focusing watershed interventions more directly on the needs of local communities is likely to bring about outcomes that address poverty. However, where local institutions and power structures are inequitable, the problem of the elite capturing benefits will still exist, with beneficiaries being local elites rather than outsiders (German *et al.* 2007, Siagian *et al.* 2006).

More recently, watershed management programs have sought to embed local participatory planning processes within broader social and political processes (FAO 2006,). The focus has shifted from working directly with local groups on land and water issues to supporting multi-stakeholder negotiation platforms that address a range of issues, including but not limited to natural resource management. Compared with past efforts, more emphasis is placed on conflict resolution and linking social, institutional and hydrological scales. Where earlier projects promoted the participation of stakeholders—and often focused specifically on local communities—more recent projects seek to foster collaboration between different types of stakeholders and stakeholder groups (FAO 2006, Hermans *et al*. 2006). Special attention is placed on strengthening and supporting the poor in their ability to participate in multi-stakeholder negotiations with diverse and powerful stakeholders.

While natural resources continue to be important livelihood assets for the poor—even the landless poor (Beck and Nesmith 2001; Jodha 1986, 1995; Dei 1992; Cavendish 2000; Fisher 2004)—the livelihood strategies of rural households are increasingly diverse. Even in rural areas, households do not depend exclusively on agriculture or on extraction of natural resources. Off-farm income from wage labor or selling of products and services contributes to the welfare of the rural poor (Barrett and Reardon 2000, Bryceson and Jamal 1997, Reardon 1997). While motivation for diversifying livelihood strategies may be either positive (pull factors) or negative (push factors), a growing number of studies suggest that such strategies do have beneficial impacts on rural livelihoods (Shivakoti and Thapa 2005, Block and Webb 2001, Lanjouw *et al.* 2001). Therefore, the impacts of environmental, industrial, transportation and other policies that often come under the ambit of modern watershed management, may have significant indirect implications for the welfare of the poor.

The relationships between poverty and watershed management in two watersheds in the Colombian Andes were investigated. Poverty is defined and measured using the Stages of Progress (SOP) methodology that looks at changes in poverty levels over time, and the reasons behind the changes at the household level (Krishna 2004, 2006b; Krishna *et al*. 2006; Krishna *et al.* 2004a,b). These reasons were examined in the context of economic and environmental dynamics to identify where and how watershed management interacts with the livelihood strategies of the poor. Poverty results were compared with other types of poverty measures, both in terms of how poverty is defined and who is defined as poor under different poverty measurement methods. The implications of the findings for policy makers and planners were prepared (for information on study sites and on discussion of findings, please refer to http://www.chronicpoverty.org/publications/details/examining-the-importance-of-watershed-resources-in-the-colombian-andes). The focus of this article is on the advantages and disadvantages of the SOP methodology.

The "Stages of Progress" methodology

The Stages of Progress (SOP) methodology is a participatory methodology that relies on the community definition of poverty at a household scale. The poverty level of each household in the community is assessed, and explanations are sought for changes in poverty status over time. The method takes its name from the stages or steps that a household passes through as it makes its way from poverty to prosperity.

To identify the poor and to understand the role of water in their livelihoods, the SOP methodology was used (www.sanford.duke.edu/krishna/methods.htm). It was developed to assess both the dynamics of poverty and the causes behind them. While national-level poverty rates are often slow to change, poverty is not a static situation. It changes as a result of seasonality, climate variability, household-level shocks (such as illness, death or divorce), life cycle changes and public policies. In addition, the number of poor people is itself constantly changing as individuals and households either escape from poverty or descend into it. Looking at the same households over time provides a better understanding of the conditions that keep people in poverty and those that move them out. It also helps with identification of the general patterns and assists in policy targeting to maximize protection and support for the most vulnerable, without pulling back those who are escaping (for example, Carter and Barrett 2006).

To define the stages, a representative group of community members must first come to an agreement on the definition of poverty, based on a shared conception of the 'poorest family in the community.' Once this is done, the group successively answers the question "What would this family do with additional resources?" until they reach the point at which the household would be considered prosperous. Because they are defined locally and with reference to a particular poor family, the stages vary by community and reflect the specific conditions and values of the community.

Once the stages are identified, the group then assigns each family in the community—based on a census, which must be obtained or constructed—to the stage where they currently are and the stage where they were at some point in the past (usually 10, 20 or 25 years ago). After they have been assigned to stages[1] tabulation is done to categorize them as follows:

A – Poor in the past, poor now
B – Poor in the past, not poor now
C – Not poor in the past, poor now
D – Not poor in the past, not poor now

For a randomly selected sub-sample of families, the community then identifies the reasons behind changes in poverty status. The final step in the methodology is to conduct follow-up interviews with a sample of families to confirm the results of the community analysis and to gather more information on specific issues. In the case of this study, interviews included questions on water use, conflicts and management at the household and community scales.

The SOP was selected for this study for two main reasons. First, a participatory method that allowed communities to define poverty and its determinants was preferred, so that all possible linkages between watersheds and livelihoods could be explored, without being restricted to a pre-defined set of potential linkages. Second, because poverty analysis was implemented as part of a watershed intervention aimed at strengthening community capacity to co-manage resources, a method that would build community capacity was preferred. In SOP, the community determines the results through a transparent process. The main results in terms of poverty trends and key reasons behind them are obtained from the focus groups; the groups have the opportunity to react to the trends and reasons and to offer their own analysis and interpretations.

Though these advantages justified the use of SOP for this analysis, the method has some disadvantages—for example, it has a strong focus on the material aspects of poverty and it is unable to address broader structural determinants of poverty (Harris in Addison, *et al.* 2008); a lack of direct compability across sites (Peralta *et al.,* 2007; Krisha, 2007), and methodological issues about quality of recall data and the handling of time periods (Krishna, 2007) which limited our ability to look at some aspects of poverty.

[1] *It is important to note that the categorisation is done by the stage and not by the poverty category, which reduces the extent to which the groups are directly classifying individual households as poor or non-poor.*

Conclusion

The SOP methodology was useful because it provided a cost-effective way of getting what is essentially a panel data set, incorporating qualitative and quantitative data. It allowed the researchers to explore a complex relationship – poverty and water – without having to impose preconceived relationships between variables. It also involved the community in a way that promotes the shared reflection on the results. As such, it is a useful approach to use at the start of an intervention, which was the way it was used in this case. An evaluation of the intervention—which was designed to build the capacity of communities to use legal and policy tools available to them to hold public, and, in some cases, mixed (public-private) institutions, accountable for fulfilling their obligations with regard to watershed management—documented impacts on a broad range of areas, including the ability of communities to interact and negotiate with more powerful stakeholders (Candelo *et al.,* 2008).

Contact Person

Nancy Johnson (n.johnson@cgiar.org)

Partner Organizations

Centro Internacional de Agricultural Tropical
Consorcio para el Desarrollo Sostenible de la Ecoregion Andina (CONDESAN), Peru
Fundación Humedales, Colombia
International Food Policy Research Institute
Maseno University, Kenya
SANA
Semillas de Agua, Chile
Universidad de los Andes, Colombia
World Agroforestry Center
World Wildlife Fund, Colombia

Key Reference

Johnson, N. 2009. *Examining the importance of watershed resources in the Colombian Andes.* Retrieved from: http://www.chronicpoverty.org/uploads/publication_files/johnson_colombia_conservation.pdf

Tags: PN20: Sustaining Inclusive Collective Action

Bibliography

Addison, T., D. Hulme and R. Kanbur 2008. Poverty dynamics: Measurement and understanding from an interdisciplinary perspective. Q2 Working Paper No. 52. Retrieved from: http://www.bupedu.com/lms/admin/uploded_file/Poverty%20Dynamics.pdf.

Barrett, C.B. and T. Reardon 2000. *Asset, activity, and income diversification among African agriculturalists: Some practical issues.* Project report to USAID BASIS CRSP. Madison: University of Wisconsin-Madison, Land Tenure Center.

Beck, T. and C. Nesmith 2001. Building on poor people's capacities: The case of common property resources in India and West Africa. *World Development*, **29**, 119-133.

Block, S. and P. Webb 2001. The dynamics of livelihood diversification in post-famine Ethiopia. *Food Policy*, **26**, 333-350.

Bryceson, D.F. and V. Jamal (eds.) 1997. Farewell to farms: *De-agrarianisation and employment in Africa.* Aldershot: Ashgate.

Carter, M. and C. Barrett 2006. The economics of poverty traps and persistent poverty: An asset based approach. *Journal of Development Studies,* **42**, 178-199.

Cavendish, W. 2000. *Empirical regularities in the poverty-environment relationship of rural households: Evidence from Zimbabwe.* Mimeo.

Dei, G. 1992. A forest beyond the trees: Tree cutting in rural Ghana. *Human Ecology,* **20**, 57-88.

FAO (Food and Agriculture Organization of the United Nations 2006. *The new generation of watershed management programmes and projects: A resource book for practitioners and local decision-makers based on the findings and recommendations of a FAO review*. FAO Forestry Paper 150.

Fisher, M. 2004. Household welfare and forest dependence in Southern Malawi. *Environment and Development Economics,* **9**, 135-154.

German, L., H. Mansoor, G. Alemu, W. Mazengia, T. Amede and A. Stroud 2007. Participatory integrated watershed management: Evolution of concepts and methods in an ecoregional program of the eastern African highlands. *Agricultural Systems*, **9**, 189-204.

Grewel, S.S., A.S. Dogra and T.C. Jain 2001. Poverty alleviation and resource conservation through integrated watershed management in a fragile foothill ecosystem. In: *Sustaining the Global Farm. Selected papers from the 10th International Soil Conservation Organization Meeting*, Purdue University and the USDA-ARS National Soil Erosion Research Laboratory, 24-29 May 1999, eds. D.E. Stott, R.H. Mohtar and G.C. Steinhard. Retreived from: http://topsoil.nserl.purdue.edu/nserlweb/isco99/pdf/isco99pdf.htm

Hermans, LM., G.E. van Halsema, and M.H. Mahoo 2006. Building a mosaic of values to support local water resources management. *Water Policy,* **8**, 415-434.

Jodha, N.S. 1986. Common property resources and the rural poor in dry regions of India. *Economic and Political Weekly*, **21**, 169-181.

Jodha, N.S. 1995. Studying common property resources: Biography of a research project. E*conomic and Political Weekly*, **30**, 556-559.

Johnson, N., J. García, J.E. Rubiano, M. Quintero, R.D. Estrada, E. Mwangi, A. Peralta and S. Granados 2009. Water and poverty in two Colombian watersheds. Water Alternatives, 2, 34-52.

Johnson, N. and A. Knox 2002. Participatory natural resource management in watersheds: Concepts, issues and challenges for research. *Annals of Arid Zones*, **40**, 1-20.

Kerr, J.M. 2002. Watershed development,environmental services, and poverty alleviation in India. World Development, **30**, 1387-1400.

Krishna, A. 2004. Escaping poverty and becoming poor: Who gains, who loses, and why? *World Development,* **32**, 121-136.

Krishna, A. 2006. Examining pathways out of and into poverty in 36 villages in Andhra Pradesh. *World Development* **34**, 271-288.

Krishna, A., P. Kristjanson, M. Radeny and W. Nindo. 2004a. Escaping poverty and becoming poor in 20 Kenyan villages. *Journal of Human Development*, **5**, 211-26.

Krishna, A., P. Kristjanson, J. Kuan, G. Quilca, M. Radeny, and A. Sánchez-Urrelo 2006. Fixing the hole at the bottom of the bucket: Household poverty dynamics in forty communities of the Peruvian Andes. *Development and Change*, **37**, 997-1021.

Krishna, A., D. Lumonya, M. Markiewicz, A. Kafuko, J. Wegoye, and F. Mugumya 2004b. Escaping poverty and becoming poor in 36 villages of central and western Uganda. *Journal of Development Studies,* **42**, 346-370.

Lanjouw, J.; Quizon, P. and Sparrow, R. 2001. Non-agricultural earnings in peri-urban areas of Tanzania: Evidence from household survey data. *Food Policy* 26(4): 385-403.

Peralta, A., J. García, A. Moreno, S. Granados, L.F. Botero, H. Rodriguez, J.A. Rubiano, N. Johnson, J.E. Rubiano, M. Quintero and R.D. Estrada 2007. Dinámica y definición de pobreza en los Andes colombianos: enfoques participativos vs enfoques objetivos *Desarrollo y Sociedad,* **58**, 209-243.

Perez, C. and H. Tschinkel 2003. *Improving watershed management in developing countries:* A framework for prioritizing sites and practices. AgREN Network Paper No. 129. London: ODI.

Pretty, J and P. Shah 1999. Soil and water conservation: A brief history of coercion and control. In: *Fertile Ground: The Impacts of Participatory Watershed Management,* eds. F. Hinchcliffe, J. Thompson, N. Pretty, I. Guijt and P. Shah; 1-12. London: Intermediate Technology Publications Ltd.

Reardon, T. 1997. Using evidence of household income diversification to inform study of the rural nonfarm labor market in Africa. *World Development*, **25**, 735-747.

Shivakoti, G.P. and S.B. Thapa 2005. Farmers' perceptions of participation and institutional effectiveness in the management of mid-hill watersheds in Nepal. *Environment and Development Economics*, **10**, 665-687.

Siagian, Y., B. Morgan, Yentirizal and Neldysavrino. 2006. *Strengthening Women's Participation through Collective action for inclusive decision-making processes: Lessons learned in Jambi Province, West Sumatera, Indonesia*. Paper presented at the CAPRi Workshop on Gender and Collective Action. Chiang Mai, Thailand, October 2005.

Tyler, S. 2006. *Comanagement of natural resources: Local learning for poverty reduction.* Focus series. Ottawa: International Development Research Center.

Mechanisms for Fostering Multi-stakeholder Dialogues in Water Resource Management Projects

Water resource management takes place in complex, rapidly changing and uncertain realities. Users may not be aware of the impact that water decisions have on other users, and even where externalities are identified, they can be difficult to manage due to problems of information, communication. The increasing number of stakeholders all competing for access to limited water resources reduces the chances for achieving consensus on use. These difficulties are further aggravated when poverty incidence is factored in.

Poor coordination among stakeholders perpetuates inefficient water use, economic and environmental damage, negative externalities and social conflicts.

With the decentralization of local renewable resource management, there is a demand for innovative approaches, methods and tools that can improve the system's adaptive capacity. After all, investments in social capital and collective action can have a major impact on helping people, especially the poor, break out of poverty traps. This document presents various mechanisms that can be employed to foster multi-stakeholder dialogues based on the experiences of and lessons identified from various water resource management projects under the CGIAR Challenge Program on Water and Food (CPWF).

Strengthening the engagement of the poor in community Processes[1]

There is a complex relationship between poverty and water. Achieving and maintaining collective action in watersheds to adequately address problems requires a high degree of coordination and cooperation. To develop solutions to overcome barriers and foster equitable and sustainable watershed resource management, there is a need to explicitly express the relationships between collective action, scale and poverty. Some mechanisms designed to achieve this are discussed below.

Conversatorio de Accion Ciudadana

The Conversatorio de Accion Ciudadana (CAC) is a politico-legal mechanism, that was implemented in three Colombian watersheds between 2005 and 2007. It is designed to address the inequalities in power and information between communities and government institutions, that often prohibit the former from exercising constitutional rights to participate and to hold the latter accountable. It is based on the idea of civil society and authorities conversing in familiar terms about issues of importance to both and arriving at agreements for action. In the end, it is expected that meaningful participation by civil society is achieved. The legal skills that private individuals learn can enable them to obtain information they had previously been denied and to compel authorities to respond within a fixed amount of time to specific concerns they had previously ignored.

CAC led to 76 concrete commitments on the part of institutions to improve the watershed residents' welfare and resource management. An assessment in late 2007 showed that compliance rates were relatively high, especially in communities which had stronger follow-up processes.

[1] *Source: http://www.capri.cgiar.org/pdf/Resources_Rights_Cooperation_H-10.pdf*

CAC: Lessons learned

- The CAC methodology can have significant human and social capital impacts on community members who participate. It can also lead to changes in the ways that communities and institutions perceive each other, in some cases, moving from antagonism to respectful collaboration.
- CAC takes time. The SCALES[1] project was thought to take 3-6 months, but it took a year and a half to complete. More time should be allocated to properly prepare the communities and make institutional contacts.
- A committed local institution with experience in community organization is the most critical determinant of success for CAC.
- The early involvement of partner institutions can lead to more meaningful participation during the negotiation phase.
- CAC impacts will be larger and will likely be more widely distributed if more community members are involved. A core team will always lead the process; however, more emphasis can be put on having them share progress and seek feedback from their communities.
- Increasing the general public's involvement with the CAC itself will make it clear to institutions that the people asking questions have the support of their communities.

Economic experiments

Economic experiments, sometimes referred to as economic games, simulate real-world situations by providing participants (players) with the same kinds of incentives that they would face in real-world decision-making situations. The experimental context allows researchers to vary the incentives—i.e., the rules of the game—and see the impacts of individual decisions' outcomes as well as collective outcomes. Participants observe both types of outcomes, and how changes in rules can affect these. The impact that this can have on individuals and on the group as a whole, especially when community-level feedback sessions are held, can serve as powerful tools enabling people to understand collective action dilemmas and can thus be a starting point for change (Cardenas and Ostrom 2004).

Economic experiments

The economic experiments were conducted in Coello River and Fuquene Lake watersheds in Colombia, and Awach and Kapchorean rivers in Kenya. Three hundred and fifty-five and 284 participants joined the Irrigation Game and Water Trust Game, respectively. The sample (participants) distribution was gathered from across basins, games and treatments. In Colombia, the economic games were conducted as part of the CACs. In Nyando, they were run independently due to problems with the implementation of the action research agenda in Kenya.

Collective action around water involves both the provision and the appropriation of the resource. Cooperation provision can be affected by the rival nature of appropriation and the asymmetries in access to the resource. To look at collective action around provision and appropriation, three experiments were used the Voluntary Contribution Game (VCM), the Irrigation Game, and the Trust Game. In all games, the participants received monetary incentives based on tokens earned during the game.

[1] *SCALES (Sustaining inclusive Collection Action that Links Economic Scales in upper watershed) is a project (PN 20) under the CPWF*

A. Voluntary Contribution Mechanism

The Voluntary Contribution Mechanism draws from reciprocity and conditional cooperation theory introduced by Sugden and applied by Fehr and Gächter. They learned that positive reciprocity compels participants to contribute something to the public good if others are willing to contribute also. To sustain contribution to the public good, participants need to be reciprocally motivated. On the other hand, negative reciprocity can play a crucial role if participants think that others have a "free ride."

Voluntary Contribution Game

1. At the beginning of each round, each player is given 25 tokens, which they could contribute to the public good or keep in a private account.

2. Participants are grouped into five people per group. The total contributions to the public fund by the five players is doubled and distributed in equal shares to all players of the group at the end of each round.

B. Irrigation Game

The Irrigation Game is a new economic experiment that demonstrates the provision and appropriation aspects of the resource. It highlights the unequal access to and provision of water resource among players.

1. In the first part of the game, the players are given 10 tokens. They will have to decide how many tokens they would want to contribute to a project to maintain water canals. The amount of available water for the group is increasing as the group contribution increases.

2. Non-contributed tokens are kept in a private account, which yields private returns. These tokens are paid at the same monetary rate as the water units to be extracted in the second stage of each round.

3. The second decision of the players involves individual water extraction from the total water produced. This decision is made based on the location of the players along the water canal. Players positions are determined randomly for the entire sequence of rounds. Thier position is represented by a letter: A for the player in the first position and E for the player in the last position. The water is allocated, therefore, according to the location in the following manner. Player A first receives all the water produced by the group project and decides how much water to extract. The remaining water is then shown to Player B at who then decides how much to extract and how much to leave to the remaining players downstream, and so on for players C, D, and E. This sequence is conducted for 10 rounds.

4. After the first 10 rounds of baseline treatment, the rules change for some groups and this change was announced to the players. Some groups are permitted to communicate, other groups faced external regulation treatments, and others continue to play under baseline conditions.

5. In the face-to-face communication treatment, players are allowed to communicate with the other players in the group before returning to their places to make their own private decisions. As in the baseline, they know the aggregate decision but not the individual decisions after each decision round.

6. In the external regulation, or penalty treatments, players are told that there would be a chance of being monitored each round. The experimenter rolls a dice in front of the participants each round, and if it landed on all the participants would be inspected.
The monitor checks the decisions of the players and the players who have taken more water than their fair share (1/5, given that there are five players) are fined. In the high– penalty treatment, the fine is the water taken in excess of the of the fairshare plus six units from the earnings; in the low–penalty treatment, the fine is just the extra amount taken.

C. Water Trust Game

The Water Trust Game is based on the standard trust game (Berg *et al.* 1995), but, in this sense, it is framed around water access and distribution between two persons located in different positions of a watershed.

1. At the beginning of the game, both players are given eight tokens.

2. Player 1 (proposer) can send a fraction of his/her initial endowment to Player 2 (responder). The amount sent by Player 1 is tripled before it reaches Player 2, who then decides how to split the tripled amount plus his/her initial endowment between himself/herself and Player 1. This increase in the amount being sent reflects how a decision in favor of watershed conservation would increase the possibilities of greater social benifits to be distributed among the watershed members.

3. In the framing, however, the decision of Player 1 was explicitly framed: if upstream, as the quantity of clean water sent to Player 2 downstream, and Player 2's decision as an economic compensation for the water provided by Player 1. If the game starts with a downstream player, such a decision is also framed as economic compensation for the water provided by Player 1.

4. The Trust Game is implemented using the strategy method, that is, Player 2 is asked

the complete strategy of responses to each possible offer by Player 1. Therefore, Player 2 has to respond, without knowing yet the amount offered by Player 1, how many tokens he/she would return to Player 1 for each possible offer by Player 1 (0, 2, 4, 6, 8 units).

5. During the session, each of the players is asked the amount expected from the other player.

Conclusion

The use of economic games or experiments for the study of issues of development and the environment has increased substantially over the last few decades. Behavioral sciences have made large contributions to the understanding of collective action and how rules and norms play a crucial role in solving the problem of managing common-pool resources and solving the dilemma of group-based property rights.

In addition to helping to understand the foundations of behavior, these games can create space for an interactive dialogue with communities facing these dilemmas. The games offer some potential for self-reflection in a dialogue among stakeholders, and even for social learning processes that create actual changes in behavior beyond the domain of the controlled game.

Contact Persons

Nancy Johnson (n.johnson@cgiar.org), Patrick d'Aquino (patrick.daquino@cirad.fr)

Partner Organizations

SCALES
Centro Internacional de Agricultural Tropical
Consorcio para el Desarrollo Sostenible de la Ecoregion Andina (CONDESAN), Peru
Fundación Humedales, Colombia
International Food Policy Research Institute
Maseno University, Kenya
SANA
Semillas de Agua, Chile
Universidad de los Andes, Colombia
World Agroforestry Center
World Wildlife Fund, Colombia

Companion Modeling
Can Tho University, Vietnam
Chiang Mai University, Thailand
Chulalongkorn University, Thailand
CIRAD – Agricultural Research for Development, France
International Water Management Institute
Ministry of Agriculture and Forests, Bhutan
Ubon Ratchathani University, Thailand

Key References

CIRAD 2010. *Companion modeling for resilient water management: Stakeholders' perceptions of water dynamics and collective learning at the catchment scale.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3901

Tags: PN25; Companion Modeling and Water Dynamics

Johnson, N. 2009. *Sustaining inclusive collective action that links across economic and ecological scales in upper watersheds.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3909

Tags: PN20: Sustaining Inclusive Collective Action

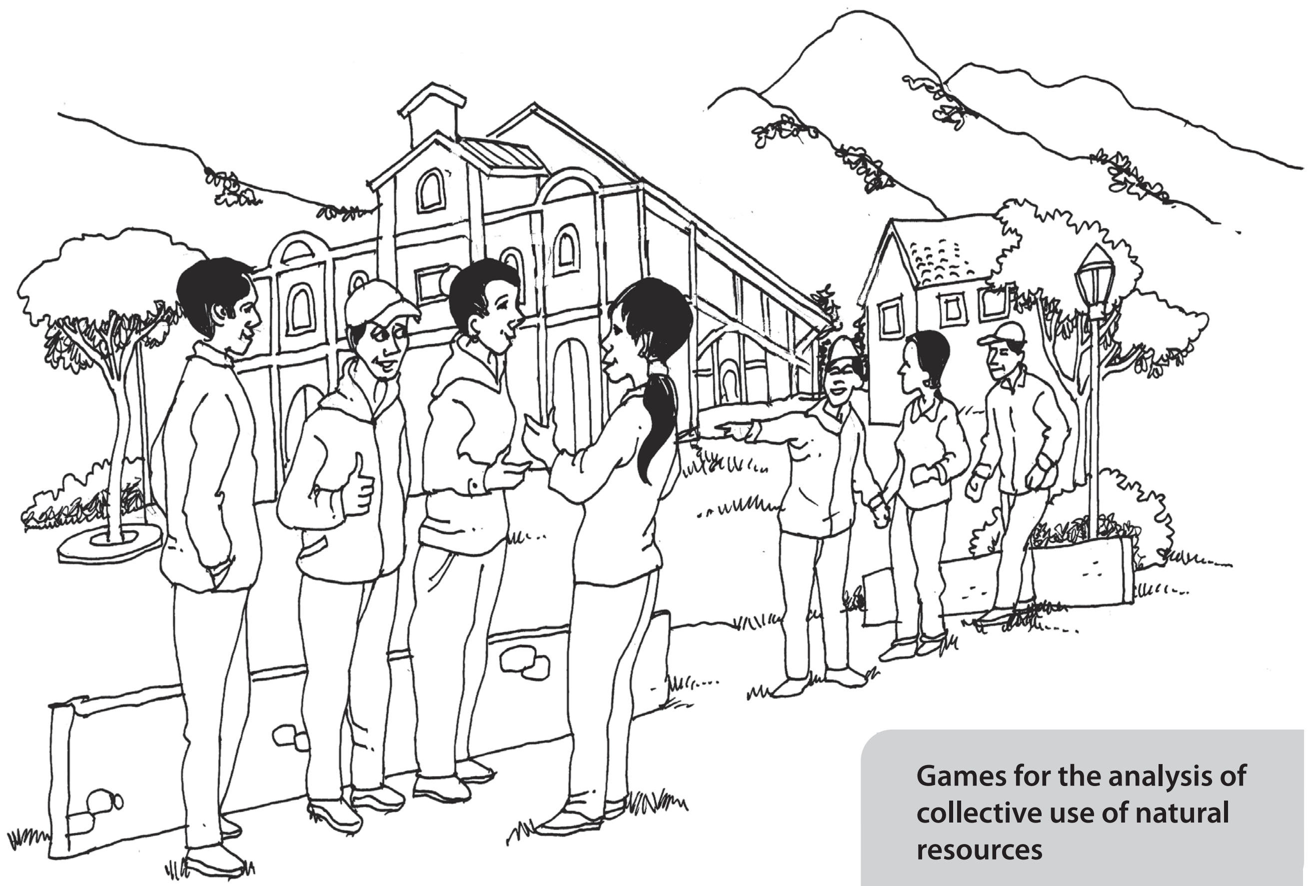
Bibliography

Cardenas, J.C., N. Johnson and L.A. Rodriguez 2009. Vertical collective action: Addressing vertical asymmetries in watershed management. Paper presented at *Workshop on the Workshop 4*, Indiana University Bloomington, USA, 3-6 June 2009.

CGIAR Systemwide Program on Collective Action and Property Rights (www.capri.cgiar.org)

Cardenas, J.C., Rodriguez, L.A. and N. Johnson 2011. Collective action for watershed management: field experiments in Colombia and Kenya. Environment and Development Economics, 16, 275-303.

Use of Games for Nurturing Upstream-Downstream Cooperation



Games for the analysis of collective use of natural resources

Payment for environmental services (PES) schemes are often designed with the twin objectives of nature conservation and added economic benefits to upland farmers whose activities have direct impact on the downstream population. The design of PES options is facilitated by simulation models such as SWAT and ECOSAUT. These tools help determine the best scenarios and areas with highest potential to deliver environmental services. However, the

SWAT is a hydrologic modeling tool that is used for different land use scenarios vis-a-vis the hydrological features of the watershed.

ECOSAUT is a model used for valuation. it provides a socio-economic and environmental assessment of the land-use scenarios and alternatives.

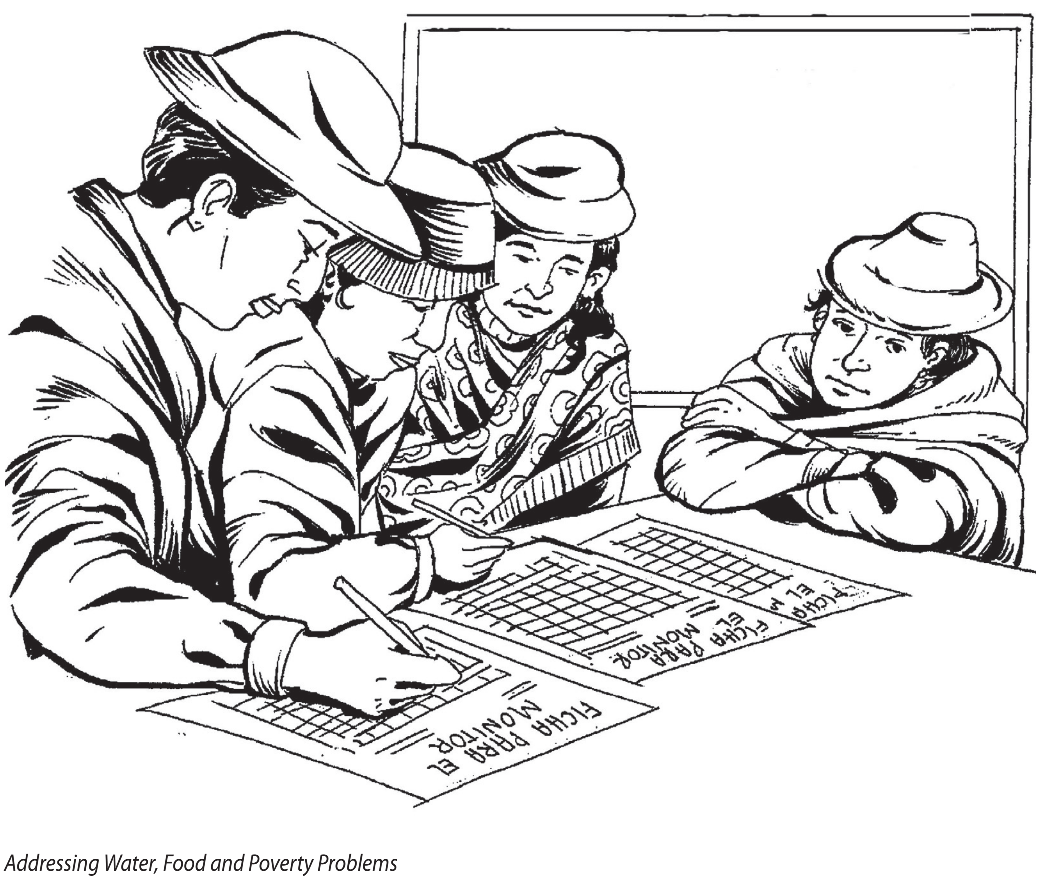
areas identified may not be where the poorest live. Moreover, rich farmers in both upstream and downstream areas, as well as other sectors downstream, may not agree to meet the added costs of PES. They may not see the value of investing in nature conservation without additional and direct returns. It is therefore important to effectively communicate to them how their support to upstream interventions will, in the long run, benefit them as well.

Communicating and getting people to work on the scenarios

Computer-generated models may be technically-sound, but they will only contribute to the success of the PES schemes if people accept the recommendations. Different scenarios need to be communicated to all stakeholder groups in a manner that is easily understood and appreciated and is non-threatening. Before finalizing any PES scheme, the communication strategy should ensure that the perspectives of both "environmental service providers" and those who will pay for the services are considered and secured their cooperation secured. In view of this, the CGIAR Challenge Program on Water and Food (CPWF) Environmental Services and Rural Development Project used economic games for exploring the willingness of service providers and beneficiaries to cooperate in developing and implementing socially acceptable PES schemes.

Let the games begin

Results from SWAT and ECOSAUT simulation models are used as inputs into the decision-making games. The decision-making games evaluate stakeholders' willingness to collaborate and negotiate amongst themselves and resolve



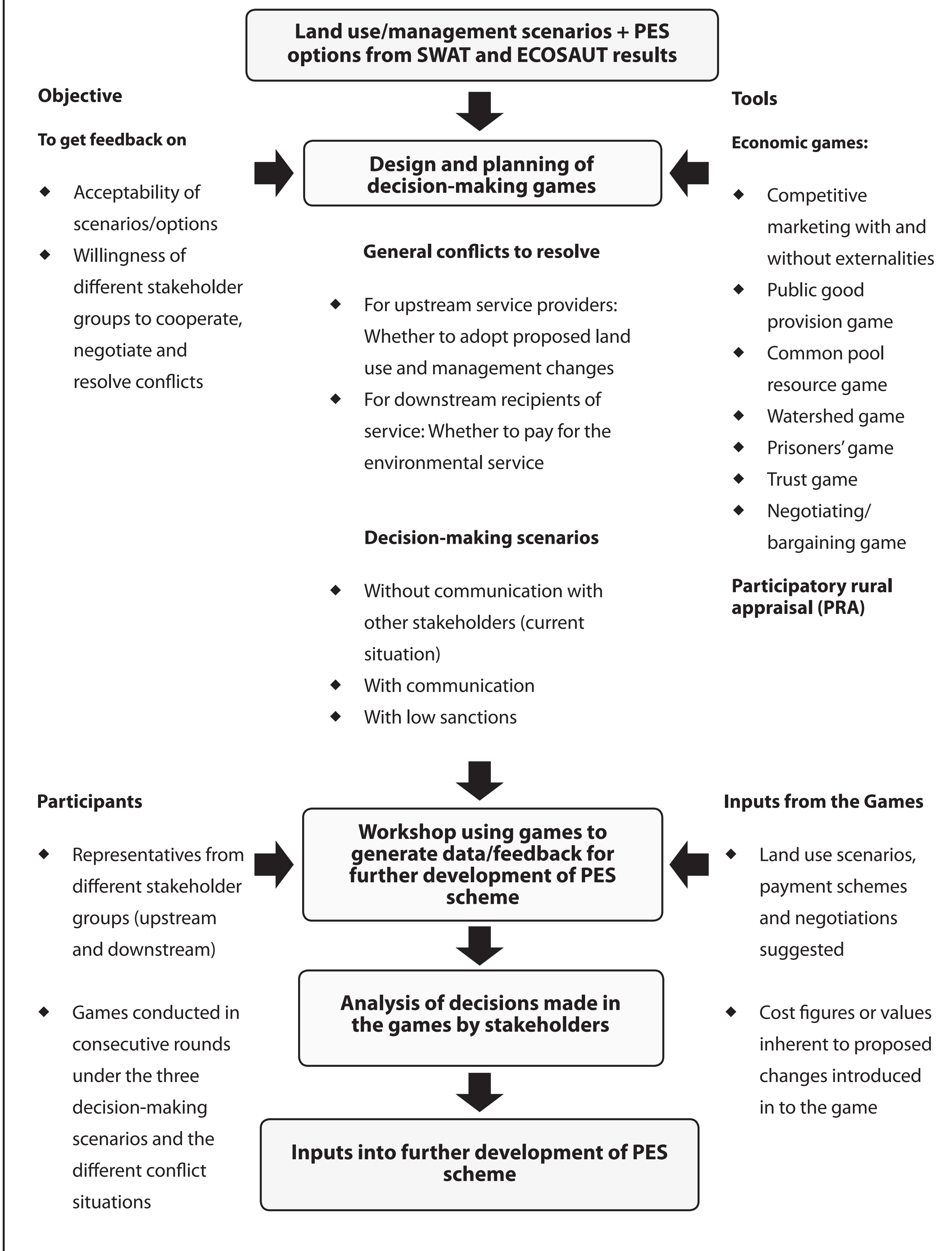


Figure 1. A Framework for Use of Economic Games in Refining PES Schemes

potential conflicts. The combined use of economic games and participatory rural appraisal (PRA) tools in simulation exercises of real-life problems (in a safe environment) is an innovative way to collect information about people's economic behavior when facing social or cooperation dilemmas (Lopez *et al.* n.d.).

The decision-making games are played by representatives from the upstream and downstream communities in the watershed area. Upstream players make the choice whether or not to change their current land-use scenarios or management practices; downstream players can provide payment to upsteam players as an incentive for changes to land-use/management practices. Their decisions are examined under different scenarios:

- a scenario without communication between players/actors (which serves as baseline)
- a scenario of negotiation where the different players are allowed to discuss before making a decision
- a scenario where decisions are enforced by the application of penalties to players (who do not shift to better management practices or do not pay the service providers)

The economic games provide answers to these questions:

- **Which stakeholder groups will continue with the same land management practices?**
- **Which will change their management practices?**
- **Which groups are willing to pay or compensate those making beneficial changes in their systems?**

The results of the games allow one to analyze of the possibilities and limitations in resolving cooperation-related conflicts and to establish to what extent reciprocity, trust, inequality and risk aversion can influence decisions in resolving environmental dilemmas (Cardenas and Ramos 2006). For details on the design and application of the games, see Estrada *et al.* (2009) and Lopez *et al.* n.d.).

Experiences and findings in the use of economic games in the Andes

1. When people understand the relationship between land use and hydological externalities such as quantity and quality of water flows, local agreements (as self-control mechanisms for implementing appropriate land uses) are easily reached.

2. Communities prefer to work with local organizations in managing economic resources because of the poor reputation of their local governments.

3. Farmers value employment generation for the landless and provision of materials for land use management more than monetary payments.

4. In one instance, economic games facilitated the creation of an inter-sectoral committee for promoting the establishment of a fund to pay for ecosystem services.

5. Involving the downstream wealthy farmers in the economic games was difficult. They own lands with good water allocation and therefore do not want to pay extra without

additional benefits to them. On the contrary, downstream small farmers participated in the economic games and showed willingness to compensate upstream farmers for their environmental services.

Lessons from the games

The conduct of economic games offered very valuable insights and helped to recognize that

1. Willingness to cooperate is dependent on good communication between the parties. However, an investment is required to initiate and facilitate the dialogue process.

2. Command-and-control mechanisms such as laws and regulations may be the only way to make the wealthy downstream farmers adhere to PES schemes.

3. Identification of win-win technological alternatives to improve the environmental and economic performance of conventional agricultural systems is essential. This may accelerate the negotiation process by incorporating new incentives for farmers beyond mere payments for environmental services.

4. PES should consider non-monetary payments such as construction of schools and health centers and livelihood-training activities. These kinds of payment can have long-term benefits for the communities. The disadvantage is that the community members who are not benefiting from these non-monetary payments would not have the incentive to deliver a service.

5. PES payments should not target individual farmers as service providers, but groups or communities to reduce transaction costs. This also ensures that the required threshold to achieve the desired impact from the service is met.

Recommendations for future economic games

Economic games have proven useful in understanding the conditions under which compensation for environmental services may be feasible.

This project has highlighted the fact that there is room for refinements in the games in order to ensure the participation of the wealthiest farmers in the games.

It is also useful to check on other stakeholders whose representation may have not been made explicit—e.g., women and children.

Adding reality to the games by using actual or factual figures instead of symbolic numbers can help to more accurately determine how willingness to pay for environmental services varies among different stakeholders.

Contact Person

Marcela Quintero (m.quintero@cgiar.org)

Partner Organizations

Autonomous Regional Corporation for Cundinamarca Province (CAR), Colombia
Centro Ecuménico de Promoción y Acción Social Centro (CEDEPAS), Peru
Centro Internacional de Agricultural Tropical
Consorcio para el Desarrollo Sostenible de la Ecoregion Andina (CONDESAN), Peru
Danish Institute for International Studies, Denmark
Entidad Prestadora de Servicios de Saneamiento, Peru
Farmer's Association of the Fuquene Watershed, Colombia
Fundacion para el Desarrollo Sostenible Territorial, Colombia
Programa de Manejo Integral de Cuencas, Bolivia
Proyecto Especial Alto Mayo (PEAM), Peru
Universidad de los Andes, Colombia
Universidad Javeriana, Colombia

Key Reference

Estrada, R.D., M. Quintero, A. Moreno and H.M. Ranvborg 2009. *Payment for environmental services as a mechanism for promoting rural development in the upper watersheds of the tropics.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3907

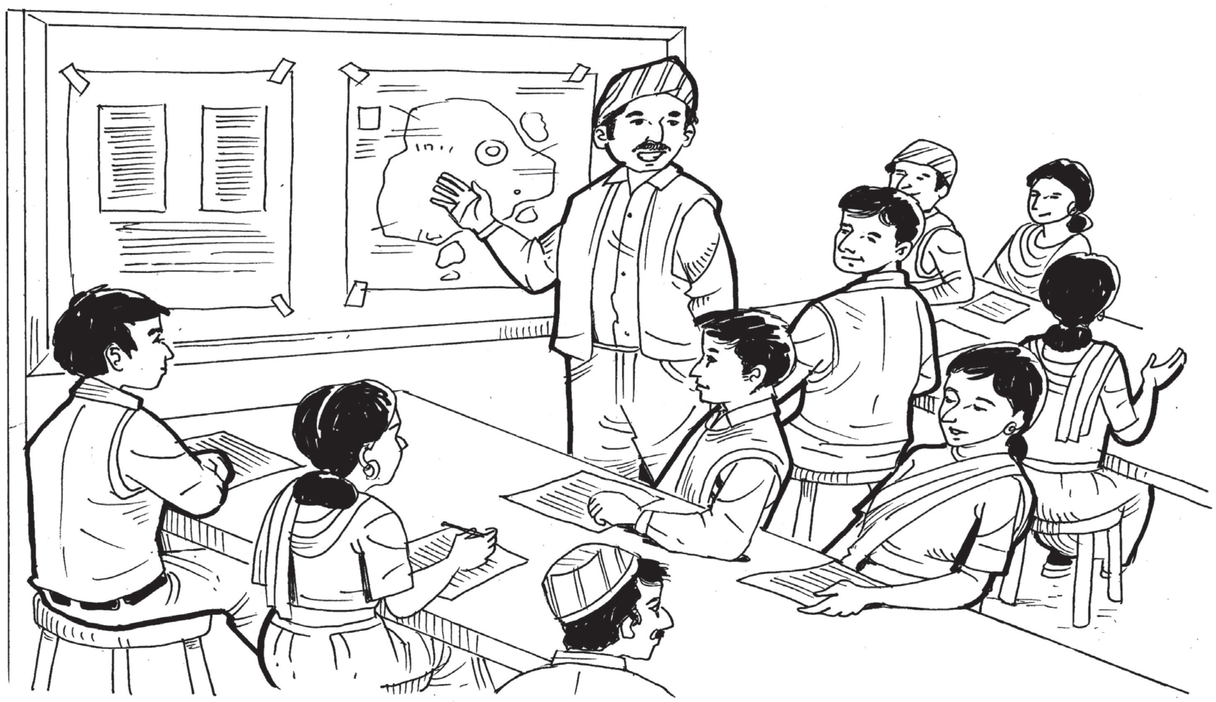
Tags: PN22; Environmental Services and Rural Development

Other References

Cardenas, J.C. and P.A. Ramos 2006. *Manual e juegos economicos para el analisis del uso colectivo de los recursos naturales.* Lima Peru: International Potato Center.

Lopez, M.C., D. Maya and J.C. Cardenas *n.d. Experimental economics and participative methodologies: Looking for theoretical and methodological bridges to analyse collective action in common-use resources management*. Universidad Javeriana, Bogota, Colombia.

Creating a Common Platform for Integrated Management of Natural Resources in Nepal



This article is based on the analysis of results from the CGIAR Challenge Program on Water and Food (CPWF) project on Resources Management of Sustainable Livelihoods. This action research followed the integrated natural resource management (INRM) principle of creating a common platform for the integrated management of natural resources.

The institutional settings for natural resource management in Nepal cannot be analyzed independently of recent changes in the national political situation and administrative organizational structure. The country was declared a democratic republic on 28 May 2008 when the monarchy system of the country that reigned for more than 200

Integrated natural resource management (INRM) defined

INRM is an approach that integrates research on different types of natural resources into stakeholder-driven processes of adaptive management and innovation to improve livelihoods, agro-ecosystem resilience, agricultural productivity and environmental services at community, eco-regional, and global scales of intervention and impact (CGIAR Task Force on INRM 2001). The Task Force suggests that the strongly and rapidly evolving community-based natural resource management organizations contribute to positive policy reform–including governance and restructuring of the country–build synergy, and enhance the capacities of local organizations.

years was overthrown. Present-day discussion and debate has been revolving around what is meant by a federal system for the country.

Against that political and institutional background, this article analyzes the experience and results of the 'project process,' which led to the evolutionary formation of a common platform for INRM. The 'process of the project' offers simple and practical ideas for the management of natural resources for the country. Expediting institutional coordination for INRM at local levels can provide a timely and valuable contribution to the natural resource policies in the country.

The Begnas Basin is a typical example of a basin where rapid land-use changes are driven by the emerging market pressures in the region, which were accompanied by the construction of irrigation systems, urbanization and delineation of community forest areas in the basin. The basin is located in Gandaki River, one of Nepal's major river systems. The basin area is about 3406 hectares, of which 1838.5 hectares is mountainous upper watershed, and the remaining 1567.5 hectares form the downstream valley floor. The goal of the action research in this basin was to create a common platform for integrated management of natural resources. The project process constituted four steps.

1. Resource and livelihood assessment

The Begnas Basin exhibits diversity–in resources and people. The basin is ethnically heterogeneous and socio-economic conditions are differentiated within the communities. Given such diversity, the project emphasized that all stakeholders must be represented and must participate from the beginning.

An analysis of livelihood activities was done based on broadly defined household incomes. It was found that cash, subsistence and nonmarket incomes form an essential component of livelihoods. Cash incomes for wealthier households, predominantly large land owners, come from the local sale of surplus agricultural and livestock products. Small landholders or poor farmers get cash income by working as wage laborers on neighboring farms, through contract farming or sharecropping and off-farm seasonal labor. Off-farm activities are also an alternative means of livelihood for poor farmers and are a coping strategy during times of crisis. Figure 1 shows the percentage of population in the Begnan basin with various income sources.

From a food security perspective, only 28% of the households have sufficient food for more than 9 months. The majority suffer from food insecurity for most of the year. These households either rent nearby farm lands or work as farm laborers to earn a living. (Figure 2)

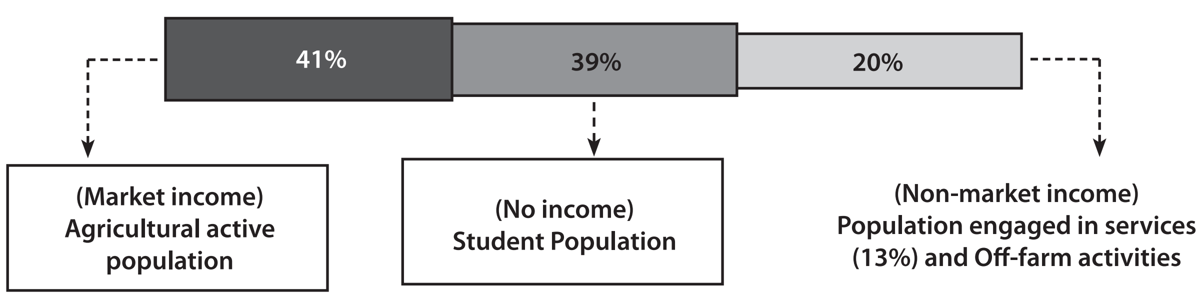


Figure 1. Population engaged in various activities in the Begnas Basin.

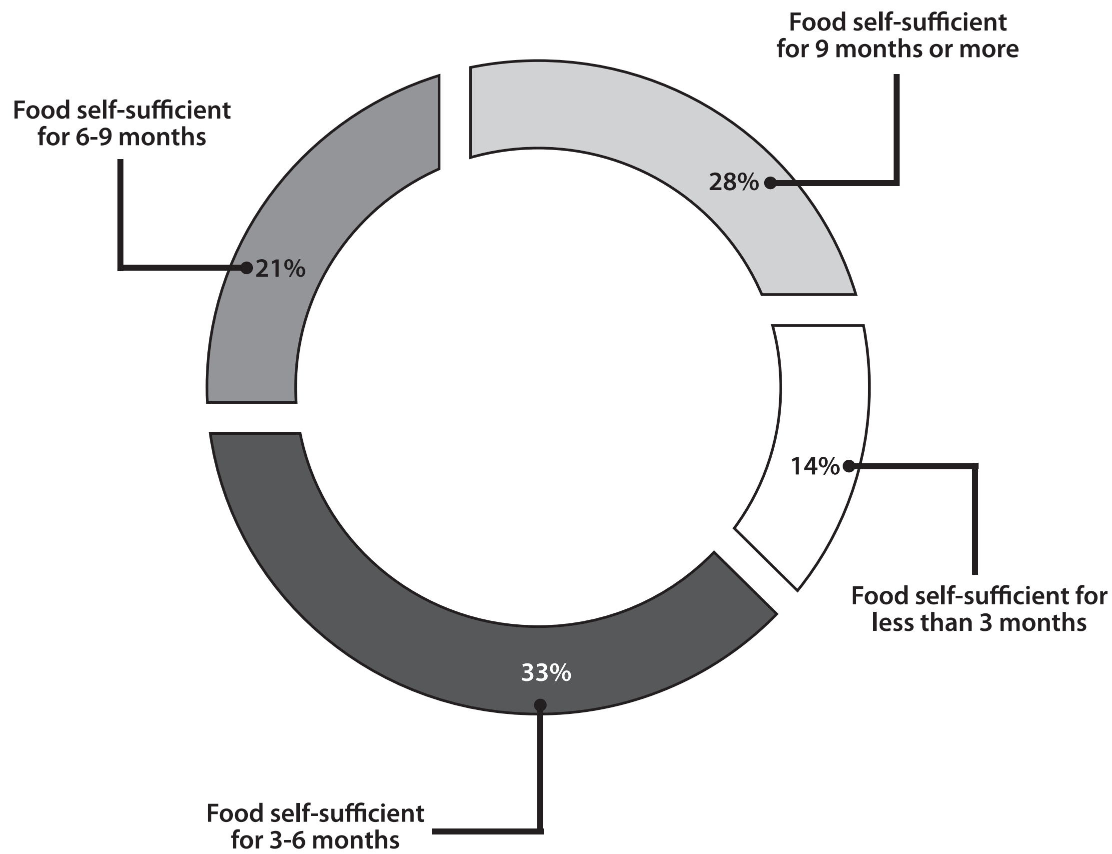


Figure 2. Household food self-sufficiency level in Begnas Basin.

2. Stakeholder and network analysis

A situational analysis of natural resources (forests and water), combined with stakeholder analysis and livelihood assessment, was done for the scoping phase of the project. It helped build rapport with community organizations in Begnas Basin and make residents aware of the INRM process at an early stage. Discussions among key individuals and community organization representatives and brainstorming of the external facilitator groups with government officials were important steps in the identification of locally relevant stakeholder groups for INRM.

3. Consensus building among community-based NRM organizations and relevant stakeholder groups

Sharing of research results with local stakeholder groups through participatory workshops at site, district, and national levels formed the heart of the process. It resulted in substantive consensus building and understanding among stakeholder groups for the creation of a common platform. Throughout the various analyses, different reactions were elicited from local communities, government bodies and relevant local user groups such as forest and water user groups. Although many stakeholders in the forest and water user groups could not grasp the concept of INRM or the need for it, people did come

Table 1. Stakeholders' opinions on benefits from integration/ linkage between forest user groups (FUGs) and water users associations (WUAs)		
S.N.	**Benefits of integration/linkage between FUGs and WUAs**	**Emphasis level**
1	Will increase cooperation between FUG and WUA	****
2	Will raise awareness among users from both institutions	**
3	Will help resolve conflicts	*****
4	Will mobilize new resources for mutual benefit	***
5	Will improve working relation with line agencies and government departments	**
6	Will create opportunities to learn from each other's experience	****

Larger number of asterisk is indicative of higher values.

together to develop a common understanding of their problems and potential solutions. Stakeholders generally valued the efforts to link up forest and water user groups (see Table 1).

4. Formation of a basin-level common platform

A common platform committee was formed, consisting of representatives of community organizations, including forest, water, fishery, and agriculture user groups using a systematic and organized process (refer to Figure 3). The members of the committee devised an action plan for the management of natural resources (water and forest) in their basin. These efforts demonstrated interest and willingness on the part of local communities to engage in INRM. The platform, registered as a local NGO, obtained recognition through registration with the local administration body.

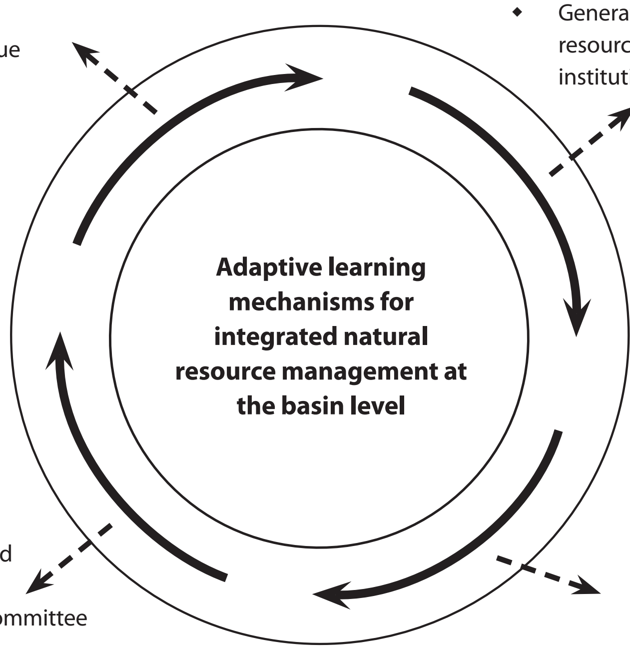
Following the negotiation and consensus-building process, the representatives of various community institutions, including community forest user groups (FUGs) and water user associations (WUAs), discussed plans in a forum. This was attended by a wide variety of stakeholder groups, such as district government agencies, local councils, local project implementers, civil society groups and community-level organizations. The communities created an ad hoc committee, consisting of 13 members who devise an action plan for the management of the Begnas Basin.

Results and discussion

Community livelihoods in Nepal are highly dependent on the management of their natural resources, which are often shared between communities, villages or districts. Forests and water are two important natural resources that people have used for livelihood enhancement.

4. **Policy process management**
- Participatory policy research and analysis
- Policy learning
- Facilitate policy dialogue
- Support policy action

1. **Preparing for learning**
- Understand resource use patterns and dynamics managers
- Generate knowledge on natural resource management and institutions



2. **Sharing**
- Stakeholder and network analysis
- Analyze knowledge, resource use and institutional dynamics
- Utilize knowledge generated by sharing among stakeholder groups

3. **Engaging stakeholders**
- Consensus building and negotiation
- Formation of ad hoc committee for common platform
- Action planning process

***Figure 3.** The CP23 process of creating a common platform for INRM at the basin level.*

Conditions that could warrant the setting up of INRM platforms:

- **Reluctance of the head enders to cooperate in water management affairs with a view to losing their water rights, control and power against the tail enders**
- **Inherent notion among many different water users and stakeholders that integration and cooperation, instead of working in isolation, will ensure a win-win situation and result in improvement**
- **Ownership and management of common property resources (CPRs) are not clearly defined and there is unequal access to benefits**
- **Low income generation from agriculture, lack of alternate income, lack of technical support and lack of resources for improving irrigation infrastructure**
- **Lack of access to government funds due to informal nature of user organizations**
- **Tail enders are being unduly affected owing to lack of irrigation water**
- **Systems to collect irrigation fees break down**
- **Ownership issues with regard to land and other resources are present**
- **Stakeholders do not contribute their due shares while still benefiting from the lake**
- **General lack of coordination and cooperation in the management of the system**

Community FUGs and WUAs have increasingly evolved into local democratic institutions. Community organizations are in a better position to contribute to constructive local dialogues on new governance structures in the country. Integrated natural resource management is all about the process of adaptive learning. This process can give useful insights into how and what form of governance models would be suitable for a country where diverse community institutions and socio-economic systems are present.

Conclusions and recommendations

Community-based organizations, such as FUGs and WUAs, have evolved through time and developed tested and proven approaches for dealing with a diversity of situations, problems, ethnic groups, and benefit-sharing mechanisms. The common platform for basin management builds on such organizations. The platform democratizes and promotes INRM by giving a voice to all stakeholders.

From a socio-democratic perspective, including the poor, disadvantaged and diverse stakeholders at the basin level, the common platform is premised on the redistribution and sharing of power and resources. This empowers stakeholders to participate meaningfully in making decisions that affect their natural resource base and to take action to resolve conflicts. This could shape the federal structuring process in the country, which needs to be an inclusive process, wherein negotiations are based on redistribution of resources and power-sharing mechanisms.

Contact Persons

Thapa S. Sabita (sabitathapa@yahoo.com)

Partner Organization

Department of Irrigation, Nepal
Institute of Water and Human Resources Development, Nepal
International Water Management Institute
Nepal Engineering College
Stockholm Environment Institute, UK
University of East Anglia, UK
World Widlife Fund, Nepal

Key References

Thapa, S., J. Soussan, D. Pant, J. Hill, U. Parajuli, K. Sharma and B. Bhatta 2008. Process-oriented integrated natural resource management (INRM) implementation at the basin level: Can it give new insights to State restructuring in Nepal?. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food,* Vol.1, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 85-88. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: PN23: Resources Management and Sustainable Livelihood

Bibliography

Task Force on INRM 2001. *Integrated management for sustainable agriculture, forestry and fisheries.* A brief report on the INRM Workshop, CIAT, Cali, Colombia, 28-31 August 2001.

Empowering Stakeholders to Co-manage Natural Resources

Community participation is recognized as an essential part of equitable and sustainable watershed management. However, meaningful participation is difficult to achieve when communities are unorganized, unaware of their legal rights and responsibilities, and lacking the information, education and confidence necessary to interact with other more powerful stakeholders.

Since upstream land use affects water quality and quantity downstream, residents may suffer (or benefit) as a result of actions of those living upstream (Swallow *et al.,* 2006). In theory, community or stakeholder participation in watershed management can be a solution to these problems.

If stakeholders are involved in decision-making, they are more likely to reach agreements that are mutually acceptable and therefore respected (FAO 2006). In practice, the power inequities between different stakeholder groups often make it difficult for them to interact on a level playing field.

A research project of the CGIAR Challenge Program on Water and Food (CPWF), Sustaining Inclusive Collective Action that Links Economic and Ecological Scales (SCALES) in the Upper Watershed, was designed to help make explicit the relationship between collective action, scales and poverty. The Conversatorio de Accion Ciudadana (CAC) methodology, originally developed by La Corporacion Asesoria para el Desarollo (ASDES), a Colombian NGO and first implemented by WWF Colombia in the 1990s , received special attention under SCALES.

CAC: Collective approach to natural resource management

CAC is a politicolegal mechanism for achieving meaningful participation by civil society. It is based on the idea of civil society and authorities conversing in familiar terms about issues of importance to both and arriving at agreements for action. The methodology consists of three phases: preparation, negotiation and follow-up. It is designed to address the inequities in power and information between communities and government institutions that make it difficult for communities to exercise their constitutional rights to participate and to hold their representatives accountable. CAC's point of entry is the Colombian constitution and the rights and responsibilities that citizens are entitled to but often do not know how to use. Trainings are conducted to teach individuals to use concrete legal instruments to obtain information or compel government agencies to promptly fulfill their obligations. This is accompanied by efforts to build social capital and increase people's knowledge of their natural resources. While the focus is on the community, training courses are also offered for public servants. This is because, in reality, many of them are also unaware of their roles and responsibilities under the constitution. This is especially true in relation to citizens' participation.

The three-pronged (environmental, social and legal) capacity building or 'preparation' phase culminates in a 1-day public meeting. In this meeting, communities invite representatives of the authorities whose mandates include the key social and environmental issues identified by the communities in the preparation phase. A structured negotiation takes place, leading to a signed agreement by representatives of institutions to undertake specific actions to improve social welfare and natural resource management. In the follow-up phase of the CAC, community representatives ensure that institutions comply with their commitments.

Varying ways of implementing CAC

While the CACs followed the same general methodology, each was implemented in a slightly different way due to differences in the lead organizations, the social, political and biophysical contexts, the available resources, and the level of support from organizations such as ASDES and WWF.

The specific interventions that the CACs undertook to increase human capital included trainings on legal rights and how to exercise them; hands-on analysis of environmental issues such as water quality, soil erosion or loss of biodiversity; workshops on identifying and analyzing problems and formulating solutions; and, especially for those who were "questioners" in the CAC itself, coaching on how to formulate questions, arguments and counter arguments, and how to speak in public.

In some cases such as in Fuquene, the main contribution to social capital occurred when participants from different communities came together to do training activities. Fundación Humedales developed a series of games to demonstrate legal and environmental concepts to people with low levels of formal education. In Coello, the coordinators were able to undertake activities such as a regional Water Forum, and the highly successful Coello Expedition, in which 40 people from all parts of the watershed spent 4 days following the river from its origin in the páramo to its outlet, learning first-hand about the watershed and about each other.

In both SCALES communities, economic experiments were conducted both as a research activity to better understand the factors that support or inhibit collective action in watersheds and as a development activity in which watershed residents participate as "players" in "games" or scenarios designed to reflect the actual incentives people face when deciding how to use resources that have both individual and social costs and benefits (Cardenas and Ostrom, 2004). The games made explicit the incentives for and against cooperation and generated discussion on how to address the constraints to collective action.

CACs have been conducted in three Colombian watersheds between 2004 and 2007:

1. Fuquene, October 2004 - February 2007 (SCALES project)
2. Coello, December 2005 - May 2007 (SCALES project)
3. Güiza, October 2004 - October 2006 (WWF and partners)

The types of impact considered under CAC are:

1. Agreement signed on the day of the meeting;
2. Human and social capital impacts among participants from communities;

Signed agreements

The CAC in Güiza, held on October 28, 2006, was the best attended. In addition to the institutional representatives, the state governor and two mayors were in attendance.

The meeting was held in the state capital rather than in the watershed itself. Thirty agreements were signed with 13 institutions, including municipalities, the environmental authority, and departments such as health, agriculture and planning (Cantillo and Gonzalez, 2008c). Though most agreements were nonmonetary, a total of more than US$1.7 million was committed for activities such as watershed planning, water and sanitation, health and agriculture.

---

* *Dates cover preparation and negotiation process*

3. Relationships between communities and public institutions.

Impacts on poverty and the environment are not addressed since these are of a long-term nature. However, implications for these kinds of impact can be inferred from the shorter term impacts that are presented.

Outcomes

The CAC methodology, as implemented in three Colombian watersheds between 2004 and 2007, led to 76 concrete commitments on the part of institutions to improve the welfare of watershed residents and the management of watershed resources.

- An assessment in late 2007 showed that compliance rates were relatively high, especially in the communities that had stronger follow-up processes.

- The CAC methodology also had significant human and social capital impacts on community members who participated and led to changes in the ways that communities and institutions perceive each other, in some cases, moving from antagonism to respectful collaboration.

- While estimating an economic rate of return is beyond the scope of this assessment, relative to the size of the investment made in carrying out the CACs, the impacts appear to be large, indicating a high rate of return.

Lessons learned

- The main lesson from this experience is that a CAC takes time. The SCALES project initially estimated that the preparation phase would take 3-6 months. In reality, it took a year and a half and even then, had it not been for the SCALES project deadlines, more time could have been used to properly prepare the communities and make the institutional contacts. Resource limitations were a part of this, but the main explanation was simply that the methodology was being applied in the local contexts by the local partners for the first time, which

made it difficult to estimate the time needed. The methodological guide being produced by the WWF and partners provides more detail for organizations interested in implementing the methodology to enable them to plan accordingly. (Candelo et al. 2008)

- Partnership with a committed local organization. Perhaps the most critical determinant of success is the presence of a committed local organization with experience in community organization. In Fuquene and Coello, the lead NGOs were relatively local in their scope prior to the CAC, but were interested in working at higher scales to address watershed issues. As such, both succeeded in increasing the recognition at the watershed scale and increasing their visibility.

- Experience has its influence. SCALES project partners had experience in Fuquene and Coello prior to the initiation of the SCALES project. In Fuquene, the experience was more of a research nature, and as a result there was more information and analysis available on the environmental and socioeconomic issues in the watershed. In Coello, experience had a research and a community development component and this appears to have provided a stronger base for the CAC.

- Link early with the public institutions to be invited to the CAC. Involving them in the process leads to more meaningful participation in the negotiation phase. This is important both for public and private sector actors. In neither CAC did the major private sector actors-e.g. dairy and potato farmers in Fuquene or rice farmers and CEMEX in Coello—play a major role. The basic CAC methodology is focused on communities and public institutions. However, the private sector is increasingly important in watershed management and innovative ways of engaging them need to be explored.

- Importance of community involvement. The impacts of the CAC will be larger and will likely be more widely distributed if more community members can be involved. A core team will always lead the process, however, so more emphasis can be put on having them share progress and seek feedback from their communities. Increasing the presence of the general public at the CAC itself will also make it clear to the public institutions that the people asking questions have the support of their communities.

Contact Person

Nancy Johnson (n.johnson@cgiar.org)

Partner Organizations

Centro Internacional de Agricultural Tropical
Consorcio para el Desarrollo Sostenible de la Ecoregion Andina (CONDESAN), Peru
Fundación Humedales, Colombia
International Food Policy Research Institute
Semillas de Agua, Chile
World Agroforestry Center
World Wildlife Fund, Colombia

Key Reference

Johnson, N. 2009. *Sustaining inclusive collective action that links across economic and ecological scales in upper watersheds.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3909

Tags: PN20: Sustaining Inclusive Collective Action

Bibliography

Beardon, H. 2008. *Building hope from chaos: Culture, politics and the protection of the Colombian Pacific mangroves.* UK: WWF.

Candelo, C., L. Cantillo, J. Gonzalez, A.M. Roldan and N. Johnson 2008. Empowering Communities to Co-manage Natural Resources: Impacts of theConversatorio de Acción Ciudadana. In: Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food, Vol. 2, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al; 201-205. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Cantillo, L. and J. Gonzalez 2008a. *Sistematizacion del Conversatorio de Accion Ciudadana del al Cuenca del la Laguna de Fuquene, Cundinamarca and Boyaca, Colombia.* SCALES project document (in Spanish).

Cantillo, L. and J. Gonzalez 2008b. *Sistematizacion del Conversatorio de Accion Ciudadana del al Cuenca del Rio Coello, Tolima, Colombia.* SCALES project document (in Spanish).

Cantillo, L. and J. Gonzalez 2008c. *Sistematizacion del Conversatorio de Accion Ciudadana del al Cuenca del Rio Güiza, Nariño, Colombia.* SCALES project document (in Spanish).

Cantillo, L. and J. Gonzalez n.d. *Sistematizacion de los conversatorios de accion ciudadana de la Cuenca de la Laguna de Fuquene, y las cuencas de los rios Güiza y Coello*. SCALES project document (in Spanish).

Cárdenas, J.C. and E. Ostrom 2004. What do people bring to the game? Experiments in the field about cooperation in the commons. *Agricultural Systems,* **82**, 307-326.

FAO 2006. *The new generation of watershed management programmes and projects: A resource book for practitioners and local decision-makers based on the findings and recommendations of a FAO review.* FAO Forestry Paper 150.

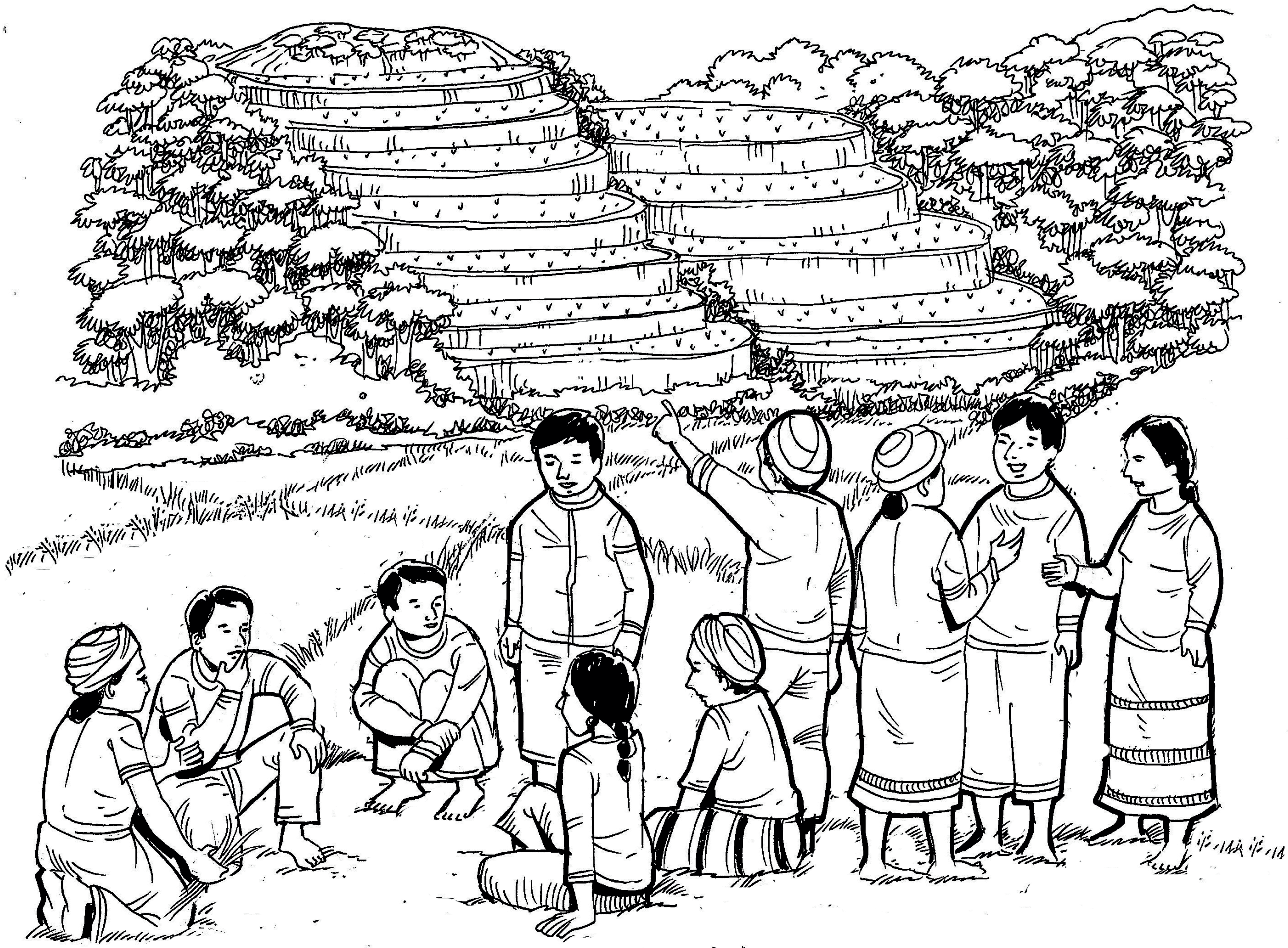
Fujisaka, S. 2008. *Impacts of the CPWF/Escalas in the Rio Coello watershed.* CPWF IA project document.

Johnson, N.; J. Garcia, J.E. Rubiano, M. Quintero, R.D. Estrada, E. Mwangi, A. Morena, A. Peralta, A. and S. Granados 2009. Water and poverty in two Colombian watersheds. *Water Alternatives*, **2**, 34-52

Swallow, B., N. Johnson, R. Meinzen-Dick and A. Knox 2006. The challenges of cross-scale collective action in watersheds. *Water International,* **31**, 361-376.

Tools for the Management of Agricultural and Natural Resources

Methodologies for Characterizing Biophysical Resource Systems in Upland Lao PDR



The upland communities of Lao PDR are typically composed of marginalized people living in severe poverty and are food insecure (WB 1995, ADB 2001). They devote most of their economic and biophysical resources to growing rice, the country's staple crop (Pandey *et al.,* 2002). Paddy rice is grown on bunded terraces in the valleys, while upland rice and some cash crops are grown under shifting cultivation systems on the steeper slopes. Increasing population drives agricultural intensification in the upland communities resulting to the degradation of agricultural resources through soil erosion, loss of water supply, and reduction of primary forest cover, which in turn caused drastic reduction in fallow periods (Schoeneberger *et al.,* 1998, Graeme and Lefroy 1999). This vicious cycle continues, depleting resources and making the community poorer and more food insecure.

Poverty assessments for the uplands of Lao PDR identified strong correlations between rice sufficiency and food security. This led the CGIAR Challenge Program on Water and Food (CPWF) Upper Catchment Rice Landscape Project partners to examine the productivity of the region's upland rice and wetland rice agroecosystems, as well as the productivity and availability of water on which these ecosystems depend. Significant spatio-temporal interactions between rice production, water, land use and other biophysical resources necessitate an approach that places agronomic alternatives in the context of the overall landscape and that enables linkages to socio-economic factors.

The project contributed to a platform of spatial modeling tools by linking spatial and watershed hydrology software into a coherent framework, satisfying the need for a system-level approach. The platform has the collective capability to simulate and analyze key upland biophysical processes on a sub-catchment scale. It enables analysis of impacts on water availability, rice production and economic flows under various land use scenarios, including upland sloping land-use mosaics and increased paddy area.

Methods

System descriptions and input data are basic requirements for model development and deployment. Hence, initial reseah focused on characterization of the biophysical resource systems of the target villages. The objectives of biophysical characterization were to (1) gain an understanding of spatio-temporal resource flows, processes and linkages for model development and preliminary analysis; and (2) build an input data set for model application. The scale of analysis was at the community level to look into interactions between water availability, rice production and poverty.

Luang Prabang province typifies the upland environment, agroecosystem and socioeconomic characteristics found throughout northern Lao PDR. Two villages within 60 km of the town of Luang Prabang—Ban Fay and Ban Silalek—were selected as project target sites. These villages share many commonalities but nevertheless represent differing ethnic composition, land area, demographics, resource endowments and histories.

Resource linkage appraisal

Upland communities manage their resources according to perceived realities. The resource linkage appraisal (RLA) track fulfilled the dual purpose of enhancing system understanding and informing subsequent recommendation domains amendable to the community. The three objectives of RLA were designed to integrate researchers' and the community' perceptions of resource availability, use, and interactions by (1) gaining a comprehensive qualitative description of the biophysical resource domain of the two target sites, focusing on land and water resources; (2) identifying perceived interactions between land use and water availability; and (3) estimating changes in land and water resource availability over time. Land and water resources were the primary drivers for other biophysical processes that are affecting the livelihoods of the communities.

The RLA was carried out using a two-pronged approach. First was a field survey of land and water resources to characterize their availability and quality in spatial terms. The field survey also provided the context for framing more effective participatory assessments. Second was a participatory assessment to gather the communities' perceptions of their land and water resources was conducted. The latter was done using informal interviews during field observation trips and focus group discussions (FGD). Various participatory tools such as resource maps, a seasonal calendar, and a resource flow matrix were integrated into the FGDs.

Land/water resource characterization (LWRC)

For the LWRC, detailed topographic, land use and hydrologic data for 2 years were collected from the Houay Hom watershed in Ban Fay. The Hom watershed covers approximately 3.8 km^2 and is entirely contained within the political boundary of Ban Fay. The watershed has key agricultural and water-use systems prevalent in the Lao uplands.

Field monitoring visits documented management decisions, seasonality and discharge characteristics of water flows and land-use regimes. These provided qualitative understanding that augmented quantitative data collection—detailed field surveys and land-phase field hydrology. The primary LWRC field methods carried out in the project are listed in Table 1.

In the field mapping survey, paddy areas, stream and conveyance networks and structures, dry-season springs and easily accessible areas were delineated and mapped. Since much of the watershed was not readily accessible and detailed land-use characterization on a watershed scale using global positioning system (GPS) units was not feasible, an alternative method was needed. Remote field mapping survey (RFMS), a ground-based method for simultaneous and rapid collection of spatial land-use and topography data over several square kilometers, was applied. Survey base points, along with key land uses and topographic formations with easy access, were mapped using a GPS unit. A laser rangefinder and

Table 1. LWRC field methods

Method	*Data type*	*Key methodological elements*
Remote field mapping survey (RFMS)	Topography; land use	Augmented RLA data in Ban Fay. Utilized a Garmin 76 global positioning system (GPS) unit, an altimeter, a compass and a Laser Technology TruPulse 200 laser rangefinder/hypsometer.
Climate monitoring (three locations)	Evapotranspiration (potential); rainfall	Automated weather station (one location); supplemental weather stations (two locations); ETgage (three locations) (www.etgage.com) Distributed across watershed to capture rainfall spatial and elevation effects. Manual and automated readings.
Streamflow monitoring (four locations)	Streamflows	High-resolution (10-min) depth measurement at the watershed outlet during dry season; daily depth measurements in dry season. Utilized velocity-area method, volumetric measurement, S-M flume (Samani and Magallenez, 2000) and rectangular culvert depth monitoring.
Paddy water level monitoring	Paddy water management	Daily manual depth measurements in two adjacent rice paddy areas at multiple levels on the toposequence.

Source: Pandey, S., et.al., 2010. CPWF Project Report: PN11 electronic compass collected height, distance and bearing data relative to the base points for land uses and terrain extrema in less accessible areas of the watershed. Base points and remote points were then translated into detailed land-use and high-resolution contour maps.

Lessons learned

- Food security and poverty issues underpin research site selection. A clear potential exists for improving rice productivity and reducing poverty, which are therefore important selection criteria when identifying study areas.

- Participatory methods increase the qualitative understanding of biophysical resource endowments and linkages. System characterization and model development should be viewed as conjoint and concurrent activities to maximize the efficiency of characterization efforts.

- It is important to build on the indigenous knowledge of traditional farming systems and thereby understand the interface between biophysical and socio-economic circumstances of communities for effective development and dissemination of technologies.

- Several technologies (e.g., ETgage for getting reference evapotranspiration and RFMS for getting land-use and topography data, especially in inaccessible areas) are useful for field hydrology and land data collection in the upland Lao context.

Contact Persons

Randall Ritzema (r.ritzema@cgiar.org)

Partner Organizations

International Rice Research Institute
Northern Agriculture and Forestry Research Centre, Lao PDR
University of California Davis, USA

Key References

Ritzema, R., R. Plant, B. Samson, B. Vongphuthone and S. Pandey 2008. System characterization for integrated resource analysis of rice-based livelihood systems in upland Lao PDR. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food,* Vol.1, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 155-159. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: PN11: Upper Catchment Rice Landscape

Bibliography

ADB 2001. *Participatory poverty assessment: Lao People's Democratic Republic.* Manila, Philippines: Asian Development Bank.

Graeme, B. and R. Lefroy 1999. *Integrated Upland Agricultural Resource Project: Report of Visit to Project Area in December 1999 and Recommendations on Soil Fertility and Related Issues.* Agronomy and Soil Science, University of New England; International Board for Soil Research and Management (IBSRAM).

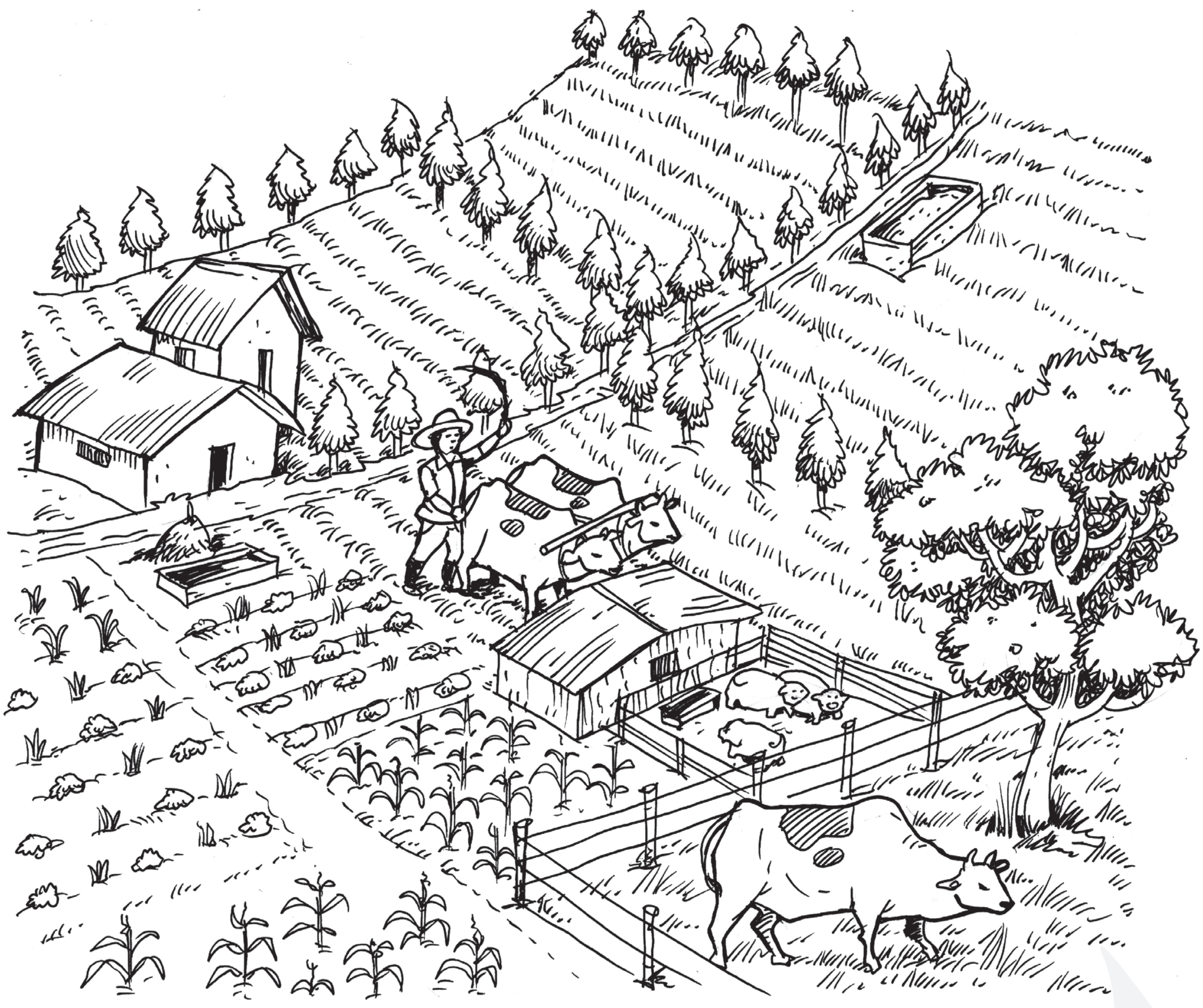
Pandey, S. et al. 2002. *Market access, food security and upland rice: some micro-economic evidences from northern mountainous regions of Vietnam.* Annual Conference of the Australian Agricultural Economics Association, Canberra, Australia.

Samani, Z. and H. Magallenez. 2000. Simple flume for flow measurement in open channel. *Journal of Irrigation and Drainage,* **126**, 127-129.

Schoeneberger, P.J. et al. 1998. *Field Book for describing and sampling soils.* Natural Resources Conservation Service, USDA, National Soil Survey Center, Lincoln, NE.

World Bank 1995. *Lao PDR: Social Development Assessment and Strategy.* East Asia and Pacific Region, World Bank.

Simulation Modeling to Develop Pro-Poor PES Schemes

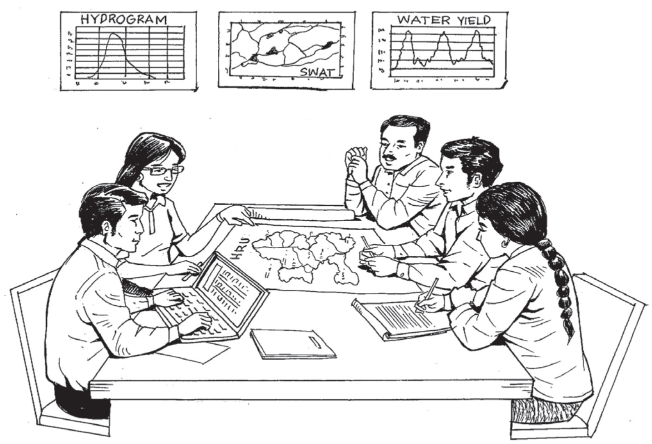


Payment for environmental services (PES) is a potential mechanism to contribute to rural sector development while at the same time preserving the environment. PES recognizes the economic value of environmental services and promotes the transfer of resources between the service providers and those who benefit from the service. Environmental service providers could be upland farmers adopting sustainable land-use and conservation measures and the recipients of the service are the people downstream who enjoy reliable water supply because of sustainable agriculture practices. In effect, PES uses environmental externalities as a driver to promote social investment and development in the upper watersheds. Meanwhile, PES has also evolved into PES-type schemes that not only offer direct payments but also comprise other kinds of incentives, like cheap loans.

Prioritizing the poor in the delivery of environmental services

Implementing PES in upper watersheds to conserve nature and at the same time increase the income of poor rural households has its difficulties. This is because areas with the highest potential to deliver environmental services are not necessarily where the poorest live. In the Andean watersheds, for example, many of the poor do not own lands and cannot, therefore partake in the incentives offered in PES as compensation for environmental services. Those with access to land may not be able to practice ecologically sound land-use as these patterns could mean a temporary decrease in net income. Understanding the potential of PES schemes to conserve environmental services and generate rural development requires an examination of many different scenarios. This is especially important when prioritizing the poorest whose options to participate in PES are limited. This task of generating and screening scenarios and options can be greatly facilitated by the use of computer-aided simulation models.

Approach for valuation of water-related environmental services



With ECOSAUT, assessment of the potential of PES is facilitated by creating scenarios to reduce negative environmental externalities and by analyzing the effect of each scenario on farm profitability and resource use. Some key questions to help form the scenarios are:

- **How would farm profitability and resource use be affected if regulations were imposed to reduce sedimentation to a given level?**
- **How would a shift to biofuels affect farm profitability and demand for farm labor?**
- **What land-use options would retain runoff at a certain maximum desired level without compromising farm profitability?**
- **What is the marginal effect of the proposed land use on sediment yields with respect to current land use?**

Assessment of the potentials of water-related environmental services to have positive impact on socio-economic conditions in the watersheds can be facilitated by the use of hydrologic and socio-economic models. An example of these simulation models is ECOSAUT. It provides an assessement of different land-use scenarios vis-á-vis hydrological services. It also gives a socio-economic and environmental assessment of the land-use scenarios or alternatives. ECOSAUT requires an understanding of computer-based linear programming and optimization models.

The shaded portion in figure 1 represents the use of the two simulation models. SWAT and ECOSAUT. These are the outputs that serve as inputs to developing PES schemes. The social acceptability of the schemes among different stakeholders could be assessed through the use of "economic games" or contingent valuation methods, among other approaches.

SWAT is used first to define the hydrological response units (HRUs). These are areas within a watershed where the hydrological response to a given input would be similar. Among other

Simulation models help

- **prioritize sites by ability to deliver the greatest amount of environmental services.**

- **increase the efficiency of investments in watershed areas, through targeting investments in the watershed.**

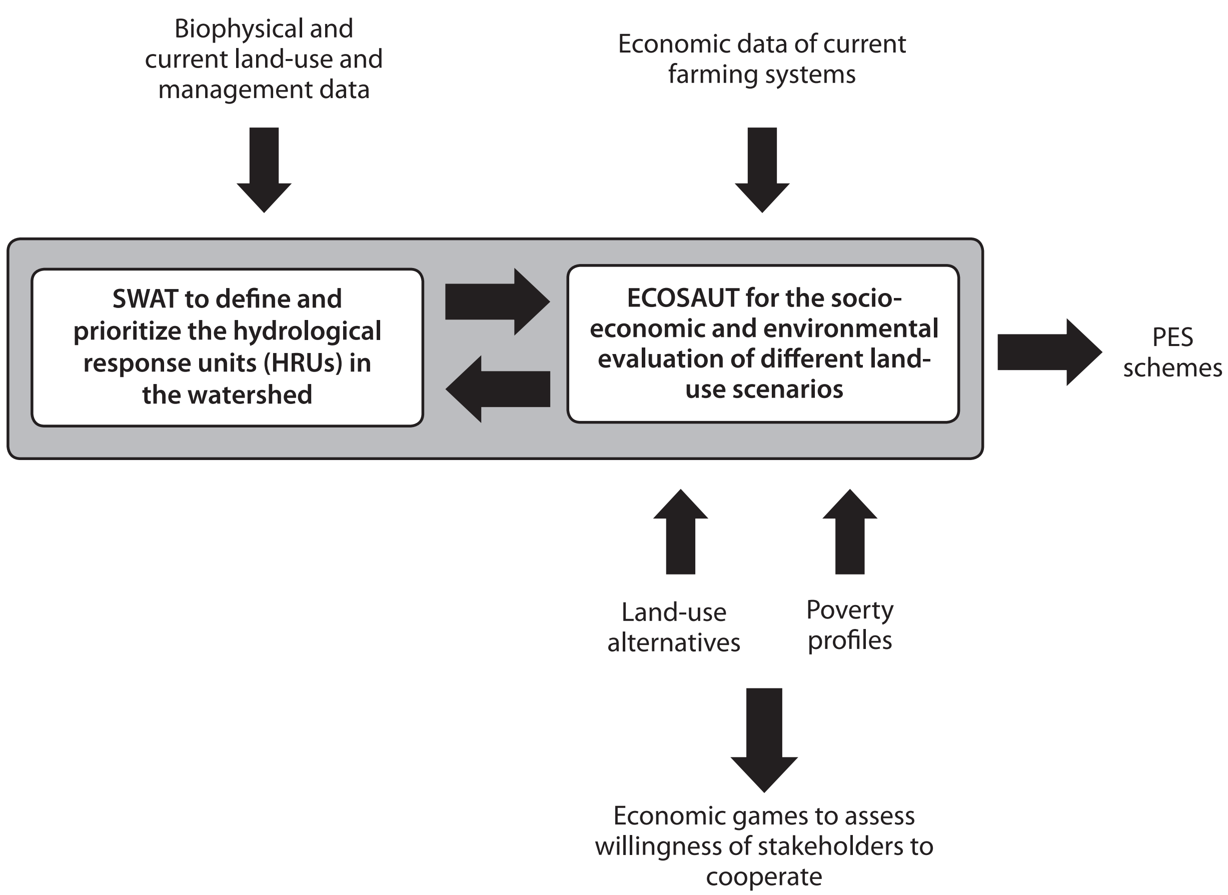


Figure 1. Developing PES schemes using simulation models SWAT and ECOSAUT

things, HRUs show the spatial heterogeneity of a watershed. In using SWAT, basic biophysical data are collected to quantify hydrological externalities in the study sites. The data are complemented by available primary data from digital elevation models, land-use maps, climatic stations and water flow gauges. Input data include topography, soil, land-use, weather, characteristics of main channels and groundwater aquifer, plant growth characteristics, land management (from tillage to harvesting) and water management (water use, water pollution discharges and location, characteristics and operation regime of ponds and reservoirs).

The second use of SWAT is in prioritizing those HRUs where water-related environmental services would have high impact. To determine these priority areas, SWAT has to be run with potential land-use/management scenarios and ECOSAUT. The ECOSAUT model integrates the valuation of the natural resources, economy and social impact with watershed management. The Consortium for the Sustainable Development of the Andean Ecoregion and its Latin American partners have developed ECOSAUT to analyze the economic, social and environmental trade-offs associated with alternative land uses. The model allows calculation of the socio-economic and the environmental costs and benefits associated with different land-uses based on perceptions of the highland farmers and the downstream communities. It estimates the quantity of an environmental service—e.g., water generation or carbon sequestration provided by a given land-use and the cost to farmers or landusers of supplying the environmental service.

Each HRU has unique soil and land-use properties. It is the level at which trade-offs between increases in hydrological services vis-á-vis different land-use scenarios are best studied.

Key findings

1. The HRUs with the highest potential to deliver environmental services are not necessarily occupied by the poorest people. Many of the poor people in the Andean watersheds do not own land. They cannot therefore capture any of the economic benefits derived from alternative land-use systems and from compensations for environmental services.

2. In Colombia, a set of minimum tillage and cover crop practices was found appropriate for improving an ecosystem service (i.e., sediment retention) with no opportunity cost. The practice positively impacts soil characteristics by improving stream flow regulation and reducing sediment production while increasing farmer income.

3. Simulation models in Colombia showed that increased accessibility to cheaper loans by small farmers could be effective in promoting conservation practices with proven positive impacts on reducing sediment yields and increasing carbon sequestration (Quintero 2009). However, this only reduced labor use implying reduced economic benefits to the landless.

4. SWAT simulations for the Altomayo watershed in Peru showed that changing the land-use in prioritized HRUs could potentially cut sedimentations by 18% while improving farmers' income. Related findings indicated that

    - Establishment of live barriers, forest plantations or shade-grown coffee may potentially reduce sedimentation by half.
    - Subsidized loans for shade-coffee adoption are better and cheaper than a permanent PES scheme.
    - Paying upstream farmers to abandon cropped areas in favor of forest re-growth is not feasible either economically or politically.

5. In the Jequetepeque River watershed of Peru, simulation results showed that reforestation, agroforestry systems and management practices in the agricultural systems to control erosion (contour strips) can reduce the production of sediments in the prioritized HRUs compared with the current land-use. Specially, reforestation and agroforestry systems can reduce the sediments by 41% and 54%, respectively.

6. For a proposed water reservoir project in the Ambato watershed in Ecuador, simulation models indicated that benefits to society would be 94% of the total benefits to be generated by the project (Estrada *et al.* 2009). The analysis showed that water consumers and society in general were the sectors that will capture more benefits and should therefore be involved in any scheme to recover investment cost and to compensate farmers upstream who may be affected by the reduction of stream flow. These results contradict the provincial government proposal to recover investment costs from the producers who were assumed to benefit most.

7. In some cases in the Fuquene watershed of Colombia, conservation tillage would increase net return implying a net economic benefit for the farmer. This means there are alternatives like conservation tillage in Fuquene with no opportunity costs. Payment or compensation for watershed services needs to be reconsidered here.

Lessons learned

◈ Understanding the spatial distribution and temporal hydrological behavior of the identified HRUs is essential to achieve high efficiency in the use of financial resources to compensate for environmental services.

◈ For the landless in the upper catchments, land-use changes promoted to provide environmental services will only generate benefits via a multiplier effect resulting from increases of labor use and income.

- Analysis of the effects of changing land-use should incorporate analysis of competitiveness because this may have more of an impact than changing the provision of an ecosystem service. This is especially important when the objective is to use PES as an entry point to ensure equitable sharing of benefits in a watershed.

- When modeling smaller watersheds, calibrating the model might not be straightforward. This is not because of the model itself, but because of watershed characteristics and the nature of streamflow and sediment measurements. Steep slopes and high intensity of peak rainfall events shorten the response time to 4 hours or less. In these situations, peak stream flows may not be reflected in the daily stream flow measurement generally measured every 24 hours.

Challenges for the Andes

There are two main challenges for the Andes where the CPWF Project was carried out. The first is to bring into practice the prioritization of HRUs by adopting appropriate land-use alternatives as evaluated through the simulation models. The second is to enhance the use of hydrological modeling by improving availability of input data related with climatic information, grasscover and soil characteristics.

Contact Person

Marcela Quintero (m.quintero@cgiar.org)

Partner Organizations

Autonomous Regional Corporation for Cundinamarca Province (CAR), Colombia
Centro Ecuménico de Promoción y Acción Social Centro (CEDEPAS), Peru
Centro Internacional de Agricultural Tropical
Consorcio para el Desarrollo Sostenible de la Ecoregion Andina (CONDESAN), Peru
Danish Institute for International Studies, Denmark
Entidad Prestadora de Servicios de Saneamiento, Peru
Farmer's Association of the Fuquene Watershed, Colombia
Fundacion para el Desarrollo Sostenible Territorial, Colombia
Programa de Manejo Integral de Cuencas, Bolivia
Proyecto Especial Alto Mayo (PEAM), Peru
Universidad de los Andes, Colombia
Universidad Javeriana, Colombia

Key Reference

Estrada, R.D., M. Quintero, A. Moreno and H.M. Ranvborg 2009. *Payment for environmental services as a mechanism for promoting rural development in the upper watersheds of the tropics.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3907

Tags: PN22; Environmental Services and Rural Development

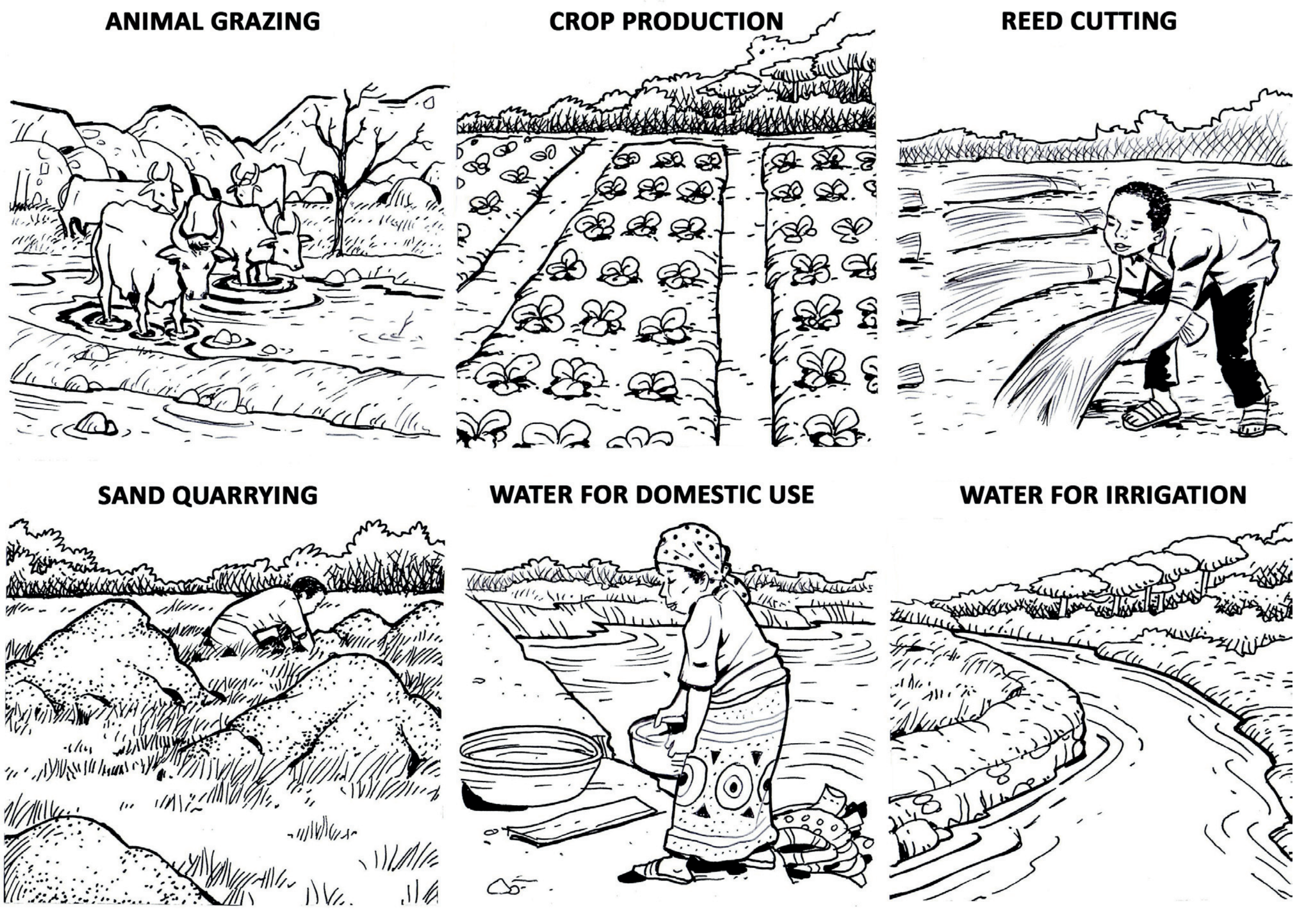
Bibliography

Estrada, R.D., N. Uribe and M. Quintero. 2009. *Costo-beneficio privado y social de las inversions realizadas en las represas de riego en la zona de Tungurahua. GTZ – Tungurahua Provincial Government*. Internal Report. Cali, Colombia.

Quintero, M. 2009. *Soil carbon sequestration and its economic valuation in conventional and conservation farming systems in the Colombian Andes.* MSc thesis, University of Florida.

Westermann, O. 2007. *Poverty, access and payment for watershed hydrological services.* PhD thesis, Department of Environmental, Social and Spatial Changes, Roskilde University Centre/ Danish Institute for International Studies, Denmark.

Framework and Tools for Wise Use and Management of Wetlands



Unplanned conversion of wetlands can lead to degradation and compromise livelihoods and other benefits derived from them.

In areas with long dry seasons, wetlands represent an important water and agricultural resource helping to mitigate the impact of drought on crop production and food availability. Altering wetlands through unplanned conversion to croplands, however, can lead to degradation and compromise the livelihoods and other benefits derived from them.

To manage wetlands is to manage variability and unpredictability. There are at least two reasons for this. First, they are part of a wider socio-economic and political context with key drivers that are not ecological in nature–e.g., markets and societal values. Second, they are complex and variable, exhibiting patterns that are not entirely predictable. These characteristics make them resilient or adaptable. The Integrated Framework for Wetland Inventory, Assessment and Monitoring (IF-WIAM) of the Ramsar Wetlands Convention evolved with these perspectives in mind, among many others. The framework integrates

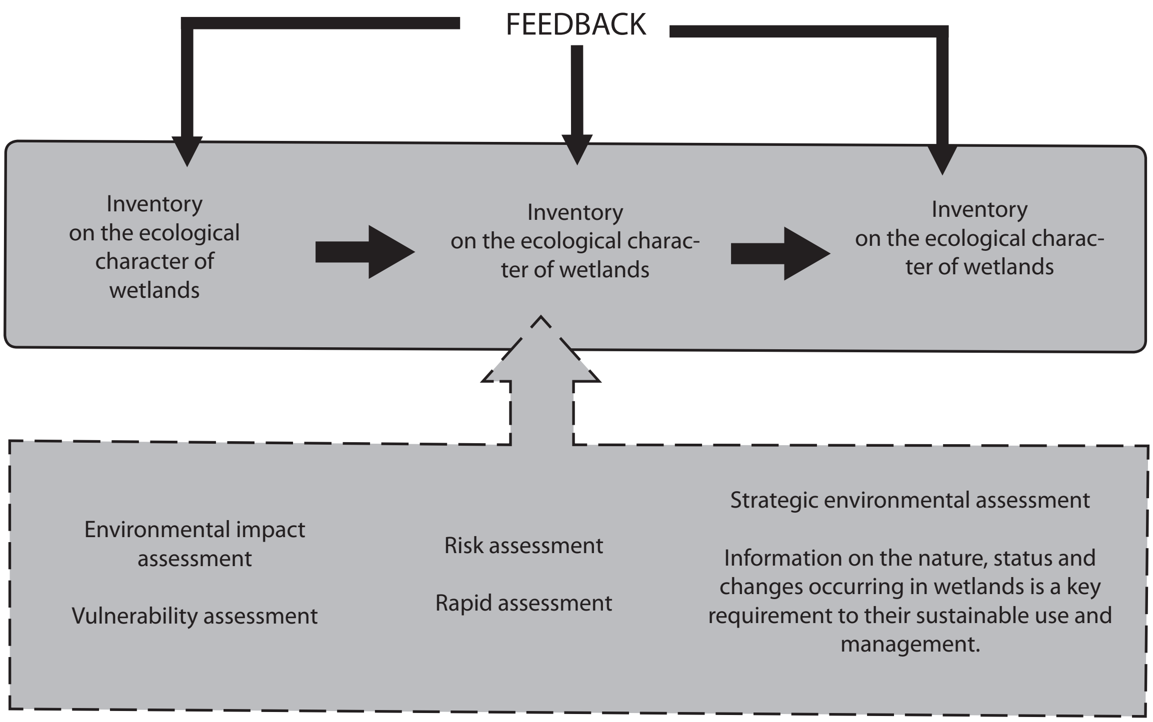


Figure 1. The Integrated Framework for Wetland Inventory Assessment and Monitoring (re-drawn based on Finlayson and Pollard, 2009).

a) complementary approaches for determining information needs at different scales given available resources; and b) tools for collecting and assessing information for the sustainable use, conservation and development of wetlands.

Wetlands are complex and variable ecosystems that can also be changed by non-ecological forces such as markets and politics. Managing the wetlands is managing this variability and unpredictability.

A framework for building up wetland information

The IF-WIAM integrates three inter-related processes for collecting and evaluating biophysical and related information necessary for the wise use and management of wetlands: inventory, assessment and monitoring. They are distinct but overlapping processes.

Wetland (baseline) inventory is the collection of information to describe the ecological character of wetland, whereas assessment is determining the status of and threats to wetlands. The latter takes into account the pressures and associated risks of adverse change in the ecological character of wetlands. Documenting information on the extent of any change in wetlands especially resulting from management actions based on assessment activities is the function of monitoring. Monitoring also updates assessment and inventory data, thus completing the circular relationship of the three components. Taken together, these processes provide the information needed for establishing strategies, policies and management interventions to maintain the defined wetland ecosystem character and hence ecosystem benefits/services.

A. Wetland inventory

The inventory provides information on the ecological components, processes and ecosystem services in wetlands. Early inventories have not included ecosystem services because Wetlands Convention has only recently considered them to be part of the ecological character of a wetland. The Ramsar Convention Handbook lists 13 steps for designing a wetland inventory. Setting the objective/s is the first of these steps since this, plus the resources available, are major factors for the design of the inventory. More than providing information, objectives of a wetlands inventory may include (Costa *et al* 1996):

- Identifying where wetlands are, and the priority sites for conservation;
- Identifying the functions and values of each wetland;
- Establishing a baseline for measuring change in a wetland; and
- Providing a tool for planning and management.

Wetland Ecosystems Services

Provisioning: source of food, fuelwood, fiber and timber

Regulating: benefits in terms of water partitioning, pest regulation, climate regulation, pollination

Cultural: spiritual, recreational, aesthetic, educational

Supporting (factors important for producing above 3 services): water cycle, soil formation, nutrient cycling, primary production

The manner in which an inventory is to be conducted depends on the objective/s and thus, there is no specific inventory method suggested. Practitioners need to work through the steps to develop the suitable inventory method, including identification of training needs and planning for contingency measures in support of the method. In the end, however, a well-planned inventory is only as effective as the personnel engaged to do it.
If resources are not enough for extensive data collection, it is still useful to undertake a simple inventory for particular wetland sites as in the Limpopo Southern Africa. Such site-based inventories are valuable in the absence of a regional inventory, provided the methods and information used go beyond specific wetland boundaries.

B. Wetland assessment

Six of the more common and inter-related assessment tools are risk assessment, vulnerability assessment, rapid assessment, economic valuation,

13 STEPS TO WETLAND INVENTORY DESIGN (Ramsar Convention Secretariat 2007b)

1. State the purpose and objectives on which decisions on methods and resources are to be made.

2. Review existing knowledge and information for their relevance to the proposed inventory work.

3. Review existing inventory methods for suitability to the stated purpose and objectives. Methods include ground-survey, aerial photography, topographical maps and satellite imagery.

4. Determine the scale and resolution of the maps to be drawn according to the minimum acceptable accuracy—e.g., 1:50,000 for a specific wetland site.

5. Establish a core or minimum data set for delineating/characterizing major wetland habitats to include its biophysical and management features.

6. Establish a habitat classification based on landform and water regimes plus other features such as vegetation, soils, water quality and size.

7. Choose an appropriate inventory method in relation to purpose and objective, the terrain, resources and time available.

8. Establish a data management system for collecting, recording and storing data in electronic and hardcopy formats. It should enable future users to determine source, accuracy and reliability of data.

9. Establish a realistic time schedule and the level of resources required, taking into account special features of the terrain, sampling techniques to use and available funding and resources.

10. Assess the feasibility and cost effectiveness of the project based on availability of trained personnel, specialized equipment needed and support for any project continuation, among others.

11. Establish a reporting procedure. Reporting of results should be timely, cost effective and in a form readily understood by others.

12. Review and evaluate the inventory. At a predetermined time, the entire process should be re-examined and necessary modifications made.

13. Plan a pilot study to fine-tune the methods and steps, adjust the time schedule and assess other needs before launching the actual inventory.

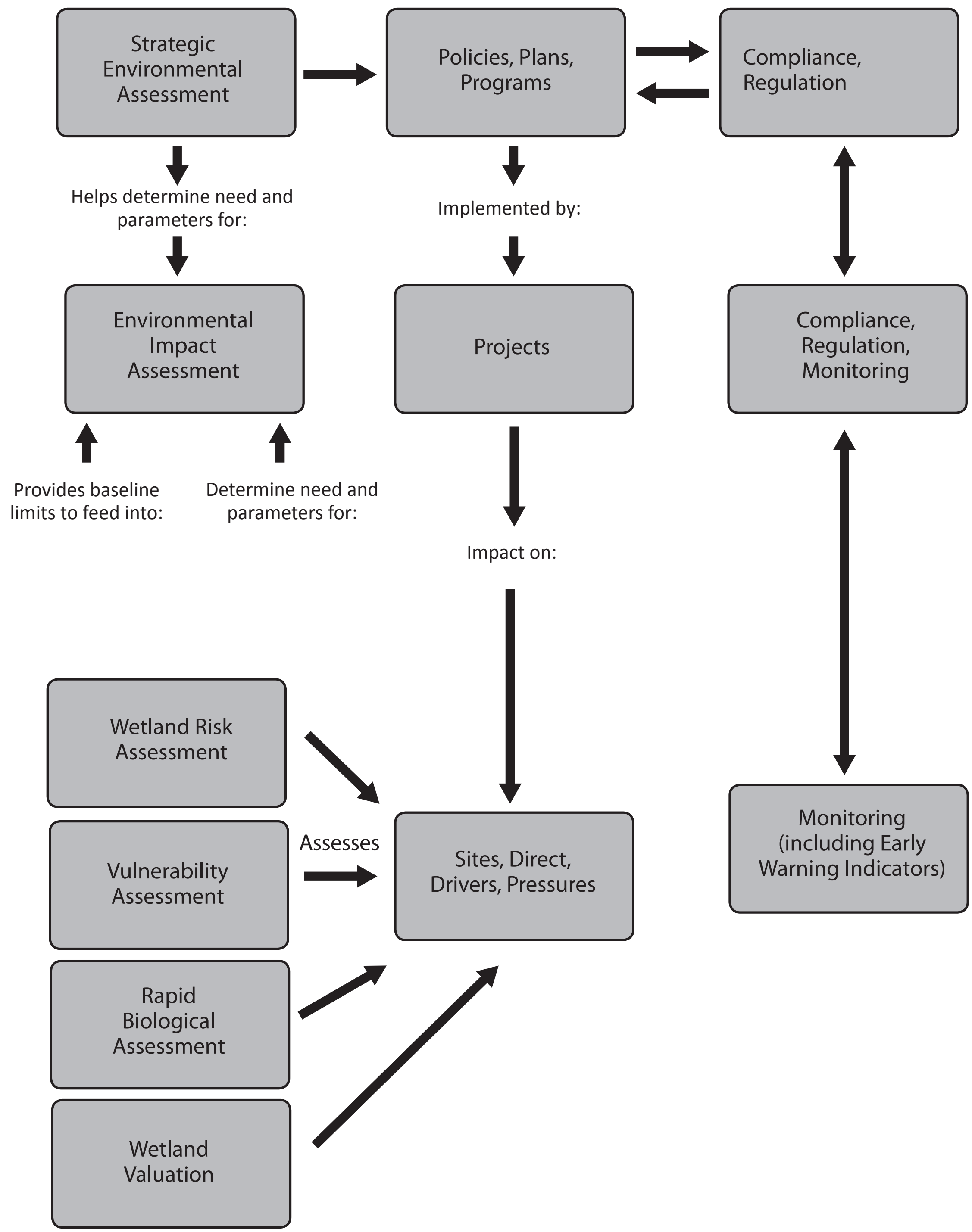


Figure 2. Relationships among the different assessment tools

Source: Ramsar Resolution IX.1.e. An Integrated Framework for Wetland Inventory, Assessment and Monitoring (IF-WIAM). 9th Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971). Kampala, Uganda, 8-15 November 2005.

environmental impact assessment and strategic environmental assessment. Figure 2 shows how these tools relate to each other. The first two are discussed in the next sections with respect to assessing risks and developing options for risk management.

1. Risk assessment

Wetland risk assessment evaluates the likelihood of adverse ecological effects occurring due to exposure to one or more pressures. It guides one on how to predict and assess changes in the ecological character of wetlands and promotes the use of early warning systems for determining when change may occur. The pressures or drivers of change include changes to the water regime, water pollution and eutrophication, physical modification to the wetland, overexploitation of biological products or fresh water and introduction of exotic species. Risk assessments observe these six steps (Ramsar 1999).

1.1 **Identification of the problem.** This is information on the characteristics of the pressure, what is to be affected and what is to be protected.

1.2 **Identification of the effects.** Field data are appropriate for assessments of multiple pressures, thus, identifying the effects best derived from field studies. Depending on the pressure(s) and resources, these range from quantitative field experiments to qualitative observational studies.

1.3 **Identification of the extent of the problem.** This involves estimating the exposure to a pressure Through information about its behavior and extent of occurrence. Information is obtained through field surveys, use of historical records, simulation modeling and field/laboratory studies.

1.4 **Identification of the risk.** This estimates the likely level of adverse ecological effects resulting from exposure to the pressure. A qualitative matrix may be used to do this. Multiple opinions or lines of evidence can help quantify the qualitative nature of assigning the risk and reduce the uncertainty associated to it. Uncertainty must be described and the risks sufficiently defined to support a risk management decision. The output, however, need not be a quantitative estimate of risk.

1.5 **Risk management and reduction.** This process utilizes information from the previous steps and attempts to minimize the risks without compromising the societal, community or environmental values. Each risk-reducing action is assessed with respect to the political, social,

Table 1. A matrix for qualitative assigning of risk based on the likelihood and consequences of exposure.

LIKELIHOOD OF EXPOSURE	CONSEQUENCES OF EXPOSURE		
	Little	**Serious**	**Catastrophic**
Low	Very low risk	Low risk	Medium risk
Medium	Low risk	Medium risk	High risk
High	Medium risk	High risk	Very high risk

economic and technical factors, as well as the benefits and limitations.

1.6 **Monitoring verifies the effectiveness of risk management decisions.** The choice of indicators to measure (i.e., what will be monitored?) is critical in this regard. They may or may not be the same as those used for effects characterization.

2. Vulnerability assessment

Vulnerability assessment determines the extent to which a wetland is susceptible to, or unable to cope with, adverse effects of climate change and other pressures such as changes in land use and cover, water regime, over-harvesting and invasion by alien species. It determines the probability of a risk event occurring and its effect on a system given its level of sensitivity, resiliency and coping capacity. It is also about developing options to reduce the adverse impacts from the risk event and formulating the desired outcome for the system within an adaptive management framework.

Gitay *et al* (2009) suggested a framework for vulnerability assessment. It has three major components: assessment of risk, risk minimization or management and monitoring and adaptive management.

2.1 **Risk assessment. Status, trends and perceptions about risks are established through** a) identification of past and present drivers of change and of existing hazards; b) assessment of present condition and recent trends in the ecological character of wetlands; c) conduct of a stakeholder analysis with the people to be affected by the changes; d) determining sensitivity and resiliency, including adaptive capacity of wetlands; e) identifying wetlands and groups most vulnerable to the changes; and f) developing scenarios with stakeholders given the risks from and interactions between the change drivers.

In any assessment, the certainty associated with the outcome should be recorded and kept in mind when making management decisions. One decision could be to undertake further monitoring to reduce any uncertainty and to use new information to reassess the risk.

2.2. **Risk minimization or management. This component has two important aspects.** The first is the identification of the specific wetlands and groups of people that are most vulnerable (i.e., with low adaptive capacity) to the risks associated with adverse changes. The second is developing the response options and determining which would best minimize the risks from changes in the ecological character of wetlands so the ability to provide the ecosystems services that people depend on can still be maintained. Response options can be regulations, strategic environmental planning, infrastructure/engineering works, rehabilitation and restoration, developing education material, improving community awareness and, developing integrated management plans. Trade-off analysis helps choose between the response options given constraints such as institutional capacity, available information and financial capacity. The desired outcomes are then specified based on the chosen option. A large adaptive capacity, high resiliency and low sensitivity of the system may sometimes mean there is no need for a management response.

In the CGIAR Challenge Program on Water and

A system can be vulnerable at a particular time but may not be at other times—e.g., vulnerability to fire increases during the dry season.

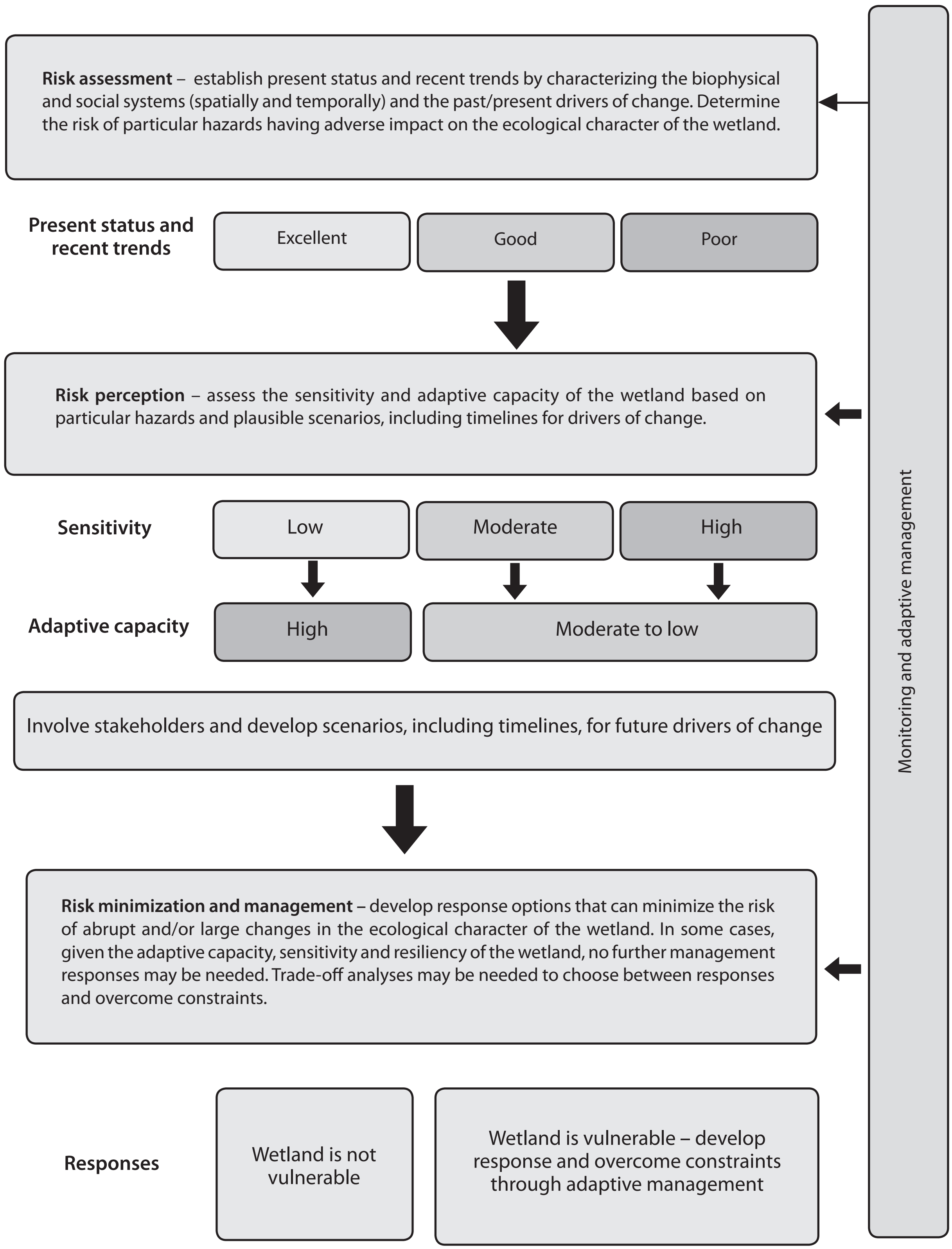


Figure 2. Relationships among the different assessment tools

Food (CPWF) Wetlands Welfare and Environmental Security project in the Limpopo Basin in Southern Africa (CPWF Project Report, 2010), trade-off analysis was done with a computer- based simulation model called WETSYS. The model simulates the impacts of alternative wetland management strategies and external pressures on wetland ecosystem functioning and community well-being. It has five interactive sectors: hydrology, crop production, natural resources, land use and community well-being. A sixth sector controls annual and seasonal cycles of activities. Wetland management options, which can be simulated using the model, include introduction of crops more adapted to wetland environment, reduction of artificial drainage, development of ecotourism and imposition of controls on wetland resource use. There were two main challenges in the development and use of the model. The first was the limited time-series data available to calibrate it, especially socio-economic information. The second was the difficulty in quantifying narratives about past land-use changes.

Table 2. Relationship between sensitivity, resiliency and vulnerability of a wetland

SENSITIVITY	RESILENCE	
	High	**Low**
Low	Not vulnerable	Vulnerable
High	Vulnerable	Very vulnerable

2.3 **Monitoring and adaptive management throughout the process**. This includes the means for measuring and making adjustments in the path to the desired outcomes. The process involves acting on early warnings, checking results of past actions and modifying project objectives and indicators in response to new findings.

C. Wetland monitoring

Monitoring addresses the issue of change or lack of change through time (Ramsar 1996) at particular places through systematic data collection over time. According to Finalyson (1996), its overall purpose is to determine the extent of change in the ecological character of a wetland as per hypothesis and objective derived from the assessment of the pressures or threats facing the wetland. In monitoring, the identification, effective measurement and use of early warning indicators are important for managers to determine whether intervention or further investigation is needed before the adverse change occurs. The earlier the signal, the more time for appropriate management responses.

The Ramsar Convention offers a structured approach for designing a wetland monitoring program at multiple scales from site-based to provincial, national and regional.

When resources are insufficient or not available for an effective monitoring program, it may still be useful to do an initial surveillance program to guide and support initial management decisions. This has been done in the Limpopo Basin project (CPWF PN 30). Table 3 on the next page presents results specific to the Missavene Wetland of the Limpopo project to show the types of information that may be generated from such initial activities. The first five columns are the results of the assessment activities, while the last column accordingly focuses on the monitoring aspects.

Table 3. Assessment and monitoring for Missavene Wetland, Mozambique
(Compiled by: S. Bandeira and D. Juizo, Universidade Eduardo Mondhlane, Maputo, Mozambique)

Identify main threats/issues in no particular order	**Outline the cause of the threat**	**Describe what part of the wetland is under threat – Which components or processes or services, and where?**	**Outline how the assessment was done – What tools or processes were used?**	**What management action can be taken?**	**Describe what monitoring is in place or proposed – What indicator is being used? What is the threshold when further action will be taken?**
Reeds (*Phragmites muaritianus*) and bulrush (*Typha capensis*) being cut	Too many people cutting reeds for building toilets and bulrush for making mats and boats	Extent of reed and bulrush being reduced Activity is unsustainable given the amount present and growth dynamics	Observation	Limit number of people harvesting resources. Limit period of cutting to allow re-growth. Allow cutting in half of reed areas only	Map distribution of reeds and bulrush per season Estimate: ◆ Growth dynamics ◆ Demand for resources Test time and place ban of cutting Test limit of % of cut.
Fires	Extensive and uncontrolled coverage of fire	Fauna and plant diversity reduced	Observation	Sensitize community to good and bad practices about fire. Consider ban on fire for small area of Missavane wetland	Document and evaluate wildfire frequency, causes and effects Ban some wildfire causes Propose guidelines on how to manage fires
Increased number of fields for crop production	Made at the expense of natural vegetation and species (some nearly extinct)	Native species being reduced Area with native vegetation also reduced	Observation and comparison	Consider increasing crop yield per area instead of increasing crop area	None so far
Reduction of grassland habitat	Too many cattle in wetlands Expansion of cropping into grasslands	Grassland		Land-use planning to consider area for agriculture development and for cattle pasture	First understand from users/ stakeholders which areas they would prefer for agriculture, pasture and other development

Lessons learned

Users and managers of wetlands face many challenges. This is because wetlands are part of a wider socio-economic and political context with key drivers that are not ecological in nature e.g., markets and societal values. A multi-faceted approach that incorporates both social and technical issues is therefore needed for the wise use and management of wetlands. The IF-WIAM has taken this into account.

The local level is the most logical entry point for effective and sustainable wetland management. This is because while wetland rules and regulations are formulated and passed at the national level, wetlands management still takes place at the local level where rules, sanctions and penalties are applied and enforced. Strong partnership with the communities is therefore essential. One partnership activity that may help reduce the pressure on wetland resources is improving the earning capacity of people from non-resource-based livelihood activities.

While the thrusts of the Ramsar Convention and the IF-WIAM are geared towards national to regional/global application, resource limitations dictates that simple inventories at individual wetland sites may be all that is possible. To maximize and expand the value of interventions at local or individual sites, the following are suggested:

- When undertaking wetland inventory, assessment and monitoring (WIAM) at individual sites, methods to be used and information to be generated should be compatible with and support the information needs at national/regional levels.

- Strong partnerships with the communities and involvement of local government officials can help ensure that wetland management

An early warning indicator is a measurable biological, physical or chemical response to a particular stress, preceding the occurrence of potentially significant adverse effects on the system of interest. An early warning provides opportunity to determine if further investigation is needed and not necessarily firm evidence of larger scale degradation. (van Dam et al. 1999).

Attributes of effective early warning indicators (van Dam et al. 1999 in Finlayson and Pollard, 2009)

Early warning indicators should have these attributes:

- **Anticipatory: provides indication of adverse change before serious harm occurs**
- **Sensitive: detect low levels/early stages of change**
- **Diagnostic: sufficiently specific to provide confidence in identifying the cause**
- **Broadly applicable to a range of causes**
- **Timely: provide information quickly enough to initiate management prior to impacts**
- **Cost-effective while providing maximum amount of information per unit effort**
- **Regionally relevant to the ecosystem being assessed**
- **Socially relevant: of value to and observable by stakeholders.**
- **Easy to measure: uses standard procedure with known reliability and low error**
- **Constant: can detect small changes, and can clearly distinguish the source**
- **Non-destructive to the ecosystem being assessed**

programs developed are appropriate and therefore sustainable. This will ascertain that the local uses of wetlands and the accrual of benefits to the locals are seriously considered. This ensures long-term awareness and incorporation of local concerns into management programs.

- Joint implementation with university partners— e.g., getting graduate school students to do research related to the wetland project can result in more in-depth analysis of specific issues on wetlands management/IF-WIAM.

Conclusion

The framework, processes and tools presented are not recipes for doing WIAM. Rather, they are to serve as a guide for developing and undertaking WIAM particular to one's context. However, since global trends such as climate change influence local settings, adaptation of the IF-WIAM at individual wetland sites must ensure that the methods and information therein can synchronize and complement with those at regional/global level as prescribed in the Ramsar Convention. This way, the various local efforts and results taken together can contribute to forming the bigger picture at the national level at the least. If this happens, then more suitable country policies and programs for the wise use and management of the wetlands may be developed. For these national policies to be implemented, enforced and sustained at the local levels, strong partnerships with the communities must be ensured. However, considering the inequities among the different stakeholders in terms of technical knowledge, understanding of institutional contexts, financial means and political power, involvement of the government is critical. Among other things, wetland management policies should include strategies to broaden the livelihood options of the poor, depending on the wetlands if pressure on the wetlands is to be reduced.

Contact Person

Max Finlayson (mfinlayson@csu.edu.au)

Partner Organizations

Association of Water and Rural Development, South Africa
Charles Sturt University, Australia
Department of Environment, South Africa
Environmental Management Agency, Zimbabwe
Fonds de Solidarite Prioritaire Echel-Eau, France
International Water Management Institute
Ministry of Coordination and Environmental Affairs, Mozambique
Universidade Eduardo Mondlane, Mozambique
University of Zimbabwe

Key References

PN 30 Project Team. 2010. *Wetlands-based livelihoods in the Limpopo basin: Balancing social welfare and environmental security.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3903

Finlayson, C.M. and S. Pollard 2009. *A framework for undertaking wetland inventory, assessment and monitoring with examples from the Limpopo Basin, Southern Africa.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/21606

Ramsar Convention Secretariat 2005. Resolution IX1.1, Annex E, An integrated framework for wetland inventory, assessment and monitoring (IF-WIAM). In: *Wetlands and water: supporting life, sustaining livelihoods. 9th Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971)*, Kampala, Uganda, 8-15 November 2005.
http://www.ramsar.org/pdf/res/key_res_ix_01_annexe_e.pdf

Tags: PN30; Wetlands Welfare and Environmental Security

Bibliography

Costa, L.T., J.C. Farinha, P. Tomas Vives and N. Hecker 1996. *Mediterranean wetland inventory: A reference manual* MedWet Publication. Instituto da Conservacao da Baturez, Lisbon, Portugal and Wetlands International, Slimbridge, UK.

Finlayson, C.M. 1996. Framework for designing a monitoring programme. *In: Monitoring Mediterratnean Wetlands*: *A methodological guide*, ed. P.Tomas-Vives. MedWet Publication. Instituto da Conservacao da Baturez, Lisbon, Portugal and Wetlands International, Slimbridge, UK.

Gitay, H., C.M. Finlayson and N.C. Davidson 2011. *A framework for assessing the vulnerability of wetlands to climate change.* Ramsar Technical Report No. 5/ CBD Technical Series No. 57. Ramsar Convention Secretariat, Glad, Switzerland and Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Ramsar 1996. Resolution VI.1, Working definitions of ecological character, guidelines for describing and maintaining the ecological character of listed sites, and guidelines for operation of the Montreaux record. In: *Proceedings of the 6th meeting of the conference of the contracting parties*, Brisbane Australia, 19-27 March 1996.

Ramsar 1999. Resolution VII.10, Wetland risk assessment framework. In: *Proceedings of the 7th meeting of the conference of the contracting parties to the convention on wetlands (Ramsar, Iran, 1971),* San Jose, Costa Rica, 10-18 May 1999.

Ramsar 2005. Resolution IX.1e, An integrated framework for wetland inventory, assessment and monitoring (IF-WIAM). In: *Proceedings of the 9th meeting of the conference of the parties to the convention on wetlands (Ramsar, Iran, 1971),* Kampala, Uganda, 9-15 November 2005.

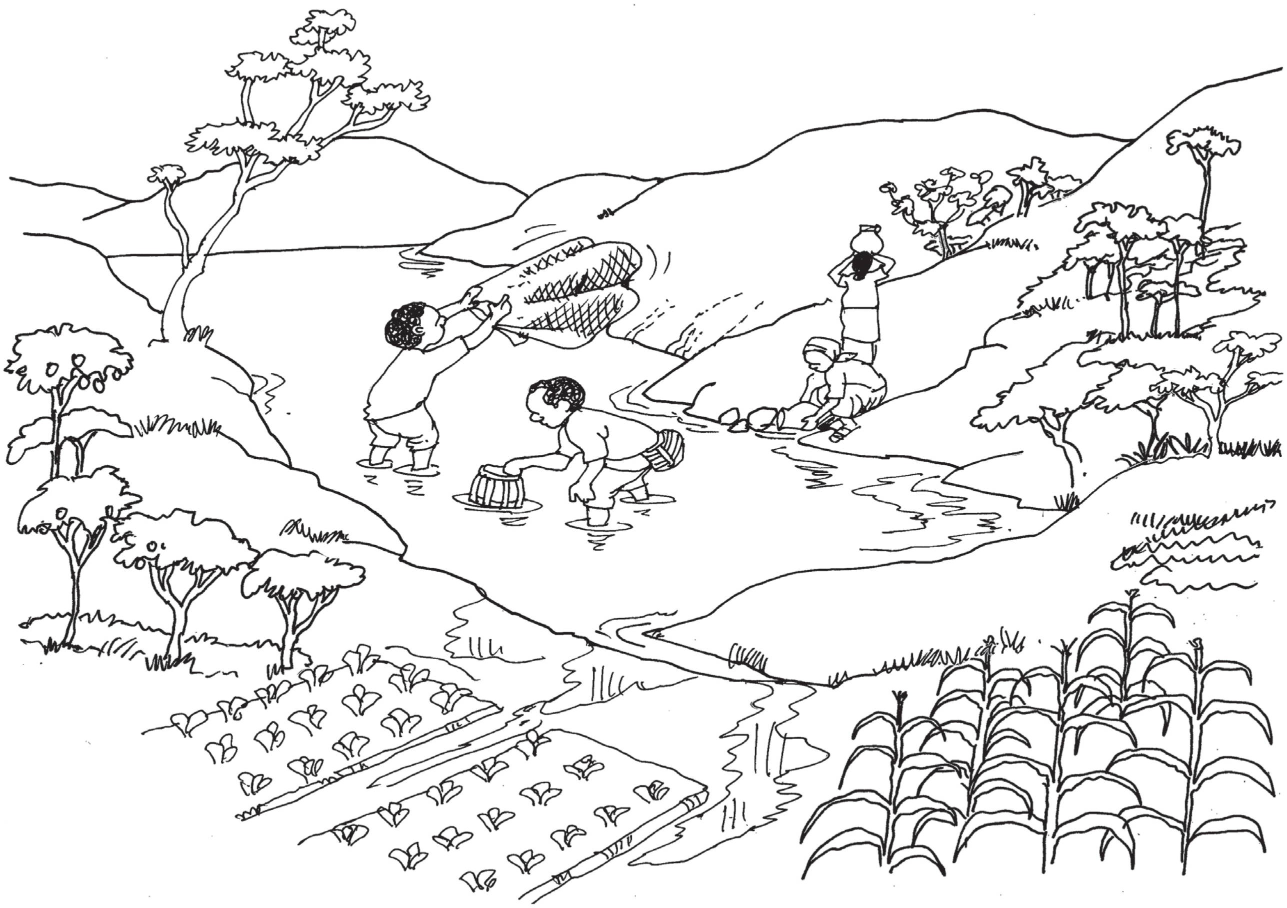
Ramsar Convention Secretariat 2007a. Inventory, assessment and monitoring: An integrated framework for wetland inventory, assessment and monitoring. *Ramsar handbooks for the wise use of wetlands,* 3rd edition, vol. 11. Ramsar Convention Secretariat, Gland, Switzerland.

Ramsar Convention Secretariat 2007b. Wetland inventory: *A Ramsar framework for wetland inventory. Ramsar handbooks for the wise use of wetlands,* 3rd edition, vol. 11. Ramsar Convention Secretariat, Gland, Switzerland.

Ramsar Convention Secretariat 2007c. Managing wetlands: Frameworks for managing wetlands of international importance and other wetland sites. *Ramser handbooks for the wise use of wetlands,* 3rd edition, vol. 11. Ramsar Convention Secretariat, Gland Switzerland.

van Dam, R.A., C.M. Finlayson and C.L. Humphreys 1999. Wetland risk assessment: a framework and methods for predicting and assessing change in ecological character. In: *Techniques for enhanced wetland inventory, assessment and monitoring. Supervising Scientist Report 147*, eds, C.M. Finlayson and A.G. Spiers, 83-145.

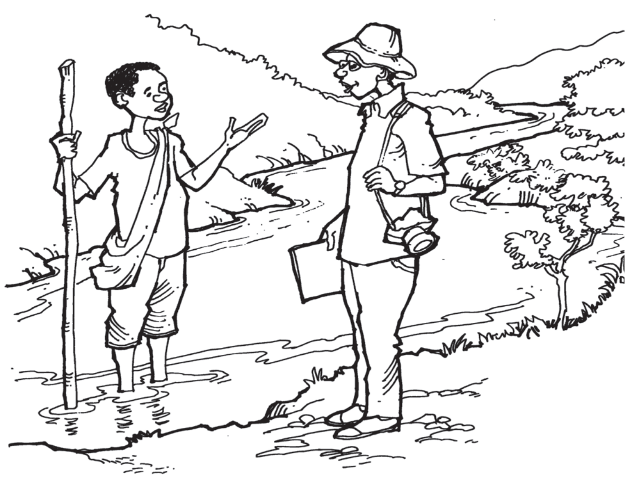
A Toolkit to Assist Small Reservoir Design and Management



Small multi-purpose reservoirs are widely utilized to supply water for domestic use, livestock watering, small-scale irrigation and other uses. The reservoirs are hydrolologically linked by streams that have been dammed. Reservoirs store a large quantity of water that has significant effect on downstream flows. They are considered as systems, with synergies and tradeoffs. Often, reservoirs are constructed with little or no coordination among the implementing partners. A significant number are functioning sub-optimally and/or are not properly maintained. This indicates that there is room for improvement in the planning, operation and maintenance of small reservoirs.

The CGIAR Challenge Program on Water and Food (CPWF) Small Reservoirs Project (SRP) began in 2005 in the Volta, Limpopo and Sao Francisco basins. The SRP team developed a toolkit to support the planning, development and management of small reservoir ensembles at the basin level as well as to ensure that small multi-purpose reservoirs are properly located, well designed and operated, maintained in a sustainable fashion, and economically viable at the local community level. There are "tools" for intervention planning, storage estimation and analysis of the hydrology, ecology and health of small reservoirs, economic feasibility and governance. The toolkit includes models and methodologies not only for analysis but also for participatory decision making. The toolkit is meant to be a "living document', wherein additional tools and experiences are to be added as they are developed.

The toolkit is designed for use by technical professionals from NGOs, research institutes, universities, donor agencies, multi-lateral organizations, and government agencies. There are approximately 30 tools and techniques presented in four topic areas, applicable at the local/ community level and basin/watershed level.



The Small Reservoir Toolkit (www.smallreservoirs.org) is organized into four topic/thematic areas.

1. The **Intervention Planning Toolkit .**focuses on developing plans, defining stakeholder and conflict relationships, fostering better communication and increasing understanding for the activity while emphasizing the importance of monitoring the implementation, adoption and changes in attitude and behavior of stakeholders.

   Examples:

- **Participatory Impact Pathway Analysis (PIPA)**. Develop a plan to better bring about desired outputs, outcomes and impacts by helping make explicit links between activities and roles of partners and users of the technology. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/I%2001%20Impact%20pathways_MLA.pdf

- **Stakeholder and Conflict Analysis (SCA)**. Assess the stakeholders' interest in the project's envisioned outcomes, their relationship with other stakeholders and relative power and capacities and to analyze the degree to which their interest conflict or complement each other. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/I%2002%20Stakeholder%20and%20Conflict%20Analysis_MLA.pdf

- **Creating Common Ground for Dialogue**. Illustrate the users' views and perceptions to foster communication. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/I%2003%20Common%20Grounds_MLA.pdf

- **Outcome Mapping**. Monitor implementation of activities and adoption of technology by focusing on the changes in the knowledge, skills and attitude (KSA) of the "boundary partners". For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/I%2004%20Outcome%20Mapping_MLA.pdf

2. **The Storage and Hydrology Toolkit** prioritizes reservoir ensemble measurements by outlining the steps required to obtain regional reservoir inventory using satellite imagery to monitor changes in small reservoir surface area, and thus, storage volumes, among others. This toolkit deals with measurement activities, from monitoring performance (by developing simple hydrological models for dammed upland watersheds based on monitoring reservoir surface areas with radar remote sensing) to predicting river discharge.

Examples:

Reservoir Ensemble Measurement

- **Reservoir Inventory Mapping**. Obtain a regional reservoir inventory with the use of satellite imagery. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIa%2001%20Reservoirs%20Inventory%20Mapping_MLA.pdf

- **Atlas of Lakes and Reservoirs**. Obtain a regional reservoir inventory using secondary data. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIa%2002%20Faso%20MAB_ML.pdf

- **Small Reservoir Capacity Estimation**. Estimate reservoir storage capacity as a function of remotely sensed surface area. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIa%2003%20Reservoirs%20capacity%20estimation_NMA.pdf

- **Near Real -Time Monitoring of Small Reservoirs with Remote Sensing.** Monitor changes in the small reservoir surface area (storage volume) with the use of radar satellite imagery. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIa%2004%20Near%20Real%20Monitoring_MLA.pdf

- **Hydrological Impact Assessment of Ensembles of Small Reservoirs**. Assess hydrological impact of ensembles of small reservoirs, particularly evaporative losses, spillage, water used for irrigation and excess irrigation drainage. This is an analytical framework that predicts what will happen when a new small reservoir is added to the collection without defining the location of the reservoir. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIa%2005%20Hydrological%20Ensemble%20Assessment_MLA.pdf

Hydrology and Physical Measures of Performance

- **Calibration of Runoff Models with Remotely Sensed Reservoirs**. Develop simple hydrological models for dammed upland watersheds based on monitoring reservoir surface areas with radar remote sensing. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2001%20Watershed%20Run-off_MLA.pdf

- **Rainfall-Discharge Relationships for Monsoonal Climates.** Develop a simple water balance models for predicting river discharge. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2002%20Run-off%20Monsoonal%20Nile_MLA.pdf

- **Deep Seepage Assessment in Small Reservoirs**. Develop a simple methodology to estimate seepage losses through the bottoms of small reservoirs. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2003%20Seepage%20Assessment_ML.pdf

- E**vaporation Losses from Small Reservoirs.** Observe evaporative losses in small reservoirs. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2004%20Evaporation%20Losses_MLA.pdf

- **Water Quantity Assessment of Silted-Up Small Reservoirs**. Estimate water stored in silted-up small reservoirs. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2005%20Silted%20up%20Reservoirs_ML.pdf

- **137Cs Radionuclide Tracer Method to Quantify Soil Erosion and Sedimentation at Hillslope and Reservoir Scale**. Estimate the amount of sediment eroded from the field, redistributed downstream and accumulated in reservoirs. This tool uses measurements of 137Cs concentration of collected soil samples in the watershed. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2006%20137Cs%20Radionuclide%20Tracer%20Method_MLA.pdf

- **Small Erosion Modeling at Small Reservoir Scale by WaTEM/ SEDEM**. Simulate soil erosion and sedimentation rates at the catchment scale; produce soil erosion hazard maps. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2007%20Soil%20Erosion%20Modeling_MLA.pdf

- **Bathymetric Survey by Depth Sonar and Lake Sediment Coring by Beeker Sampler to Identify Sediment Badges and Siltation Rates of Small Reservoirs**. Monitor changes in reservoir morphology, measure the thickness of accumulated soil particles and calculate siltation rates. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IIb%2008%20Bathymetric%20Survey_MLA.pdf

3. **Ecosystem and Human Health Toolkit.** Aims to reduce health risks and increase health benefits from small reservoirs. Surveys are conducted for general health inquiry, epidemiological and vector studies and other related contamination or quality assessments.

   Examples:

- **Participatory Health Impact Assessment.** Identify relevant health issues associated with small reservoirs and to improve their operation to mitigate health risks. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2001%20Participatory%20Health%20Impact%20Assessment_MLA.pdf

- **Health Questionnaires**. Assess the prevalence of water-related diseases at the reservoir cluster or river basin level. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2002%20Health%20Questionnaires_MLA.pdf

- **Epidemiological Survey**. Determine infection rates of key water-related diseases. This tool uses standard biomedical methodologies. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2003%20Epidemiological%20Survey_MLA.pdf

- **Vector Studies**. Understand the ecological preferences of vector organisms in relation to small reservoirs. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2004%20Vector%20Studies_MLA.pdf

- **Water Quality Assessment**. Assess the suitability of reservoir water quality for different uses. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2005%20Water%20Quality%20Assessment_MLA.pdf

- **Cyanobacteria, Cyanotoxins and Potential Health Hazards in Tropical Small Reservoirs**. This tool is a documentation of the algal bloom observations in Burkina Faso. Use this to better understand the issues and risks. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2006%20Cyanobacteria_ML.pdf

- **Agricultural Intensification and Ecological Threats around Small Reservoirs**. Analyze the impact of anthropological and agricultural activities near the reservoir. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2007%20Pesticides%20and%20Agricultural%20Intensification_ML.pdf

- **Small Reservoir Water Quality Monitoring Using Plankton Abundance and Diversity**. Assess reservoir water quality through changes in the abundance and diversity of organisms. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2008%20Water%20Quality%20Assessment%20Plankton%20Limpopo_ML.pdf

- **Indicators.** Identify impact indicators. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/III%2009%20Indicators_MLA.pdf

4. **The Institutions and Economics Toolkit.** Deals with water allocation application, which includes financial accounting models. It aims to estimate the effects on yield of climate and weather deviations and the effects on yield and water consumption of improved irrigation practices. This toolkit also deals with governance of water resources and with visualizing, discussing, monitoring, evaluating and improving situations in which many different actors influence outcomes.

Examples:

Water Allocation

- **Water Evaluation and Planning (WEAP).** Use this model to plan water allocation schemes. This model is linked with groundwater model MODFLOW, water quality model QUAL2K and socio-economic models for tracking changes in livelihood over time. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IVa%2001%20WEAP_ML1.pdf

- **Financial Accounting Model.** Use this model to estimate initial and recurring farm-level costs of water-related infrastructure and to estimate price and income consequences of increased crop production. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IVa%2002%20Financial%20Accounting%20Model_ML.pdf

- **Water-Limited Yield Model.** Use this model to estimate the effects on yield of climate and weather and to estimate the effects on yield and water consumption of improved irrigation practices. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IVa%2003%20Water%20Limited%20Yield_ML.pdf

- **Small Reservoir Water Allocation Strategy**. Use this model to estimate water productivity and social values to make informed decisions on the allocation of scarce water resources. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IVa%2004%20Water%20Productivity%20Limpopo_ML.pdf

Institutions and Governance

- **Institutions and Governance of Small Reservoir Water Resources**. Use this tool to describe the indigenous practices, legal frameworks and institutions that are most conducive to equitable, win-win and pro-poor investments. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IVb%2001%20Institutional%20Governance_ML.pdf

- **Net-Map (Influence Network Mapping).** Use this tool to understand, visualize, discuss, monitor, evaluate and improve situations in which many different actors influence outcomes. For more information, visit http://

www.smallreservoirs.org/full/toolkit/docs/IVb%2002%20Networking%20Mapping_MLA.pdf

- **Social Capital.** Use this tool to assess and analyze social networks within a community to determine how cooperation in that community influences "who participates, and how" in the development of a collective good such as a small reservoir. For more information, visit http://www.smallreservoirs.org/full/toolkit/docs/IVb%2003%20Social%20Capital_ML.pdf

Key findings

The key findings from SRP require follow—through from the community, local, national and, if relevant, international partners. Some key findings include the following:

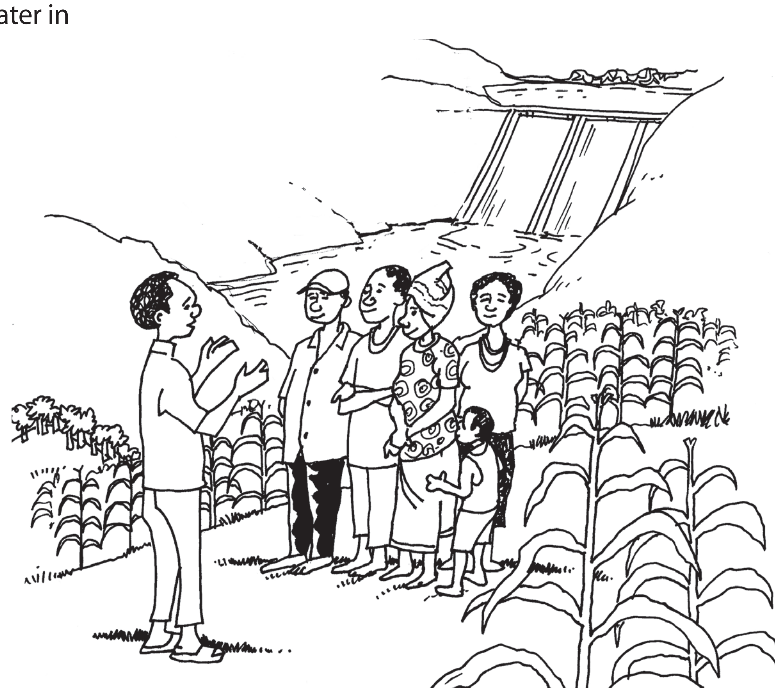
1. Results show that evaporation from small multi-use reservoirs in the savanna setting was under half of what was assumed on the basis of an analogy with oases in deserts and was less than that from cropped areas of similar size. The social and production advantages of storing water in community reservoirs nearer to where it is used by individual households need not be balanced against worries about excessive evaporative losses.

2. Combined satellite and field measurements show that the downstream impact of small reservoirs can be minimal. For instance, in the Volta Basin, quadrupling the number of small reservoirs would result in the consumption of less than one percent of the total available water.
3. Small reservoirs are less costly to operate and maintain than pumped systems and do not require recurrent expenditures for parts and fuel. Fish production, recreational and other non-consumptive uses are supported by small reservoirs. Groundwater mining results in escalating costs of extraction and eventual depletion of available supply.

4. Small reservoirs are managed by traditional leaders, local communities, NGOs and local governments. Therefore, technical and financial assistance from various organizations may be required.

5. Surface water in the small reservoirs is rarely suitable for human consumption; yet, it is often used for drinking without treatment. This risky behavior will continue to be an issue.

6. Most small dams are supposed to be built according to recommended design, construction and maintenance guidelines. Their current physical condition is poor because of lack of maintenance and unclear lines of responsibility among the government, NGOs and the communities.



Conclusion

Small reservoir systems are sustainable, cost-effective solutions to increase yield and improve livelihoods in semi-arid communities. The project showed that strengthening ties between donor agencies, government and traditional leadership is key to the improved design, use and governance of small reservoirs.

Contact Persons

Marc Andreini (mandreini2@nebraska.edu), Tonya Schuetz, Alden Senzanje, Lineu Rodriguez, Winston Andah, Philippe, Cecchi, Eline Boelee, Nick van de Giesen, Eric Kemp-Benedict, Jens Liebe

Partner Organizations

European Space Agency Tiger Project 2871
Global Change and Hydrological Cycle (GLOWA) Volta Project
Institut National de la Recherche Agronomique, Morocco
Mekelle University, Ethiopia
Zimbabwe National Water Authority

Key Reference

Andreini, M. et al. 2010. *Small multi-purpose reservoir ensemble planning.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3773

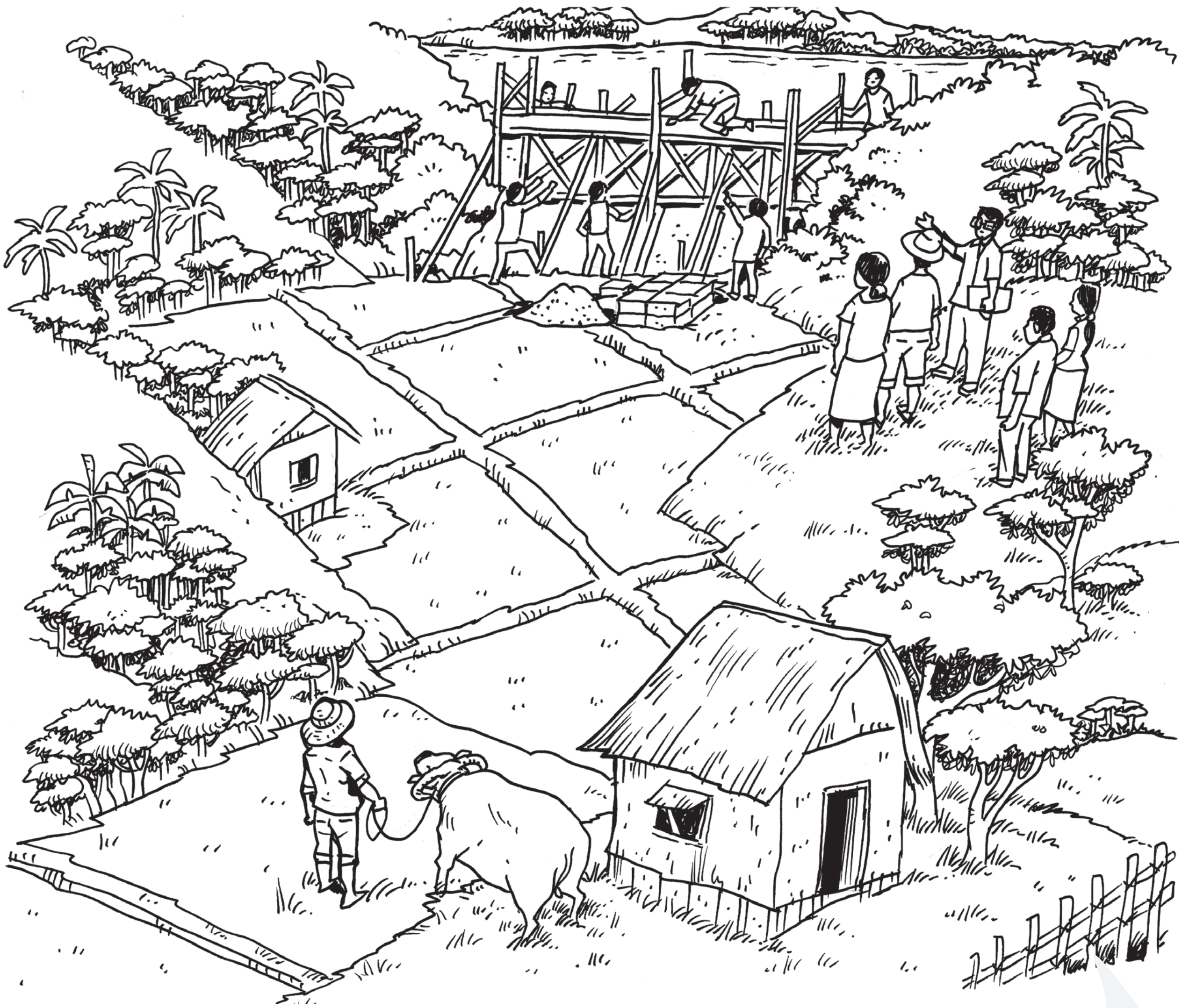
Tags: PN46; Small Multi-purpose Reservoir Planning

Bibliography

The Small Reservoir Toolkit (www.smallreservoirs.org)

Woolley, J. 2010. *Legacy of PN46: Management of small reservoirs.* Unpublished manuscript.

Improved Decision Making for Dam Planning and Operation



Construction of large dams in Africa is set to increase in the near future. The new dams have the potential to bring significant social and economic benefits. To maximize these benefits, negative impacts associated with dam building in the past must be avoided. This requires better planning and management of dams. In this context, the CGIAR Challenge Program on Water and Food conducted research in the Nile and Volta Basins that illustrates the importance of environmental and social issues and provides specific recommendations on how to better incorporate these issues in the planning and operation of dams.

The research identified seven key issues deemed the most important for intervention efforts. Further analysis of these issues resulted in specific recommendations intended to enhance the benefits as well as to avoid or mitigate the adverse impacts of dams.

1. Enhance stakeholder input to the decision-making process

Stakeholder participation is key to improving decision making and governance in the planning and operation of dams. For decisions to be sustainable, it is important that local people feel involved and that their points of view are acknowledged and, where possible, acted on. This requires empowering all stakeholders to be involved in the decision-making process at the outset. Many government policies acknowledge the need for participation and some experience has been gained in Africa. For example, in Senegal, the water requirements of different stakeholders utilizing different natural resources were identified, and this informed modeling efforts to determine dam release regimes on the Senegal River. In South Africa, attempts to involve stakeholders in planning flood releases from the Pongolopoort Dam have been only partially successful. In both cases, local stakeholders were only involved after the dams had been built and the adverse impacts had occurred. Even when people disagree with the decisions made, they are more likely to be accepted if they have been consulted and have actively been involved in the decision making.

Recommendations

- **Share information openly and improve the transparency of decision-making processes for all stakeholders.**
- **Make the decision-making process cooperative rather than adversarial.**
- **Empower weaker stakeholders by providing them with information that relate directly to concerns which they themselves identify.**

2. Improve options assessment

A comprehensive option assessment, as described by the World Commission on Dams (WCD), is critical for sustainable development. In any given situation, development needs should be matched to the most appropriate development options. Hence, before a dam is built, a "need assessment" should be conducted and a dam (or dams) must be identified as the most feasible/beneficial option.

Recommendations

- **Option assessments need to be conducted early in the process, before decisions on the type of investment are made.**
- **Such assessments should identify the costs and benefits (and to whom) of all possible options and screen out those that are not-feasible. Decisions should not be guided by financial concerns alone. Non-monetary benefits also need to be considered and some form of multi-criteria analysis is essential.**

Clearly, a comprehensive assessment requires a detailed evaluation of the ability (both positive and negative) of different options to fulfill needs.

3. Improve consideration of downstream environmental and social impacts

By their modification of flow-related ecological processes, dams can reduce opportunities for people whose livelihoods are dependent on riverine ecosystems. Environmental flows are the flows released from a reservoir in order to maintain valued features of the ecosystem, including those elements that support livelihoods. They are essential for the sustainable and equitable development of aquatic resources. Many countries of sub-Saharan Africa would benefit significantly from programs to build capacity in environmental flow assessment.

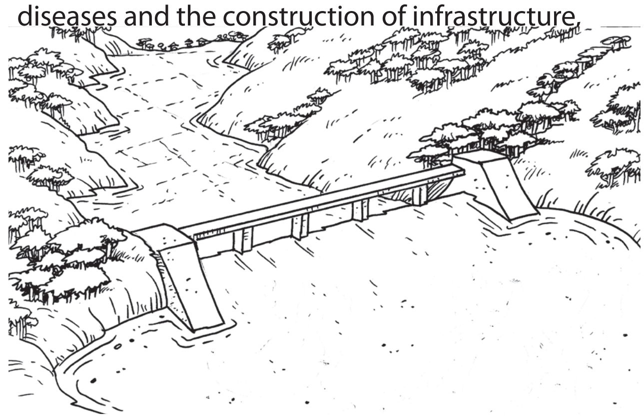
Recommendations

- **Environmental flow requirements should be developed using the expert opinion of national ecologists, hydrologists, social scientists and others who have detailed knowledge of and experience of with the region's rivers.**

- **Such environmental programs should deal explicitly with livelihood issues and research to better understand flow-ecology-livelihood links as well as how to proceed with limited knowledge.**

4. Consider possible health impacts and the role of dam operation in mitigation

In Africa, there are particularly strong links between diseases and the construction of infrastructure,



including dams. However, public health impacts arising from the construction and operation of dams are often poorly understood and often overlooked during planning for and operation of dams. Public health agencies are often not involved or only marginally involved. As a result,

Recommendations

- **The use of existing models, which simulate the mechanisms underlying disease vector dynamics and their relations to the environment, is a good starting point for predicting the likely impacts prior to dam construction.**
- **Health impact assessments (HIAs), which are similar to EIAs but with a focus on health provide a systematic approach for screening, assessing, appraising and formulating management plans to address key public health issues. They need to be a standard tool in dam planning.**

adverse disease impacts are often passed to health authorities to deal with, rather than being more fundamentally incorporated into the planning process. Inadequate consideration of public health impacts can seriously reduce the envisioned benefits of large dams and, in some circumstances, may undermine their sustainability.

An innovative approach to disease control that has not been widely explored in Africa is the use of dam management as a form of environmental control, for example, reducing malaria by managing reservoir water levels to reduce mosquito breeding habitats. Research conducted in Ethiopia has shown that, at least under certain circumstances, manipulation of water levels has the potential to reduce breeding habitats by drying out puddles around reservoir shores.

5. Improve mechanisms for compensation and benefit-sharing

The primary beneficiaries of dams often live far away from where the dams are located. Those who live closer to the dam, either upstream or downstream, are the most likely to be adversely affected. Too often, in project planning and implementation, national interest has been the primary consideration and local concerns are neglected.

Ensuring equitable outcomes from development requires that measures are developed to sufficiently offset any negative impacts. The construction of a dam should be a development opportunity for all. This means ensuring stable improved livelihoods of all affected people. However, in the past, the focus has generally been on immediate compensation and relocation and, even when this has been done well, little thought has been given to how livelihoods are best enhanced and supported in the long term. A key component, almost never considered, is how to retain stable social structures, particularly in displaced communities.

Recommendations

- **Share some of the benefits generated by a dam with the communities directly affected.**
- **Project plans must include "attractive" compensation and incentives to the affected population. This means a package that improves or at least restores the social and economic base of those affected.**
- **Ensure a more equitable distribution of benefits as well as accountability of those agencies entrusted with benefit redistribution by designing a transparent system for establishing and implementing compensation schemes.**

6. Improve follow-up to EIAs conducted for dams

Currently, environmental impact assessments (EIAs), in various forms, are the primary tool for examining the environmental and social consequences, both beneficial and adverse, of large dams. They are widely viewed as safeguards to ensure that environmental damage is minimized and adverse social impacts are avoided. However, to be effective, EIAs require competent and comprehensive follow-up, which involves the implementation of measures taken to mitigate the adverse environmental and social impacts of a project, plus monitoring to determine their effectiveness. Without some form of systematic follow-up to decision making, EIAs simply become a mechanism to secure a development permit, rather than a meaningful exercise in environmental management.

Recommendations

- **Effective policies and institutions need to be in place.**
- **Ensure that project managers have the tools necessary to facilitate effective monitoring of impacts and to predict potential consequences of changes arising from construction and operation of dams.**
- **Provide dam operators with tools to assist in the archiving, analysis and interpretation of data collected in monitoring.**

7. Improve water resource management in transboundary basins

Africa is a continent with a large number of rivers that cross international borders, so-called "transboundary" rivers. When a dam is built on a river that flows entirely within the borders of a single country, the costs and benefits associated with the construction of the dam are borne by individuals and groups within that country alone. However, when a dam is built in a transboundary basin, a different calculus must be made. In the absence of a well- defined water-sharing agreement, construction of dams in upstream riparian states can lead to tensions between countries if downstream states feel that these dams are depriving them of water to which they are entitled or for which they have a need. In many instance control of water by upstream states is viewed as an issue of national security by downstream nations.

Recommendations

- **Create a knowledge base from which riparian countries can draw and to which they can contribute information relevant to the sustainable development of water resources.**
- **Develop a common basis for policy and strategic analyses, facilitating dialogue/ negotiations between riparian states.**
- **Develop tools for the integrated management of infrastructure (including large dams) throughout the basin with the objective of maximizing benefits and minimizing costs for all the riparian countries.**

Contact Persons

Matthew MCartney (m.mccartney@cgiar.org), Jackie King (jackie.king@watermatters.co.za)

Partner Organization

International Water Management Institute

Key Reference

McCartney, M. and J. King 2011. Use of decision support systems to improve dam planning and dam operation in Africa. R4d Series No. 2. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food http://hdl.handle.net/10568/3623

Tags: PN36: Improved Livelihoods in Dam Management

Bibliography

Amerasinghe, F. and E. Boelee 2004. Assessing the impact of irrigation development on the environment and human health. In: *Proceedings of the inception workshop on IWMI-BOKU-Siebersdorf-EARO-Arbaminch University collaborative study on the impact of irrigation development on poverty and the environment,* Addis Ababa, Ethiopia, 26-30 April 2004,. Addis Ababa, Ethiopia: International Water Management Institute (IWMI).

Hämäläinen, R.P. 2004. Reversing the perspective on the applications of decision analysis. *Decision Analysis,* **1**(1)

Keefer, D.L., C.W. Kirkwood and J.L. Corner 2004. Perspectives on decision analysis applications, 1990- 2001. *Decision Analysis,* **1** (1).

Loucks, D.P. and E. van Beek 2005. *Water resources system planning and management:* An introduction to methods, models and applications. Paris, France: United Nations Educational, Scientific and Cultural Organization (UNESCO).

McCartney, M.P. 2006. *Report on the International Working Conference: Enhancing equitable livelihood benefits of dams using Decision Support Systems*, Adama/Nazareth, Ethiopia, 23-26 January 2006. Addis Ababa, Ethiopia: International Water Management Institute.

Mustajoki, J., R.P. Hämäläinen and M. Marttunen 2004. Participatory multicriteria decision analysis with Web-HIPRE: A case of lake regulation policy. *Environmental Modelling & Software,* **19**, 537-547.

O'Callaghan, J.R. 1996. *The interaction of economics, ecology and hydrology.* London: Chapman and Hall.

A Geobrowser to Enhance Stakeholders' Roles in Water Policy Development

Water productivity in the Andes of South America is limited and threatened by continued deforestation and land in protected areas and key water-producing zones, growth of the industrial sector (mining and hydropower) and the increasing demands of urban centers. These activities result in flooding, soil erosion, sediment yield, and water quality deterioration, all of which impact on the health, livelihood and well-being of both upstream and downstream populations. The unbalanced distribution of water and the lack of capacity to capture and maximize water resources aggravate poverty in the region. If water resources of the Andes are to be managed effectively and equitably, stakeholders, particularly the water users, must all work together in a coordinated fashion. A decision support tool such as the web-based AguAAndes Policy Support System (AguAAndes PSS), with the availability and use of high quality reliable data, could help ensure coordinated water management by various stakeholders across the Andes.

The challenge for coordinated action

The diverse physical and social contexts of Andean communities is a major reason for legislation on integrated water resource management (IWRM) to be adopted by different intermediary stakeholders, each with their own ideologies, rules and interests. This co-existence of formal and informal groups and institutions makes it necessary to develop a better understanding of their synergies as well as conflicting issues. The lack of coordination among them and their respective distinct objectives (i.e. energy, agriculture, health/social, conservation) can lead to inconsistencies, overlaps and even conflicts of policies, regulations and sectoral development plans. Where formal regulations are in place, enforcement has been limited by insufficient financial/human resources and by existing norms of the informal institutions.

Water management policies and legislations often:

- **Do not recognize the long tradition of rules/customs of peasant communities.**
- **Favor the private sector when providing technical assistance to communities to improve water supply, irrigation and small hydropower systems.**

Institutional trends in Andean countries on agricultural water management have leaned towards participation, decentralization and transfer of management to local governments. This, however, has to be accompanied by appropriate education, skills training and a common information base for dialogue that water user associations can access for making informed decisions. Hydrological analysis should be integrated into this information base and in water resource management assessments in support of policy making. It is in these contexts that a geobrowser-based Policy Support System (PSS) has been developed with local stakeholders for the management of water in the Andes. Called the AguAAndes PSS, its purpose is to provide a common baseline of high- quality information and tools for policy negotiations that are transparent and accessible to all.

The AguAAndes PSS: A knowledge integration tool

The web-based AguAAndes PSS is a tool for the management of the region's water resources, used to identify upstream-downstream interactions, especially, within the context of hydropower projects and payments for environmental services (PES) schemes. This PSS involves three key activities: understanding context, analyzing investment/interventions, and examining likely consequences and impacts.

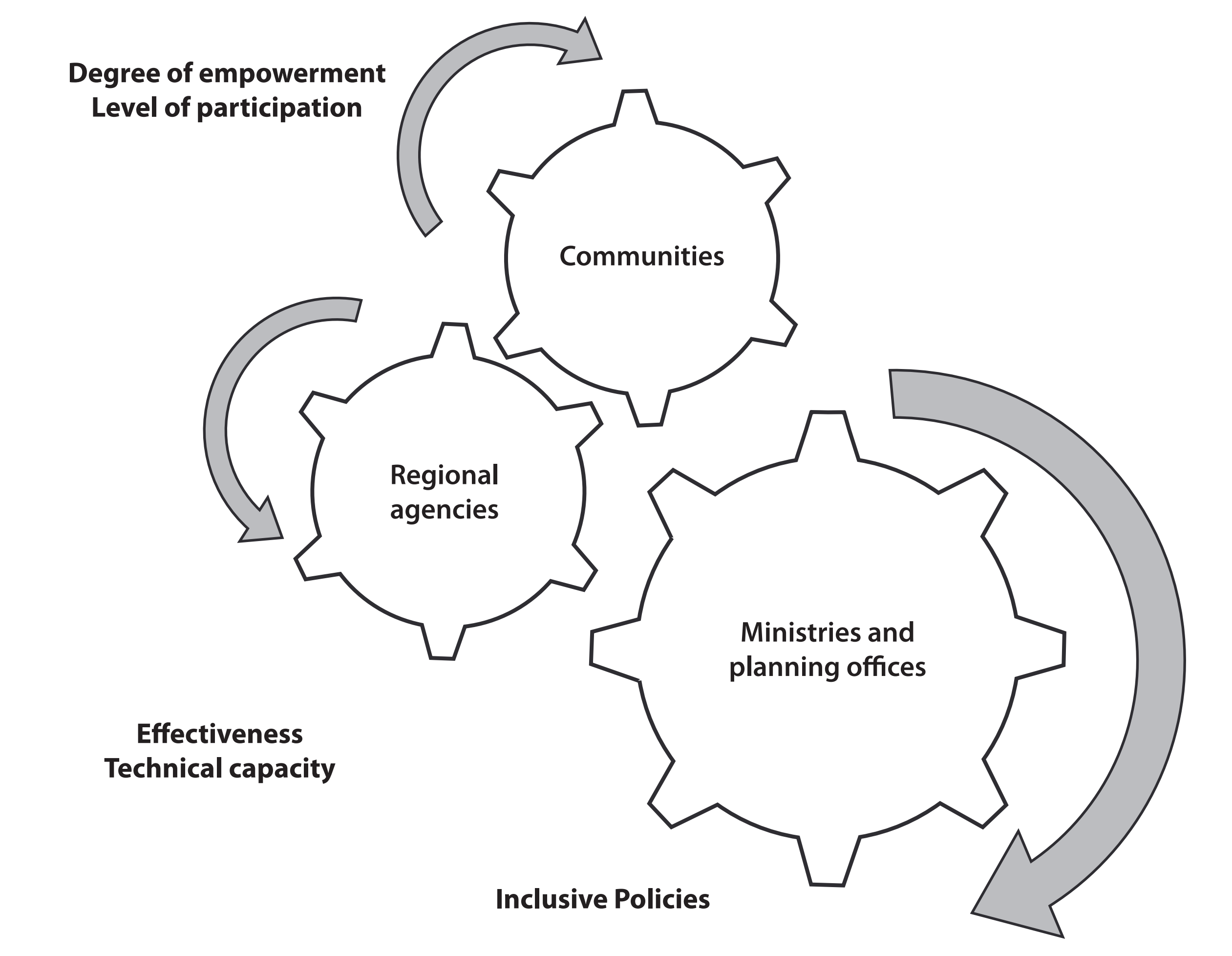
Two premises in the development of the PSS:

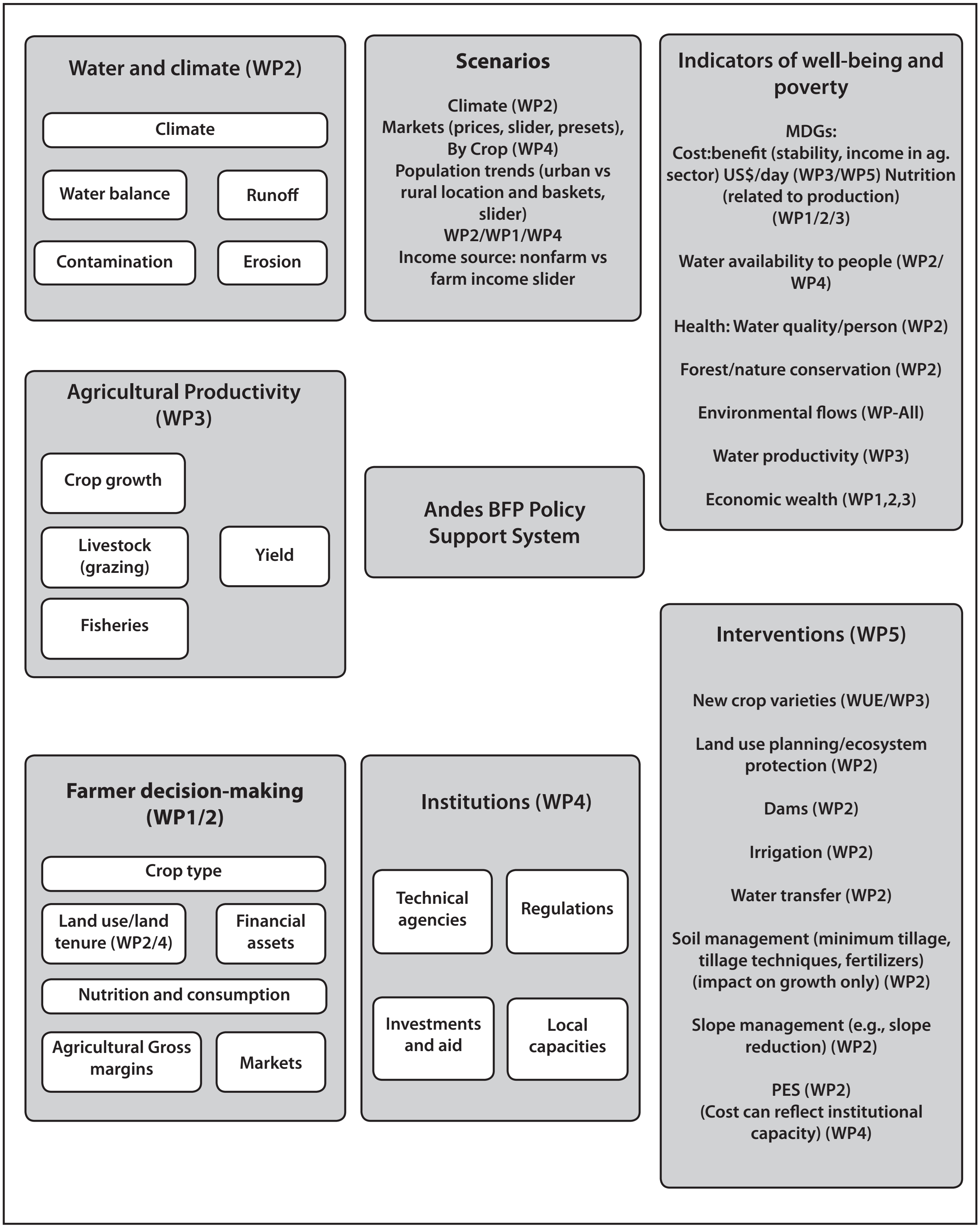
- **Policies are more effective and equitable when based on both the natural and social sciences.**
- **Key stakeholders involved from the initial steps in developing the PSS will be its main users.**

Use of the AguAAndes PSS and its modeling capabilities was intended to answer questions about impacts of climate change in a particular area, the impacts of land-use change on downstream water supply to cities/dams and agricultural systems, and the current institutional constraints to particular interventions in specific zones. The research activities were integrated within a knowledge base and organized into modules or work packages (WP) as described in the following matrix. Then, in combination with mathematical and computer-based spatial models, the following outputs were generated:

- Diagnosis of the current status of water poverty, water productivity, environmental security and institutional context
- Maps of long-term average water availability and trends
- Maps of resource sensitivity to land use and climate change

Conceptual understanding of the way water institutions at three different levels should work and potential performance indicators. (Mulligan et al 2008)





General structure of the Andes Basic Focal Project (BFP) Policy Support System with accompanying lists of interventions and performance indicators

[1] *For details on the conduct of the WPs, the methods and the models to be used for generating the PSS outputs, see the Appendices section in Mulligan et al (2009).*

Matrix of PSS work packages (WP)	
MODULE	**Data sources, methods and modeling tools for generating PSS outputs and analysis**
WP1: Poverty analysis for determination of levels and distribution of poverty	Census data; household survey; standard poverty mapping using the livelihoods framework (Bebbington, 2001); Bayesian network modeling; unsatisfied basic needs (UBN) approach (Schuschny and Gallopin, 2004); small area estimation (SME) method of Ghosh and Rao, (1994); human development index (HDI) by Sagara and Najam, (1998)
WP2: Water availability analysis for regional GIS analysis of rainfall, fog and snow melt; climate change and land use change scenarios	TRRM Rainfall Climatology (Mulligan 2006a); WorldClim (Hijmans *et al*, 2005); FIESTA model; Water Scarcity Model for the Andean Systems of Basins (computation of effect of factors contributing to water scarcity); household and agriculture spreadsheets (water accessibility costing)
WP3: Water productivity Analysis	Crop per drop agricultural water productivity; environmental flows from protected and non-protected areas using the FIESTA model; fisheries model to assess site suitability for aquaculture
WP4: Institutional analysis on water rights and tenure	Workshops to qualitatively assess organizational performance along these seven criteria: representativeness of interests, respect and credibility, confidence, mission clarity, confidence, information, compliance with laws and rules, and cohesion in group; Survey of institutional needs and perspectives; institutional environmental Index (IEI)[2]
WP5: Intervention analysis	Primary (interviews) and secondary data collection on significant interventions for water resource management qualitative data analysis using the Community Capitals Framework (Flora and Flora 2004). The seven capitals are human, social, political, cultural, financial, built and natural capital.

[2] *The institutional environmental index (Hodgson 2006) reflects to a certain extent the quality of life in each municipality, in terms of service provision such as education, health, potable water, security, and investments in infrastructure, among others. When the quality and quantity of any of these services are is high, it is assumed that this indicates the presence and functioning of institutions and effective government or communal actions providing for local development. In contrast, when low values are scored, it is assumed that the conditions for these indicators are inadequate and hence, the desired institutional support is lacking.*

- Maps of the poverty outcomes of changing access to water
- Maps of the sensitivity of food production to climate (variability and change) and land-use change
- Database of organizations, institutions, and intervention projects and likely outcomes of a range of these in the basin
- Summary of points of contact and types of data/information required by institutions

Further notes on AguAAndes

The AguAAndes is based on the simTerra policy support framework (www.ambiotek.com/simterra) that allows direct access to global and regional databases in usable form at no cost. Its technical, computing and GIS capacity requirements are minimal since users do not need to install or manage local software or databases because all applications are run on the online-server. Users need to only define an area for policy support. The system prepares the available datasets that can then be run for particular parameters, policy options and scenarios for climate and land use. Results are presented to the user in map form and as charts. The AguAAndes PSS also comes with a series of policy exercises to familiarize users with the tool. Two such exercises enable users to carry out a baseline simulation and a climate change simulation. The first allows users to define a baseline simulation of climate and hydrology for any part of the Andes at 1 km spatial resolution. The second defines the impact of climate change. The AguAAndes PSS can be accessed at www.policysupport.org/links/aguaandes.

Findings

In a survey[3] conducted as part of the WP5 of the PSS in the Andes region, the following was discovered:

1. Thirty percent of the respondents had no experience in PSS while 90% attributed their lack of relevant knowledge of computer-based PSS as a factor in their low uptake of the web-based PSS tool.
2. Almost half of the respondents believed that the low level of usage of existing computer-based policy support is due to lack of reliable data. A third of the respondents agreed that spatial analysis and modeling tools are also being used to trigger the generation and use of reliable data.
3. Low levels of staff training/capacity (35%) and poor quality of computer equipment (24%) in governance institutions were reasons for the low uptake of computer-based policy support within the region.

[3] *Respondents to the survey were 46% development workers, 26% scientists, 21% students, and 9% public sector employees from seven countries in the Andean region.*

4. About half of the respondents considered the national public sector development agencies and local municipal planning offices as the sectors most likely to benefit from the PSS.
5. Water and water productivity were not on top of the agenda for many of the respondents who indicated that:

   a. The highest priority in Andean watersheds is soil erosion (71%).
   b. The effects of soil erosion on agricultural livelihoods should be considered more in the policy making process (44%).
   c. The institutional approach regarding the management of water resources is important (48%).
   d. The quality of access to water is important (66%).
   e. Implementation of PES be made a priority (58%).

Poverty levels are twice as high in the upstream parts of watersheds compared with those downstream, according to unmet basic need indicators. The less-poor lower basin benefits from water services supplied by the poorer upper basin. But residents of the upper basin receive no compensation for land use practices that support water resources.

Lessons learned

- Given the weak relationship between poverty and water in general, there is a need to analyze how poverty and its associated factors influence problems related to water management on a case-by-case basis. Interventions should consider not only the effect of water problems on poverty, but also how poverty exacerbates water problems.

- The lower living standards in the upstream portion of the Andean basins suggest that PES schemes can potentially improve water management in those areas.

- PES should be included in future PSS as it is an effective way to improve institutional water management and increase cooperation between different water users and institutions.

- With climate change being the big unknown, policies should not rely on projections of land use and landscape changes alone. Rather, more emphasis should be given to better understanding the sensitivity of water and production systems to change and paying particular attention to careful management in those areas where those sensitivities are high, irrespective of the highly uncertain projections for change.

- Legislation and norms designed to generate integrated water resource management are in practice adjusted by a variety of intermediary stakeholders, each with their own ideologies, rules and interests. Inclusion and active involvement of these stakeholder groups are therefore essential in developing appropriate water management policies.

Conclusion

AguAAndes is no silver bullet because its outputs are highly dependent on the quality of available data, on the social-scientific knowledge of the systems being simulated and on the availability of skilled staff and equipment. It does, however, provide a common information base for discussion of what is and what is not known in an area, democratizes knowledge and serves as a tool for knowledge integration and development for any area within the Andes.

Contact Person

Mark Mulligan (mark.mulligan@kcl.ac.uk)

Partner Organizations

International Center for Tropical Agriculture
King's College London, UK
Universidad Autonoma de Occidente, Colombia
National University of Colombia (UNAL)

Key References

Mulligan, M. et al. 2009. *The Andes Basin Focal Project.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: PN63; BFP Andean

Bibliography

Bebbington, A. 2001. Globalized Andes? Livelihoods, landscapes and development. *Ecumene: A Journal of Cultural Geography,* **8**, 414-436.

Ghosh, M. and J.N.K. Rao 1994. Small area estimation: an appraisal. *Statistical Science*, **9**, 55-93.

Hijmans, R.J., S.E. Cameron, J.L. Parra, P.G. Jones and A. Jarvis 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, **25**, 1965-1978.

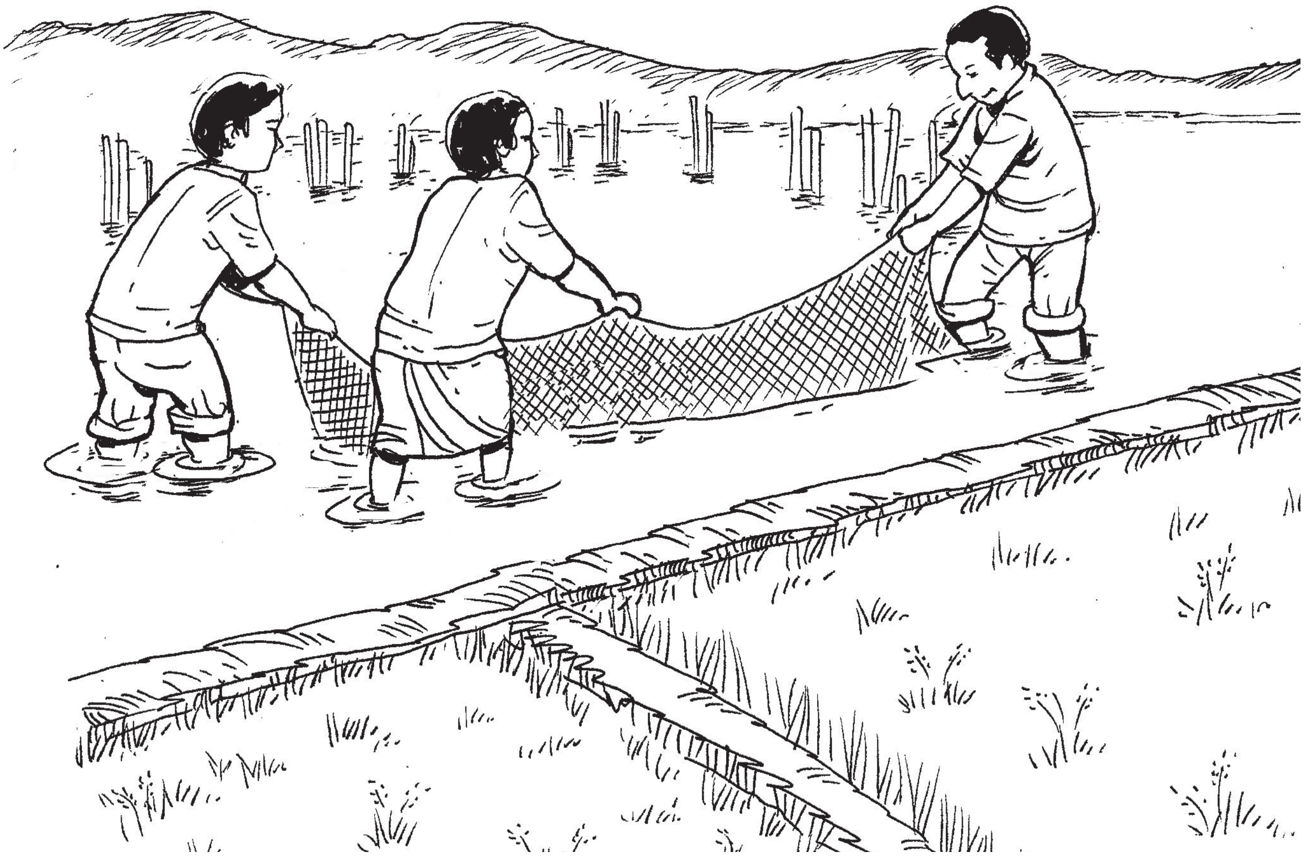
Hodgson, G.M. 2006. What are institutions? *Journal of Economic Issues,* **40**, 1-25.

Mulligan, M., J. Rubiano, D. White, G. Hyman and M. Saravia 2008. Participatory modeling and knowledge integration -Basin Focal Project (BFP Andes): concepts and advances. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food*, Vol 1, Addis Ababa, 10-14 November 2008, eds. E. Humphreys *et al.*; 143-145. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Mulligan, M. 2006. *Global Gridded 1 km TRMM Rainfall Climatology and Derivatives. Ver1.0 Database*. Retrieved from: www.ambiotek.com/1kmrainfall

Schuschny, A.R. and G. Gallopin 2004. *La distribución espacial de la pobreza en relación a los sistemas de ambientales en América Latina. Comisión Económica para América Latina y el Caribe (CEPAL).* Serie Medio Ambiente y Desarrollo No. 87. United Nations. Santiago de Chile, Chile.

Agroecosystem Analysis Methods to Support Decision-Making for Water Allocation



Cambodia is the fourth largest producer of freshwater fish in the world (Keskinen 2003) with an estimated total catch of approximately 400,000 tons per year (t/yr) (van Zalinge and Nao 1999). Fish and fish products are an important source of nutrition, livelihood and income for the entire country, especially in the rural areas (Ahmed *et al.* 1998 in Keskinen 2003).

In the Tonle Sap area, in particular, fishing-related activities play a very important role. In villages bordering the lake, fishing naturally forms the major livelihood activity of many people. Even in the floodplain, in areas not adjoining permanent water bodies or small rivers or streams, fisheries often play a critical role in terms of subsistence. For instance, during flooding or wet season, fishing takes place in flooded forest areas and rice fields (Keskinen 2003). Moreover, it appears that in the dry season, people from many communes (communes are subdivisions of the districts in Cambodia) migrate to the floodplain area from their villages and engage in fishing. Since rice cultivation alone is inadequate to obtain income for daily subsistence, especially during certain times of the year, farmers have diversified their livelihood activities to engage in fishing. Thus, fisheries and farming systems are closely interlinked in Cambodia. The preservation and enhancement of both systems and the contributions that these can make to the livelihoods of the poor require a comprehensive and integrated approach.

Agroecosystem analysis: application to Cambodia's needs

Agroecosystem analysis (AEA) is a methodology for analyzing of agricultural livelihood systems and for planning and prioritizing research and development activities. It was developed in the late 1970s and has since been used for research and extension planning in a range of locations and environments. In Cambodia, the AEA at the commune level was initiated in 2001; in 2004, this approach was officially adopted as a national policy for agricultural development, with the Department of Agriculture and Extension (DAE) of the Ministry of Agriculture, Forestry and Fisheries (MAFF) as the executing agency. Commune agroecosystem analysis (CAEA) is used by the DAE for agro-ecological analyses at the commune level and is the primary need-assessment and planning tool for the agriculture sector. By mid-2010, a CAEA had been conducted at least once in more than 500 of the 1,621 communes nationwide. CAEA uses multi-disciplinary investigation and participatory analysis to understand and describe the major farming systems practiced in each commune and to identify and prioritize the most important problems facing the farmers. Systems analysis is then conducted to plan interventions to address problems and identify opportunities.

Bringing fishery dimensions into CAEA

Until 2008, CAEA had focused mainly on agricultural issues, but problems of the fishery sector that are closely interlinked to agriculture in Cambodia were not adequately addressed. Moreover, the existing data collected were insufficient to encompass the range of variables required to address the combined use of water by fisheries and agriculture and development interactions. As a result, significant uncertainties were creating a bias or impeding effective decision making on the management of water for co-existing agriculture and fishery systems. CAEA users recognized this weakness and were in agreement that the water and fishery component should be strengthened.

In this regard, the CGIAR Challenge Program on Water and Food (CPWF) project, entitled "Commune Agroecosystem Analysis to Support Decision-Making for Water Allocation for Fisheries and Agriculture in the Tonle Sap Wetland System", was undertaken. The main aim of the project was to improve fisheries considerations in the CAEA process. This would facilitate better planning at the commune level in addition to identifying institutional and policy considerations. This included not only the biophysical aspects of fisheries but also the socio-economic, livelihood and governance aspects as well to ensure a holistic view of the main issues that need to be taken on board.

The revised CAEA adopted a more holistic approach through incorporation of fisheries variables and looking at land, water, livelihood and institutional issues that influence commune development planning.

A number of changes to the CAEA tools were made and subsequently field-tested in the four pilot CAEA exercises (in two communes that had an earlier CAEA report and two communes that had not).

Changes were of two main types. First, entirely new tools were introduced to address important water resource, fishery and livelihood issues not covered by the original CAEA tools. Second, existing tools were modified to better address key issues in a more complete or comprehensive manner.

Methodology development process

The methodology adopted in the project was based on a three-stage process:

- Stage one – screening and scoping
- Stage two – field-testing of the revised CAEA tools and methodologies
- Stage three – finalizing revision of the CAEA and highlighting management and policy implications

Each stage included a number of key activities.

Screening and scoping

Key variables and existing data collection sytems in the context of the CAEA were reviewed and the range of additional fishery parameters needed to be considered in the CAEA were determined. The review was essentially of fishery parameters organized in the context of four components: (a) land and water resources; (b) fishery biology; (c) livelihood and governance and (d) integration across the first three sectors and disciplines.

The integration of all revised outputs led to the first revision of CAEA to enhance the integration of fisheries into agroecosystem analysis.

A stakeholder workshop was held to present the first results of the project and recommendations for integrating fisheries in agroecosystem analysis, in particular at the commune level. Workshop outputs further contributed towards refining the CAEA revisions proposed. The workshop participants were mainly government officials from the departments of Agriculture, Fisheries, Environment and Water Resoures, NGOs, and the project partners and team.

Field-testing of the adapted CAEA

Selection of suitable sites was carried out using the following key criteria:

- Coverage of a wide range of agroecological zones
- Significance of fisheries in the commune
- Pairs of sites 'with vs without' implementation of CAEA.
- At least one site with significant irrigation development.

On the basis of the above criteria, four communes (in two provinces) were selected: Chamnar Krom (with CAEA) and Samproch (without CAEA) in Kampong Thom Province and Sna Ansar (with CAEA) and Sya (without CAEA) in Pursat Province.

To undertake a comparative analysis of the old and revised methodology, two of the communes selected had an earlier CAEA report and two did not. Both sites (where the adapted CAEA was implemented for the first time) were closely comparable with and had conditions similar to those of the communes where an original CAEA was carried out.

After each pilot testing in a commune, the CAEA manual was revised, incorporating the lessons learned during data collection and analysis Revisions and recommendations were made on both the CAEA tools and the process.

After pilot testing was completed in the first two sites, a 'mini-stakeholder' workshop was held to reflect further on the revisions made in the first two rounds of testing and to discuss and obtain feedback from key stakeholders before proceeding to field-testing at the third and fourth sites that did not have an earlier CAEA report. Two key aspects were covered in this workshop: a review of the CAEA tools and the CAEA process.

Finalizing the revision of the CAEA and highlighting management and policy implications

A final stakeholder workshop was held, its main objective being to present and discuss the results from the CAEA field-testing in the four communes and discuss the revised CAEA manual. The extent of benefits to the commune planning processes, through the revised CAEA approach was explored. Steps to improve the institutionalization of the CAEA results in the commune development planning process were also discussed.

Tools and methods with emphasis on land, water Resources and fisheries

A number of spatial and temporal tools were applied during the RRA stage of CAEA to gather information on land, water resource and fisheries at the commune level. In certain cases, a number of new tools were introduced. In other instances, existing tools were modified to better address key issues in a more comprehensive manner. The tools are:

Spatial analysis

- Maps and overlays
- Water-body attribute analysis matrix
- Fish species assessment table
- Water resource use matrix
- Flow diagrams
- Transect diagram

Temporal analysis

- Land and water resources management strategies
- Historical profile
- Seasonal calendar

Maps and overlays

In the old CAEA manual, true-to-scale sketch map layers for overlaying of administrative boundaries, land use, soil types, water resources, etc. were used to identify AEA zones. It was based more on diagrams and schemas than on maps. In the revised CAEA manual a specific checklist is provided with rivers, streams, boeungs (natural ponds or small lakes) and other important water resources (including main fishing grounds, places for fish refuge, feeding and breeding - thus showing much utility for fisheries considerations) and irrigation systems (functioning systems and those in disrepair) identified.

Water resource use matrix

This tool is used to improve understanding about the use of different water sources in the commune at different times of the year. It was included in the old 2007 CAEA manual but was not applied under this matrix form in the original commune reports. In the revised CAEA manual, a new template was used, with additional parameters on resource characteristics (water quantity, quality, productivity, reliability, equitable access) that are explicitly linked to the water body attribute analysis matrix (WBAAM) through water body types.

Flow diagrams

Flow diagrams are used to describe the flow of materials, money, information, labor, etc., between the different zones in the commune. In the old CAEA Manual, a range of visual representations were suggested, with a note that these are "equally valid, and selection should be made according to the preference and familiarity of the participants." Minimal information on fisheries were included in these diagrams. In the revised CAEA manual, the flow diagram was split into two separate diagrams and color coding was introduced to present the up-down system hierarchy, flows into and out of the commune and zone-to zone interactions, including fish migration in wet and dry seasons.

Transect diagrams

Transect diagrams are used to describe and compare agroecosystems based on a list of physical and socio-economic parameters. Digital photos can be used to illustrate the ecosystems. Before the project, this tool included fisheries in terms of both land use and opportunities, but fisheries were only associated with the water resource zone where wild fish were identified as a resource (not in other zones). Several issues and opportunities pertaining to this zone were identified, but other opportunities in other zones were possibly overlooked.

Land and water resources management strategies

In the old CAEA manual, land management strategies were developed for agroecological zones by using a template of land type, land use, strategy and technical elements by zone. The strategies were not provided in this form in reports; only identification of issues/questions/innovations was mentioned. In the revised CAEA manual, strategies for managing of water and fishery resources were added separately.

Conclusion

It is clear from the project results and analyses that the project has significantly improved the way fisheries, water resources and livelihoods are now addressed by CAEA. When comparing the new CAEA outputs and previous CAEAs conducted in the two control communes, it is apparent that the revised CAEAs reflect an emerging recognition of the importance of awareness-raising and capacity development at the community level as compared with the previous narrower focus solely on agricultural production systems.

The insights gained by addressing fisheries, water resources and livelihood issues in the commune in a more comprehensive manner and the potential value of the knowledge gained in commune planning were key lessons. Awareness-raising and capacity development at the community level proved to be a key contributing factor, especially in the context of early endorsement and buy-in of the revised tools by national partners who then promoted these revised tools for use in other projects, that they were involved in.

Contact Persons

Sonali Senaratna-Sellamuttu (s.senaratnasellamuttu@cgiar.org), Samonn Mith, Chu Thai Hoanh, Robyn Johnston, Eric Baran, Mark Dubois, Mak Soeun, Ian Craig, So Nam, Laurence Smith

Partner Organizations

Department of Agricultural Extension, Cambodia
Inland Fisheries Research and Development Institute, Cambodia
International Water Management Institute
School of Oriental and African Studies, UK
World Fish Center

Key Reference

Sellamuttu, S.S., S. Mith, H. Chu Thai, R. Johnston, E. Baran, M. Dubois, M. Soeun, I. Craig, S. Nam and L. Smith 2010. *Commune agroecosystem analysis to support decision making for water allocation for fisheries and agriculture in the Tonle Sap wetland system.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3865

Tags: PN71: Water Allocation in the Tonle Sap

Bibliography

Ahmed, M., N. Hap, V. Ly and T. Marites 1998. *Socio-economic assessment of freshwater capture fisheries of Cambodia – Report on a household survey,* Project for the management of freshwater capture fisheries of Cambodia. Phnom Penh, Cambodia: Department of Fisheries, Cambodia; Danish International Development Assistance (DANIDA); Mekong River Commission (MRC).

Keskinen, M. 2003. *Socio-economic survey of the Tonle Sap Lake.* Finland: Water Resources Laboratory, Helsinki University of Technology.

van Zalinge, N.P. and T. Nao 1999. Summary of project findings. Present status of Cambodia's freshwater capture fisheries and management implications. In: *Proceedings of the Annual Meeting of the Department of Fisheries,* Phnom Penh, Cambodia, 19-21 January 1999, eds. N.P. van Zalinge, T. Nao and L. Deap; 11-20. Phnom Penh, Cambodia: MRC Secretariat and Department of Fisheries.

Improving the Implementation of Environmental Impact Assessment Follow-up

Environmental impact assessment (EIA) is a process that attempts to identify, predict and mitigate ecological and social impacts of development activities. It also helps to assist decision-making and to achieve sustainable development. The effectiveness of EIA depends on several factors. The quality of EIA guidelines, EIA reports and implementation and follow-up of EIA recommendations are of particular importance (Arebo 2005). According to the Australian Environmental Protection Agency (EPA Australia 1995), EIA follow-up is needed because relatively little attention is paid to the actual effects arising from project construction and operation. Without some form of systematic follow-up to decision-making, EIA can simply become a paper chase to secure a development permit, rather than a meaningful exercise in environmental management to bring about real environmental benefits. Implementation of EIA recommendations is not done frequently (Noble and Storey 2004). This is a recognized problem not only in developing countries, but also in many industrial countries. Successful implementation of EIA recommendations requires that policies and institutions be strengthened to facilitate adequate follow-up.

The aim of this study was to determine the critical factors affecting the successful implementation of EIA mitigation measures developed to minimize environmental and social impacts of the Koga irrigation and watershed management project in the district of Mecha, Amhara National Regional State, Ethiopia. This scheme foresees the development of 7,000 ha of smallholder dry season irrigation, supplied with water from a reservoir constructed on the Gilgel Abbay River. questions addressed were:

The research

1. To what extent have EIA-recommended mitigation measures been implemented by the project proponent?
2. How do regulatory bodies ensure implementation of EIA-recommended mitigation measures?
3. How and to what extent did the public participate in the EIA process?
4. What are the likely downstream impacts of the project and to what extent where they considered?

In particular, it studied the extent to which EIA-recommended mitigation measures have been implemented by the project proponent. It looked into how regulatory bodies ensure the implementation of EIA-recommended mitigation measures. and the extent to which the public participated in the EIA process.

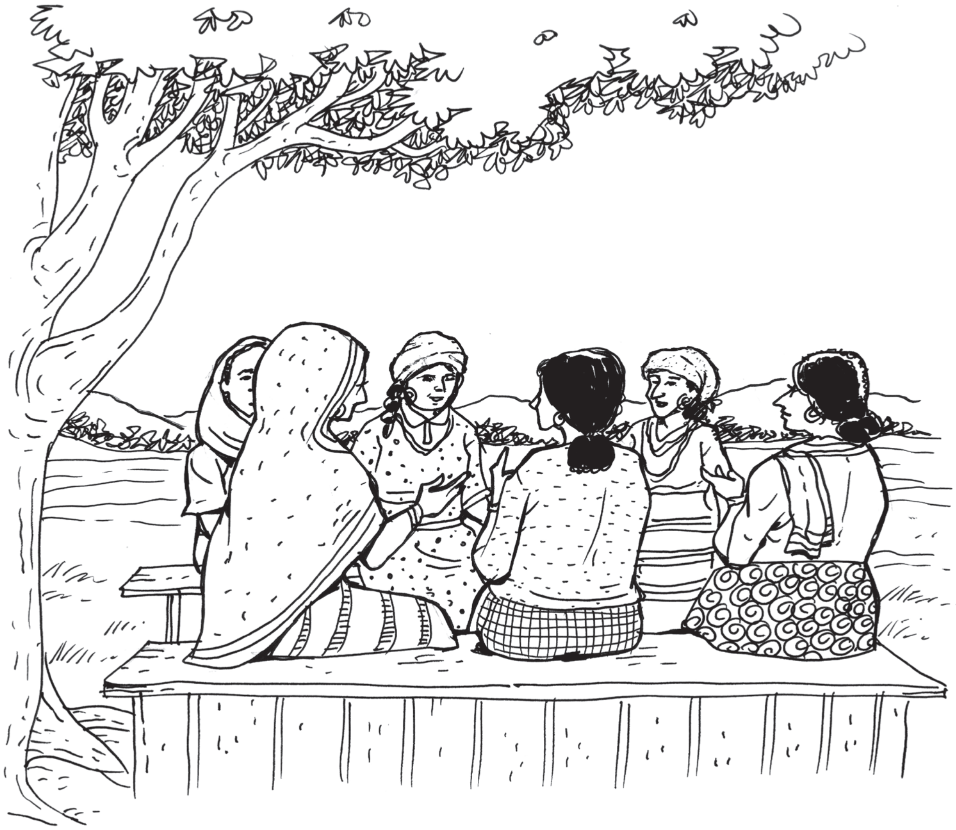
Generally, EIA procedures in Ethiopia are carefully considered and result in well-formulated environmental impact statements and plans. The implementation of proposed mitigation measures and monitoring of actual environmental impacts, however, form a weak link in the EIA process. As a result, projects still cause negative environmental and social impacts. This report is on the study conducted to follow up EIA–recommended mitigation measures in the Koga irrigation and watershed management project.

Methods

The research method comprised a literature review and fieldwork. The literature review centered on issues of sustainability and links to EIA and the Millennium Development Goals (MDGs) as well as EIA experiences in Ethiopia and other countries. Project-specific reports (i.e., the Environmental Management Plan [EMP], accomplishment reports, monitoring reports and permit conditions) were also reviewed. For the fieldwork, semistructured and structured questionnaires were used.
This enabled the perceptions and opinions of specialists from the project and the Ethiopian Environmental Protection Agency [EPA], the communities (located upstream and downstream of the dam) and management bodies (from the project, EPA, and other groups) to be gathered. The extent of public participation in the project was assessed using the Aarhus practice evaluation criteria for public participation, adopted from the European convention on public participation (Hartley and Wood 2004). Finally, observations were made by visiting the site to independently assess the progress made in implementing the EIA recommendations. Analyses conducted included comparison of the perceptions of different stakeholders on the accomplishment of the project with the EMP and the accomplishment reports.

Results

Most of the documents (Acres and Shawel 1995; WAPCO and WWDSE 2005; KIWMaP 2006; EPLAUA 2006; MacDonald 2004a, b, c, d; ADF 2000, 2001) fulfilled requirements and provided satisfactory information on the probable impacts of the Koga project, as well as mitigation measures to



minimize environmental problems. Predicted impacts considered in the EMP included impacts on water resources, water quality, air, noise, land, ecology, command area development or induced development, and demographics and socio-economics. However, there was no mention of the likely impacts of the dam on downstream flooding, fisheries, and riparian vegetation. A review of the EMP indicated some limitations in the planning process, including the lack of the following mechanisms/components: public consultation, evaluation of different project scenarios and possible alternatives and a monitoring plan for erosion and siltation. A review of the project progress reports indicated that, of the 20 major plans identified in the EMP for implementation, only two activities (planting forest seedlings and livestock development) have progressed satisfactorily. Watershed management measures, public health, and resettlement/compensation payments) were progressing unsatisfactorily. The remaining 15 activities were either moribund or not reported.

Perception of the farming community

Interviews conducted with farmers focused on public participation and implementation of mitigation measures. Farmers were asked to comment on the likely impacts of the scheme, what they knew about the EIA,and more generally, how decisions relating to the scheme were communicated to them. Farmers were asked if the project material was presented in a way that was understandable to them. We found that many farmers recognize the possible environmental impacts that could affect their livelihoods. Downstream communities expressed concern about adverse impacts on drinking water, fisheries, traditional irrigation, forestry products, and firewood. Nineteen percent of the interviewees agreed that communication criteria for the project were completely fulfilled, 14% nearly fulfilled, and 26% partially fulfilled. The remaining 41% said that the project did not provide project materials in a clear format, implying that communication

criteria were not fulfilled. Thus nearly half of the interviewed people living in the catchment did not have a clear understanding of the project documents or the project itself, based on the materials provided by the project team. Moreover, neither downstream nor upstream farmers felt that they had participated in decision-making related to the project. These findings confirm the result of the stakeholder analysis indicating that decisions pertaining to the construction of the dam have been made with little public consultation and with insufficient explanation of intended project objectives (Gebre *et al.* 2007).

Perception of specialists

The interviews conducted with specialists focused on implementation of EIA recommendations and the EMP. The results obtained from the interviews indicated that 70% of the specialists thought that the environmental mitigation measures recommended in the EIA were not being adequately implemented. In addition, 90% of the specialists thought that the EMP was constrained by weaknesses in institutional arrangements, time schedules, finance, limited integration of the EMP within the overall project schedule and limited capacity of project staff.

Perception of management bodies

The interviews with staff from the management bodies focused on the institutional arrangements and regulations to ensure that EIA-recommended activities are undertaken. We found that the Koga project has no official permit, as required by the national environmental legislation. Instead, the African Development Bank (the donor funding the scheme) required that an EIA be undertaken and then approved the EIA documents. The African Development Bank also prepared its own EIA summary (ADF 2000). There are several national institutions involved in the Koga project:

- The Amhara Regional Water Resources Bureau is responsible for hosting the project management unit that coordinates the construction and implementation of the project.
- The Amhara Regional Agriculture Bureau is responsible for implementing the watershed management component.
- The Environmental Protection, Land Administration and Use Authority (EPLAUA) is responsible for overseeing environmental aspects of the project and is also responsible for land redistribution and compensation.

Staff interviewed in these institutions either knew nothing or stated that they had 'no opinion' about the lack of an official permit. There were no environmental specialists in either the scheme management team or among the various consultants employed by them. Consequently, the project has not undertaken any formal monitoring of environmental impacts. Furthermore, the EPLAUA has only undertaken surveillance/monitoring once in the 4 years since the project commenced. There was no regular monitoring of any environmental impacts, and recommendations for monitoring cited in the EIA were not being followed. For various reasons, including lack of capacity and financial constraints, the institutions tasked with ensuring that the EIA recommendations be implemented are not fulfilling their responsibilities.

Challenges

The primary objective of EIA follow-up activities should be to ensure that project managers are able to realize intended project outcomes. As this study has shown, the effectiveness of the follow-up in the Koga scheme is limited by weaknesses in several key areas (Figure 1). Constraints arise due to technical reasons as well as limitations in human, financial and technical capacity.

- Lack of monitoring, which means that managers are unable to make informed decisions
- Lack of relevant expertise in the project management team
- A weak regulatory and institutional framework

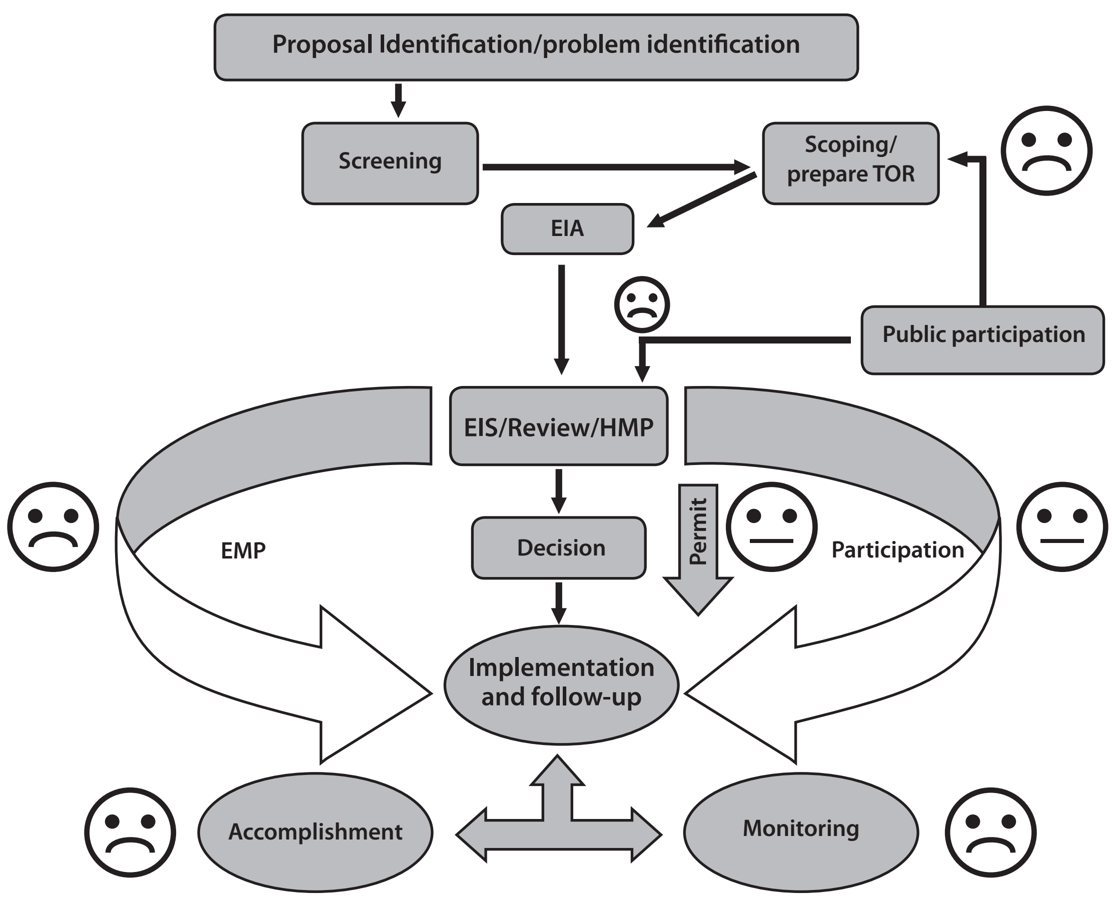


Figure 1. ***Schematic diagram illustrating points of weakness in the EIA process undertaken for the Koga Irrigation and Watershed Management Project.***

- Lack of public participation and the absence of a strong civil society to ensure that EIA recommendations are implemented

As a result of these limitations, it is not possible to determine the long-term consequences of cumulative environmental impacts. It is possible that the sustainability of the project could be undermined.

Recommendations

It is recognized that all development projects have adverse biophysical consequences. Ideally, these will be kept to a minimum through the proper implementation of recommendations from EIAs. Based on the findings of the study, the following recommendations are made to improve the follow-up of EIA implementation in development projects in Ethiopia:

- Enforcing certification mechanisms provides a critical first step in the EIA follow-up process, and is essential if project proponents are to take their environmental responsibilities seriously.
- Implementation of EIA follow-up measures would be greatly improved by clearly defining and dividing tasks and responsibilities between those organizations that are supposed to implement them.
- Mechanisms are required to strengthen public participation in project decision-making processes. This is essential to ensure cooperation and consensus building between different stakeholders.
- Project management teams need to take environmental concerns seriously. It should be mandatory that they include staff with relevant environmental expertise and the knowledge required to implement EIA recommendations and monitoring requirements.
- The finances required to implement EIA recommendations should be identified and ringfenced at the commencement of projects. This should include funds required by the relevant regulatory bodies to monitor compliance.
- Appropriate incentives and legal mechanisms need to be developed to encourage compliance with EIA recommendations.

Conclusion

The EIA documents, which were prepared during the feasibility study, were generally satisfactory. One weakness, however, in the EIA was the lack of a proper estimation of the environmental flow releases downstream, of the dam. Many of the activities planned in the EIA were not implemented in a satisfactory manner. Lack of consultation and public participation were major constraints to the implementation of EIA recommendations. To improve the sustainability of the project, attention needs to be given to improving public participation, regulatory activities, and institutional arrangements. The Koga scheme is the first in Ethiopia to combine irrigation and watershed management within a project that will ultimately be managed by local farmers. Consequently, it is widely perceived to be a learning experience that can be used to inform future irrigation development in the country. To maximize the benefits to be gained from future development projects (not only irrigation schemes), it is essential that the lessons learned are acted upon.

Contact Person

Matthew McCartney (m.mccartney@cgiar.org), Wubneh Abebe, Wim Douven, Jan Leentvaar

Partner Organizations

Addis Ababa University, Ethiopia
Amhara National Regional State, Bureau of Agriculture, Ethiopia
International Water Management Institute
Southern Water, South Africa

Key References

McCartney, M.P. 2009. Improved planning of large dam operation: Using decision support systems to optimize livelihood benefits, safeguard health and protect the environment. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3926

Abebe, W.B., M. McCartney, W.J.A.M. Douven and J. Leentvaar 2008. Environmental impact assessment follow-up in the Koga Irrigation Project, Ethiopia. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food*, Vol.3, 10-14 November 2008, Addis Ababa, Ethiopia, eds. E. Humphreys et al.; 52-55. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: PN36: Improved Livelihoods in Dam Management

Bibliography

Acres, S. 1995. *Feasibility study of the Birr and Koga irrigation project, Koga catchments and irrigation studies, Annexes Q-T.*

ADF 2000. *Summary Environmental Impact Assessment, Koga Irrigation and Watershed Management Project.*

ADF 2001. *Koga Irrigation and Watershed Management Project: Appraisal Report.*

Arebo, S.G. 2005. *Improving Environmental Impact Assessment for Enhancing Sustainable Water Resources Developments in Ethiopia.* MSC thesis, UNESCO-IHE Institute of Water Education, Delft.

EPA Australia 1995. *International Study on the Effectiveness of Environmental Assessment*. Canberra, Australia: Environment Protection Agency.

EPLAUA 2006. *Koga Irrigation and Watershed Management Project Field Monitoring Report*. EPLAUA, Environmental Protection Study Policy and Control Department. Bahir Dar, Ethiopia.

Federal Democratic Republic of Ethiopia Environmental Protection Authority 2000. *Environmental impact assessment guideline document.* Addis Ababa, Ethiopia.

Gebre, A., D. Getachew and M. McCartney 2007. *Stakeholder analysis of the Koga Irrigation and Watershed Management Project*. Report for the International Water Management Institute.

Hartley, N. and C. Wood 2004. Public participation in environmental impact assessment implementing the Aarhus Convention. *Environmental Impact Assessment Review,* **25**, 319- 40.

Bibliography

KIWMaP. 2006. *Koga Irrigation and Watershed Management Project: Progress of watershed management project component implementation*. Preliminary Draft Report.

MacDonald, M. 2004a. *Koga Irrigation and Watershed Management Project: Interim Report*.

MacDonald, M. 2004b. *Koga Irrigation and Watershed Management Project: Hydrology Factual Report*.

MacDonald, M. 2006c. *Koga irrigation and watershed management project: Dam Design Final Report*.

MacDonald, M. 2006d. *Koga Dam and Irrigation Project: Design Final Report. Part 2: Irrigation and Drainage*.

Noble, B., and K. Storey. 2004. *Towards increasing the utility of follow-up in Canadian EIA. Environmental Impact Assessment Review,* **25**, 163-80.

WAPCO and WWDSE 2005. *Environmental monitoring and resettlement plan for Koga irrigation and watershed management project,* Volume I and II (Draft).

Scaling-Up and Out

Institutional Practices to Scale Up Watershed Management Research

Given the intrinsic complexity of a dynamic resource such as water and the multiple relationships that its natural flow entails, water research requires taking into account different levels and scales of biophysical and socio-economic variables if inferences are to be applied elsewhere. This research explored the scale-dependent nature of water research projects and characterized their strategies for scaling up. Adoption of appropriate strategies could help accelerate the acceptance of the technology by target farmers. This, in turn, will increase the availability of technology options and lead to more efficient use of existing natural resources to benefit the poor.

The main expected project outputs were institutional innovations, such as methods, processes and approaches for supporting decision-making by different stakeholder groups. Institutional innovations may be more flexible than other types of technologies, in that they can be applied in a range of biophysical environments.

Methods

The methodology consisted of key literature consultation, an electronic discussion, a mid-term workshop with various stakeholders (e.g., researchers, NGOs) from Asia, Africa, Latin America and Europe and a detailed case study analysis (Gündel *et al.,* 2001). The leaders of 16 projects under the coordination of Water and People in Catchments Theme of the CGIAR Challenge Program on Water and Food (CPWF) were invited to answer a questionnaire designed to collect data and determine good practices for scaling-up research in natural resources. Eight of them responded, as listed in Table 1. The questionnaire followed the frameworks by Gündel *et al.,* (2001) and the DFID-NRSP (2002) guidelines. The latter focused on communications and emphasized that for scaling-up to be feasible, research team's must be develop and implement sound communication strategics as an integral part of the research process. This would ensure that new knowledge will be available for uses (development practitioners, planners, farmers) informs that that they can utilize and adopt (DFID-NRSP 2002). Both sets of guidelines are complementary, and at the time of the research, were considered to be the state of art. Definitions were not provided in the questionnaire in order to avoid biases in the responses.

Table 1. Participating CPWF research projects

Title	Basin
8-Improving Water Productivity in Karkheh: Improving On-farm Agricultural Water Productivity in the Karkheh River Basin	Karkeh
17-IWRM for Improved Rural Livelihoods: The Challenge of Integrated Water Resource Management for Improved Rural Livelihoods, Managing Risk, Mitigating Drought and Improving Water Productivity in the Water-Scarce Limpopo Basin	Limpopo
20-Scales Sustaining Inclusive Collective Action That Links Across Economic and Ecological Scales in Upper Watershed	Andes Nile
23-Research Management for Sustainable Livelihoods Linking Community-Based Water and Forest Management for Sustainable Livelihoods of the Poor in Fragile Upper Catchments of the Indus-Ganges Basin	Indo-Ganges
24-Livelihood Resilience in Dry Areas Strengthening Livelihood Resilience in Upper Catchments of Dry Areas through Integrated Natural Resource Management	Karkeh
25-Companion Modeling and Water Dynamics Companion Modeling for Resilient Water Management: Stakeholders' Perceptions of Water Dynamics, and Collective Learning at the Catchment Scale	Mekong
40-Integrating Governance and Modeling Integrating Knowledge from Computational Modeling with Multi-stakeholder Governance: Towards More Secure Livelihoods through Improved Tools for Integrated River Basin Management	Volta Nile
46-Small Multipurpose Reservoir Ensemble Planning and Evaluating Ensembles of Small, Multi-purpose Reservoirs for the Improvement of Smallholder Livelihoods and Food Security: Tools and Procedures	Limpopo Sao Francisco

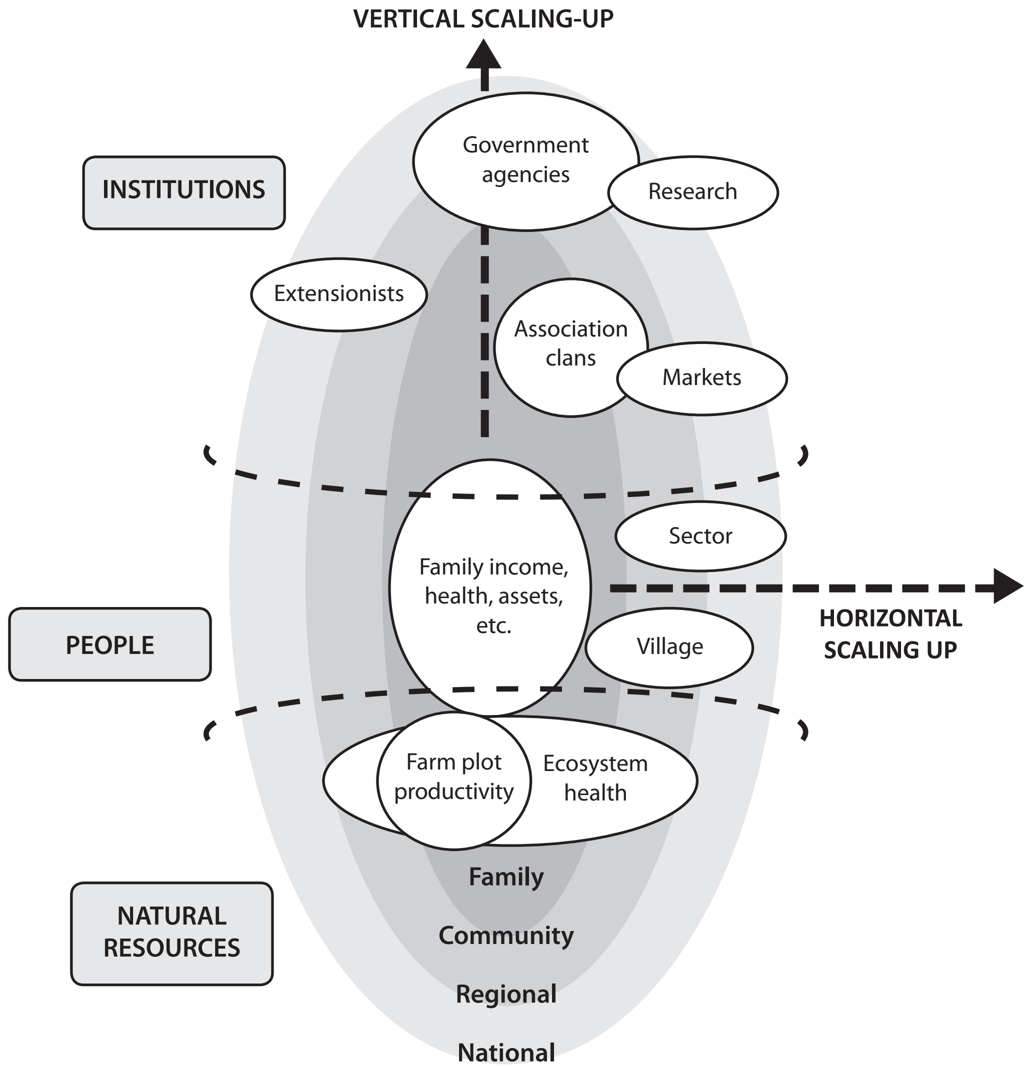


Figure 1. Vertical Horizontal Scaling-up modalities

Horizontal and vertical scaling up

Horizontal scaling up is sometimes referred to as scaling out across geographical boundaries. It is the geographical spread to more people and communities within the same sector or stakeholder group, commonly referred to as dissemination.

Vertical scaling up is institutional in nature and involves expansion to other sectors/stakeholder groups, from grassroots organizations to policymakers, donors, development institutions and international investors. Figure 1 shows the framework for this concept.

Gündel *et al.* (2001) identified prerequisites for successful scaling up that need to be fully considered at the research pre-project and implementation phases. One example is the framework checklist produced in a CGIAR-NGO workshop (Table 2). This framework recognized specific pathways for scaling up, starting from the identification of needs, to having people or events

Table 2. Framework checklist for planned scaling-up

The pilot stage	The 'sparks'	Managing the scaling-up process: Planning and implementing	Managing the scaling-up process: Monitoring evaluation	The desired impact	The desired outcome
Small-scale initiative	Crisis, questions, success Individuals, champions Critical mass Political and initiatives Advocacy Markets Communities identify need to scale up Need to show impact Global trends	Vision is a dynamic Catalysts Actors (not targets) Decision and approach to scale up is based on various aspects—vision, successes, applicability Capacities Scale up ability to influence decision not just technology or process Identify strategies for local participation Spontaneous diffusions Factors	Requirements Monitoring Indicators Benefits Costs	More quality benefits to more people over a wider geographic area, more equitably, more quickly and more lasting	Empowerment and social change

Source: International Institute of Rural Reconstruction (2000).

to serve as 'sparks' or catalysts to initiate a planning stage, through to the management and outcomes of the scaling up process.

CPWF Projects: Scaling Up Strategies

A selection of CPWF Water and People in Catchments Theme research projects were subjected to a detailed analysis of their scaling up strategies. Project leaders were invited to answer a questionnaire, designed to collect data on good practices for scaling-up research in natural resources, which were selected from the frameworks by Gündel et al. (2001) and the DFID-NRSP (2002) report. The DFID-NRSP guidelines focused on communications and emphasized that "for scaling up to be feasible, research teams must develop and implement sound communication strategies as an integral part of the research

Box 1. Principles for scaling up identifiedin a CGIAR–NGO Committee, Workshop

Five major principles

- **Partnerships (catalyst role, networking, farmer-driven, stakeholders-actors)**
- **Financial sustainability (market development and access)**
- **Management: start small, simplify and build on success for effective management**
- **Policy support: change policies to create enabling environment**
- **Local capabilities should be based on existing local dynamics, capacity building-strengthening, organizational development, participation**

Followed by more detailed principles and approaches

- **Involvement of multiple stakeholders and coalitions and alliances**
- **Consensus building**
- **Sustainability considerations**
- **Market development, access and viability**
- **Indicators and measures of success**
- **Expanding capacity and use of participatory approaches**
- **Engagement with and sense of ownership at grassroots level**
- **Knowledge and capacity building and sharing at all levels, systematization of experiences**
- **Development of grassroots organization**
- **Accountability**

Source: International Institute of Rural Reconstruction (2000).

process. This would ensure that new knowledge will be available for users (development practitioners, planners, farmers) in forms that they can utilize and adapt" (DFID-NRSP 2002). Both sets of guidelines are complementary, and at the time of the research, were considered to be the state of art.

Results

Nature of project objectives

Four of the projects aimed to strengthen local capacity for innovation around equitable and sustainable management, four to support local stakeholder forums and five to implement scaling-up strategies. Only one of the projects did not have objectives directly related to scaling up. Half of the projects addressed biophysical issues and the other half, mainly institutional ones.

Representativity

Representativity refers to the project catchments that have biophysical, social, institutional, and/or economic characteristics that can be found in other catchments in the tropics, in the same basin or in other basins. Thus, water access is restricted and is the primary cause of existing conflicts between uses and users at different locations in the watersheds. Poverty and the high dependence on agriculture were also identified. However, there are many other important characteristics that make the projects site-specific, which are important to consider and anticipate for scaling up.

Key characteristics for replication

A supportive institutional environment, in which natural resource management strategies are designed and implemented, is the most important factor in project replication. There is disagreement, however, about what this means since some projects think that the presence of institutions is important, while others responded that the lack of existing institutions was better for the project, since it left space for the creation of new ones. The existence of water externalities was mentioned, as well as poverty and dependence on income from agriculture. In terms of biophysical factors, a dry environment and water scarcity were considered important for most, although some mentioned a lower limit of annual rainfall.

Scale

All projects considered themselves as scale-dependent because of the kinds of problems they are dealing with, not only in biophysical terms but also in institutional terms. What happens at one scale has an influence on the others. There are social dependencies between scales due to projects' work with institutions such as households or catchment organizations. Water productivity was considered by itself a scale-dependent issue. Bringing these findings into a wider context required the identification of relevant audiences or institutions in charge of the use and/or dissemination of results. Institutional scale was considered as most important, especially since replication of the projects is linked with factors such as an appropriate institutional environment and the willingness of households, farmers and institutions to participate and to try innovations. The following table (Table 4) provides an overview of key scaling-up elements that were covered in the CPWF projects studied.

Other key socio-economic and politicial characteristics

- **Willingness of farmers to participate and incorporate innovations**
- **Markets poorly developed; land smallholdings with lack of clear property rights**
- **Socio-economic and ethnic heterogeneity in the composition of social groups**
- **Widespread existence of complex relationships between water users**

Outputs

The importance that projects place on institutional factors for replication is hampered by the relative lack of importance placed on institutional issues. The representativity of sites suggests that it will be difficult for projects to do systematic validation along non-biophysical scales.

This finding is a refection of the complexity of the problems water research projects are dealing with. There are no simple, straightforward solutions.

On budgeting

Around 17% of the total budget (10% minimum and 30% maximum) is spent on scaling up. Some argued that this will depend on the type of project, and some others found this difficult to estimate. The average figure, however, obtained here is twice that recommended in Gündel's framework. Allocation of resources or reducing resources allocated to core research is recommended to anticipate scaling up.

Table 3. Good practices for scaling up as applied by CPWF-T2 projects (Gündel et al. 2001)

			Has this element been considered by your project? (Yes/No/ NA: No Answer/P: Partially)							
Project Phase	**Scaling-up-process-elements**	**Strategic elements toward successful scaling up**	**25**	**24**	**20**	**23**	**40**	**17**	**46**	**8**
		1. Engaging in policy dialogue on pro poor development agendas 2. Identify community, institutional and environmental enabling and constraining factors to scaling up 3. Appraisal of institutional capacity of agencies involved in scaling up required	Yes Yes Yes Yes Yes	No No Yes	Yes Yes Yes	Yes Yes Yes	Yes Yes Yes	No No No	NA NA No	 Yes
Pre-project	Identifying target groups	4. Identifying appropriate research objectives and outputs within development processes to ensure widespread uptake	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
		5. Identify indicators and planning, monitoring and evaluation methods to measure impact and process of scaling up	Yes	No	No	Yes	Yes	No	No	NA
		6. Building networks and partnerships to increase local ownership and pathways	Yes Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		7. Develop appropriate funding mechanisms to sustain capacity for expansion and replication	Yes	No	No	No	Yes	No	Yes	Yes
		8. Building capacity and institutional systems to sustain and replicate	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Implementation	Partnership forging Networking Raising of awareness Policy dialogue Monitoring, evaluation and support studies Exit strategy	9. Demand-supply and support actors identified	NA	Yes	No	Yes	Yes	P	Yes	NA
		10. Other resource organizations contribute with products and by building technical capacity	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		11. Multi-media dissemination of findings	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		12. Aggregate and assess findings from individual projects and derive policy-relevant information	No	Yes	Yes	Yes	Yes	No	Yes	Yes
		13. Central to scaling up processes in providing evidence to influence policy makers, in deciding what should be scaled up and how this might be achieved	No	Yes	Yes	Yes	Yes	No	Yes	Yes
		14. Concerted action required on regional level	No	No	Yes	Yes	Yes	Yes	NA	No

Table 4. Good Practices for Scaling Up Applied by CPWF-T2 Projects (Gündel et al., 2001)										
			Has this element been considered by your project? (Yes/No/ NA: No Answer/P: Partially)							
Project Phase	**Scaling-up-process-elements**	**Strategic elements toward successful scaling up**	**25**	**24**	**20**	**23**	**40**	**17**	**46**	**8**
	Dissemination	15.Should involve the target group as disseminators	Yes	Yes	No	Yes	Yes	P	Yes	Yes
Post project	Impact assessment	16.Built upon monitoring and evaluation. Representatives of target group become part of assessment team. Technical and livelihoods assessment required	Yes	Yes	No	Yes	Yes	Yes	NA	NA
		17.If any other scaling-up strategy(ies) foreseen or currently in use by your project, please add it/them in here	NA	NA	No	No	NA	NA	NA	NA

Challenges

Challenges in scaling up these research results include

- Institutional factors such as institutional instability
- Lack of appropriate local capacities, which is prevalent in almost all the projects
- Reluctance to change, particularly replication of projects and its scale dependence
- Lack of appropriate information
- Lack of knowledge about what is 'actionable' at institutional levels
- Limited amount of resources to invest in capacity building required for implementation of projects outputs and
- External sources of uncertainty, attributed to market fluctuations and climate variability.

Institutional uncertainties are not exogenous factors that affect success or failure but rather are aspects of the institutional environment upon which successful scaling up will depend. For example, if the stability or capacity of certain types of institutions is critical for success, then it is necessary to assess criteria that are likely to be met in the areas in which the project is targeting its outputs.

Conclusion

The importance of a people-centered vision to scaling up is prevalent from this review. Introducing a quality dimension to the definition without neglecting the quantitative dimension and highlighting the importance of time, equity and sustainability dimensions are of particular importance in the natural resource management context.

A majority of research cases took a narrow perspective on scaling up and emphasized the existence of knowledge and technologies. The challenge is to improve how to get these technologies out to the target groups over a wider geographical area (horizontal scaling up). Many of the development-oriented cases acknowledged the multi-dimensional nature and complexity of scaling up, and stressed the importance of institutional processes and learning, and the need to include a range of stakeholders from various sectors.

Scaling up is about creating sustained poverty alleviation and increasing local capacity for innovation on larger scales. The review and case studies showed that there are no simple rules to achieving scaling up. Attempts focus either on geographical and quantitative dimensions of scaling up, or on institutional processes. These two are not mutually independent pathways, but synergistic and overlapping. A key finding is that research has to be integrated within wider pro-poor development processes.

While no blueprint methods for scaling up can be found, the report concludes from case studies and wider experiences that creating an impact from research results has, in the past, focused heavily on the 'post-project' stage. Many of the key strategies that were identified as prerequisites for successful scaling up need to be addressed extensively during the pre-project and implementation phases. The strategic framework that was developed places its main emphasis on the preparatory and implementation stages of research. Many of the elements are not within traditional research activities, and are often related to good development practice, but nevertheless have a direct bearing on success in scaling up research. These results convey that projects see the value in institutions and institutional environments, but they cannot characterize and understand them as extensively as they can the biophysical environments. This suggests that projects could benefit from the greater involvement of political or social scientists.

Contact Persons

Jorge Rubiano (jrubianom@gmail.com) and Sabine Gündel

Partner Organizations

International Livestock Research Institute
King's College London, UK
Michigan State University, USA
Natural Resources Systems Programme (NRSP) of the UK Department for International Development (DfID)

Key References

Rubiano, J.A., A. Peralta and N. Johnson 2008. Scaling-up watershed management research projects. In: *Fighting poverty through sustainable water use: Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food,* Vol 1, Addis Ababa, 10-14 November 2008, eds. E. Humphreys et al.; 114-118. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Gündel, S., J. Hancock and S. Anderson 2001. *Scaling-up Strategies for Research in Natural Resources Management: A Comparative Review.* Chatham, UK: Natural Resources Institute.

Tags: CPWF Theme 2; Water and People in Catchments

Bibliography

DFID-Natural Resources Systems Progamme (DFID-NRSP) 2002. *Scaling-up and communication: Guidelines for enhancing the developmental impact of natural resources systems research.* Retrieved from: http://www.eldis.org/vfile/upload/1/document/0903/NRSP_scaling.pdf

Hancock, J., F. Proctor and C. Csaki 2003. *Scaling-up the impact of good practices in rural development: a working paper to support implementation of the World Bank's rural development strategy.* Report Number 26031. Washinton DC: Agriculture and Rural Development Department, the International Bank for Reconstruction and Development.

IIRR 2000, Going to scale: can we bring more benefits to more people more quickly, workshop highlights, IIRR Silang,Cavite, Philippines.

Using Private Extension Agents to Improve Farm Income in Cambodia

What prevents small farmers from adopting new proven agricultural technologies? Access to markets and income level are important, but there are other factors as well. The first factor is having access to information and skills training. The second is having strong local support systems with the ability to deliver affordable, demand-responsive products and services related to the technologies. As one strategy to strengthen local support systems, the CGIAR Challenge Program on Water and Food (CPWF) Innovative Market-Based Strategies project in Cambodia trained farmers to be private extension agents (PEAs).

Sustained adoption of new technologies depends on improving not only water productivity in the farms but also farmers' income. In the promotion of affordable irrigation systems in Cambodia, farmers are encouraged to plant high-value crops such as vegetables. Interventions put special emphasis on market integration. They recognize the role of the private sector in providing local and affordable access for farmers to mature technologies released by research institutions. Farmer-PEAs are seen as providing this link to the supply chain.

PEAs are farmers recruited and trained to become 'mobile retailers' of agricultural products and services. Their services include provision of technical advice and market information, even buying farmers' produce, which they sell to wholesalers.

Once farmers become fully integrated into the market, the farmer-PEAs take on the responsibility of providing market and technical information, even technical backstopping. The PEAs, therefore, also serve as a link between farmers and research institutions. They can also be vehicles for extending the technologies to other farmers within the same community. This then allows government researchers and extension workers to shift their attention to the promotion of mature technologies in other communities.

Farmer-to-farmer approaches encourage them to become fully integrated into the market value chain by developing select farmers into PEAs. However, the strong focus on the business orientation of this approach poses the risk that PEAs will prioritize their business interests over the interests of their fellow smallholder farmers.

Findings important to the scaling up/out agenda

From the CPWF experience and from a review of field experiences on PEAs (Roberts *et al*. 2008), the following were noted:

1. PEAs provided products and services that raised farmers' incomes by an average of 50%. However, many PEAs did not earn enough to continue as PEAs.

2. There were many repeat clients, indicating that PEAs were providing services and products valued by farmers. These repeat customers required less intensive support than new customers.

3. Offering in-kind credit for inputs (to be repaid at harvest) was a popular service among both poor and better-off farmers and was an effective way for PEAs to attract clients.

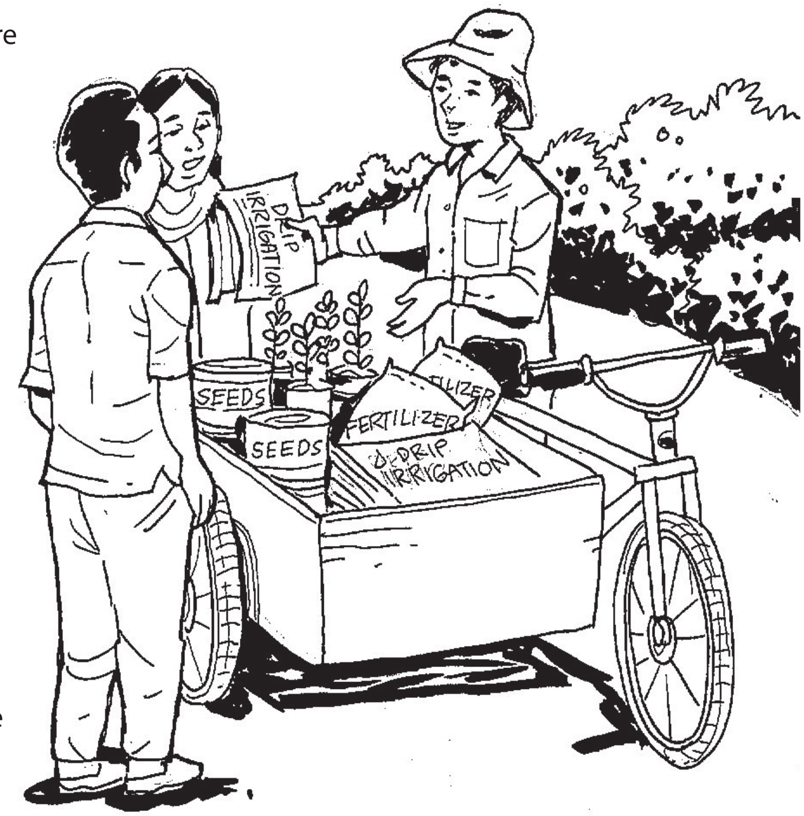
4. The prices of farm inputs were more important to farmer-clients than the services offered with them. Thus, PEAs could not charge more than the market price for their products, inspite of the added value they provide through giving advice and follow-up service. This resulted in PEAs often preferring wealthy clients who needed less credit, could repay loans, and required less technical support.

5. Incentives (e.g., project stipends) to PEAs had positive and negative effects. Positive effects were a) PEAs focusing on developing their skills and in reaching the poorest 40% in the villages and b) some PEAs being able to rely less on the project for financial support. A negative effect was that some PEAs were motivated by the stipend only and this became an added, unsustainable cost to the project.

6. Overlapping PEA territories led to more competition and more choices for farmers but decreased the profitability of the agent's business.

7. PEAs with additional skills (e.g., animal health services) were able to supplement their PEA income and continue their business as PEAs when the project ended. One of them showed that it was possible to run a sustainable PEA business purely through providing farm inputs, using a bicycle to minimize operational costs.

8. PEAs selected by the community were more active over the longer term.



Lessons learned

1. Technologies must be able to address socio-economic contraints if they are to be adopted at the farm and community levels.

2. Participation of all stakeholder groups and farmer-to-farmer approaches are key elements of any communication strategy and plan for the successful and large-scale promotion of technologies. This includes effectively linking the farmers, research and the supply chain.

3. Participatory and interactive methods such as farmer field schools, are effective for knowledge sharing and training of farmers and PEAs.

4. Provision of baskets of choices, a wide range of technologies and suppliers of related products/services, is most beneficial to farmers.

5. Promotion of high-value crops for increased farm income encourages farmers to adopt and invest in the technologies/innovations.

Conclusion

The experiences from the project provide further proof of the critical role of farmers in the scaling up process. In particular, emphasis should be placed on farmer-to-farmer approaches in developing enabling policies and support systems for the speedy and affordable adoption of appropriate technologies, especially by the poorest farmers. Supporting the PEA experience may be one step in this direction. In its ideal form, the role of the farmer-PEAs is more than selling products or services; they play a broader role in helping small farmers analyze farm-business operations, compare performance against local benchmarks, identify areas where products and services can offer the most return for investment and then support the farmers in making needed changes. In this sense, the PEA is more of a small-farm business analyst with a genuine interest in the success of the farmer's whole livelihood system.

There is, however, danger in PEAs working more for their own business interests and leaving out the poor farmers. Stakeholder workshops and planning of communication strategies must take into account agreement on a set of policies and procedures towards upholding the true objective for adopting the PEA mechanism. Identification, selection and training of the PEAs will be critical policy elements that the different stakeholder groups will have to agree on, develop, implement and monitor.

Contact Person

Michael Roberts (mroberts@ide-cambodia.org)

Partner Organizations

Canadian International Development Agency
International Center for Soil Fertility and Agricultural Development
International Development Enterprises
Provincial Department of Agriculture, Cambodia
The World Vegetable Center

Key Reference

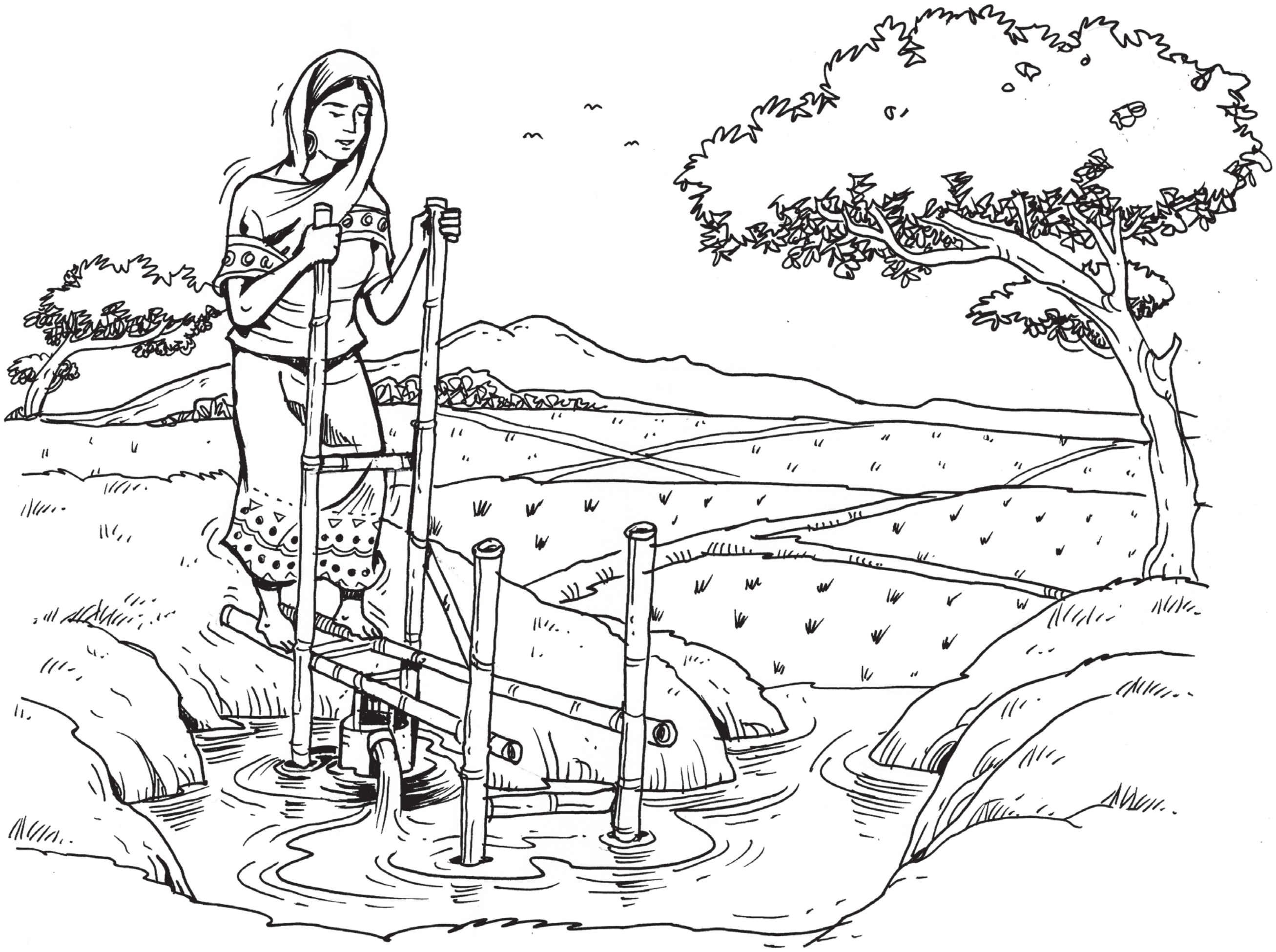
Roberts, M. 2008. *Demonstration and documentation of innovative market-based strategies to realize agricultural income through increased on-farm water productivity and market integration.* CPWF Small Grants Final Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: SG502; Innovative market-based strategies

Bibliography

Roberts, M., A. Long and N. Baxter 2008. *Provision of agricultural support services to small farmers through private-sector agents: A review of selected field experience in Cambodia.* International Development Enterprises.

Why Small Farmers Should Invest in Irrigation Technologies



Developing irrigation solutions adapted to the situation of smallholder farmers can contribute to the improvement of agricultural water productivity, farm productivity and household income. Coming up with irrigation options based on appropriate and innovative technologies is one thing; convincing cash-poor farmers to invest in them is another. If these solutions are to be marketed to the small farmers, agricultural extension work must be complemented with developing a strong supply chain that focuses on the small farmers as its clientele base.

Make the supply chain responsive to small farmers' need for irrigation

"Selling" irrigation options to small farmers

In the absence of affordable irrigation, it is difficult for small farmers to engage in agriculture as an enterprise and to rely on it for their primary source of income. Even the rental of engine-driven pumps is beyond their paying capacity. While other irrigation devices are available, these are mostly designed for medium- and large-scale farmlands, used by only 10% of the total farming population. In effect, this deprives the other 90% (poor and marginal farmers) of irrigation solutions suited to their small landholdings and budgets. Where these are available, there is a lack of awareness on, and access to, such irrigation technologies. The challenge is to bring these irrigation solutions to the small farmers and influence them to invest in the technologies.

How it was done in Jharkhand and Bihar, India

The CGIAR Challenge Program on Water and Food (CPWF) Sustainable Dissemination of Low-cost Irrigation Technologies Project showed a way to test-market a variety of irrigation solutions to meet the diverse needs of small farmers in India. An Irrigation Solution Matrix (ISM) for Jharkhand and Bihar was eventually developed based on the experience. The process that was adopted is illustrated in Figure 1. The strategy was to demonstrate irrigation solutions to farmers and make these technologies affordable and available in the market by stimulating the private sector supply chain. The development of a strong supply chain was facilitated by nurturing, training and linking manufacturers, distributors, dealers and village-level assemblers.

From information on water availability and sources, soil characteristics, crops, agriculture seasons and socio-economic conditions in the region, the diverse conditions faced by farmers in different

Activities for promoting irrigation solutions

- **Live demonstrations during village festivities and council meetings**
- **Farmers' meetings in the villages**
- **Exposure visits by local farmers to successful adopter farmers**
- **Mobilizing opinion leaders to spread good words about the products**
- **Video van shows of the products at strategic places in the villages**
- **Periodic meetings with partners such as manufacturers, dealers and NGOs**
- **Use of campaign materials such as handouts, wall paintings, billboards and dealer boards**

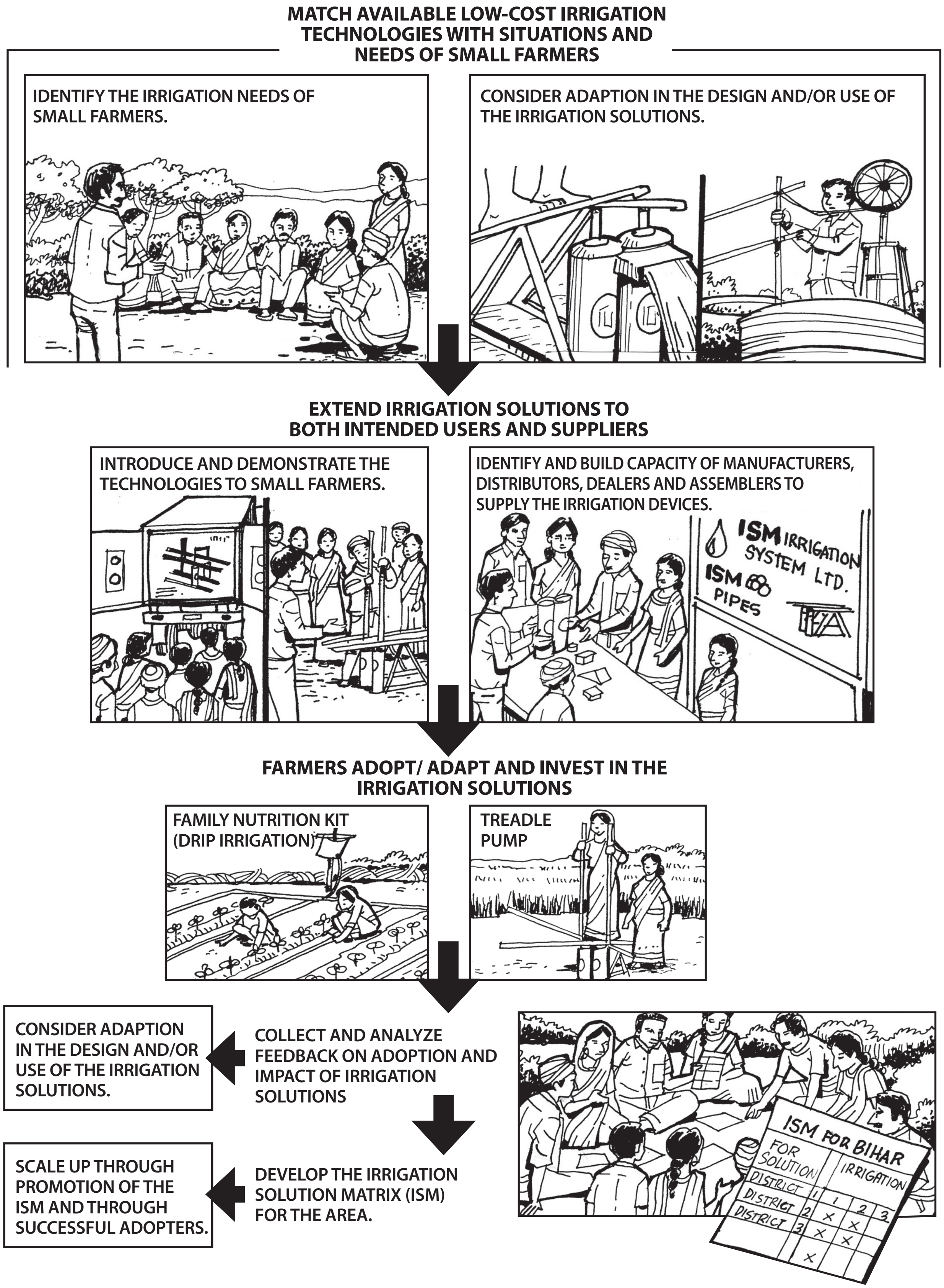


Figure 1. Process adopted for test marketing irrigation solutions in Jharkhand and Bihar

geographical units were identified. Accordingly, irrigation solutions already available were then matched with the situations and extended to farmers as options using various promotional activities.

In the case of Jharkhand and Bihar, the technologies included the surface treadle pump, rope and washer pump, family nutrition kit, low-pressure sprinklers and low-cost drip irrigation systems. These were introduced and demonstrated in 16 districts to small farmers who decided which technology to invest in. Farmers who eventually purchased the devices were trained on the use and maintenance of the units.

While introducing irrigation solutions to farmers, supply chain partners were trained in various aspects of manufacturing, distribution, installation and maintenance of the technologies. The partners who served as marketing channels included manufacturers, village-based distributors, dealers, government sales depots, even NGOs. Manufacturers were trained to fabricate units according to product design and quality standards. The fabricated units were passed on to distributors and dealers for selling in remote rural areas. For drip irrigation kits, manufacturers were identified to supply the components for the locally designed kits. Self-help groups, agri-input and hardware dealers were then trained to install and assemble the kits. They were also linked to component manufacturers to ensure the availability of parts in remote rural areas. These dealers promoted and sold the kits directly or through agents.

Through research or surveys, the extent of adoption and the impact of various irrigation solutions in different situations may be established. An ISM for the area can be developed from the responses. The ISM can be an instrument to scale up use of the irrigation solutions by bringing them to the attention of researchers and policy makers.

Findings from test marketing of irrigation options

In Bihar and Jharkhand, the comprehensive demonstration of irrigation solutions has led to a change in attitude of the smallholders as they realized the benefits accruing from the technologies. Consequently, this has resulted in good initial sales and adoption of the irrigation solutions. This steady early demand has facilitated the establishment of a vibrant supply chain to deliver the technologies to the smallholders. Other impacts included the following:

- Development of active pro-poor markets, which allowed small farmers to participate both as buyers of irrigation technologies and as vendors of high-value produce.
- Enabling 3,116 smallholder farmers to grow more crops per unit of land. This has increased on-farm work days, livelihood opportunities and household incomes.
- Giving regular work to 225 village-level technology installers, who are either small farmers, daily wage earners or unemployed youth.
- Carbon savings as promotion of manually powered treadle pump and rope and washer pump replaces diesel pumps and ensures controlled drawing down of groundwater and precious fossil fuel resources.

Lessons learned

- Once farmers learn about the productivity-boosting benefits of various irrigation solutions, they are quick to adopt them.
- Exposure visits to successful adopter farmers builds confidence among other farmers in the area in adopting the new technology and obtaining its benefits.
- As more farmers from neighboring areas hear and see the success stories of adopter farmers, they want to find out more about the technologies, leading to greater demand for the technologies.
- There are two important lessons with regard to strategies for scaling up irrigation solutions based on the market-development approach. The first is to seriously consider making changes in existing technologies to meet farmers' needs. The second is the use of effective promotional strategies suited to the regional socio-economic situations.

Letting irrigation solutions flow

If location- and need-specific, affordable irrigation solutions are made available in the market, smallholder farmers will buy them. Policy support is needed to enable research on developing irrigation solutions for poor small farmers. If there is no support, irrigation solutions within the price range that is affordable to smallholders will not be available. Public-private sector partnership models need to be developed with the smallholders' needs in mind.

Contact Person

Amitabha Sadangi (amitabha@ide-india.org)

Partner Organizations

India Development Foundation
International Development Enterprises
International Water Management Institute
Skoll Foundation, USA

Key Reference

International Development Enterprises India 2008. *Sustainable dissemination of low-cost irrigation technologies which impact lives of smallholders of Jharkhand and Bihar, India*. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tags: SG512; Sustainable Dissemination of Low-cost Irrigation Technologies

Bibliography

International Development Enterprises India *n.d.* Technologies. Retrieved from http://www.ide-india.org/Tech_Intro.aspx

International Development Enterprises India *n.d.* Integrating poor into market systems (IPMAS). Retrieved from http://www.ide-india.org/IntegratingPIMS.aspx.

Enhancing Technology Generation and Dissemination for Wider Uptake and Impact

There is an increasing pressure on water resources in sub-Saharan Africa due to unprecedented and competing demand for water among agriculture, ecosystem services, and other uses. Various technologies and practices have been developed in the region to increase the productivity of crop and livestock systems. These technologies and practices have failed to be adopted by the end-users, however, because the interventions were developed without considering the socioeconomic concerns of target communities, their systems, and their institutions. They commonly fail to respond to social preferences, indigenous knowledge, and local skills.

Participatory research proved to be effective in enabling small-scale farmers and local decision makers to identify and develop technologies, but adoption of interventions by the end-users at a wider scale remains challenging. Appropriate policies and institutions must be developed and local communities must be involved in decision-making (Gleick 2003, de Fraiture *et al.* 2007).

Challenges in targeting production systems and clients

- **Horizontal and geographic spread of technologies have been limited, even with facilitation of public institutions and NGOs.**
- **Technologies across agroecologies and social strata are inappropriate and spread of technologies and approaches that demand collective decision and policy support is limited (e.g., grazing land management).**
- **Production systems and socioeconomic categories have demanded diverse technological innovations and approaches to bring about immediate change.**
- **Production objectives among stakeholders vary–e.g., some households have concentrated on marketable livestock-related commodities, whereas others focus on food security and self-sufficiency.**
- **Resource-poor farmers, especially those far away from markets, have been facing difficult decisions over the use of scarce resources in their production systems.**
- **Decisions on the allocation of resources have often been made in association with immediate financial gains and food security, with limited assessment or appreciation of the impact of management decisions on other system components (e.g., feed production, soil fertility management).**
- **There has been a need to characterize, package and disseminate the technologies to various recommendation domains (agroecologies, cropping systems, cultural values, system niches and other system scenarios).**
- **Farmer-to-farmer dissemination of technologies through existing social networks–be they defined by area of residence, friendship, kinship, marriage, religion or other factors–has been a successful approach (Adamo 2001), although reach was limited.**
- **Production systems have differed in agroecology, socioeconomic and policy dimensions as well as institutional constraints and household priorities.**
- **Interaction with research and development also has varied from community to community.**

Identification of key entry points

Identification of key entry points is the initial action that is strategically applied to assure smooth and effective engagement with communities and institutions. Entry points are essential to build trust between the community and outside actors, arouse their interest and keep their spirits high. They have certain properties that lead to the desired objective of promoting 'win-win technologies' at farm and higher scales. These include various interventions in the form of attractive technologies, policies and incentives. The most apparent entry points, however, were often crop varieties, although farmers have slowly shifted their interest to water conservation measures and bund management that combined fruit trees and multipurpose forages.

Strategically, entry points must have certain properties that will lead to the desired objectives of promoting win-win technologies. They must be of high priority and must bring about a successful solution to a community problem; quick in bringing benefits, in particular, higher household income; and accessible to most households and easy to adopt.

Linking technologies in Ethiopia

By linking the entry point technologies with soil conservation (e.g. forage grasses and multipurpose trees), farmers in southern Ethiopia were able to get multiple benefits in the form of increased crop yield, livestock feed, and fuelwood. Further intensification was possible with more horticultural crops, production of fodder (grasses and leguminous trees and shrubs) for zero grazing, while serving soil conservation and other uses.

Promoting linked technologies

The term 'linked technologies' was coined to define interrelated technologies applied simultaneously at plot level to render multiple benefits and facilitate adoption of technologies. The research teams employed several participatory techniques to link individual technologies to foster visible farm benefits (Amede *et al.* 2006). Linking technologies facilitated change from a commodity orientation to a more holistic and systems approach, whereby farmers were in the forefront throughout technology development, dissemination and impact assessment. In general, the linked technology approach best enabled development workers, research organizations and recipient communities to jointly address poverty and natural resource degradation in a holistic manner. As farmers' interest gradually increased in adopting the simple entry-point technologies, the research teams created access to a wider range of, and more complex and linked, technologies (Figure 1).

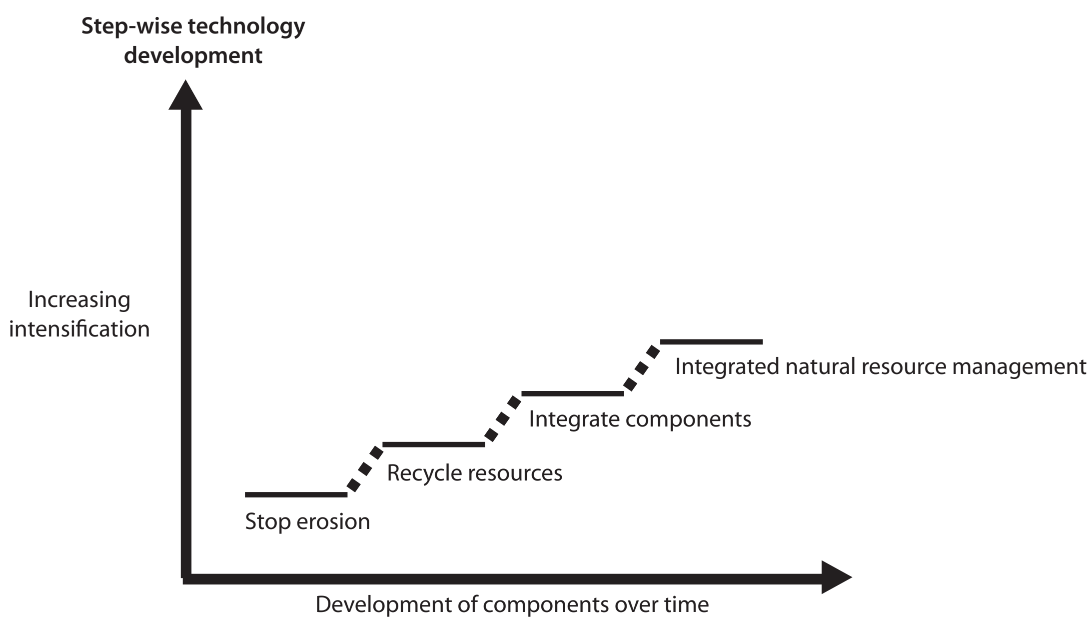


Figure 1. ***Step-wise integration of various technologies and approaches to improve natural resource management in the Ethiopian highlands (Amede*** et al. ***2006).***

Strengthening linkages and partnerships

It is critical to create favorable linkage mechanisms among the actors to provide more options, other interventions and expertise. This is done through

- Holding periodic stakeholder meetings and workshops for feedback exchange and experience sharing to create a common understanding of visions, goals and objectives.
- Building genuine partnerships and linkages with farmers, related organizations and development actors facilitating dissemination.
- Stakeholder partnerships negotiated in such a way that all parties clearly understand and fulfill their responsibility and are committed to work together.
- A commodity approach, which requires that it be augmented with an integrated agroecosystem approach so that interrelated enterprises, heterogeneous circumstances and innovation systems can be taken into account. This requires an ability of development partners to analyze and work with systems.

Community facilitation

Facilitators with appropriate skills and experience are needed to organize actors and help their groups to function. This is critical to build social capital for managing communal resources. It is also an efficient tool to reach many farmers quickly. They help build capacity so they can make demands, manage themselves, participate in research and development (R&D) activities and have their own activities, considering resource status, wealth, age and other stratifications that might affect needs and priorities. Farmers are empowered and their ability to conduct their own experiments is improved. It is crucial to document farmers Indigenous Technical Knowle dge (ITK) and build upon it by the research and development agenda.

Supportive research and extension organisation

Creation of a favorable policy and a conducive working environment in research and extension systems plays a pivotal role in the internal and external efficiency of technology dissemination processes. This was demonstrated by the establishment of researcher-farmer-extension linkage steering groups at the Ethiopian Institute of Agricultural Research. The availability of adequate resources, coupled with good and visionary leadership, is thus needed for the execution of effective extension.

Local organizational capacity

Facilitation of farmer organizations help improve effective technology development and dissemination and collective action. A community change management approach is required for group facilitation in managing common natural resources (e.g. grazing land management). Organizing farmers into strong farmer research groups (FRGs) creates an entry point into the community for researchers, extension personnel and development staff to work closely together (Amede *et al.* 2006). Empowering the groups using participatory approaches is fundamental to enable them to meaningfully participate. Moreover, working together requires patience and respect for the communities' social values and affairs. Farmer capacities are built through training, visits, and experience-sharing discussions, and general facilitation.

Basket of technological options

There is a need to ensure sustainability of technology used by improving access to and availability of multiple technological options (e.g., annual forages with various maturity periods). The technological options should be appropriate to the needs, interests and local conditions of the farmers. Involvement of end-users in the development of the technologies heightens the probability of appropriateness and, therefore, adoption.

Market orientation

Promotion of effective technology requires effective market orientation through research by farmers. Forage and water management interventions are linked to marketable livestock enterprises. There is a need to consider agencies and actors associated with markets as key stakeholders. Institutions help farmers identify market imperfections and incorporate the interests and priorities of stakeholders involved in marketing fields.

Conclusions

Current policies need to be adjusted to support technology generation and dissemination ensuring that large numbers of farmers have access and can use them. There is a need to foster supportive and conducive infrastructure and related policies to ensure that research, extension, and development outputs reach users. Similarly, the International Livestock Research Institute and the International Water Management Institute have recognized the need to make research more demand-driven and responsive to client needs by ensuring the participation of users in the process of agricultural technology development and through developing the capacity and confidence of those making the demands.

In general, principles and values inherent in supporting technology generation and dissemination may include

1. **Inclusiveness**. Different social groups of farmers should have equal access and opportunity to be part of research processes and participate in the decision-making process on communal and their own specific problems (problem differentiation).
2. **Monitoring to improve research and extension processes**. There is a need to continuously monitor progress at the farm and landscape levels, whether or not research is problem-driven or demand-oriented, and examine the relevance of research to the community to improve approaches and strategies so as to deliver technical options in a sustainable manner.

3. **Trust and value indigenous knowledge and skills:** Researchers and service providers should understand systems and farmers' situations, value farmers' knowledge, and trust in farmers' potentials and capabilities (e.g., that they are experts in their own situation). This calls for building genuine partnerships with farmers and other stakeholders.

4. **Build capacity for self reliance and empowerment:** There is a need to build farmers' capacity to manage their own affairs (self-reliance); improve stakeholder participation (dialogue, interactive, multiple ways); improve access to choice of technologies; create flexibility and options; improve quality of facilitation; develop a sense of joint ownership (role clarification, trust, transparency, confidence); and promote experiential learning–a way of learning-by-doing that is relevant to both researchers and farmers.

Contact Persons

Don Peden (pedenonpender@shaw.ca), Mengistu Alemayehu, Tilahun Amede, Seleshi Bekele Awulachew, Hamid Faki, Amare Haileslassie, Mario Herrero, Everisto Mapedza, Denis Mpairwe, Musa Tibin, Girma Taddesse, Paulo van Breugel

Partner Organizations

Agricultural Economics and Policy Research Center, Sudan
Animal Resources Research Corporation, Sudan
Ethiopian Institute of Agricultural Research
International Livestock Research Institute
International Water Management Institute
Makerere University, Uganda

Key Reference

Peden, D. *et al.* 2009. *Nile basin livestock water productivity.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3927

Tags: PN37; Nile Livestock Water Productivity

Bibliography

Adamo, A. 2001. *Participatory agricultural research processes in Ethiopia using farmers social networks as entry points.* Occasional Publication Series No. 33. Cali, Colombia: International Center for Tropical Agriculture.

Amede, T., R. Kirkby and A. Stroud 2006. Intensification pathways from farmer strategies to sustainable livelihoods: AHIs' experience. *Currents,* **40/41**, 30-37.

Amede, T., T. Belachew and E. Geta 2001. Reversing the degradation of arable land in Ethiopian Highlands. *Managing African Soils: No. 23*. London: IIED.

Amede, A., H. Assefa and A. Stroud (eds.) 2004. *Participatory Research in Action.* Ethiopian Experiences. Ethiopian Agricultural Research Organization and the African Highlands Initiative, Addis Ababa, Ethiopia.

de Fraiture, C., D. Wichelns, J. Rockström and E. Kemp-Benedict 2007. Looking ahead to 2050: scenarios of alternative investment approaches. In: *Water for Food, Water for Life: A Comprehensive Assessment of Water Management,* ed. D. Molden; 91-145. London: Earthscan, and Colombo: International Water Management Institute.

Delgado, C.L. 2003. Rising consumption of meat and milk in developing countries has created a new food revolution.
Journal of Nutrition, **133**, 3907S-10S.

Gleick, P. 2003. Global freshwater resources: Soft path solutions for the 21st century. *Science,* **302**, 1524-1528.

Molden, D., K. Frenken, R. Barker, de C. Fraiture, B. Mati, M. Svendsen, C. Sadoff and C. Finlayson 2007. Trends in water and agricultural development. In: Water for Food, Water for Life: *A Comprehensive Assessment of Water Management*, ed. D. Molden; 57-89. London: Earthscan, and Colombo: International Water Management Institute.

Bibliography

Parthasarathy Rao, P., P.S. Birthal and J. Ndjeunga 2005. *Crop-Livestock Economies in the Semi- Arid Tropics: Facts, Trends and Outlook.* Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Peden, D., G. Tadesse and A. Misra 2007. *Water and livestock for human development. In: Water for Food, Water for Life: A Comprehensive Assessment of Water Management,* ed. D. Molden; 485-514. London: Earthscan, and Colombo: International Water Management Institute.

Solano, C., H. León, E. Pérez, L. Tole, R.H. Fawcett and M. Herrero 2006. Using farmer decision making profiles and managerial capacity as predictors of farm management and performance in Costa Rican dairy farms. *Agricultural Systems,* **88**, 395-428.

Steinfeld, H., P. Gerber, T. Wassenaar, V. Castel, M. Rosales and C. de Haan 2006. *Livestock's long shadow. Environmental issues and options.* Rome: FAO.

Participatory Impact Pathway Analysis: A Practical Method for Project Planning and Evaluation

Participatory impact pathway analysis (PIPA) is a practical planning and evaluation approach developed for use with complex research-for-development activities. PIPA is initiated with the conduct of a participatory workshop where stakeholders make explicit their project's impact pathways (that is, the assumptions and hypotheses about how their project will achieve an impact, also known as "theory of change"). An online manual on PIPA is found on boru.pbworks.com/w/page/13774903/Frontpage.

PIPA improves evaluation by helping managers and staff to formalize their project's impact pathways and to monitor progress, encouraging reflection, learning and adjustment along the way.

Steps in the PIPA workshop

Construction of problem trees

Participants begin by clarifying the cause-and-effect logic of their projects by drawing a problem tree that begins with the identification of problems the project could potentially address and ends with problems that the project will directly address. When working with several projects from the same program, presentations of problem trees help participants better understand each other's aims, a prerequisite for successful program integration.

Visioning

Participants describe a vision of project success 5 or more years in the future in terms of who is doing what differently, how project outputs will scale out and who will benefit.

Developing a network perspective

PIPA balances the cause-and-effect logic of the problem tree with a network perspective, in which impact results from interactions between actors are drawn within what is referred to as on 'innovation system'. These interactions are modeled by drawing

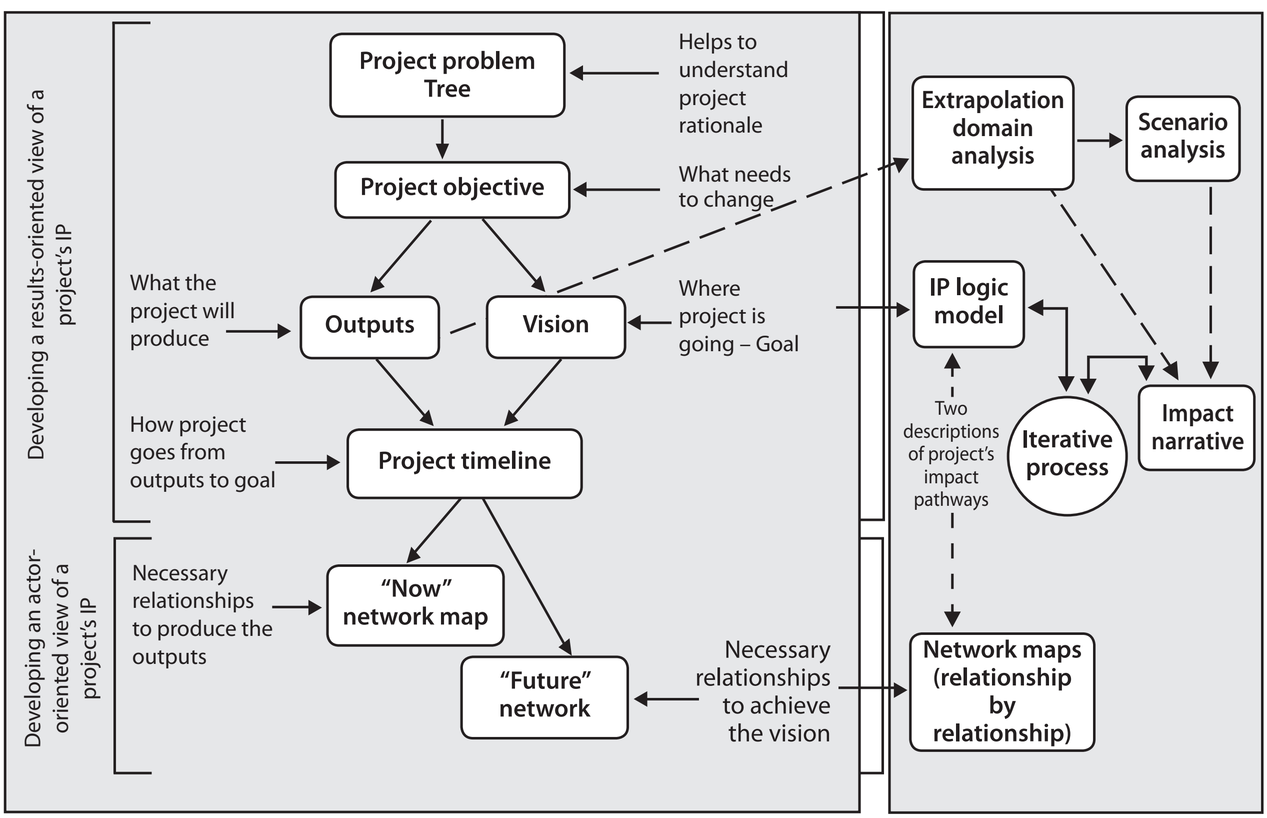


Figure 1. The PIPA process

network maps that show important relationships between actors. Participants draw a 'now' network map showing current key relationships between stakeholders and a 'future' network map showing how stakeholders need to link together to achieve the project's vision.

Participants then devise strategies to bring these changes about. The influence and attitude of actors are explicitly considered.

Defining the outcomes logic model

The two descriptions of a project's impact pathways are integrated in the outcomes logic model. This model describes in table format (see Table 1) how stakeholders (i.e., next users, end users, politically-important actors and project implementers) should act differently if the project is to achieve its vision. Each row describes changes in a particular actor's knowledge, attitude, skills (KAS) and practice, and strategies to bring these changes about. The strategies include research to develop project outputs with next users and end users who subsequently employ them.

The Impact Logic Model

After the workshop, participants may wish to go one step further and discuss how changes described in the outcomes logic model might eventually lead to social, economic and environmental impacts. In this case, the facilitators use workshop outputs to construct a first draft of an impact logic model (see in figure 2). An impact narrative should also be written explaining the underlying logic, assumptions and networks involved.

Monitoring and evaluation

1. During the PIPA workshop, participants develop a vision for their project and describe the impact pathways (in the form of an outcomes logic model) to achieve that vision. The project then implements strategies, which lead to changes in KAS and practices of the participants involved. Project Monitoring and Evaluation staff derive indicators to measure progress towards these outcomes.

Table 1. Expected changes and strategies to achieve project vision

Actor (or group of actors who are expected to change in the same way)	Changes in practice required to achieve project's vision	Changes in KAS' required to support this change	Project strategies to bring about these changes in KAS

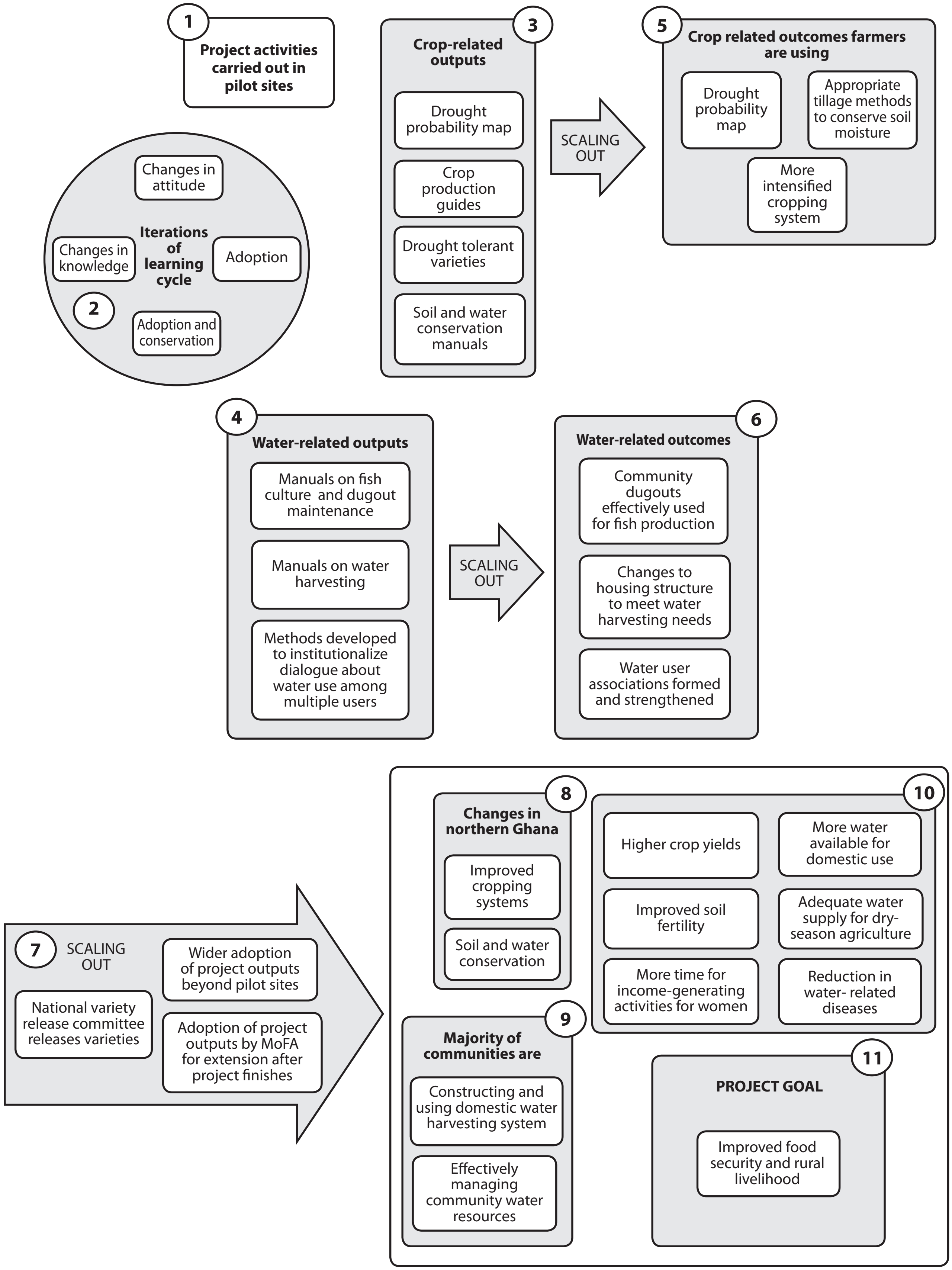


Figure 2. Example of an Impact Logic Model for the CGIAR Challenge Program on Water and Food (CPWF) Strategic Innovations in Dryland Farming Project

2. A workshop is held 6 months later to reflect on progress. The vision is modified on basis of what has been learned. The outcomes logic model is revised where necessary and corresponding changes are made to project activities.

3. The process continues. The project may never achieve its vision (visions are generally used to motivate and stretch), but it does achieve real improvements.

Results

PIPA goes beyond the traditional use of logic models and log frames by engaging stakeholders in a structured participatory process, promoting learning and providing a framework for 'action research' on processes of change. The two logic models provide predictions of future impact that can be used in priority setting. They also provide impact hypotheses required for ex-post impact assessment. The specification of impact pathways, using PIPA or outcome mapping, is now a recommended good practice in the CGIAR for monitoring and evaluation and as a precursor activity to ex-post impact assessment.

Conclusion

From an innovation systems perspective, technological change can emerge from the actions of a network of stakeholders, and credit cannot be easily apportioned to individual stakeholders. Project and basin impact pathways show the predictions of the sets of outcomes and interactions that will lead to technological changes, including those outcomes that the project will not influence but are essential for final impact. The inherent complexity of innovation systems means that impact pathways must be viewed as estimations based on existing and imperfect knowledge. These impact pathways must evolve in response to new knowledge and changing circumstances.

Contact Person

Boru Douthwaite (b.douthwaite@cgiar.org)

Partner Organizations

Concordia University, Canada
International Center for Tropical Agriculture (CIAT)
International Potato Center (CIP)
University of Oxford, UK

Key Reference

Douthwaite, B., S. Alvarez, K. Tehelen, D. Cordoba, G. Thiele and R. Mackay 2008. Participatory impact pathway analysis: A practical method for project planning and evaluation. In: *Fighting poverty through sustainable water use. Proceedings of the CGIAR Challenge Program on Water and Food 2nd International Forum on Water and Food, Vol. 4,* Addis Ababa, Ethiopia, 10-14 November 2008, eds. R.S. Bayot and E. Humphreys; 31. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Tag: Impact Assessment

Other References

Alvarez, S. and B. Douthwaite 2009. *Impact assessment of research in the CPWF*. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Douthwaite, B., B.S. Alvarez, S. Cook, R. Davies, P. George, J. Howell, R. Mackay and J. Rubiano 2008. Participatory impact pathway analysis: A practical application of program theory in research-for-development. *Canadian Journal of Program Evaluation,* **22**, 127-159.

Douthwaite, B., S. Alvarez, G. Thiele and R. Mackay 2008. Participatory impact pathways analysis: *A practical method for project planning and evaluation.* ILAC Brief No. 17. Maccarese: Institutional Learning and Change Initiative.

Flood, R.L. 1999. *Rethinking the fifth discipline.* London and New York: Routledge.

Harrington, L.W., F. Gichuki, B.A.M. Bouman, N. Johnson, C. Ringler, V. Sugunan, K. Geheb and J. Woolley 2006. *CGIAR Challenge Program on Water and Food, Changing the way we manage water for food, livelihoods, health and the environment: Synthesis 2005*. CPWF Synthesis Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

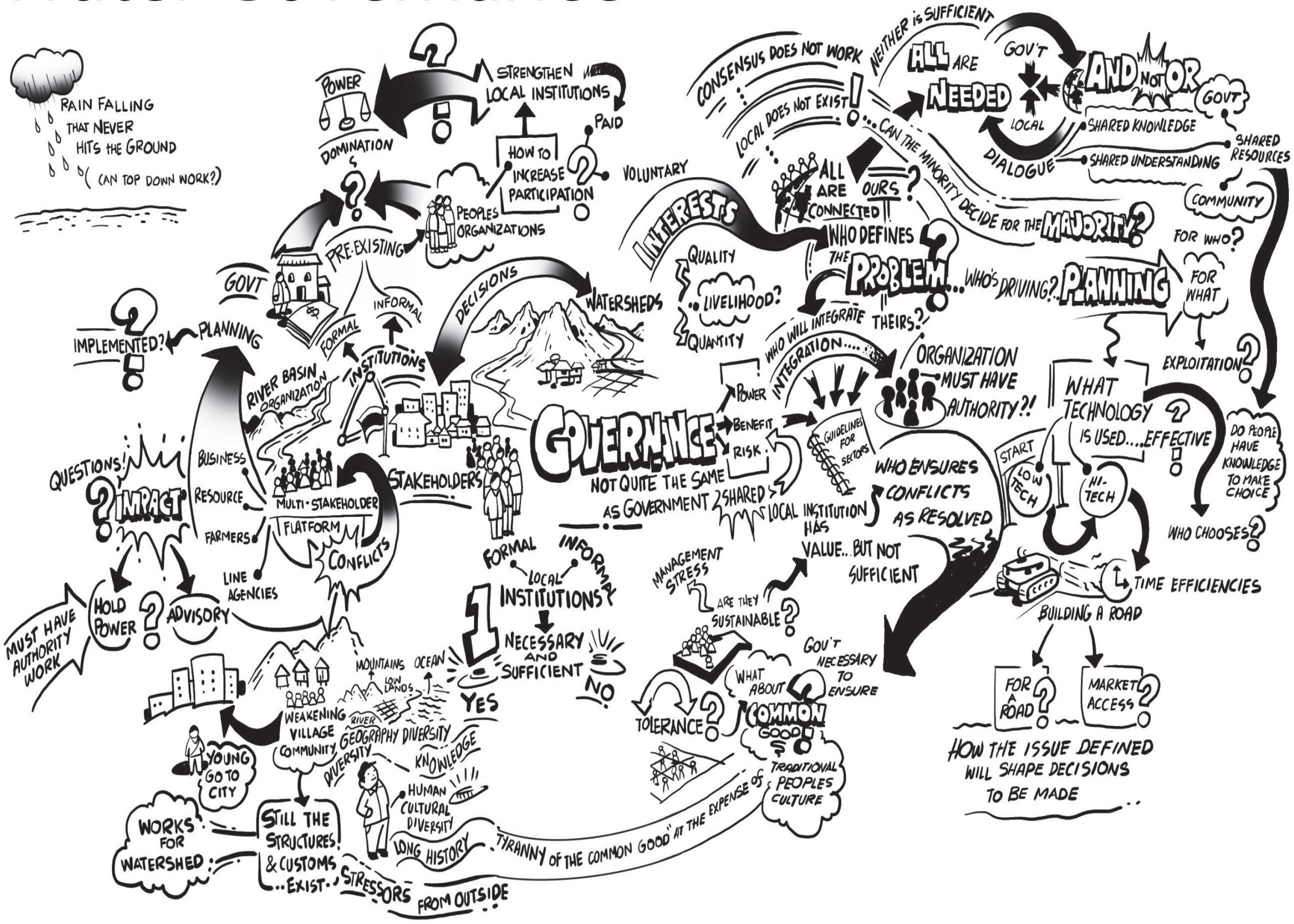
Impact Pathways Wiki. Retrieved from http://boru.pbworks.com/w/page/13774903/FrontPage

Rubiano, J. and J. Garcia 2009. *Improving knowledhe for targeting interventions: willingness of individuals to participate and calculation of institutional environmental indices.* Working Draft.

Schiffer, E. 2007. The power mapping tool: *A method for the empirical research of power relations.* IFPRI Discussion Paper 00703. Washington, D.C.: International Food Policy Research Institute.

Water Governance

Supporting Regional Networks to Facilitate Collective Action in Water Governance



The Mekong River flows through China, Myanmar, Laos, Thailand, Cambodia and Vietnam. The livelihoods of people in these countries depend on the Mekong and its tributaries for water, food (especially fish and rice), transport and many other 'services' provided by the natural environment. The dominant economic development model relies heavily on exploiting natural resources, including building large dams and irrigation infrastructure. This infrastructure for energy and agriculture, along with urban and industrial expansion, has impact on water flow, water quality, wild fisheries and other components of the ecosystems. Creating fair and effective national and transboundary water governance arrangements to deal with these sorts of issues is a major challenge for the Mekong River, the Basin and the wider Mekong Region. Networks have a constructive role to play.

The M-POWER network—the name derived from the Mekong Program on Water, Environment and Resilience (M-POWER)—is building capacity and connecting transnational researchers and policy makers across the Mekong Region.

Two of M-POWER's flagship action research projects have been supported by the CGIAR Challenge Program on Water and Food (CPWF). Enhancing multi-scale water governance project, examined public participation and deliberation separation of powers, accountability of public institutions, social and gender justice, protection of rights, representation, decentralization and dissemination of information. This was organized around empirical comparative studies and themes, exploring how water governance could better meet the needs of societies to negotiate between competing interests. Improving Mekong water resource investments and allocation choices project has contributed to water allocation policy and practice, studying and experimenting with a wide range of decision-support tools.

M-POWER: Collective engagement and collaboration

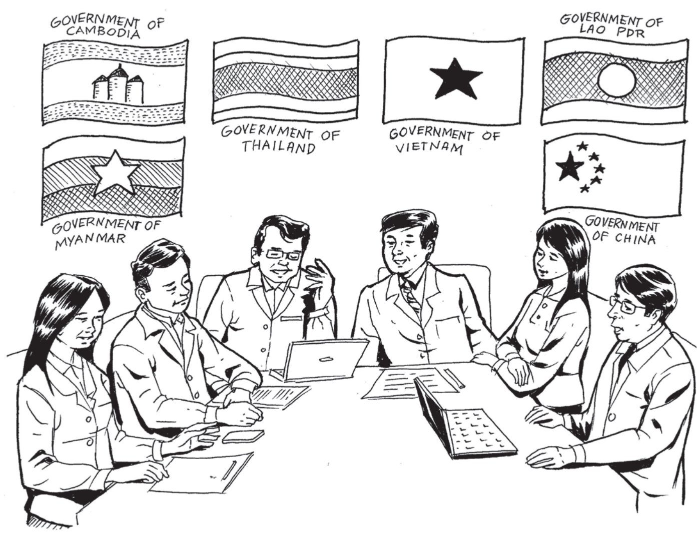
M-POWER was established in 2004 as a group of scholars grappling with water governance issues in the Mekong Region. It evolved into a regional knowledge network actively engaged in research, organizing, convening and facilitating dialogues and assessments, and lobbying to influence policy decisions through collective efforts.

The goal of M-POWER is to contribute to the improvement of livelihood security, human and ecosystem health in the Mekong Region through democratizing water governance.

M-POWER has a Steering Committee (SC) that provides guidance to this regional collaboration.

Defining Network Roles

The M-POWER network has played a constructive role in bringing greater knowledge and collective action to regional water governance. Key elements of its experiences and success include:



1. Creating space for dialogues and deliberation

Countries in the Mekong Region have diverse political structures characterized by centralized political systems, which hinder open discussion of various governance-related issues. M-POWER has provided secure, informed and professionally organized dialogue spaces where stakeholders can learn about and debate on local, national and regional water resource development.

M-POWER knowledge 'successes'

- **Building capacity of Mekong Region researchers and dialogue convenors**
- **Increasing understanding of regional water governance and economic development issues**
- **Integrating knowledge and feeding it into water governance policy processes**

2. Working as a knowledge hub

Networks can facilitate the rapid mobilization of knowledge for collective action, as well as dynamic and organized sharing of experiences and tactics. Through this, networks become a "knowledge-based group of experts and specialists who share common beliefs about cause-and-effect relationships in the world and some political values concerning the ends to which policies should be addressed" (Haas 2009).

3. Policy inputs

Regular interaction through dialogues, international forums and conferences effectively brings together water governance actors that contribute to policy-making. Various communication products and contemporary developments on water governance issues are shared using listservs, the media, public presentations and formal publishing.

4. Critiquing and demonstrating water governance tools and processes

M-POWER has evaluated a range of water governance tools and processes across the Mekong Region, including

- **Multi-stakeholder platforms (MSP) and other consensus-building processes**
  Policy-influencing dialogues involving of diverse stakeholders with interdependent problems, who agree to work together to pursue workable, negotiated agreements.
- **Scenarios and modeling**
  Tools that test the impacts of changes in population, technology and service models, among other variables.
- **Environmental flows**
  A tool that assesses how much of the original flow regime of a river should continue to flow in order to maintain specified valued features

of the ecosystem and hydrological regimes of the river. Environmental flow requirements are linked to a predetermined objective in terms of the ecosystem's future condition.

- **Cumulative impact assessment**
  A tool that analyzes the cumulative impacts of multiple activities.
- **Strategic environmental assessment (SEA)**
  An assessment tool for high-level option assessment in advance of development decision-making.
- **Payments for ecosystem services (PES)**
  Transaction schemes in which defined ecosystem services are purchased, contingent upon a custodian continuing to enable the provision of that service.

A review of these processes and tools showed that much benefit could be gained from:

- Involving MSPs to explore alternative futures and constructively search for solutions to resolve water allocation disputes;
- Improved decision making with better emphasis on sustainable use, fairness and consensus building through negotiation processes that retain elements of competition and collaboration;
- Participation of representatives from marginalized people in scenario building, which can improve transparency in water allocation by clarifying and probing actors' causal assumptions about what drives societal well-being;
- Environmental flow assessments, which clarify risks and benefits of different flow regimes on different water users and ecosystems;
- Scenario building, flow assessments, multi-stakeholder dialogues and transparent negotiations becoming normal practices prior to major infrastructure investments;
- Water allocation becoming the results of a negotiation process that assesses options and impacts thoroughly prior to reaching agreements and making interventions; and
- Focusing on fairly distributed rewards, minimized and fairly apportioned risks, respected rights and actors performing their responsibilities.

Lessons learned

Knowledge and policy networks such as the M-POWER build rapid and flexible response capacity that is crucial for dealing with growing uncertainties and adapting to change. Lessons from M-POWER's dialogue experiences include:

- Strengthening local representation offers valuable local inputs into planning and implementation of water-governance-related policies and practices.
- Improving the quality of deliberative processes draws wider and more substantive inputs from stakeholders.
- Enhancing the constructive interplay between institutions, both horizontally and vertically, requires linking non-state and state actors at various levels.

Contact Person

John Dore (johndore@loxinfo.co.th)

Partner Organization

The M-POWER (Mekong Program on Water, Environment and Resilience) Regional Research Network

Key References

Lebel, L., R.C. Bastakoti, and R. Daniel 2010. *Enhancing multi-scale Mekong water governance.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3782

Tags: PN50; Multi-scale Mekong Water Governance

Dore, J., F. Molle, L. Lebel, T. Foran and K. Lazarus 2010. *Improving Mekong water resources investment and allocation choices.* CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food. http://hdl.handle.net/10568/3868

Tags: PN67; Improving Mekong Water Allocation

Bibliography

Dore J., L. Lebel and F. Molle 2012. A framework for analysing transboundary water governance complexes, illustrated in the Mekong Region. *Journal of Hydrology,* **466-467**, 23-36.

Haas, L. 2009. *Short briefing on the MRC Strategic Environment Assessment (SEA) of Proposed Mainstream Dams. Line-Agency/ Developer Dialogue Meeting,* Vientiane, Laos, 20 October 2009. Presentation. Vientiane, Lao PDR: MRC.

Lazarus, K., N. Badenoch N. Dao and B. Resurreccion (eds.) 2011. *Water rights and social justice in the Mekong Region*. London: Earthscan, London.

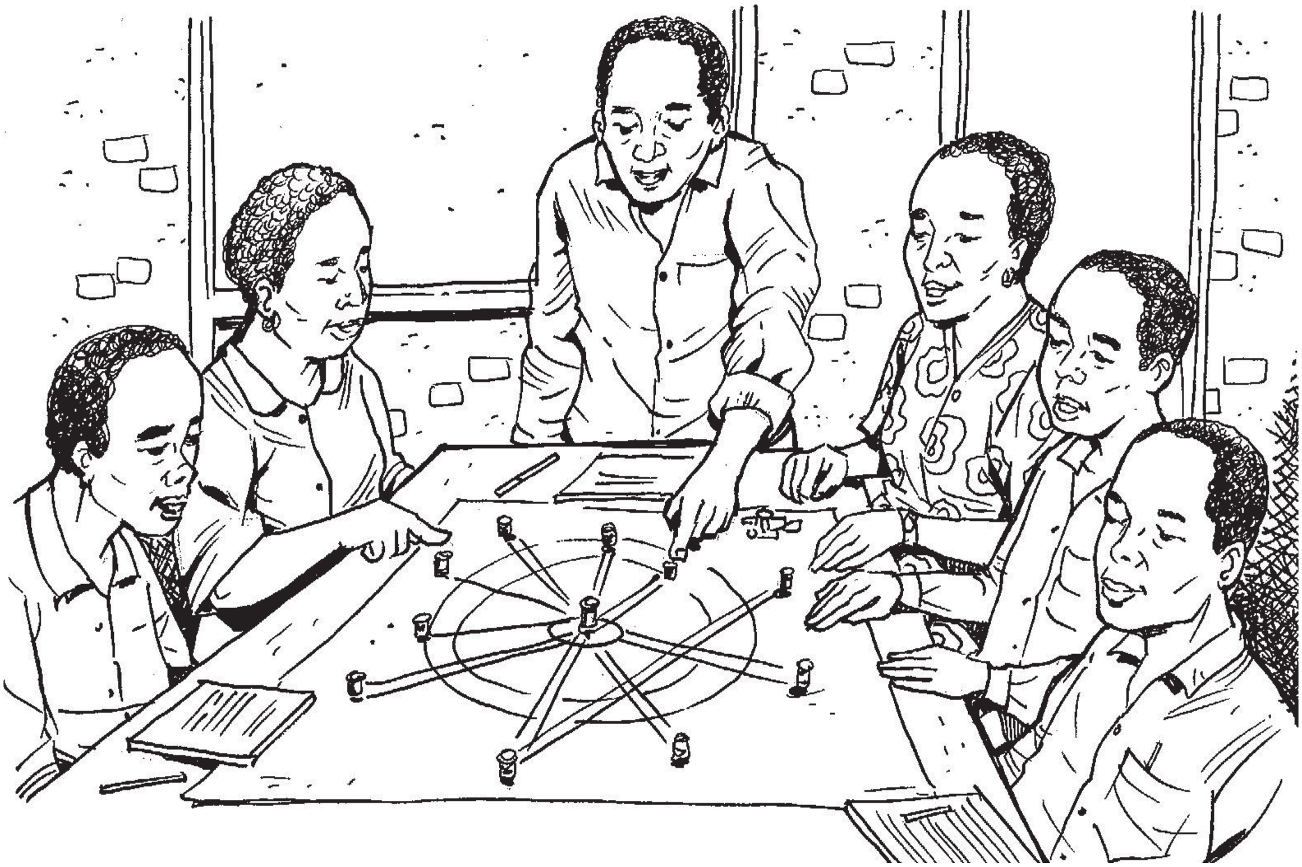
Lazarus, K., D.J.H. Blake, J. Dore, W. Sukraroek and D.S. Hall 2012. Negotiating flows in the Mekong. In: *Politics and development in a transboundary watershed: The case of the lower Mekong Basin,* eds. J. Ojendal, S. Hansson and S. Hellberg; 127-153. New York: Springer-Verlag.

Lebel, L., J. Dore, D. Rajesh and Yang Saing Koma (eds.) 2007. *Democratising water governance in the Mekong Region*. Chiang Mai, Thailand: Mekong Press.

Molle, F., T. Foran and M. Kakonen M (eds.) 2009. *Contested waterscapes in the Mekong Region: Hydropower, livelihoods and governance.* London: Earthscan.

M-POWER 2011. *M-POWER Strategic Guide 2011, Mekong Program on Water, Environment and Resilience.* Vientiane, Lao PDR. Retrieved from: www.mpowernetwork.org

Integrating Governance and Modeling for Better Use of Water Resources



Land and water resources in river basins need to be managed in economically efficient, environmentally sustainable and socially acceptable ways if they are to remain productive. Integrated simulation models, developed in close collaboration with multiple stakeholders, can help. One such research effort by the CGIAR Challenge Program on Water and Food (CPWF) is the project "Integrating governance and modeling". The project made use of computer models and Net-Map. These were found to be very useful in understanding interactions and fitness of solutions in addressing governance problems. Multi-stakeholder governance structures such as river basin management boards benefit from access to policy-relevant information about the economic, social and environmental impacts of different options for managing water resources. The tools were tested in project sites in the upper east region of Ghana (representing the early stage of basin development) and in the Maule region of Chile (representing the advanced stage of river basin development). The way farmers interact with and react to changes in their economic and natural environments was simulated using computer modeling or the Mathematical Programming-Based Multi-Agent System (MP-MAS) developed by Hohenheim University in Germany. The project collaborated with stakeholders, such as water-user associations and members of irrigation and agricultural administration.

The project also led to the development of an innovative method for research and organizational development, called Influence Network Mapping (Net-Map), to support the establishment of the White Volta Basin Board in Ghana. Net-Map was subsequently integrated in the participatory impact pathway analysis (PIPA) approach and is now being used by international research and development organizations and universities worldwide.

Using Net-Map to work with stakeholders

Net-Map (http://netmap.wordpress.com) is a participatory research method, which combines elements of stakeholder mapping and ranking techniques with social network analysis. The method is particularly suited to find out how much influence different actors have (or had) on achieving defined outcomes, and what the sources of their influence on those outcomes are. Influence as defined in this context is based on Max Weber's definition of power, which holds that an actor can induce others to act according to his or her will, despite potential resistance from those actors. The method can be applied to individual respondents or groups.

In 2008, Eva Schiffer won that year's CGIAR Promising Young Scientist Award for developing Net-Map.

The idea of developing Net-Map came to Schiffer after being involved in the CPWF PIPA workshop, where each project in the Volta Basin drew a network of actors on which their project had influence. Schiffer's original idea was based on her observation that the relative influence of different partners needed to be included in the network analysis. How Schiffer came to conceptualize Net-Map is an example of the potential for network meetings and workshops to lead to innovation.

In Ghana, Net-Map was applied to help board members to better understand the networks that they needed to rely on in order to pursue their development and environmental goals effectively. The application of the Net-Map method assisted the board in forming strategic partnerships with the district assemblies. Net-Map was also used as a diagnostic tool to analyze policy processes in Chile.

Net-Map is user-friendly because it is easy to learn and apply, appeals to researchers and implementers, allows for quantitative and qualitative analysis and focuses on questions that are of general concern as people attempt to achieve goals in social settings.

Net-Map has been used in more than 25 projects in Africa, Europe and Asia; in projects involving the World Bank, FAO, IFAD, Red Cross, IFPRI, Inter-American Development Bank, ICARDA, African Peer Review Program, InWent, and ILRI; and in universities in the developed and developing world. Visit (http://netmap.wordpress.com/) for more details.

Refined and field-tested agent-based modeling tool using MP-MAS

The MP-MAS is a software application package for simulating land-use changes in agriculture and forestry. It is a combination of farm economic models and several biophysical models to simulate crop yield response. Household- and community-

MP-MAS is a freeware application developed at Hohenheim University and can be downloaded from http://mp-mas.uni-hohenheim.de. MP-MAS simulates the interactions of farm households with other households and the biophysical environment. The software combines household models with growth models and hydrological models.

level surveys were carried out in Chile and Ghana to generate data for MP-MAS. The surveys also provided in-depth data for studies on specific governance problems, using econometric methods. Stakeholder workshops were held regularly to ensure that the computer-based decision tools could be developed and validated in close interaction with the concerned stakeholders.

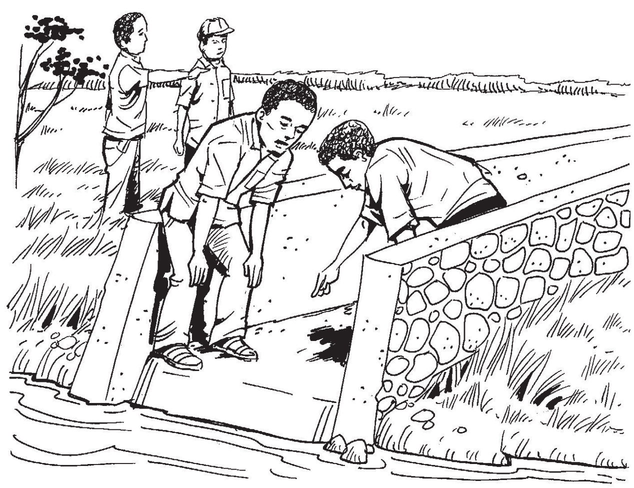
The project applied MP-MAS to develop a decision-support tool for the two river basin organizations. MP-MAS simulated how farmers interact with each other and react to changes in their economic and natural environment. A key innovation of the project was the development of the tool in close interaction with multiple stakeholders, including water user associations and members of the irrigation and agricultural administration. This interaction, which occurred through individual consultations, workshops and training sessions, ensured that the MP-MAS simulations addressed the needs and priorities of different stakeholders and took their local knowledge into account.

Agent-based simulation models have shown much promise in encouraging stakeholder interaction in natural resource management, especially in combination with role-playing games and other qualitative research approaches. But, to date, no practical experience existed with using agent-based simulation as a 'quantitative' interactive tool. This project is the first that coupled cutting-edge simulation software such as MP-MAS (an agent-based model) with WASIM-ETH (a process-based hydrology model).

Areas of policy change

Making optimum use of the Ancoa Dam

Using MP-MAS helped water user associations and the irrigation administration better understand how the benefits from investing in the proposed Ancoa Dam in Chile will be distributed. This will assist both the farmers and the administration to



make optimum use of this large-scale investment. MP-MAS also showed that the government needs to pay more attention to reaching smallholder farmers when reforming the subsidy programs for irrigation investments. Smallholders with insufficient water rights, who benefit from unused water resources and spill-overs in the present system, may not only fail to benefit, but may even lose sources of income as a consequence of irrigation investments. This underlines the need to identify alternative income sources for them. Both the water user associations and the irrigation administration in Chile have decided to use MP-MAS for future planning and management.

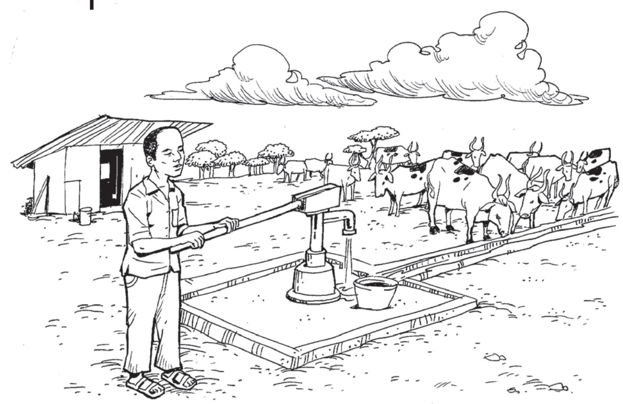
Modeling shows that irrigation and water makes fertilizer much more profitable in Ghana helping farmers to move out of poverty.

Farmers in Ghana who have access to irrigation could triple their fertilizer use if they had access to credit, even if the fertilizer is not subsidized. Considering the international policy debate on fertilizer use in Africa, this is an important insight that shows how access to irrigation is in making fertilizer more profitable. MP-MAS simulation results also show that farmers in the semi-arid north of Ghana who do not have access to irrigation will not move out of poverty, even if they have access to fertilizer and credit, thus highlighting the need for giving them access to irrigation. MP-MAS simulations also indicate that pumping water directly from the river is not a viable option at current prices.

Governance is a major challenge to expansion.

The project revealed that, even though investing in small-scale reservoirs is a promising strategy to expand access to irrigation in northern Ghana, it is confronted by major governance challenges. A survey conducted under the project showed that out of 19 small reservoirs constructed with substantial donor funding between 2000 and 2006 in the upper east region of the country, only three were in fact used for irrigation. Problems in procurement and construction of the reservoirs were identified as major constraints, next to shortcomings in the required technical expertise. This project suggests that these problems be addressed before donor agencies invest in new small reservoirs, for example, by strengthening the accountability of contractors and the irrigation administration to local water user organizations and their elected representatives.

Outcomes and impacts



In Ghana, the project had three major impact pathways:

- When it comes to water governance, critical decisions and investments are undertaken at the district level. It is not necessarily those who are in the hierarchy who are most influential.
- The Ministry of Food and Agriculture can now use the information generated through agent-based modeling for designing agricultural programs.
- Donor agencies and the Ghana Irrigation Development Authority are at the center of the third impact pathway, which focuses on the improvement of small reservoirs.

Taken together, the three pathways have the potential to improve the use of a considerable amount of funding that the government and donors are planning to invest in the northern part of Ghana. Moreover, the project has important messages for other countries in Africa that aim to use small-scale irrigation.

In the case of Chile, the project has four major impact pathways, which involve the following organizations:

- the National Agricultural Research Institute (INIA),
- the National Irrigation Commission (CNR),
- the National Agricultural Development Institute (INDAP), and
- the umbrella organizations of the water user associations in the region (JdVs).

INIA has become the host institution for the MP-MAS computer tools, and the other organizations have started to use MP-MAS to make informed decisions. The expected impact is a more efficient use of water resources in the region and a more equitable use of public funds spent on water resource development. The findings from Chile are also relevant to a range of other countries, especially those that are at a similar stage of river basin development and those that aim to follow the 'Chilean model.'

Conclusion

River basin organizations are complex governance structures that govern the use of important water resources all over the world. Their access to policy-relevant information is important for the negotiation and resolution of sustainability issues in their jurisdiction. MP-MAS and Net-Map are useful tools that help unearth information relevant to the river basin organizations' operations and predict outcomes from a whole range of possible options.

Contact Person

Eva Schiffer (eva-schiffer@web.de)

Partner Organizations

International Food Policy Research Institute
Institute of Statistical, Social and Economic Research, University of Ghana
Instituto de Investigaciones Agropecuarias (INIA), Chile
Leibnitz Center for Environmental Research, Germany
Universidad de Talca, Chile
Universitat Hohenheim, Germany
Water Resources Institute, Ghana

Key Reference

IFPRI. 2010. *Integrating knowledge from computational modeling with multi-stakeholder governance: Towards more secure livelihoods through improved tools for integrated river basin management*. CPWF Project Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.
http://hdl.handle.net/10568/3771

Tags: PN40; Integrating Governance and Modeling

Bibliography

Harrington, L.W., E. Humphreys, A. Huber-Lee, S. Nguyen-Khoa, S. Cook, F. Gichuki, N. Johnson, C. Ringler, K. Geheb and J. Woolley 2008. *A summing up: synthesis '07*. CPWF Synthesis Report. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food.

Schiffer, E. and J. Hauck 2010. Net-Map: Collecting social network data and facilitating learning through participatory influence network mapping. *Field Methods,* 22, 231-249.

Woolley, J. 2010. *Legacy of PN 40: Integrating governance and modelling.* Unpublished manuscript.

Assessing Institutional Capacities for Flood Disaster Risk Reduction

Floods are the most frequent and devastating of natural disasters in the Asian region and, like disasters in general, their impacts have grown in spite of our improved ability to monitor and describe them (White *et al.* 2001).

States no longer respond to disasters, they manage disaster risks, and do so with increasingly sophisticated institutional frameworks. Throughout Asia the retreat of disastrous floods is followed by the sprouting of new agencies and institutional arrangements for planning and coordination. But are these efforts leading to reduced risks? Are capacities for risk reduction being institutionalized? Are the livelihoods of poor and vulnerable groups being secured?

These are primarily questions about politics, institutional capacities and performance. Our primary thesis is that there are important political components to interventions in vulnerability and disaster reduction programs. Our aim is to help identify where institutional arrangements are themselves contributing causes of vulnerability.

In this paper, we derive and present an initial framework for assessing institutional capacities for flood disaster risk reduction. This paper is organized around sections discussing five questions that build up to this framework: When is a flood a disaster? Who and what should be at risk? Who is or should be responsible? How were risks of disaster changed? How was performance evaluated?

When is a flood a disaster?

In the tropical parts of Asia, most of the major cities have grown in the deltas literally building on the foundations of a rice-growing civilization. The landscape has been managed for floods for centuries. Communities whose livelihood depends on the productive functions of "normal" seasonal flood cycles have learned to live with floods and have embraced their arrival with songs and dances.

Over the last few decades, industrialization and the accompanying processes of urbanization have led to very different land-use patterns, economic structures and livelihood bases. Political organization has also changed. Floods are now perceived as much more threatening events by people for whom the idea of living with floods is anathema to a modern society built around highways and the automobile.

As the potential of floods, when they occur, to be a disaster has increased, societies have invested more in prospective structural measures (Takeuchi 2001). Decades of economic growth also mean that the domestic resources available to households, firms and state authorities to address "disaster" risks and events have substantially increased in most countries. At the same time, what constitutes a flood disaster has correspondingly shifted from an emphasis on losses of life and famines from crop failures, to losses of property and investments.

These distinctions reflect changing perceptions and beliefs about societies' relationship to nature. Floods are now more likely to be seen as a hazard that has to be controlled. Although all groups may be negatively affected by "catastrophic" floods, impacts of "normal" and some "major" flood regimes may vary among different livelihood-based groups. What is perceived and regarded beneficial by rural farmers may be seen as disastrous and hazardous by the urban population. Therefore, it is important to expose whose perspective defines a flood event as "hazardous" and disastrous. Not surprisingly, an operational definition of what constitutes a flood disaster remains a contentious political issue (Few *et al.* 2004).

There are two main discourses on flood disasters (Adger 1999, Bankoff 2004, Dixit 2003). The first and dominant view is that flood disasters are inherently a characteristic of natural hazards. Disasters arise inevitably when the magnitude of a hazard is high. This contrasts with the alternative discourse that sees flood disasters as being jointly produced by interaction of the physical hazard and social vulnerabilities. This alternative discourse brings into the fore social relations, structures, institutions and governance in understanding flood disaster. This view posits that flood disasters are the result not only of natural hazards but also of socio-economic structures and political processes that make individual, families and communities vulnerable (Blaikie *et al.* 1994, Dixit 2003).

Who and what should be at risk?

This is the central unasked question in disaster management. Framing disaster as solely a technical problem has constricted spaces for participation and transparency and in the process conceals the politics of shifting risk to already vulnerable groups. The only way sharing of involuntary risks can be negotiated is to have interests of marginalized and vulnerable groups represented, the quality of evidence debated and challenged and authority held accountable for its decisions. Alternative dialogues, the mass media and acts of civil disobedience may be critical to raise issues of flood disaster programs. Without opportunities for deliberation, women-headed households, the elderly, ethnic minorities and other marginalized groups are unlikely to benefit and may even be disadvantaged by programs and policies aimed at reducing risks of flood disasters.

Debate, consultation and planning procedures for flood and disaster management need to be assessed by criteria similar to those used to analyze "good governance" (Table 1). In particular, focus is needed don issues of participation, representation and sources of knowledge. In most countries, such assessment would highlight how, at least until fairly recently, the public has been treated as irrelevant to the technical exercise of assessing and managing risks and designing institutional responses.

Things may be changing. A return to a community-based flood disaster management is being widely promoted by international agencies, but only cautiously adopted by national ones (ADPC 2000, Few 2003, Morrow 1999).

The key idea is that greater involvement of the public in decisions about all stages of a disaster cycle will make better use of local knowledge and capacities and help identify risks and pragmatic opportunities to address them. Early results of community-based flood management strategy (CFMS) pilot areas in Bangladesh suggested huge dividends in reducing vulnerability of affected communities during the 2004 flood (Ahmed *et al.* 2004).

The area requiring the most profound engagement with wider stakeholder groups is in assessing and addressing the underlying causes of vulnerability. State agencies usually find it very difficult to do as it requires addressing fundamental issues of governance and social justice that may undermine positions of authority.

Extremely low asset levels, poor access to natural resources and insufficient rights to public goods and services are often at the core of these vulnerabilities (Blaikie *et al.* 1994, Dixit 2003).

In contrast to the neglect of questions about "who will be at risk" questions of "who will pay" are intensely debated from day one. The main debate is often between levels in the administrative hierarchy: should funds come from the local, regional or the central budget? Local governments often find they need to locate additional sources to fund recovery and rehabilitation operations.

Constant debates and controversies between the 'center' and the regions requesting increased involvement and support from the central authorities, especially at recovery stages where mobilization of significant funds is essential, can turn into conflicts and gridlocks that weaken institutional performance.

In many places, there is a need to go beyond participation being defined as simply informing the public or being seen as an opportunity to shift the burden onto communities for actions that should have been the responsibility of public and authorities (Lebel and Sinh 2007). Participation should result in empowerment of marginalized and vulnerable groups in decision-making around who and what should be at risk (Osti 2004).

Framework for assessing institutionalized capacities and practices with regard to flood-related disasters

Function	**Phase of disaster cycle (Timing)**			
	Mitigation (Well before)	**Preparedness (Before)**	**Emergency (During)**	**Rehabilitation (After)**
Deliberation What should be done?	How were decisions made about what and who should be at risk? Whose knowledge was considered and whose interests were represented?	Was the public consulted about disaster preparations? How were decisions to give special powers to particular authorities made?	How were decisions made about what and who should be saved or protected first? What special directives or resolutions were invoked?	How were decisions made about what is to be on the rehabilitation agenda? Whose knowledge was considered and whose interests were represented?

Function	Phase of disaster cycle (Timing)			
	Mitigation (Well before)	**Preparedness (Before)**	**Emergency (During)**	**Rehabilitation (After)**
Coordination Who is responsible?	What national basin-level policies, strategies or legislation were in place to reduce risks of disaster? What structural measures were undertaken to reduce likelihood of severe flood events? To what extent were laws and regulations regarding land use in flood prone areas implemented?	How were responsibilities divided among authorities and the public? Was an appropriate early warning system implemented? Were public authorities well prepared?	How were specific policies targeting emergency operations implemented? Were there gaps between stated responsibilities and performance of key actors? Who was in charge?	Were the resources mobilized for recovery adequate? Were they allocated and deployed effectively? How was rehabilitation integrated into community, basin or national development?
Implementation How was it done?	What measures were taken to improve coping and adaptive capacities of vulnerable groups?	Was the public well informed? How were specific national or basin-level policies targeting disaster preparedness implemented?	How were emergency rescue and evacuation operations performed? Were special efforts made to assist socially vulnerable groups? Were there any measures taken to prevent looting?	Did the groups who most needed public assistance get it? Who benefited from reconstruction projects? Was insurance available and used and, if so, how were claims processed? Was the compensation process equitable and transparent?
Evaluation Was it done well?	How is the effectiveness of risk reduction measures assessed?	How is the adequacy of preparedness monitored?	How is the quality of emergency relief operations evaluated?	How is the effectiveness of the rehabilitation programs evaluated?
	To whom and how are authorities held accountable? Were institutional changes made to address capacity and practice issues learned in the previous disaster cycle?			

Who is or should be responsible?

Being able to count on institutionalized capacities to mobilize and coordinate resources when and where they are needed is crucial in all phases of the disaster cycle, sometimes with very little scope for delay or errors of judgment. Because there are many uncertainties involved in knowing where disasters will occur, and exactly how they will unfold, it is important that this "institutionalizing" aspect fosters flexible and adaptive responses that rely on coordination.

Coordination among agencies and stakeholder groups is important for flood mitigation, in particular, the design and execution of programs and policies to help address underlying causes of extreme vulnerability (Lebel *et al.* 2011).

Mobilizing adequate funds, both for protection measures before an event and for recovery, and rehabilitation of affected areas and livelihoods after is the core "coordination" and "cooperation" issue for local authorities, because it has a large bearing on their ability to implement plans. What will be the major sources of funding? Who will benefit most from their deployment? (Kitamoto *et al.* 2005).
If local authorities have the capacity and legal framework that enables them to seek loans and private-sector cooperation, then they may be able to secure more and diverse funds for disaster risk management.

Coordination of activities across phases of the disaster cycle is necessary because there is often need to link or transfer responsibilities and budgets for programs over time. One approach is through limitedlife but clear objective cross-agency and multi-stakeholder task forces that can help guide these transitions.

How were risks of disaster changed?

Wonderful planning and coordination mean nothing when it comes to reducing the risks of disaster if there is no follow-through, because of corruption or other institutionalized incapacities that prevent appropriate use and allocation of these resources.

Assessing institutionalized capacities to effectively use resources and execute critical actions requires several different kinds of measures, corresponding to different kinds of resources and actions. At the simplest and most conventional level, we need to look at actual structural and non-structural responses made in preparing for, and responding to, flood disasters.

Forecasting and early warning systems are often the weakest element in the chain of purpose-built institutions for reducing risks of flood disasters. First, there are the technical challenges of obtaining critical information and sharing it in a timely fashion. Second, there are organizational and individual behaviors that undermine otherwise sound information-sharing arrangements.

In most countries, a national-level institutional framework for emergency response is well established. Normally, such frameworks incorporate a set of administrative structures, governmental programs and legal frameworks defining the conduct and interactions between specialized task forces, that are usually well trained and able to perform skillfully in extreme situations. Often, the military is involved.

For the most part, implementation always lags far behind promises and ideals when it comes to addressing the underlying causes of disasters.

Consider, for example, issues related to housing and road construction both in mountain areas and in floodplains. Economic imperatives would argue for taking structural measures to protect these investments before disasters strike, rather than exploring their role as contributing causes of disasters after the fact. Poorly constructed roads destabilize slopes or act as channels for debris in mountain areas, whereas in deltas and wetland areas, they can prevent and alter natural drainage, thus increasing the duration and height of floods.

During post-disaster periods, there is often a flurry of programs, investments and rule changes. All such actions are far more likely to be followed up and implemented if there is a significant group of stakeholders involved, who have a sense of ownership and responsibility for them. This means going beyond the project-bounded logic of "implementation" ending when the final budget item of the initial action has been spent, towards integrating projects and programs into local development. In a real sense, it is about creating a sense of stewardship for disaster risk management. This is most likely to be fostered when there is significant decentralization to local authorities who are, in turn, accountable to local affected communities.

How was performance evaluated?

The performance of institutions and organizations should be monitored and evaluated. This has to be done with a degree of independence or the opportunities for organizations to learn, for authorities to be held accountable, and for success at reducing the risks of the next disaster will themselves be reduced.

The presence of institutionalized evaluation and monitoring procedures of the disaster management system is a must. Otherwise, there can be no improvements in performance or adjustments to take account of changing contexts such as altered flood regimes resulting from climate change. A more thorough assessment would also need to take a historical perspective to review the extent to which learning had actually taken place (Krausmann and Mushtaq 2005), above and beyond factors simply reflecting technological change or increasing wealth. Apart from social learning, conventional learning by key individuals about risks, vulnerable groups and places or about experiences from other places and times may be important in reducing risks of disaster too. The capacity for current arrangements to foster these kinds of learning should also be assessed.

An assessment framework like the one we are now discussing could itself be part of an institutionalized learning process by key disaster organizations. Regular assessment exercises by particular publics and bureaucracies could consult expert advice as needed. Thorough and well-communicated research could contribute to such evaluations.

Assessing institutionalized capacities and practices

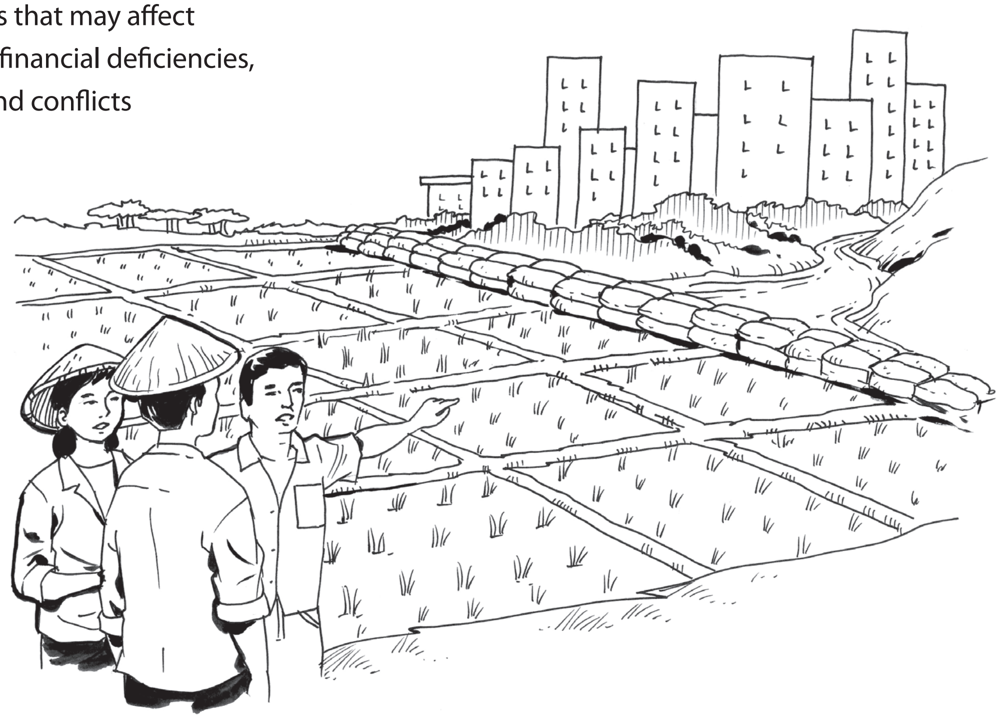
From our brief review, it is clear that significant capacities to reduce the risks of flood disasters lie both within actors and in the relationship among actors. Institutionalized capacities arise from the relations that regularly define roles and responsibilities and rules of engagement, in ways that enhance the capacity of actors institutionalized capacities.

Relationships among actors have different functions that may be institutionalized (Lebel *et al*. 2006). We derive a framework focused on four classes of institutionalized capacities and practices (See table). The capacity for deliberation and negotiation is important in ensuring that interests of socially vulnerable groups are represented and different kinds of knowledge can be put on the table for discussion and that, ultimately, fair goals are set. The capacity to mobilize and then coordinate resources is often critical to prevention and response actions. The capacity to skillfully use those resources to carry out actions transforms potential into implementation. Finally, the capacity for evaluation is important because it can be the basis for continuous improvement, adaptive course corrections and learning by key actors. We can also ask questions about each kind of relationship across four conventionally designated phases of the disaster cycle. In the case of evaluation, these questions are similar and largely cross-cutting.

Finally, gaps between stated policy goals and practice or those between design and action contribute to increased vulnerabilities. A broad variety of factors influences institutionalized practices. External factors that may affect implementation include financial deficiencies, administrative barriers and conflicts between organizations, corruption, poverty, lack of economic incentives and low participation and awareness. Situational factors might block or alter the performance of institutions or modify the designed pathways for implementation of policies and tools.

Conclusions

Inspite of the better understanding of disasters, losses of life and property from flood disasters remain unacceptably high and are increasing (Vorobiev *et al.* 2003; White *et al.* 2001). Institutional reforms with the aim of reducing the risks of flood-related disasters have largely been unsuccessful. There are five main reasons. First is the misplaced emphasis on emergency relief to the detriment of crafting institutions to reduce vulnerabilities and prevent disasters. Second is the self-serving belief that disaster management is a technical problem that calls for expert judgments that systematically exclude interests of the most socially vulnerable groups. Third is the over emphasis on structural measures, which again and again, have been shown to be more about re-distributing risks in time and place than reducing them (Blaikie *et al.* 1994, Lebel and Sinh 2009). Fourth is the failure to integrate flood disasters into normal development planning in flood-prone regions. Fifth is the failure to recognize the importance of learning for building and maintaining social and ecological resilience (Adger *et al.* 2005, Wong and Zhao 2001).



This article suggests that a moderately systematic approach to diagnosis of institutionalized capacities and practices in flood disaster management is feasible and will yield practical insights.

In most flood-affected and -dependent regions, especially in the developing world, institutionalized capacities and practices to reduce the risks of flood disasters remain weak. This is especially true in the fast developing regions where the entire livelihood and socio-economic context is in flux and traditional institutions may no longer be relevant and functioning well and new relationships among firms, communities and state agencies have not emerged or kept pace with shifting risks. The mature industrial and services economies have fewer institutional gaps, but they still face the daunting challenge of escalating costs from the legacy of controlling, rather than living with, floods. The prospects of climate change further exacerbating the effects of flood regimes. Institutional challenges are going to become more important and tougher. A systematic approach to making diagnosis of institutionalized capacities and practices (Lebel *et al.* 2006b) in flood disaster management could help societies identify critical gaps beforehand and thus learn more from experience.

Contact Person

Louis Lebel (lebel@loxinfo.co.th)

Partner Organization

The M-POWER (Mekong Program on Water, Environment and Resilience) Regional Research Network

Key Reference

Lebel, Y.L., E. Nikitina and J. Manuta 2006. Flood disaster risk management in Asia: An institutional and political perspective. *Science and Culture*, **72**, 2-9.

Tags: PN50: Multi-scale Mekong Water Governance

Bibliography

Adger, N.W. 1999. Social vulnerability to climate change and extremes in Coastal Vietnam. *World Development,* 27, 249-269.

Adger, N.W., T. P. Hughes, C. Folke, S. R. Carpenter and J. Rockstrom 2005. Social-ecological resilience to coastal disaster. *Science* 309, 1036-1039.

ADPC 2000. *Community-based disaster management. Trainer's Guide. Bangkok,* Thailand: Asian Disaster Preparedness Centre.

Ahmed, A.U., K. Zahurul, K. Prasad, S. N. Poudel and S. K. Sharma 2004. *Synthesis of manuals on community flood management in Bangladesh, India and Nepal.* Asia Pacific Journal of Environment and Development 11.

Bankoff, G. 2004. In the eye of the storm: the social construction of the forces of nature and the climatic and seismic construction of god in the Philippines. *Journal of Southeast Asian Studies,* **35**, 91-111.

Blaikie, P., T. Cannon, I. Davis and B. Wisner 1994. *At risk: Natural hazards, people's vulnerability, and disaster.* Routledge London.

Blaikie, P.M. and J. S. S. Muldavin 2004. Upstream, downstream, China, India: the politics of environment in the Himalyan region. *Annals of the Association of American Geographers*, **94**, 520-548.

Dixit, A. 2003. Floods and vulnerability: need to rethink flood management. *Natural Hazards*, **28**, 155-179.

Few, R. 2003. Flooding, vulnerability and coping strategies: local responses to a global threat. *Progress in Development Studies,* **3**, 43-58.

Few, R., M. Ahern, F., Matthies and S. Kovats 2004. *Floods, health and climate change: a strategic view.* Working Paper No. 63. Tyndall Centre for Climate Change Research.

Kitamoto, M., E. Tsunozaki and A. Teranishi 2005. Institutional capacity for natural disaster reduction in Japan. USER Working Paper No. 2005-11. Unit for Social and Environmental Research, Chiang Mai University, Chiang Mai.

Krausmann, E. and F. Mushtaq 2005. A methodology for lessons learning experiences at the European level. In: *Measuring vulnerability and coping capacity to hazards of natural origin: concepts and methods,* ed. J. Birkmann. Tokyo, Japan: UNU Press.

Bibliography

Lebel, L., S. Khrutmuang and J. Manuta 2006. Tales from the margins: small fishers in post-Tsunami Thailand. *Disaster Prevention and Management,* **15**, 124-134.

Lebel, L., B. J. Manuta and P. Garden 2011. Institutional traps and vulnerability to changes in climate and flood regimes in Thailand. *Regional Environmental Change*, **11**, 45-58.

Lebel, L., E. Nikitina, V. Kotov and J. Manuta 2006. Assessing institutionalized capacities and practices to reduce the risks of flood disasters. In: *Measuring vulnerability and coping capacity to hazards of natural origin: concepts and methods,* ed. J. Birkmann; 359-379. Tokyo, Japan: UNU Press.

Lebel, L. and B. T. Sinh 2007. Politics of floods and disasters. In: *Democratizing water governance in the Mekong region,* eds. L. Lebel, J. Dore, R. Daniel and Y. S. Koma; 37-54. Chiang Mai, Thailand: Mekong Press.

Lebel, L. and B.T. Sinh 2009. Risk reduction or redistribution? Flood management in the Mekong region. *Asian Journal of Environment and Disaster Management,* **1**, 23-39.

Morrow, B.H. 1999. Identifying and mapping community vulnerability. *Disasters*, **23**, 1-18.

Osti, R. 2004. Forms of community participation and agencies' role for the implementation of water-induced disaster management: protecting and enhancing the poor. D*isaster Prevention and Management*, **13**, 6-12.

Takeuchi, K. 2001. Increasing vulnerability to extreme floods and societal needs of hydrological forecasting. *Hydrological Sciences Journal,* **46,** 869-881.

Vorobiev, U., V. Akimov and U. Sokolov 2003. *Catastrophic floods of the beginning of the XXI century* (in Russian). Moscow: Desk, Press.

White, G.F., R. W. Kates and I. Buron 2001. Knowing better and losing more: the use of knowledge in hazards management. *Environmental Hazards,* **3**, 81-92.

Wong, K. and X. Zhao 2001. Living with floods: Victim's perceptions in Beijiang, Guangdong, China. *Area*, **33**, 190-201.