Synthesis 2006

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CGIAR Challenge Program on Water and Food

Contents

Executive summary

The purpose of this report is to summarize and synthesize activities and achievements of the CPWF through the end of 2006.

The CPWF is a CGIAR Challenge Program designed to take on the global challenge of water scarcity and food security. It takes the form of an international, multi-institutional research-for-development initiative that brings together scientists, development specialists, and river basin communities in Africa, Asia and Latin America. It seeks to create and disseminate international public goods (IPGs) helpful in achieving food security, reducing poverty, improving livelihoods, reducing agriculture–related pollution, and enhancing environmental security.

This Challenge Program is a three-phase, 15-year endeavor. Several years have passed since the start of Phase 1 (2003-2008) which began with an inception phase in 2003 and was followed by full CPWF launch in January 2004. Research projects began field operations in mid-2004. This synthesis report, then, only describes work carried out in the first two and a half years of the Program.

During this time, CPWF has conducted its research on water and food in nine benchmark basins, organized around five different themes. This work is being implemented through "first call projects", "basin focal projects", "small grant projects" and "synthesis research". This present report is one example of the latter.

CPWF projects have made considerable progress in developing innovative technologies, policies and institutions to address water and food issues. Some projects focused on improving agricultural water productivity. Others focused on developing mechanisms to inform multi-stakeholder dialogue and negotiation, or explored ways to value water used to produce ecosystem services. Advances were also made in understanding water-food-poverty links, and their regional and global policy context.

Projects and outputs

One part of the CPWF's work has focused on increasing water productivity in rainfed environments. Achievements include the further development of conservation agriculture for no-till sowing into crop residues; "slash and mulch" to replace "slash and burn" practices in hillside systems; water harvesting systems for dryland locations; understanding livelihood vulnerability and farmer's coping strategies; and developing and encouraging the distribution (through participatory varietal selection and seed schemes) of drought-tolerant varieties of sorghum, wheat, and other crops.

Progress has also been made in increasing water productivity in irrigated and salt-affected environments, especially where water is scarce and there are opportunities to increase water productivity. Examples include development and testing of salt-tolerant germplasm for rice and other crops to make more effective use of salt-affected areas; understanding how to use wastewater in irrigated peri-urban agriculture to produce vegetables that are safe and nutritious; and aerobic rice management practices and development of new germplasm to produce more rice with less water in water-scarce areas.

The CPWF has also worked on developing ways to foster multi-stakeholder dialogue and negotiation. Examples include advances in understanding in how to use "payment for environmental services" (PES) so that downstream water users can influence upstream water management; progress at the global level in fostering an increased awareness of and appreciation for multiple-use water systems (MUS); strategies for dealing with seawater incursion into rivers; improvements in the understanding of indigenous water

use institutions in Africa to help identify new approaches to transboundary water governance; improvements in managing small reservoirs in dry areas; and advances in strengthening multi-stakeholder governance structures by identifying problems, shaping policy options, and enabling stakeholder evaluation of options via simulation models.

Ecosystem services and environmental flows have been important subjects. One example is the evaluation of trade-offs among crop, livestock and other ecosystem services in wet lowlands and riverine swamps in the Limpopo basin. Work proceeds in several basins on the development of methods for estimating the value of water used to produce ecosystem services, beginning with the identification of these services. Rice fields, for example, provide unique (but often unrecognized) services such as providing a habitat for birds and fish, recharging groundwater, mitigating floods, controlling erosion (through terraces), flushing salts from the soil, providing water filtration, and regulating temperature/ climate.

In the area of integrated river basin management, ways have been found to introduce livestock into the water productivity equation while capacity-building is being used as means of addressing seemingly intractable problems of groundwater governance. A new series of whole-basin research projects ("Basin focal projects") have made progress in understanding the consequences of water management in one location on water availability in other locations in a basin, and in linking CPWF projects with related non-CPWF activities and with development agencies.

Policy research has been conducted on global and national issues (globalization, trade, and sectoral policies). This includes research on water rights reform and the use of multi-stakeholder platforms to ensure rights for the poor under global change processes. Further examples of research on policy issues include work on incentives, investment and financing of agricultural water development; transboundary water policy and institutions; and adapting to changes in the global water cycle.

Challenges and opportunities

This report suggests a number of areas where CPWF projects might be able to go even further in integrating and strengthening their work.[1] These include:

- Building more systematically on what is known – for some questions in some basins, a body of experience already exists, which can serve as a foundation for further advances by the CPWF
- Fostering greater sharing of information and experience across projects working on similar issues in similar environments
- Paying more attention to scaling out and up of technical and institutional innovations studied at the farm or community level
- Designing institutional innovations for sustainability
- Expanding work on methods for understanding and managing downstream and cross-scale consequences of innovation
- Encouraging improved integration across themes and between themes and basin focal projects

[1] The cut-off date for information used in this report is December 31, 2006. During the course of 2007, the CPWF began to address many of the suggestions noted in this section.

- Understanding how the global or national policy context may pre-determine the extent to which farm- or community-level level technical or institutional innovations can be widely adopted.
- Confronting the question, "To what extent does success in improving crop water productivity truly help solve problems of poverty and food insecurity?"

Introduction

In November of 2006, an International Forum on Water and Food was held in Vientiane. Subsequent to its deliberations, the Forum issued what has come to be known as the "Vientiane Statement". This statement contains a vivid description of water-related problems at the global level and what can be done about them through research, development, investment, and policy change. Ending with a call to action, the Statement begins as follows:

"We recognize the huge global problems posed by hunger, poverty, and disease. These same problems inspired the adoption of the Millennium Declaration by the United Nations. We recognize the many obstacles to overcoming these problems, among them climate change, resource degradation, and impaired ecosystems. We perceive, however, the presence of a further issue of paramount importance, one that must be addressed if the Millennium Development Goals are to be achieved: the rapidly unfolding and unprecedented crisis of global water scarcity . . . Growing and urbanizing populations will need more water for household consumption, power generation, and industrial production – and for increased food production and the provision of important ecological services. Over the next 20 years, food production must increase by over 30%, much of it in poor, water scarce developing countries. This must be achieved without excessive damage to ecosystems . . . We seek a more water and food secure world, one where wise water management, innovative technologies and effective institutional arrangements work together towards eliminating hunger, poverty and disease, and where ecological services and resource quality are preserved. Such a world is within our reach."

For the past several years, the CGIAR Challenge Program on Water and Food (CPWF) has planned and carried out an aggressive and innovative program of research on the very issues raised by the Vientiane Statement. The purpose of this report is to summarize and synthesize activities and achievements of the CPWF through the end of 2006.

Challenge Programs

Several years ago, the Consultative Group on International Agricultural Research (CGIAR) decided to incorporate a programmatic approach to research planning and funding to complement existing approaches. The result was a set of Challenge Programs (CPs). A CP is defined as a time-bound, independently-governed program of high-impact research that targets the CGIAR goals in relation to complex issues of overwhelming global and/or regional significance, and requires partnerships among a wide range of institutions in order to deliver its products.

The CGIAR Challenge Program on Water and Food (CPWF)

The CPWF is a CGIAR Challenge Program designed to take on the global challenge of water scarcity and food security. It takes the form of an international, multi-institutional research-for-development initiative that brings together scientists, development specialists, and river basin communities in Africa, Asia and Latin America. It seeks to create and disseminate international public goods (IPGs) helpful in achieving food security, reducing poverty, improving livelihoods, reducing agriculture–related pollution, and enhancing environmental security.

This Challenge Program is a three-phase, 15-year endeavor. Several years have passed since the start of Phase 1 (2003-2008) which began with an inception phase in 2003 and was followed by full CP launch in January 2004. Research projects began field operations in mid-2004.[2] This synthesis report, then, only describes work carried out in the first two and a half years of the Program.

Research Activities

For the past couple of years, CPWF has conducted most of its research on water and food in nine benchmark basins, organized around five different themes. This work is being implemented through "first call projects", "basin focal projects", "small grant projects" and "synthesis activities".

First call projects: The greater part of the CPWF research agenda is implemented through specific projects that were evaluated and selected through a competitive grant process. CPWF's first call for project proposals yielded a portfolio of 50 high quality projects, of which more than 30 currently receive funding. Most of this report will be devoted to describing the activities and synthesizing the outputs of these projects.

Small grant projects: The 14 small grant projects (whose total cost is equivalent to less than one average "first call" project) exemplify the Program's commitment to research that results in practical outcomes for communities on the ground. These projects aim to identify existing small-scale or local-level water and/or agricultural management strategies or technologies that have the potential to improve agricultural water productivity at a wider scale. Accounts of their activities and outputs have not been incorporated into this synthesis document.

Basin focal projects: Basin Focal Projects (BFPs) add value to Program research by marshaling and making available knowledge, for specific benchmark basins, on water availability and access, water productivity, water poverty, the policy and institutional context within which water-related investments are made, and opportunities for water-related interventions that help meet Program and partner developmental goals. The design, plans, activities and accomplishments of BFPs through 2006 are summarized in a separate section.

Synthesis: The Challenge Program on Water and Food deals with complex, diverse and dynamic systems for which a growing number of stakeholders are generating information. Synthesis research is needed to make sense of the large body of dispersed and disciplinary literature and data that accumulates over time, and to package it in ways that meet the needs of different users. This report is one example of synthesis research.

Water productivity

Water productivity is a fundamental concept in the CPWF and is used in one way or another by most projects, themes and basins. In the context of agriculture, water productivity is defined as agricultural output per unit of water depleted. Crop water productivity is a measure of the ratio of crop outputs and services per unit volume of water depleted. Similarly, livestock water productivity is the ratio of livestock outputs and services per unit volume of water depleted. Crop and livestock outputs and services can be measured in value terms when water has multiple uses. Water depletion is estimated in similar ways regardless of whether the water is used in crop production, livestock or fisheries production, or urban and industrial use. It is the amount of water made unavailable for reuse, through evaporation, contamination or flow to a saline sink.

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[2] Text for this section was adapted from the Vientiane Statement and from introductory material featured in the CPWF 2005 synthesis document.

Benchmark basins

The CPWF believes that research to address issues of water productivity is best conducted in the context of an entire river basin. How water is managed within a basin can have huge effects on agricultural productivity and sustainability, livelihoods, income distribution, and the provision of ecosystem services – defined here as the provisioning, regulating, cultural and supporting functions of ecosystems. An integrated approach is essential to understand how these interrelate. CPWF uses the river basin as a basic unit of analysis to achieve a holistic understanding of natural systems and how they interact with human activity.

Nine benchmark river basins have been selected that present diverse biophysical, socioeconomic and institutional settings. These are the Andes system of basins, and the Indus-Ganges, Karkheh, Limpopo, Mekong, Nile, São Francisco, Volta and Yellow river basins. The selected basins cover Africa, Asia and Latin America. Some basins, such as the Volta or the Limpopo, combine intense poverty with extreme water scarcity in areas dominated by rainfed agriculture. Others, such as the Indus-Ganges or the Yellow River, feature large populations of poor people that are increasingly affected by water and land degradation in both irrigated and rainfed areas. Together, these nine basins contain sufficient variety to represent most of the water and food challenges of developing countries. By focusing on these major basins, CPWF hopes to make significant contributions toward achieving the Millennium Development Goals.[3]

Themes

CPWF themes are a means for addressing different aspects of the water and food challenge and serve to package information at different scales. The CPWF research strategy concentrates its attention on five thematic areas, each one led by a specialist from a different CGIAR center. Theme leaders lead collaborative efforts to understand how the main drivers affecting water and food security evolve over time, and how changes in these drivers will affect future water and food security. The five themes are:

Theme 1: Crop water productivity improvement

Theme 1 seeks to improve crop water productivity by addressing problems of abiotic stress, such as drought, salinity, and nutrient deficiencies. Means for achieving this include crop genetic improvement for stress tolerance, crop and agroecosystem management, landscape management, and innovative institutions and supporting policies.

The challenge confronting Theme 1 is rather broader than might appear on the surface. It is not merely to develop technologies that improve crop water productivity – but rather, to do so in ways that increase food security, reduce poverty, and improve the resilience of farm family livelihoods to unanticipated shocks, e.g., weather and price variability – while simultaneously sustaining or increasing the volume of clean water available for downstream use

[3] Sections on water productivity and benchmark basins were taken from the 2005 synthesis document, with only minor changes.

Theme 2: Water and people in catchments

Theme 2 is concerned with water, poverty and risk in upper catchments. It focuses attention on the multiple ways that people manage water between the plot and the basin scale. Formal or informal institutions often exist for the governance of springs, streams, ponds, wetlands, potable water systems, and other water resources. In many instances, there are opportunities for improving their equity and efficiency. At times, institutions may not be in place to "internalize" important "externalities", as when upstream land and water management practices affect people downstream.

Theme 2 seeks to identify institutional and technological innovations that improve people's capacity to manage water collectively, with special attention paid to ensuring that the needs of women and the poor are not overlooked.

Theme 3: Aquatic ecosystems and fisheries

Theme 3 focuses on fisheries and aquatic ecosystems, their contribution to poor peoples' livelihoods, the value of the ecological services that they provide, and the ways in which estimates of these values are (or are not) taken into account when decisions are made regarding water use. 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 examines environmental water requirements and the valuation of ecosystem goods and services, and seeks innovative ways in which to improve the productivity of aquatic ecosystems through policies, institutions, and governance.

Theme 4: Integrated basin water management systems

Theme 4 helps develop technologies and management strategies compatible with the principles of Integrated Water Resource Management (IWRM). It seeks innovative institutional arrangements and decision-support tools and information to help establish IWRM strategies in basins.

These strategies are based on the fact that, within a river basin, water resources become available and are used for a succession of purposes, e.g., production of plants, animals and fish; rural and urban direct consumption; industrial use and power generation; river transport; and the preservation of wildlife habitat and ecological processes. There may be sizeable opportunities for enhancing water productivity through multiple and sequential uses of water as it cascades through the basin. Effective water resource management at the basin scale takes account, where possible, of medium- to long-term processes of change, e.g., population growth, migration, urbanization, economic growth, and opportunities for water development.

Theme 5: Global and national food and water systems

CPWF Theme 5 is concerned with those international, national and regional policies and institutions that directly or indirectly influence water and food – and how these policies and institutions can be shaped so that the powerful and ubiquitous processes of global change benefit the poor rather than harming them.

Theme 5 research covers two kinds of policies and the links between them: policies specific to the water sector, such as water institutions, economic incentives, and investment strategies; and policies that lie outside the water sector, but indirectly affect water availability and quality, such as those on trade, climate, and macroeconomic issues. This theme also concerns itself with investments and financing for agricultural water development and water supply; transboundary issues, whether defined in classical terms of national boundaries, or in increasingly important boundaries of sectors and subnational boundaries; and changes in the global water cycle and opportunities to adapt to these changes.

In this synthesis, activities and accomplishments are discussed separately for each theme. Each thematic discussion concludes with a final section on "reflections and observations". These are intended to draw attention to opportunities for improving CPWF efficiency and effectiveness through stronger cross-theme integration.

Capacity-building and communication

CPWF projects do more than just conduct research. They also serve as platforms for capacity-building among project partners and stakeholders. Capacity-building covers a wide range of activities, including workshops for information exchange, short training courses, opportunities for learning through hands-on collaborative research and even support for formal course-work and thesis research by students.

Related to capacity-building are the questions of communication and communities of practice. CPWF Theme Leaders and Basin Coordinators, along with the CP coordination unit, work with project coordinators to foster communication within and among projects. Activities and accomplishments through the end of 2006 related to capacity-building are summarized in a separate section of this report.

The synthesis process

The notion of synthesis suggests a process of combining separate elements, thoughts, ideas, or information to form a coherent whole. In the context of the CPWF, synthesis research seeks to help make sense of the large body of dispersed data and information that accumulates over time, and to package it in ways that meet the needs of different users. The very fact that the CPWF research agenda is implemented through distinct projects, in multiple basins, with varying levels of emphasis on five different themes, underscores the importance of a conscious and systematic approach to synthesis.

This synthesis document is largely based on first call competitive grant project reports submitted in late 2006. In many ways it differs from its 2005 predecessor, which analyzed and described in some detail the following:

- The conceptual frameworks adopted by the five themes
- The goals, objectives, and research questions for each theme, and how these relate to specific issues or problem areas
- The subject matter addressed by each CP project, and progress made by the end of 2005 in launching project activities
- The distribution of projects across themes and basins, some apparent imbalances in this distribution, and implications for the coherence of the CP agenda
- CP achievements with regard to process (vision, design and implementation) and substance (technologies, policies and information)

Like the 2005 synthesis report, this document uses a thematic orientation in describing and synthesizing progress being made by different projects. It describes these projects in greater detail, however. Projects have had an additional full year to operate and the present report tries to take advantage of the flood of new information now emerging.[4] In addition, it discusses Basin Focal Projects, Program investments in capacity-building, and selected non-project activities, e.g., the International Forum on Water and Food.

The focus of cross-theme discussion has also changed. The 2005 document emphasized the distribution and sharing of projects across themes and basins, and implications for Program balance and coherence. In contrast, the 2006 document calls attention to opportunities for closer integration across themes, and between themes and Basin Focal Projects. Opportunities are identified in the areas of innovation systems and scaling out; understanding and managing downstream and cross-scale consequences of innovation; the sustainability of institutional innovations; and the effectiveness of water-related interventions to address questions of poverty and food security.

Finally, this 2006 synthesis document should be seen as a base from which multiple synthesis products will emerge in 2007 and the years to come.

[4] Just as in 2005, this present synthesis does not attempt to evaluate the quality of research conducted by any particular project, nor does it aim to draw conclusions on the suitability of any particular technology or policy intervention. Those are best left to programs of monitoring and evaluation, and impact assessment.

Theme 1 – Crop water productivity improvement

"For poor farm families, crop production serves many purposes. It provides food for the farm household, cash from the sale of marketable commodities, fodder and feed for livestock, organic residues and green manures to enrich and protect soils, and employment for family members. Food security, farm family health and crop production tend to be closely linked, and the interventions used to achieve increased crop production typically have some effect on the quality of land and water resources. Crop production is frequently the single most important source of employment in rural areas. The resulting incomes allow farmers to invest in further on-farm income raising activities, and farmers and landless laborers . . . to buy goods and services, thereby generating further employment elsewhere in the economy.

"In areas where populations are growing rapidly, agricultural and non-agricultural sectors increasingly compete for water supplies. Improvements in crop water productivity make possible an expansion in crop production without a corresponding increase in water use . . ."
(2005 CPWF synthesis report)

Goal and objectives

CPWF Theme 1 seeks to improve crop water productivity by addressing problems of abiotic stress, e.g., drought, salinity, and nutrient deficiencies. Means for achieving this include crop genetic improvement for stress tolerance, crop and agroecosystem management, landscape management, innovative institutions, and supporting policies.

In reality, of course, the challenge confronting Theme 1 is much broader. It is not merely to develop technologies that improve crop water productivity – but rather, to do so in ways that increase food security, reduce poverty, and improve the resilience of farm family livelihoods to unanticipated shocks, e.g., weather and price variability – while simultaneously sustaining or increasing the volume of clean water available for downstream use. While increased crop water productivity is important, improved land and labor productivity may be equally important in many instances. Ultimately, work associated with Theme 1 aims to enable poor people to benefit from higher levels of production, increased opportunities for employment, and lower food prices.

Taken together, Theme 1 projects and activities share the common goal of "[helping reduce poverty] *through . . . adoptable technology and useable information to help resource-poor farmers to overcome the effects of drought, water-logging and salinity."* [5]

Participants and partners in Theme 1 aim to reach this goal by realizing four objectives:

<u>Plant breeding and evaluation for water-efficient and stress-tolerant crops</u>: "The development of salt-tolerant crop varieties will enable farmers to make better use of saline land and water. Introducing drought-tolerant varieties will help save water under irrigated conditions and [will greatly increase land and water productivity in rainfed areas] . . . varieties that tolerate water-logging and flooding will reduce the impact of poor drainage on yields."

<u>Water-saving farm practices</u>: "In areas where uneven rainfall results in floods or droughts, improved and well-managed irrigation systems can provide superior water storage and delivery under both irrigated and rainfed conditions. When using irrigation,

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[5] Theme 1 goals and objectives are taken from the CPWF Medium-Term Plan 2006-2008. pp. 24-29

farmers will be encouraged to reduce water withdrawals by relying as much as possible on rainwater, and in rainfed systems, to introduce supplemental irrigation as dictated by the needs of the crop and the pattern of rainfall."

Need-based water supply: "Some stages of plant growth and development, especially flowering, are extremely sensitive to stress. It is important that supplemental irrigation be available at the right time to achieve high productivity with current varieties, or that new varieties that tolerate drought or salinity during sensitive stages are produced."

Policies and institutions: "There is an urgent need for policies and institutions that will give farmers and communities access to the financing needed to achieve the expected gains in production and water savings."

There is considerable overlap across these objectives. Increased crop water productivity is more likely to be achieved when all four objectives are pursued simultaneously. In drought-prone rainfed environments, for example, the best way to increase crop water productivity may be through a combination of drought-tolerant varieties and water harvesting practices, with suitable support from policies and institutions. Similarly, in salt-affected irrigated environments, success may emerge from a combination of salt-tolerant varieties, changes in crop selection or cropping patterns, improved land and water management practices, and institutional innovations.

For ease of exposition, Theme 1 activities and outputs will be discussed separately for four different production environments: dry rainfed, wet rainfed, salt-affected, and irrigated. Problems, technologies, and research activities all vary across these environments.[6]

Improving crop water productivity in "relatively dry" rainfed environments

There is considerable potential to increase rainwater productivity in unfavorable dryland environments by increasing yields through improved varieties and their management, together with increased in-field capture of rainfall. While average total annual rainfall in these environments is not necessarily low, it does tend to be unpredictable. The beginning of the rainy season may be erratic, there may be extended dry spells or the rains may finish early, resulting in terminal drought stress.

Several Theme 1 projects focus on rainfed agroecosystems in relatively dry environments. Four of these are located in sub-Saharan Africa (Limpopo, Nile and Volta basins), while two are in the Karkheh and Yellow river basins. Most of these projects emphasize the development and introduction of new crop, soil, water or nutrient management practices, following an integrated approach that combines new germplasm with crop, soil, water or nutrient management practices and supporting policies. All projects focus on increasing land and rainwater productivity through improved varieties, agronomic management and greater use of in-field rainfall (through soil management to increase infiltration and mulching to conserve moisture) as means of reducing risks related to drought.

Crop improvement

Plant breeding for drought-tolerance and other desirable traits is being conducted in several projects. Breeding is most heavily emphasized in Project 2 ("*Improving Water Productivity of Cereals and Food Legumes in the Atbara [Nile] River Basin of Eritrea*"). This project works on the development and selection of improved varieties of barley, wheat, legumes and other crops; soil and agronomic management; and the establishment of seed production systems.

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[6] Discussion of activities and outputs of other Themes are structured according to their MTP objectives.

Project 2 features the use of participatory research, most strongly in the areas of varietal selection (PVS), plant breeding (PPB) and project planning and implementation, but increasingly in agronomic management. Because end-user and stakeholder participation is featured in all project activities, project 2 participants feel confident in claiming that, "Eritrea [including 2] is leading the way in participatory research". Varietal evaluation during the first two years of the project has led to the identification of local landraces capable of greatly increasing yields of barley and *Hanfetse* (mixed barley/wheat), while germplasm has been identified with the potential to greatly increase wheat, lentil and faba bean, chickpea yields, sometimes several fold, following backcrossing of desired traits into the locally adapted landraces.

For the Eritrean highlands, research results indicate a large interaction between genotype and environment for important cereal and grain legume species. In the undulating uplands of Eritrea, production environments (rainfall, temperature, soils, humidity, disease pressure) vary greatly over short distances. This underscores the importance of participatory methods for local evaluation and selection of germplasm, and for seed increase. On their own, researchers would not be able to identify the best adapted varieties for more than a few locations. The project has begun seed multiplication of superior lines, and the groundwork has been laid for establishing Village Based Seed Enterprises (VBSE), an institutional innovation designed to serve as the principal future mechanism for local multiplication and distribution of promising germplasm.

Crop improvement is also an important activity in Project 6 ("*Empowering Farming Communities in Northern Ghana with Strategic Innovations and Productive Resources in Dryland Farming*") working in the Volta basin. During the first two years of the project, efforts were made to improve yield potential under terminal drought of the commercial sorghum variety *Kapaala*, and to develop early maturing cowpea and cassava varieties with desirable consumer traits that can escape terminal drought stress. Ten sorghum lines with improved drought tolerance, eight cowpea lines with earliness and high yield potential, and four cassava clones that show fast bulking of tuberous roots have been developed. Seed multiplication is underway to facilitate on-farm farmer testing and selection starting.

One practice being assessed by this project is rather curious: the transplanting of sorghum and millet. Participatory trials carried out by 70 participating farmers in seven communities, using their own sorghum varieties, indicate that transplanting results in earlier harvesting, higher yields (on average about 50%), and reduced infestation of *Striga* (a parasitic weed that affects sorghum and maize). Understandably, late-maturing lines performed better than early-maturing lines under transplanting. Partial budget analysis, based on farmer trials, showed a 38% increase in returns to transplanted sorghum compared with direct seeding.

Project 1 ("*Increased Food Security and Income in the Limpopo Basin through Integrated Crop, Water and Soil Fertility Options and Public-Private Partnerships*") is assessing the performance of drought-tolerant, early-maturing varieties of sorghum, maize, groundnut, cowpea and pigeon pea. The project does not engage in plant breeding as such, but rather uses available varieties identified as promising by past research.

The project undertakes comprehensive on-farm evaluation of varieties, and their management, in "Mother and Baby" trials in several locations in multiple countries. These are conducted in partnership with local farmers and extension workers. The Mother and Baby trial methodology enables rigorous scientific comparison of varieties and management factors while simultaneously allowing on-farm evaluation with far more farmer participation than would be possible with traditional replicated experiments.

Mother trials are conducted on-farm and/or on-station and are managed by researchers, extension workers and farmers. Baby trials are farmer-managed, contain fewer treatments per trial, and are designed to ensure adequate replication of all treatment combinations across participating farmers. Seed production of promising varieties of sorghum, maize, groundnut and pearl millet has been completed for on-farm evaluation in 2007. Two of the introduced groundnut varieties have performed well on the sandy soils in Mozambique over the past two seasons.

In Project 5 ("*Enhancing Rainwater and Nutrient Use Efficiency for Improved Crop Productivity, Farm Income and Rural Livelihoods in the Volta Basin*") on-farm trials have identified recommended species/varieties for further evaluation and dissemination in higher rainfall (maize) and lower rainfall (sorghum, cowpea) areas in the Burkina Faso portion of the Volta Basin. Information on crop improvement for drought tolerance is not yet available from Project 8, ("*Improving On-farm Agricultural Water Productivity in the Karkheh River Basin*").

Water-saving farm practices and need-based water supply

Five CPWF projects in drought-prone environments (projects 1, 2, 5, 6, 17) are assessing a wide range of soil and agronomic management practices for their effects on land and water productivity. Many of the soil management practices being investigated (including tied ridges, contour ridging, Zai pits, and trenches) seek to increase rainfall infiltration by reducing run-off. Some practices, such as mulching and intercropping, are intended to reduce unproductive soil evaporation. Intercropping with a legume may also confer benefits to soil fertility. Other practices, such as fertilizer micro-dosing (very precise applications of very small amounts of fertilizer) aim to increase the amount of output per unit of rainfall received. Micro-dosing helps farmers increase crop yields and profitability, giving them the confidence and resources to make further investments in inputs.

Project 1 is conducting field research in the Limpopo basin on intercropping, crop rotations, mulching, manure/compost trenches, fertilizer micro-dosing, tied ridges and pot holing. Initial results generally show benefits from mulch for growth and yield of maize and groundnut, and considerable response of maize to application of N fertilizer. Regarding groundnut, a mulch x variety interaction has been observed in some environments. One explanation is that, for some varieties, the presence of mulch exacerbates disease.

Little response was seen to pot holing and other methods for increasing infiltration in Mozambique – perhaps due to the sandy (permeable) soils and/or above-average rainfall in the season during which trials were conducted (such practices are most beneficial in relatively dry years.) While most research results have not yet been released, early findings reinforce the need to evaluate technologies in the agroecological environments for which they are intended. Related to this, there is a need to identify the agroecological circumstances within which a particular technology performs well. This facilitates scaling out, and reinforces the "international public goods" (IPG) nature of the research.

Another project in the Limpopo basin, Project 17 ("*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*") is assessing comparable practices. Their approach, however, has been to utilize the copious amounts of information on these technologies that have accumulated over past years (and decades). They report that:

"*Examination of over 10 years of agro-hydrological and agro-economic studies from southern African shows that an integrated approach is required . . . recent studies in Zimbabwe and*

Mozambique show that significant increases in yield can only be obtained when soil fertility management is combined with good crop husbandry, e.g. timely planting and weeding . . . Soil-water conservation approaches, e.g. winter weeding and conservation tillage, can reduce risk and increase yield, as can the application of supplementary irrigation . . . Various soil-water conservation approaches have been developed and promoted for the semi arid areas of Zimbabwe .

Tillage methods evaluated in this study include deep winter plowing, no-till tied-ridges, modified tied-ridges, clean and mulch ripping, and planting basins [pot holes]. Data collected from the various trials since the 1990s show that mulch ripping and other minimum tillage practices consistently increased soil water content and crop yields compared to traditional spring plowing. Trial results also showed higher soil loss from conventionally plowed plots compared to . . . minimum tillage practices." [7]

Project 5 ("*Enhancing Rainwater and Nutrient Use Efficiency for Improved Crop Productivity, Farm Income and Rural Livelihoods in the Volta Basin*") is studying similar technologies in the Volta basin. Cooperating farmers have been encouraged to test a small number of land and water management practices, selected by them from a larger group of prototypes. Among other things, farmers chose to test:

- Soil fertility management practices (cereal-legume crop rotations, fertilizer micro-dosing, mulching with the leaves of *Acacia spp.*)
- Soil and water conservation practices (regularly spaced ridges across the slope, Zai pits, mulching with *Acacia*)
- Diversification to tree crops such as *Ziziphus mauritania* planted in regularly spaced half-moons along ridges
- Boundaries and wind breaks of *Acacia* to reduce evaporation and provide firewood and seeds for chicken feed as well as leaves for mulch.

Early results show good responses to fertilizer micro-dosing and the replacement of sorghum monoculture with sorghum – cowpea rotations. Project 5 includes Zai pits in all recommended practices, and has identified fertilizer options suitable for various levels of financial outlay.

Curiously, most of these practices being tested are already well known in target countries and some were being used by farmers well before the project commenced.

In Eritrea, project 2 is conducting on-farm evaluation of nitrogen fertilizer use and measures for increasing rainfall infiltration and conserving soil moisture conservation (tied ridges, weeding). This is being done on three very different soil types. Over two seasons, there have been consistently large responses to fertilizer and smaller responses to tied ridges and weeding. Surprisingly, however, no interactions have been observed. This suggests either that water availability is not limiting or, more likely, that there are other constraints to crop water use that need further investigation.

The projects described above all have a sub-Saharan Africa focus. There is one other project, located in Asia, which studies land and water management in dryland environments. This is Project 12, ("*Conservation Agriculture for the Dryland Areas of the Yellow River Basin: Increasing the Productivity, Sustainability, Equity and Water Use Efficiency of Dryland Agriculture, while Protecting Downstream Water Users*"). This Project adapts and tests

[7] Project 17 Annual Report No. 2, September 2005 – August 2006. Page 8

"conservation agriculture", interpreted in the Yellow River context as permanent soil cover combined with reduced or zero-tillage and direct sowing. The inspiration for this project comes from the success of conservation agriculture and related resource conserving technologies in South America and South Asia, and builds on earlier work by Chinese institutions and ACIAR within China. [8]

The Yellow River passes through several Provinces of China which are characterized by extensive soil degradation and compromised hydrologic cycles – the river practically ceased flowing at one stage during the previous decade. Project 12 conducts research in dryland areas in four of the Provinces: Shandong, Henan, Ningxia and Inner Mongolia. A notably rich and detailed technical report on research outcomes has been made available by project partners.[9] Here are a few highlights:

- Trials on residue management, tillage and crop rotations have been carried out in all four Provinces. Technology performance was notably better in the moister, warmer southern Provinces of Shandong and Henan. In the two colder, drier northern Provinces, soil temperature is as important as soil moisture. Residue retention does help conserve soil moisture – but it also leads to lower soil temperature which delays crop establishment and shortens the growing period. Residue loss to wind and water erosion was found to be an issue demanding further attention.

- In some Provinces, farmers have become accustomed to the use of plastic film for "mulch". Research designs have been modified to integrate traditional conservation agriculture practices with the use of plastic film.

- Soil and productivity monitoring was conducted for all sites. Measurements were taken throughout the season on soil temperature, soil moisture and microbiological activity. Meteorological, soil and crop data from Ningxia Province were assembled for use in the Erosion Productivity Indicator (EPIC) to model the effect of conservation agriculture technologies on soil degradation.

- Modification of seed drills continues for their use in direct sowing. In Inner Mongolia, prototype maize and minor grain no-till planters were constructed and field tested. In Shandong and Henan the PBR no-till drill has undergone two cycles of modification and adaptation based on experiences in the 2005 and 2006 seasons. Equipment adaptation is a collaborative effort between project scientists and private sector machinery manufacturers.

- Socio-economic surveys have identified three factors that favor farmer adoption of conservation agriculture: enforcement of government restrictions on residue crop burning, scarcity of family labor, and the presence of subsidies for equipment purchase.

Policies and institutions

One of the Theme 1 objectives included in the 2006-08 MTP was the development of "policies and institutions that will give farmers and communities access to the financing needed to achieve the expected gains in production and water savings." In dryland environments, projects have tended to emphasize policies and institutions related to seed supply systems, fertilizer packaging and availability, and input and product markets.

[8] Project 8, working in the Karkheh basin in Iran, also conducts research on dryland areas. Detailed information on project outputs, however, is not yet available.
[9] Project 12 Nine-month Milestone Report. March – September 2006: Technical Appendix

Projects 1 and 5 have undertaken reviews of approaches to improving farmer access to micro-credit and input and product markets, and market surveys to identify potential opportunities in several project areas in Zimbabwe, South Africa, Ghana and Burkina Faso, but are preparing to articulate the next steps.

Project 1 has found that there is a considerable potential for micro-credit and improved input supply (availability, quality, range of pack sizes, minimum price through bulk buying) in South Africa. One private company (Progress Mills) already has many depots in the Limpopo Basin providing some of these services through a warrantage system.

The warrantage system enables farmers or producer organizations to "mortgage" their production of cereal grains at harvest time and secure a loan to carry out income-generating activities during the off-season. In this way farmers are not compelled to sell what they produce at the relatively low post-harvest grain price. "Mortgaged" grain is stored in a clean, secure place. Farmers may sell some of their grain when prices rise, or (after re-paying their loan) retrieve it for home consumption.

Project 1 is evaluating a range of models for seed production and supply of seed and other inputs. To date the project has been successful in convincing some input supply companies to make fertilizer available in small packs of 5, 10 and 20 kg. They are finding that once farmers start using small amounts of fertilizer, they gradually gain the confidence to use larger amounts. Farmers are also responding positively to trials of the warrantage system in project 5 in Burkina Faso, and see particular value in avoiding food shortage during the lean time before the next crop is harvested, when prices are high.

In the Nile basin, project 2 is engaged in encouraging the development of Village Based Seed Enterprises (VBSE), an institutional innovation designed to serve as the principal future mechanism for local multiplication and distribution of promising germplasm. In the Finally, in the Yellow river basin, project 12 is exploring the apparent importance of subsidies in farmer adoption of conservation agriculture implements – and some of the unanticipated effects of subsidy policies: ". . . current Chinese mechanization policy focuses attention on equipment for medium-large tractors, e.g., 50+ hp, whilst small farmers require adapted direct planting equipment for small tractors, e.g., 25 hp . . ."

Complementary activities

Most Theme 1 projects have launched complementary activities that contribute to the achievement of MTP objectives. These activities are for the most part related to information management, scaling out and risk assessment. Such activities include baseline socioeconomic and agroecological surveys, the delineation of agroecological zones, and the calibration and use of simulation models.

A good example is project 1. This project has made a major investment in a comprehensive baseline survey, whose objective is to " . . . set priorities for points of intervention in terms of water, crops, soil fertility and health aspects; establish baseline levels of farmers' knowledge, levels of adoption and constraints to uptake of improved crop, water and soil fertility technologies; establish baseline levels of farmers participation in input and output markets, access to credit, extension market information and social networks; [and] establish baseline on effects of HIV/AIDS on smallholder livelihoods including crop management practices . . ." [10] Reconnaissance surveys were completed for 24 villages, and formal surveys were completed for about 1000 households distributed across 48 villages, in each of two countries, Zimbabwe and South Africa. There are plans to conduct some modest baseline survey activity in Mozambique as well.

[10] Project 1 Six Monthly Progress Report. January – June 2006. Pp 2-3.

Expectations are high that, when survey results become available, they will convey important information and will provide insights into Theme 1 research opportunities.

Project 1 has made further investments in agroecological zoning for site similarity analysis and to provide an objective basis for selection of a few representative benchmark sites for crop – soil fertility and water management technology verification.

Surveys of on-farm conditions in the Limpopo have also been conducted by Project 17. Survey results reveal that farm family livelihoods and well-being are influenced by such factors as climate variability, geographical location, economic shocks, employment opportunities, impact of HIV/AIDS, market access, and government policies governing water management. In areas surveyed within Zimbabwe, "A significant population still relies on farming as a livelihood source but most income is realized from goat sales, not cropping. Despite this scenario, interventions are still heavily directed [towards] short-term relief rather than long-term development initiatives that can alleviate poverty and provide livelihood security."

Few other Theme 1 projects working in dryland environments dedicate this level of effort to baseline surveys or zoning. Most, however, do characterize research sites and, on occasion, calibrate and operate simulation models. Project 6 (Volta), for example, has released a report on farm conditions in the project area regarding household assets, income, expenditure, health, education, and access to and use of water. Project 5 (Volta) used remote sensing to generate land use maps of study areas, and collected data to calibrate and adapt the DSSAT-Century and APSIM models. These models will be used to assess the climatic risk of different land and water management strategies in terms of land and water productivity and externalities (deep drainage, surface runoff). Using historical weather data, the models can generate cumulative probabilities of particular outcomes, e.g., how frequently the use of a particular technology may result in a level of economic loss that farmers cannot tolerate.

Improving crop water productivity in "relatively wet" rainfed environments

Only two Theme 1 projects conduct research on water productivity in relatively wet rainfed environments. These are Project 11 ("*Rice Landscape Management for Raising Water Productivity, Conserving Resources and Improving Livelihoods in Upper Catchments of the Mekong and Red River Basins*") and Project 15 ("*Quesungual Slash-and-Mulch Agroforestry System (QSMAS): Improving Crop Water Productivity, Food Security and Resource Quality in the Sub-humid Tropics*"). The former project works in the Mekong basin. The latter works in working in the Lempa River upper watershed, Honduras; the Calico watershed, Nicaragua; and places in the Andes basins. Although they are located on opposite sides of the globe, they share common concerns: how to reduce poverty and improve farm family livelihoods and food security by enhancing the productivity of water and other resources in sloping upland areas that receive relatively high levels of rainfall, and therefore are susceptible to soil erosion and land degradation.[11] Despite sharing common concerns, the two projects employ rather different means in dealing with them.

[11] In the principal Project 15 study area in Honduras, for example, annual rainfall levels are around 1400mm

Crop improvement

Crop improvement for food staples, e.g., maize and beans, is not a major activity within Project 15. Rather, the emphasis is on a version of conservation agriculture based on slash and mulch practices (described below). Project 11, in contrast, seeks to use improved varieties and management as a key entry point for improving crop yields and water productivity. This project works in the rainfed uplands of Laos, northern Thailand, and northern Vietnam, where agroecosystems are rice-based and rice is the principal food staple. In these regions lowland (puddled, transplanted, flooded) rice is grown in the river valleys, sometimes with irrigation, while upland rice is grown on the lower slopes where soils are relatively poor and fragile, and water is limiting.

An array of new rice cultivars and management practices are is being tested, each matched to particular land types or market conditions. These include glutinous and non-glutinous cultivars (Laos), normal and hybrid varieties (Vietnam), and innovative "aerobic" rice cultivars. Under these conditions, drought tolerance is less important than cold tolerance and other traits that farmers find desirable, e.g., " . . . medium to short growth duration, with large and long panicles, large grain size, high tillering and medium plant height . . ." Clear opportunities to improve rice yields through varietal change – without increasing water use – have already been identified.

The project does not engage in plant breeding as such; rather it takes existing materials and makes them available for farmer testing and selection. It has also begun to take advantage of the ". . . substantial genetic variability among land races with some showing high tolerance to stresses in intensive upland systems."

Water-saving farm practices and need-based water supply

Even in relatively wet rainfed environments, water can be scarce and water saving practices important. In Project 11, water may be abundant in one part of a sub-basin or catchment, and scarce in another. In the Thailand research site, for example, "Water availability for crops is more of a problem for lowland households than for upland households . . . Upland farmers generally do not grow crops during dry season which influenced their perception of water shortage for crops [sic]. Water use conflict is almost absent in the uplands. While 14% of the lowland farming households reported water use conflict, only one upland farmer reported some conflict." [12]

Be that as it may, "water scarcity" is relative. Farm families in the Limpopo or Volta may be satisfied that water is abundant if their crops are not affected by drought. In contrast, farmers in the Mekong uplands may feel that water is scarce if there is not enough to cultivate puddled rice. Certainly, one constraint to expanded terracing for paddy rice is lack of water (others are construction expense and the limited area suitable for terracing).

Where water is scarce, water productivity remains important. One promising way to improve water productivity in project 11 study areas is through system intensification and diversification (more value of output per unit rainfall depleted). This is an area that Project 11 will further explore in coming seasons.

It might be argued that erosion control is even more important than soil moisture conservation in sloping uplands. In the Vietnam site of Project 11, trials are being conducted on the use of mulch from crop residues to improve yields and reduce erosion. However, it is Project 15 that really emphasizes the use of mulch for erosion control purposes.

[12] Project 11 Annual Report, January-December 2006. Page 3.

Project 15 is being implemented in Honduras and Nicaragua, with a recent expansion of activities to Colombia. It studies ". . . what happens when hillside agroecosystems shift from slash-and-burn to slash-and-mulch ("*Quesungual*") practices. Specifically, it looks at no-till planting of maize and related crops on hillsides into a permanent soil cover derived from the slashing of re-grown native forest vegetation. In these systems, field burning is controlled through community-led collective action. This project shares a number of elements – permanent soil cover and direct sowing with zero tillage – with project 12. In both cases, the need for erosion control is an important driving factor. In Project 15, however, soil cover is based on slashed forest vegetation while in Project 12 soil cover comes from crop residues." (2005 CPWF synthesis report)

It should be noted that the *Quesungual* technology emerged from the multi-year "FAO-Lempira Project" in Honduras and is largely farmer-developed. Because of this, Project 15 research has focused less on technology development *per se* and more on answering questions such as:

- What is the extent of adoption? (approximately 6000 ha, largely in Honduras)
- What are the consequences of adoption? (reduced erosion, reduced water turbidity, increased earthworm populations, increased soil carbon, higher yields, lower costs)
- What are factors governing adoption? (collective action to prohibit burning practices, incentives to foster integration with markets)
- How might these practices be further scaled out? (spatial analysis to identify other areas in Latin America where this system may be most appropriate, farmer-to-farmer exchanges)

<u>Policies and institutions</u>

The two Theme 1 projects being implemented in relatively wet rainfed environments both anticipate a role for policies and institutions in accelerating the adoption of improved practices. Project 11 anticipates that policy interventions as well as technical interventions will be developed to overcome constraints to the productivity of rice-based systems, and that institutional innovations for water sharing and water use will be designed to improve poor people's access to water. Future reports will describe progress in this area.

<u>Complementary activities</u>

Just as is the case in dryland environments, Theme 1 projects in wet rainfed environments are conducting complementary activities, among them diagnostic and baseline surveys, spatial analysis and simulation modeling. Different projects, however, have different purposes for adapting and applying simulation models. In dryland areas, models are used to assess the riskiness of different technologies in variable climates. In wetter areas, there is greater emphasis on hydrology, and modeling the downstream consequences of upstream interventions.

Project 15 has built on the previous experience of (and data gathered by) the FAO-Lempira project in defining a <u>baseline</u> for the Honduras research site. Collection of new baseline data is being done in the Nicaragua and Colombia sites.

The project team also reports using <u>spatial analysis</u> to help identify other areas in Latin America most suitable for the introduction of *Quesungual* systems. They suggest caution, however, in designing scaling out activities. They note that "Some general principles of the QSMAS that are transferable include no burning and no-till management for steep environments that promote soil cover". They warn, however, that "Although there is great potential for the QSMAS to be adopted in other regions of the world it is important to realize that any project supporting its validation has to commit time and resources within the context of a long-term framework. Changes in social capital take much more time than changes in other [kinds of] capital."

Project 11, although a relatively new project, has made already made a substantial investment in information management. Secondary data has been collected from official sources for such topics as general land use, water resources, rice yields, cropping calendars, demographic structure and poverty status. In some sites a GIS platform has been built and spatial data have been gathered on land use, elevation, village locations, roads, major streams and rivers, soils, etc. Participatory land use and resource mapping information has been gathered from focus groups. And in at least one site, plans have been made to gather hydrological data, for use with the MIKE SHE simulation model to assess the downstream and cross-scale consequences of introducing alternative land and water management scenarios and strategies.

Improving crop water productivity in salt-affected environments

Salinity is a particularly important issue for Theme 1 in rainfed lowland rice systems in the eastern Indus-Ganges, and in irrigated environments affected by secondary salinization in the Indus and Karkheh basins.[13] Approximately 21m ha of agricultural land in Asia is salt-affected, including 9m ha of saline/sodic soils. Salt-affected lands may be inland, with severely affected and partially reclaimed saline/sodic soils, or in coastal areas. They are typically left barren, or planted during the wet season with local rice varieties and landraces with high salt tolerance but low yield potential. Salinity stress is exacerbated by drought. This may occur at the time of crop establishment, during the growing season, or when the rainy season ends prematurely. Salinity problems undermine food security and livelihoods for an enormous number of poor people.

Crop improvement

Many crops are sensitive to salt. Rice, for example, is sensitive to salinity at its seedling and reproductive stages. CPWF Project 7 ("*Development of Technologies to Harness the Productivity Potential of Salt-Affected Areas of the Indo-Gangetic, Mekong, and Nile River Basins*") is making good progress towards developing rice and non-rice varieties for salt-affected areas in several basins. Progress has been most rapid in the Indo-Gangetic and Mekong Basins. Advances in crop improvement for salt-tolerance include progress in understanding salinity tolerance mechanisms; the identification of markers and the development of marker-assisted selection for the major QTL (Saltol) associated with salt tolerance in rice; and accelerated efforts to incorporate salinity tolerance into locally preferred, adapted, high yielding varieties for the many diverse salt-affected locations.

Varietal requirements for rice demonstrate great spatial variation. They are influenced by soils, climate, cropping practices, and grain quality preferences and other socio-economic factors. Participatory varietal evaluation and selection (PVS) is therefore essential. Project 7 has launched a PVS program featuring a range of salt tolerant, high yielding rice genotypes. This program is active in several locations in India, Bangladesh and Vietnam. Initial efforts to increase seed of superior genotypes have begun in some project sites.

Rice grown in salt-affected areas also typically suffers from a range of other abiotic stresses, such as zinc deficiency and iron toxicity. Therefore, Project 7 has also

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[13] Theme 1 also participates in the work of project 10 on managing the coastal fresh-saline interface in the Mekong delta. This project, shared across several Themes, is discussed in the section on Theme 3.

undertaken a crossing program to develop lines with tolerance to multiple abiotic stresses in addition to salinity, and has undertaken screening for zinc efficiency.

A key trait being incorporated in improved varieties for rainfed, salt-affected areas is early maturity, which also helps save water by reducing irrigation withdrawals for rice cropping where irrigation water is available or affordable. Shorter duration rice varieties will also facilitate the establishment on residual moisture of a post-rice crop. This avoids the need for pre-sowing irrigation and allows timely establishment of such crops. This in turn tends to result in higher yields and better crop water productivity of the post-rice crop and the total cropping system.

Finally, Project 7 is helping develop salt-tolerant crops other than rice. These can be established after rice on residual moisture or, under some circumstances, can replace rice altogether. Advances include the development of techniques for screening pigeon pea, groundnut and fodder crops for salt tolerance. The project has achieved improved understanding of the mechanisms of salt tolerance in these crops which will lead to more efficient identification of and breeding for salt tolerant germplasm. On-farm testing of pearl millet and sorghum genotypes has commenced, together with on-farm evaluation of the performance of a range of other salt tolerant genotypes during the dry season (vegetables, medicinal herbs).

Water-saving farm practices and need-based water supply

Project 7 is also developing crop and resource management strategies that are complementary to salt-tolerant varieties.

Often, farmers operating on saline/sodic soils cannot afford the gypsum treatment typically recommended for soil reclamation. NARES institutions collaborating with Project 7 have long been aware of this problem and developed, even before project initiation, a range of low-cost reclamation methods, e.g., the use of industrial by-products, low rates of gypsum, and green manures. They also developed practices for increasing rice yields in salt-affected soils, e.g., changes in nutrient, transplanting and rice nursery management. Such practices become more feasible when combined with salt-tolerant varieties because these are more responsive to improved management. Project 7 is helping scale out these technologies by integrating them into programs of participatory varietal selection where farmers evaluate and select salt-tolerant cultivars.

A combination of tolerant varieties and improved management practices can contribute to higher rice yields and substantially higher water productivity. Their adoption can also reduce the likelihood that farmers will abandon salt-affected fields in mid-season. Note that in drier years, farmers sometimes do abandon these fields, even after having applied two or three irrigations, as they cannot afford the cost of diesel to continue to irrigate. In the absence of improved practices, it is more likely that vast amounts of valuable water will be lost to unproductive evaporation.

Policies and institutions

Project 7 has established an effective network for exchange of genetic material and knowledge of the performance of this material in salt-affected environments. This includes the establishment of a special International Rice Soil Stress Tolerance Nursery (IRSSTON) for coastal saline and inland and sodic areas, within the Consortium for Unfavorable Rice Environments (CURE). CURE was established in 2002 as a vehicle for linkage between IRRI and NARES in selected countries in Asia for joint research activities in rainfed rice in unfavorable environments.

Complementary activities

Within Project 7, benchmark studies have been completed. Reports from India and Bangladesh have been compiled and submitted while similar reports are in progress in Vietnam and Iran. Data collected include biophysical characteristics of salt affected areas, constraints to rice cultivation, information on farmers' practices, innovations in coping with stresses, constraints to adoption of improved technologies, land holding size, sources of irrigation, prevailing dominant cropping systems and crop varieties and cultivation cost, among others.

Improving crop water productivity in irrigated environments

Theme 1 projects in relatively dry rainfed areas are very much concerned with drought stress. These are mostly located in sub-Saharan Africa. Theme 1 projects in wet rainfed environments, based in Latin America and Southeast Asia, tend to focus on erosion and resource degradation. In contrast, Theme 1 projects in irrigated areas, largely working in Asia, are most concerned with water productivity in irrigated lowland rice in places where water availability for irrigation is declining. The principal interest, of course, lies in the consequences of improving water productivity for food security, incomes, livelihoods and the environment.

Aerobic rice

"The 'aerobic rice system' is a simple name for what is in effect a complex and revolutionary way of growing rice without puddling. Aerobic rice uses specialized rice cultivars and complementary management practices to achieve very high rice yields – with only 50-70% of the water typically required for puddled rice systems. Aerobic rice systems have been recommended for irrigated or rainfed rice-growing areas where water is too scarce or expensive to allow puddled rice cultivation. As water becomes . . . scarce, aerobic rice practices may become more important for much larger areas." (2005 CPWF synthesis report)

Water in irrigated areas becomes scarcer when:

- There is simply less of it (declining groundwater tables, siltation of reservoirs, diversion of water to competing users)
- Its quality has deteriorated (chemical pollution, salinization)
- It has become more expensive to use (cost of pumping).

Crop improvement

Within the CPWF, the development of aerobic rice systems is carried out by Project 16 ("*Developing a System of Temperate and Tropical Aerobic Rice (STAR) in Asia*").

Breeding and evaluation of aerobic rice for water-scarce irrigated environments is not entirely new. It began in the 1980s by China Agricultural University in selected rice-growing regions of the Yellow River Basin. Collaboration with IRRI began in the late 1990s. This was carried out within the Irrigated Rice Research Consortium (IRRC) and the Consortium for Unfavorable Rice Environments (CURE).

Project 16 builds on this work. In partnership with IRRC and CURE, it helps evaluate and select varieties (developed by these breeding programs) for a range of new target environments including the sub-tropical, irrigated regions of the Ganges River Basin in India, favorable rainfed uplands in Laos and Thailand, and tropical irrigated lowlands in southern Philippines. Varietal evaluation includes on-station trials, researcher-managed on-farm trials, and participatory varietal selection (PVS) in farmers' fields.

Three aerobic rice varieties capable of producing yields of 4-6 t/ha, and using 30-50% less water than traditional lowland rice, have been released in China and private seed companies have begun to distribute aerobic rice seeds. In Project 16 project sites in China, farmers who tested aerobic rice in 2005 were able to sell virtually all of their crop to their neighbors as seed. In the Philippines, four aerobic varieties perform very well, but are susceptible to root diseases. Several varieties were identified for nation-wide evaluation in Laos in 2007. In India and Thailand, evaluation is at a much earlier stage.

Water-saving farm practices and need-based water supply

Using a combination of field experiments, monitoring in farmers' fields, and crop growth simulation modeling, Project 16 has confirmed that aerobic rice yields of 4-6 t/ha are obtainable in areas located at the margins of major rice-growing regions in the Yellow river basin. These "marginal" areas have normally been considered inappropriate for rice. The yield levels mentioned above were achieved with only 2-3 supplemental irrigations (150-225 mm), along with moderate levels of rainfall (115-670 mm per season) in areas with deep water tables (>2m). In comparison, traditional puddled, transplanted, continuously flooded ("lowland") rice produces 6-9 t/ha but uses much more water (total 900-1300 mm), even in the presence of very shallow water tables (<0.2 m). Irrigation water productivity is much higher for aerobic rice than lowland rice.

From the farmers' viewpoint, aerobic practices may be the only possible way to grow rice when water becomes scarce. In water-short but flood-prone areas, such as are found in parts of northern China, the substitution of aerobic rice for maize or cotton can substantially reduce the risk of crop loss from flooding. From the viewpoint of the whole river basin, aerobic rice practices may help maintain food security under conditions of water scarcity. And if adopted over very large areas, it may also be a means of freeing up substantial amounts of irrigation water for alternative downstream uses.

Use of aerobic rice culture can also benefit other crops in the production system. There are vast areas in the Yellow and Indus-Ganges basins where rice is grown in rotation with wheat. Because aerobic rice production systems do not require puddling, they provide more favorable conditions for wheat establishment after rice harvest. They also create the possibility of incorporating conservation agriculture practices (zero or minimum tillage, residue retention) into the total crop production system.

The work of Project 16 has inspired non-project partners, especially in the Philippines, to conduct research on aerobic rice management practices. This work has resulted in initial technology guidelines for aerobic rice production in China and the Philippines (wet season). These guidelines have also been incorporated in a draft manual on water management for rice in general, targeted at NARES partners and extension workers. Finally, the project is exploring what threats there may be to the long-term sustainability of aerobic rice systems, in order to find responses to these threats before they become truly important.

Policies and institutions

Research results from Project 16 and allied efforts have begun to inform research priority-setting in several countries. The Chinese government, for example, is providing additional funding support for aerobic rice research and development. In the Philippines, the National Irrigation Administration (NIA) and PhilRice (CPWF project partners) have included training on aerobic rice in their capacity-building curricula for farmers and extension officers. Various other non-project partners are picking up the development of aerobic rice technology including the Philippines Bureau of Soil and Water Management and Central Luzon State University. It is too early, however, for the potential water-saving capability of aerobic rice technology to have entered into broader policy debates.

Reflections and observations

In the 2005 synthesis, a number of opportunities were identified where the CPWF might be able to further improve coherence, increase research efficiency, and accelerate progress towards achieving development goals. Opportunities mentioned included encouraging cross-project learning, strengthening agroecological zoning and site similarity analysis for scaling out, and examining the basin-level consequences of farm-level interventions.

These opportunities – and others – are still present.

- <u>Building on what is known</u>. Questions of soil fertility management, soil water management, water harvesting, and reduced tillage have been of high priority in semi-arid sub-Saharan Africa for several decades. Enormous investments in research and development have been made in these topics over many years by the Rockefeller Foundation, DFID, GTZ, IFAD and other development assistance agencies. Some of these funds have supported long-standing and highly-effective networks, among them the Soil Fertility Network for Southern Africa and the African Conservation Tillage network. CPWF Theme 1 projects in dryland areas might benefit by drawing more systematically on the accumulated knowledge and understanding of how particular technologies perform under different conditions in these environments. Project 17 has shown the way.

- <u>Information-sharing across projects</u>. Within sub-Saharan Africa, Theme 1 manages four projects working on questions of poverty, food security, vulnerability, drought stress and water productivity in dryland environments. These projects are examining similar technical and institutional interventions within comparable (though not identical) climatic and socio-economic environments. Increased communication and information-sharing across these projects might accelerate the development and testing of more suitable technologies for larger areas. The same can be said for the four Africa projects and the two parallel projects working outside of Africa.

- <u>Downstream consequences of farm-level interventions</u>. With few exceptions, Theme 1 projects take little account of the possible downstream and cross-scale consequences of field-level interventions. For example, if aerobic rice practices were to be adopted on 5m ha in China, what might be the effects on the quantity and quality of water for downstream users? If more water were to become available, how might this most effectively be used? Improved integration of project efforts with Theme 4, and/ or with Basin Focal Projects seems desirable.

- <u>Anticipating social and economic consequences of technical change</u>. It would seem fair to ask Theme 1 projects the following question: "If your project is entirely successful in developing and fostering widespread adoption of new technologies, policies and institutions to improve crop water productivity, how far does this take you towards meeting developmental goals?" To what extent does complete success in improving crop water productivity help solve problems of poverty and food insecurity? Integration of effort with Theme 2, and/ or with Basin Focal Projects, might help provide answers.

- Sustainability of institutional innovations. Several Theme 1 projects intend to foster the development of local institutions for seed multiplication and dissemination. In doing so, these projects might wish to examine the lessons learned by others who have taken this path. New, community-level institutions for seed multiplication typically are difficult to sustain.

- Scaling out and conditional extrapolation domains. Some reporting from Theme 1 projects lacks specificity regarding the conditions that govern the performance of different technologies. Proper information management should allow projects to describe more systematically the agroclimatic and socioeconomic conditions that favor farmer adoption of a particular practice. These "conditional statements" (if conditions are X, then you might wish to explore the use of Y) could be helpful in organizing activities related to scaling out and up. In this regard, it should be noted that Project 16 has begun developing maps of possible extrapolation domains for aerobic rice in China. Maps of potential rainfed yield, water productivity, irrigation requirements, irrigated yield, etc., have been developed by combining a calibrated crop growth model (ORYZA2000) with GIS, utilizing suitable weather and soils data

- Fostering complex adaptive innovation systems. Most Theme 1 projects conduct researcher-managed research, participatory assessment and even simulation modeling with regard to alternative crop and resource management practices. As was seen in the above discussion, there is no shortage of prototype technologies. The challenge is to facilitate the creation of dynamic innovation systems for tailoring prototypes to local environmental and socio-economic circumstances. Innovation systems are an organic, dynamic, self-directed social process, a co-evolution of interventions and stakeholders. At its best, this process grows and gathers speed, with increasing involvement by more stakeholders – until, at some point (the 'tipping point'), a technology begins to be spontaneously and widely adopted, a suitable policy is shaped and implemented, or an institutional innovation takes hold. Integration of Theme 1 effort with other themes might be needed in facilitating and encouraging the development of innovation systems.

Theme 2 – Water and people in catchments

"Consider water flowing through a river basin. Its journey commences with rainfall or snow accumulation in a catchment. As this water flows downstream, it may be used for a succession of beneficial purposes – the production of plants, animals and fish; rural and urban direct consumption; industrial use and power generation; and the preservation of wildlife habitat and ecological processes. [Because water flows downstream] upstream water management affects the welfare of downstream populations. People living all the way upstream, in the catchments, have first access to water resources and their water management practices impinge on all downstream users . . . In contrast, people living all the way downstream, e.g., in coastal areas, often must get by with whatever water resources come their way after these have been exploited, depleted, or polluted by the combined set of upstream users. Downstream people, however, are not necessarily powerless. The concept of "reverse flows" recognizes their potential ability to influence water availability through certain actions, e.g., direct payment to upstream users or lobbying of government institutions . . ."

"Because water management in upper catchments affects everyone else in the basin, policymakers tend to emphasize conservation goals for these areas. But catchments may also be home to large numbers of poor people. In some parts of the world, upper catchment communities are often economically, politically and culturally marginalized, and their limited livelihood options center on the exploitation of land, water and forest resources. Equity considerations suggest that resource management in upper catchments should allow for continued productive use of water and other resources by local communities, while also conserving these resources for downstream populations. These two competing objectives must somehow be reconciled . . ."

(2005 CPWF synthesis report)

Goal and objectives

CPWF Theme 2 is concerned with water, poverty and risk in upper catchments. Taken together, Theme 2 projects and activities share the common goal of "*Improving sustainable livelihoods for people who live both in upper catchments and downstream, through improvements in water management at multiple scales"* [14]

Participants and partners in Theme 2 seek to reach this goal by realizing three objectives:

Understanding water and poverty in upper catchments: "This [objective] generates knowledge of the significance of water to the rural poor in upland catchments, determines the impacts of water management, and identifies new opportunities. It identifies the demand for and constraints on investment in water management and other related technologies, [and] develops appropriate solutions and adapted responses to alleviate constraints through a combination of technical and institutional changes."

Understanding biophysical and social processes in catchments: "The outcomes of catchment management are jointly determined by the interactions of social and biophysical processes. Such processes are scale and site specific. However, basic principles will be identified and models and methodologies produced in the form of decision support tools."

[14] Theme 2 goals and objectives are taken from CPWF. 2005. Medium-Term Plan 2006-2008. pp. 30-35

Enabling change: "This [objective] tests social learning and organizational processes that allow people to derive benefits from water and reduce the risk of human-induced hazards. It [fosters] processes of participatory action research [to modify] institutions that mediate upstream and downstream relations . . . so that the most vulnerable and poorest communities are able to derive more benefits from water."

Understanding water and poverty in upper catchments[15]

Some Theme 2 work can be described as finding ways to reduce poverty in catchments through improvements in water productivity. To do this successfully, it is first necessary to have a good understanding of the role and importance of water in the livelihoods of the poor. As it happens, connections between water and poverty can be subtle and complex and are often poorly understood. Sometimes poverty can be reduced by improving access to water, or by improving the productivity with which water is used. Other times, however, the real opportunities to reduce poverty lie elsewhere. It is even possible to envision occasions in which effective poverty reduction strategies result in water degradation, with trade-offs between peoples' livelihoods and environmental conservation.

It is most important to understand of the role of water in the livelihoods of the poor when:

- designing water management interventions aimed at reducing poverty
- designing poverty reduction strategies that take account of consequences for downstream water management and availability
- challenging the introduction of water management and/ or resource conservation strategies that unintentionally penalize the poor

Improving access to water

There is ample evidence that diversification of livelihood strategies at the household scale can reduce poverty by increasing opportunities and reducing risk. Often such diversification depends on reliable access to water resources. When water is available, farm families can undertake a variety of productive activities, some of them going well beyond conventional irrigated agriculture. These include livestock watering, dairy production, brick-making, beer brewing, gardening, and orchard plantations.

The importance of access to water was vividly illustrated for the Limpopo basin by project 17 ("*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*"). In a study of drip irrigation kits in Zimbabwe, project researchers found that use of drip kits can reduce by up to 50% the need for irrigation water. Farmers with water can utilize drip kits to increase irrigated area and income from irrigated agriculture. Unfortunately, many of the poorest farmers have no water resources of their own – they share them with other irrigators and with other, higher priority uses such as livestock watering and domestic use. It became apparent that offering drip kits to the poor can be unsuitable unless access to water is also improved. Based in this finding, a protocol for sustainable drip kit distribution has been developed and adopted by a number of the relevant NGOs in Zimbabwe.

As a follow-up to the above, Project 17 continues to seek ways to increase water availability for the poor. Project researchers have discovered that there is, in fact,

[15] The following sections draw on a draft 2006 Theme 2 synthesis by Nancy Johnson.

potential for groundwater development. In the driest parts of the Limpopo Basin, alluvial aquifer systems have been located that can provide safe and reliable water storage for domestic and agricultural use. The development of these water resources, however, must be carefully planned and monitored to avoid salt intrusion.

The project also found that most small dams in the Limpopo are under-utilized and/ or highly silted up and that interventions to reduce silt inflow or to de-silt dams will reduce evaporative losses (shallower dams lose a greater proportion of their stored water to evaporation). Doing so can potentially have a major impact on the livelihoods of the poor by allowing an expansion of irrigated agriculture.

It is possible to improve peoples' access to rainwater by reducing evaporation and run-off, thereby conserving water for productive use. Project 17 has confirmed that several soil-water management practices developed and promoted for the semi-arid areas of Zimbabwe can be effective. Practices that were evaluated include deep winter plowing, no till tied ridges, modified tied ridges, clean and mulch ripping, and planting basins. Data compiled from trials conducted over many years show that mulch ripping and other minimum tillage practices consistently increase soil water content, improve crop yields, and reduce soil loss, when compared to traditional spring plowing. Further examples of improved rainwater productivity were given in the section on Theme 1.

Multiple use systems (MUS)

One innovative way to improve water management in ways that can benefit the poor is the introduction of systems designed to support multiple uses. One Theme 2 project, Project 28 ("*Models for Implementing Multiple-Use Water Supply Systems for Enhanced Land and Water Productivity, Rural Livelihoods and Gender Equity*")[16] is entirely devoted to this topic. As noted in the 2005 synthesis,

"Virtually all people use water for a multiplicity of domestic and productive purposes. Poor people living in upper catchments are particularly likely to rely on a wide range of water-dependent activities for their livelihoods. This "multiple uses of water" strategy increases their welfare – and also tends to increase water productivity . . . Unfortunately, most water supply systems have been designed with a single use in mind, e.g., irrigation or direct consumption. Not infrequently, they are simply unable to cope with the demands (volume of water required or the timing of water delivery) that may be placed on them by the "multiple uses of water" strategies often preferred by poor households. The answer may lie with water supply systems that are multiple-use by design."

During 2006 an "MUS review and planning workshop" finalized an agreed generic framework for designing, implementing and up-scaling MUS systems. This framework has been adopted for use in five basins. Learning alliances dedicated to MUS are active in Bolivia (community and intermediate levels); Colombia (intermediate); Ethiopia (through CRS and its partners); Nepal (community, intermediate and national levels); India (community level); South Africa (community, intermediate, and national levels); Thailand (community, intermediate, and national) and Zimbabwe (intermediate and national).

Project 28 is also doing advocacy work with environmental and water ministries. Along with local communities and other participants in local watershed planning, these ministries typically have a say in the design and replication of water supply systems. It is therefore important that they fully understand the potential benefits of MUS.

[16] www.musproject.net

Project participants have recently made notably good progress in fostering the development, raising awareness and attaining commitment for MUS. The concept of MUS has been embraced by many more water professionals and poverty-focused development agencies than had been foreseen at the start of this project. Statements of the following kind are emerging:

- "It is an open door that is now finally being pushed."
- 'The dynamics around the acceptance of MUS are the same as the way in which 'farmer-managed irrigation schemes' were suddenly fully recognized in the 1980s, thanks to scientific underpinning of what is basically well known."
- "[MUS stands for] integration where integration matters to advance the Millennium Development Goals."
- "The World Bank is integrating the [MUS] concept in the same way as sanitation was integrated in domestic water services in the 1980s"

MUS was accepted as a stand-alone Topic Session at the World Water Forum in Mexico, where the concept received unambiguously positive feedback. As a final example of its swift acceptance at the highest levels, the top management of the Department of Water Affairs and Forestry, South Africa, gave a full endorsement of the MUS concept

<u>Payment for water conservation and environmental services</u>

Water management interventions can help reduce poverty by improving the access of poor people to water resources, by improving the productivity with which they use water – or, less conventionally, by providing them with financial compensation for increasing the quantity and enhancing the quality of water available for downstream communities. This latter option – payment for environmental services or PES – is the focus of project <u>22</u> ("*Payment for Environmental Services as a Mechanism for Promoting Rural Development in the Upper Watersheds of the Tropics*"). This project asks the following questions:

- How can sources of negative externalities (location and magnitude) be identified?
- How can priority areas within a watershed be selected that have a relatively high potential to modify negative externalities and produce downstream social benefits?
- How can social benefits of farm-level interventions be measured at watershed and basin scales of analysis?
- What are important trade-offs among rural income, environmental externalities and employment generation that are generated by alternative land use strategies?
- What criteria should be used to disburse PES credits in order to achieve expected environmental and socioeconomic impacts?
- How can PES systems achieve political and institutional sustainability?

What Project 22 is doing to answer such questions is discussed in a later section.

<u>Limits to poverty reduction through water management</u>

Protecting and strengthening poor households' access to water is important. Nonetheless, access alone is often not sufficient. Even in rural areas, income diversification through non-agricultural or off-farm employment is frequently the main pathway out of poverty. Participatory analyses from Kenya, Colombia, Bolivia and Peru by projects 20 ("*Sustaining Inclusive Collective Action That Links across Economic and Ecological Scales in Upper Watersheds (SCALES)*") and 22 found that issues of water and water access were often not the most critical factors determining household welfare.

When employment opportunities for the poor are concentrated in activities that also tend to cause environmental damage, trade-offs appear between poverty and the environment. Assessing these trade-offs may require analysis at multiple scales. Water management, especially at community and catchment scale, is relevant to the livelihoods of the poor, but the relationships can be subtle and indirect. Participatory methods such as those used by Project 20 and Project 22 are cost effective way of detecting these complex relationships. Project 24 ("*Strengthening Livelihood Resilience in Upper Catchments of Dry Areas by Integrated Natural Resources Management*") plans to go a step further to quantify and assign an economic value to the direct and indirect impact of water management on poverty using a social accounting matrix developed for the Karkheh basin.

Understanding biophysical and social processes in catchments

Upstream land and water management affects the quantity and quality of water available to people downstream. These upstream – downstream links are the basis for watershed management programs and for programs featuring payment for environmental services. In order for them to be efficient, effective and equitable, these programs must be designed in ways that take account of fundamental relationships between land use and hydrology. They must be able to anticipate the likely magnitude and distribution of the economic and social benefits and costs associated with alternative land use strategies. They must have the capacity to conduct a rigorous scientific assessment of the potential for agricultural land use changes to enhance ecosystem services and contribute to sustainable rural development. Such capacity is lacking in many PES schemes. Theme 2 is working to change this through a combination of research and capacity building.

Understanding catchment hydrology and the impacts of land use

Through Theme 2 research, a better understanding is emerging of the links between land use and hydrology. In one example, researchers in the Limpopo basin working in project 17 assessed land use changes and their effects on water resources in the Insiza sub-catchment in Zimbabwe. Using 35 years of discharge data, flow duration curves (FDCs), maximum flows, number of days with zero flows and runoff coefficients were analyzed. Landsat images were processed to examine changes over a ten year time period (1990-2000) in population density in communal areas, land use, and dam management. The study found that, because of changes in rainfall patterns, flows at the sub-catchment scale (2,260 km^2) decreased from the 1960s to the 1990s. At the meso-scale (400 km^2) runoff was found to have increased from 2% to over 6% over the same time period. This was attributed to agricultural intensification and changes in dam management.

Project researchers estimated the likely effects on water balances if specific land use practices were widely adopted. For example, weeding was found to positively affect infiltration. The extent to which weeding is performed over large areas can affect catchment and basin-level water balances. The impacts on water balances of mulch-based conservation agriculture or other field-level "water harvesting" practices will be assessed in the near future, both within the project and in conjunction with an agriculture-based PES initiative.

Relationships between land use and hydrology are also being studied in the Andes by project 22. This project uses the concept of the Hydrological Response Units (HRU) – defined as the minimum hierarchical level required to integrate hydrological dynamics and performance of production systems. They are, in essence, spatial units with similar climatic characteristics, soils, land cover and topographic conditions.

In delineating HRUs, hydrological, edaphic, topographic and climatic data were combined with production system data. Project researchers have been able to quantify for each HRU such variables as the levels of sediment yield, water yield and N and P deposited in downstream lakes. They have been able to identify the location and magnitude of negative externalities, and often who is causing them. This work is progressing in five sites: Fuquene (Colombia), Ambato (Ecuador), Tunari (Bolivia), Altomayo and Jequetepeque (Peru).

With the HRU structure in place, researchers developed and applied a model for ex-ante evaluation of alternative land use. This model, called ECOSAUT, allows users to quantify and value the economic, social and environmental impacts of land use changes at the watershed scale – including trade-offs among rural income, environmental externalities and employment generation. It does this by identifying HRUs that respond uniformly to land use change. HRUs are then ranked in terms of their contribution to environmental externalities, which allows identification of priority areas for intervention (i.e., maximum impact with minimum area affected). Potential land uses are analyzed in terms of their impact on agricultural production, farm income, labor use, and catchment hydrology. Results allow decision makers to see the tradeoffs between social, economic and environmental outcomes associated with a given land use change.

This approach has resulted in a greater appreciation of the potential for conservation agriculture and agroforestry systems to reduce negative externalities. When farm-level, near-term benefits to farmers are high, spontaneous adoption can be anticipated. In other cases, however, the importance of social and environmental benefits might justify providing farmers with incentives to adopt – payment for environmental services.

With support from Theme 2, Project 22 researchers are developing and implementing an innovative "training of trainers" program designed to build teams of experts in selected CPWF basins who can use the concepts and tools for studying agriculture-based PES, and who can also train others. The initiative will include several Theme 1 and 2 projects (Projects 6, 11, 15, 17, and 20) as well as the regional soils research networks in Africa, Southeast Asia and Central America.

Understanding catchment hydrology and climate change

A statistical analysis was conducted by project 17 of 50 years of precipitation, temperature and runoff data from locations in the Mzingwane catchment of the Limpopo basin. The result shows declines across the catchment in precipitation, and increases in maximum and minimum temperatures. Observed trends are compatible with those predicted by global circulation models (GCMs), as described in the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (IPCC SRES).

The trends observed have disturbing implications. Zimbabwe's second largest city, Bulawayo, obtains water from the Upper Mzingwane sub-catchment. The long-term reliability of this supply appears to be threatened. Moreover, most people in the catchment are smallholder farmers, dependant on rainfed agriculture. Reduced and erratic precipitation threatens their food security. The sustainability of rural livelihoods and urban water supplies may require an integrated strategy that includes water demand management in urban centers, investment in soil water conservation for smallholder farmers, expansion of recycling by large water users, and development of alternative employment and livelihood opportunities.

Enabling change – social learning and institutional innovations

It was stated earlier that a good understanding of the role of water in the livelihoods of the poor is needed when designing poverty-reducing water management interventions. At some point, it becomes useful to shift emphasis from the former (achieving improved understanding) to the latter (using this new understanding in the design and implementation of action programs for change). In the context of Theme 2, action programs tend to feature social learning and institutional innovations. These are what create incentives for field-level change in agricultural and water management practices by farmers and other stakeholders.

Pilot PES schemes

As described above, project 22, working in the Andes basins, is using a simulation model to quantify the economic, social and environmental impacts of land use changes at the watershed scale. Impacts being studied include trade-offs among rural income, environmental externalities and employment generation. One set of land use practices that emerged as having the potential to reduce negative externalities were conservation agriculture and agroforestry. Pilot PES schemes were introduced in several countries to take advantage of these opportunities.

In Fuquene (Colombia), a low interest credit fund was established (using government and development assistance resources) to compensate farmers for some of the initial costs of adopting conservation agriculture. Eligible practices were those with proven social and environmental benefits. In this scheme, credit is being administered via farmers associations. Association members tend to be better-off farmers, but project staff negotiated with associations and convinced them to represent non-member small farmers as well. Financial and operational sustainability of this scheme was enhanced be increasing interest rates by 0.5% to cover costs of technical assistance. Farmers' associations have since accepted responsibility for fund management. An audit confirmed that 100% of capital disbursed in the first round of loans was recovered.

A similar scheme is being developed in Altomayo (Peru). Here the main interest is in replacing maize – pasture systems with agroforestry systems (including shaded coffee) in catchments supplying water to Moyobamba city. Inspired by results from ex-ante evaluation of land use scenarios using ECOSAUT, a committee was created in Moyobamba to organize the functioning and management of a PES fund. Represented on the committee are the Regional government of San Martin, the municipalities of Moyobamba and Nueva Cajamarca, irrigation district representatives, farmer group and religious group representatives, and the local water supply company.

Using watershed games to foster collective action

Payment for environmental services is one way to internalize externalities in watersheds. There are other ways, however, that rely less on financial incentives and more on collective action, negotiation, or policy change.

Collective action is of special interest to Theme 2 researchers working in project 20. These researchers seek to identify factors that favor the growth of collective action institutions, especially those that span social or ecological scales. In doing so, they use methods drawn from "experimental economics", a gaming approach to simulating realistic situations in which an individual's decisions affect not only his or her own payoffs, but those of other players as well. When engaged in gaming, participants face real incentives – they take decisions to allocate real resource, after which they receive real pay-offs. Recently, researchers have begun to use gaming approaches to analyze determinants of collective action in developing countries among users of common property resources. Project 20 uses gaming in a watershed context to examine how people cooperate in water management and how trust can be fostered between upstream and downstream water users.

In Fuquene (Colombia), project researchers used a "voluntary contribution" game, in which players start with tokens that they can either keep and cash in for money, or invest in a public good. Payoffs to investment in the public good depend on how many others also invest. Incentives are such that everyone would be better off if they all invested everything in the public good, but possibilities for free riding do exist and some players find them irresistible. In the game, as might be expected in reality, players in Fuquene generated only 70% of maximum possible benefits. In other words, public goods were under-provided. Allowing players to communicate and make mutual commitments increased this to 82%.

A variation on this is the "irrigation game". Players also must choose whether or not to invest in a public good, the difference being that benefits generated from the public investment are not divided equally. Instead, early players are allowed to take their benefit first while others must wait and make do with what is left. The idea is to simulate the relationship between upstream and downstream water users, in order to investigate how people behave when they face choices between what is personally beneficial to them and what is good for and fair to others. As expected, achieving cooperation is more difficult under this set of incentives. Communication still improves outcomes; however the threat of fines for taking more than one's "fair share" does not.

These games are useful in assessing the size of losses from failure to cooperate. By changing the rules of the game or the composition of the player groups, researcher can also see how different individual, social and institutional factors affect collective action, and therefore, gain insights into how to motivate cooperation. In addition, games stimulate interest in communities in the topics of common property and collective action. Months after games concluded, participants continued to discuss and analyze the results. The games gave solid substance to what had been vague or unvoiced perceptions.

<u>Using companion modeling to foster social learning</u>

The use of gaming approaches is being taken one step further in the Mekong basin by project <u>25</u>. ("*Companion Modeling for Resilient Water Management: Stakeholder's Perceptions of Water Dynamics and Collective Learning at the Catchment Scale*"). This project uses what they call "companion modeling", where agent-based models are combined with participatory role-playing games. This approach is said to feature "participatory methods to elicit stakeholders' knowledge and perceptions of water dynamics, examine scenarios of resource sharing, and stimulate dialogue" in order to help resolve water-related conflicts among stakeholders."

Companion modeling was developed as a participatory modeling technique to support local decision making processes providing a suite of models that would allow stakeholders to work together with researchers to identify and analyze the implications of land and water use scenarios. The methodology is being tested and adapted in Project 25 as part of action research with communities in the Mekong designed to help communities manage their water resources more equitably and sustainability and at the same time help researcher understand more about how individuals and communities make decisions about water management.

Project 25 conducted a companion modeling exercise in a watershed in northern Thailand where unequal access to irrigation water was a pressing issue. Modeling allowed stakeholders to examine different water management options proposed by different stakeholder groups. A representative of a government agency suggested building a large reservoir above the village. Other participants pointed out that this would benefit relatively few farmers. A community leader suggested constructing a series of small weirs, with water shared within small user groups of three or four households. This was more generally acceptable, despite some disagreement from participants whose plots were located outside the range of the weirs. It was decided to examine the proposal more closely by subjecting it to gaming.

Two small weirs were added across the two creeks of the gaming board. The government representative suggested that the resulting water should be allocated proportionally to farm size, a water-sharing rule favoring well-off farmers. At first, this suggestion was not contested. In later gaming sessions, villagers decided to see what would happen if a different water-sharing rule were used, one in which the same amount of water were allocated to each beneficiary of the weir, with the possibility of temporarily loaning water rights to other members in case of excess. The modeled outcome was highly attractive.

At a later date, when an opportunity arose to invest public funds in irrigation infrastructure, community members agreed to propose the more generally attractive option. Modeling and gaming had allowed them to understand the huge difference in benefits (and benefit distribution) associated with different water management options.

Enabling change – policies to foster integration across scales and sectors

The kinds of action research described above can stimulate processes of change that spread beyond the initial sites. Achieving widespread impact, however, typically requires creating a policy environment that supports rather than blocks collective learning and change across sectors and scales.

Watershed management often involves many government departments. The policies of these departments are not always consistent or complementary. In India and Nepal, Project 23 ("*Linking Community-Based Water and Forest Management for Sustainable Livelihoods of the Poor in Fragile Upper Catchments of the Indo-Gangetic Basin*") has identified opportunities to facilitate better integration of natural resource management practices among forest and water users in upper catchments, through a better integration of forest policies and water policies. Project 28 is bringing together irrigation and domestic water sectors in many countries in support of multiple use systems (MUS).

Fostering inter-communication and information sharing across sectors (e.g., forests vs. water) is important. For widespread impact to be achieved, however, it is equally important that information be shared across scales. Regarding MUS, for example, activities at the national scale (e.g., harmonizing policies across domestic and productive water sectors) and regional scale (e.g., investment in water infrastructure) should not become obstacles to local-scale creativity in designing and operating MUS systems. Project 28 partners and stakeholders are working on models for achieving this in practice.

Reflections and observations

Central to the work of Theme 2 is the conviction that a good understanding of the role of water in the livelihoods of the poor is needed: (1) when designing poverty-reducing water management interventions; (2) when shaping poverty reduction strategies that take account of water-related consequences; and (3) when critically assessing resource conservation strategies that may penalize the poor. The value of "improved understanding" is greatly increased, of course, when put to practical use in the design and operation of action programs for change. Doing so may require expanded links between the work of Theme 2 and other CPWF themes, and with BFPs.

- Downstream consequences of farm-level interventions. One of Theme 2's three objectives is to achieve a better "understanding [of] biophysical and social processes in catchments", including "understanding catchment hydrology and the impacts of land use". Several Theme 2 projects are engaged in preparing datasets and simulation models for this purpose. Frequently, however, other CPWF projects, managed by other themes, are also working in the same basins in the development of land use management options. This is particularly the case for Theme 1. Improved cross-theme integration could facilitate the use by all themes of modeling tools developed by Theme 2, thereby facilitating the consistent assessment of downstream consequences for a far larger set of land use options. The PES initiative, funded through Theme 2 coordination and involving Themes 1, 2 and 4, is an example of how this can be done.

- Catchment hydrology and climate change. A few Theme 2 activities touch on hydrology and climate change. This would seem to an area needing a coordinated and integrated effort by the CPWF. All five themes can make important contributions to understanding the deleterious effects of climate change in benchmark basins on the livelihoods of the poor, and the extent to which new water-related innovations can ameliorate some of these effects.

- Farm-level technical change and poverty. In the above section touching on Theme 1, the following question was posed: "If your . . . project is entirely successful in developing and fostering widespread adoption of new technologies, policies and institutions to improve crop water productivity, how far does this take you towards meeting developmental goals?" "To what extent does success in improving crop water productivity help solve problems of poverty and food insecurity?" Given the emphasis in Theme 2 in understanding the role of water in the livelihoods of the poor, Themes 1 and 2 might wish to join forces with Basin Focal Projects in seeking answers to such questions.

- Enabling change and scaling out. The third objective of Theme 2 is to "enable change". In the context of Theme 2, this takes the form of developing institutional innovations to foster collective action and social learning in ways that help meet development goals. Institutional innovations described above include payment for environmental services, learning alliances for multiple use systems, and the use of gaming and companion modeling to "examine how people cooperate in water management and how trust can be fostered between upstream and downstream water users", to "assess. . . the size of losses from failure to cooperate" and to see how "different individual, social and institutional factors affect collective action [and to] gain insights into how to motivate cooperation". But what about scaling out? How does one go about fostering the generalized use of these institutional innovations such that they affect large numbers of people in all benchmark basins, thereby making a perceptible contribution to achieving developmental goals? Links with Theme 5 on broader policy influence could be useful here.

Theme 3 – Aquatic ecosystems and fisheries

"Over large parts of Africa, Asia and Latin America, freshwater fisheries provide poor rural families with a high quality food, rich in the protein, minerals and unsaturated fats needed for healthy children. But as demand for water increases and water development plans are launched, the interests of the poor sometimes receive a low priority from policymakers, planners and resource managers. A similarly low priority may be given to preserving the environmental and ecological functions of aquatic ecosystems . . . More information might help. Policymakers and planners might be able to improve their decision-making if they had easier access to better information on such issues as: trade-offs among alternative uses of wetlands; the value of [goods and services] produced by aquatic ecosystems; the environmental flow requirements of rivers; how aquatic ecosystems affect water productivity; and ways in which aquatic ecosystem productivity might be improved through innovative technologies, policies, institutions and systems of governance."

(2005 CPWF synthesis report)

Goal and objectives

CPWF Theme 3 is concerned with fisheries and aquatic ecosystems, their contribution to poor peoples' livelihoods, the value of the ecosystem services that they provide, and the ways in which estimates of these values are (or are not) taken into account when decisions are made regarding water use.

The value of a unit of water sold to an urban consumer is easy to estimate, as is the value of a unit of water used to irrigate crops. It is far more difficult to quantify the value of a unit of water used to provide ecosystem services, which encompass all provisioning, regulating, cultural and supporting functions of ecosystems. Just because a value is not easy to estimate, however, does not mean that it is negligible. Decision-makers ignore at their peril the value of goods and services provided by aquatic ecosystems.

Theme 3 projects and activities share the common goal of "*Improving water productivity through sustainable use of aquatic ecosystems and thereby enhancing livelihood opportunities, food security, health and nutrition of the poor communities*." A principal means of reaching this goal is through the development of " . . . *decision support tools for planners and water managers, the application and dissemination of which, will provide quality information on the governance, value and water requirements of these ecosystems and ways to enhance their productivity*." [17]

Participants and partners in Theme 3 aim to reach this goal by realizing the four objectives described below. Specific research questions are posed with respect to each objective. As will be seen, there still are more questions than answers.

<u>Policies, institutions and governance</u>: "First and the foremost is a need for strong policies, institutions and governance arrangements, built on this innovative approach and an increased technical capacity to design and implement it."

<u>Valuation of ecosystem goods and services</u>: "There is a strong need for the valuation of aquatic ecosystems and the tradeoffs among different water users. Such valuation will lead to achieving increased water productivity by incorporating the values of aquatic ecosystems and improving their management."

[17] Theme 3 goals and objectives are taken from the CPWF Medium-Term Plan 2006-2008. pp. 36-41

Environmental water requirements: "Research on environmental flow requirements will complement this work by generating meaningful decision support tools for the water managers to allocate water while accommodating the genuine needs of riverine ecosystems."

Improving water productivity in aquatic ecosystems: "The normal definition of water productivity as 'the quantity or value of goods produced per unit measure of water consumed' is inadequate to describe all the benefits achieved from water bodies. Appropriate new tools are necessary for defining and measuring water productivity in the context of aquatic ecosystems."

Policies, institutions and governance[18]

In general, governance comprises the traditions, institutions and processes that determine how power is exercised, how [stakeholders] are given a voice, and how decisions are made on issues of public concern. Attributes of good governance are often said to include accountability, transparency and participation, and their key components: authority, order, capability and autonomy.[19] It is fair to ask, of course, whether these attributes are always applicable to governance questions regarding natural resource management, regardless of country or culture.

What are the factors that influence people's access to and control over, aquatic ecosystems and their resources?

Theme 3 seeks to identify management and governance options that foster consistency between two things: (1) people's access to and control over aquatic ecosystems, and (2) the biophysical characteristics of those systems. Such consistency is more likely to occur when the biophysical/ ecological characteristics of a resource are taken into account when designing or reforming governance systems. For instance, should decentralization of governance be the same for a floodplain fishery as for a lake fishery? Probably not. Among other things, the "best" governance systems for an aquatic resource may be influenced by the extent to which that resource is under- or over-exploited.

When dealing with aquatic resources, some governance questions are fundamental. "Who gets the water"? "How is this decided"? "What are the trade-offs when water is allocated across uses and users"? These questions are by their very nature cross-sectoral.

Cross-sectoral issues are important in most CPWF projects managed by Theme 3. This is regardless of whether the project begins from the perspective of production, valuation, or governance. While historical development has essentially focused on the development of agriculture, especially irrigated agriculture, improved consideration of fisheries and aquatic ecosystems at a later stage (now that its value is better recognized) inevitably requires expanding the scope of research to other users of water and also to the ecosystem. This also implies dealing with conflicts and finding ways to resolve them.

Project 35 ("*Community-Based Fish Culture in Irrigation Systems and Seasonal Floodplains*"), working in the Indus-Ganges and Mekong basins, focuses on governance systems that are designed to more efficiently utilize aquatic resources that hitherto have been under-exploited. These governance systems are based on collective action.

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[18] This and following sections draw on "2006 Theme 3 Draft Synthesis" by Sophie Nguyen Khoa.

[19] The description of governance is taken from a glossary of terms used by Health Canada. Attributes of good governance are those described in a state-of-the-art review commissioned by Theme 3 (Béné and Neiland, 2006).

In several benchmark basins, substantial areas of agricultural land in floodplains and deltaic lowlands are subjected on a regular basis to seasonal flooding which may last for several months. Some of these lands are used during the dry season for irrigated agriculture. When flooded, however, they normally cannot be used for crop production. Although floodwaters may perform ecological and environmental functions (e.g., flushing of silt, revitalization of wetlands), they typically are not used in ways that contribute directly to the livelihoods of the poor. In this sense, water productivity is low.

There is reason to believe, however, that there are untapped opportunities for using these waters to support managed aquatic production systems, e.g., by enclosing parts of flooded areas to produce a "crop" of specifically stocked aquatic organisms. Harnessing these opportunities, however, depends on getting governance right, in this case communal management of aquatic resources during floods, integrated with individual property rights for agriculture.

Changes in cultural arrangements are exemplified by Project 35 in Bangladesh and Vietnam where community-based fish culture during the flooding season can rotate with individual-based rice culture during the dry season. Preliminary results show that lower costs of rice production and increased net returns can be obtained with no reduction in the fish catch. The benefits from fish culture are distributed among group members according to sharing arrangements pre-negotiated at the beginning of the season. In such cases the share of the fish catch allocated to poor landless members can be a relatively large part of their incomes, given their general lack of alternatives.

The variety of options experienced by different societies in various biophysical contexts shows that, beyond the required attributes of good governance, management and policy-decisions need to ensure that options are adequately designed or selected in relation to biophysical and socio-economic characteristics of the site under study. This also shows that research efforts should not aim to develop a single blue-print for governance, but rather should help identify and evaluate a range options, thereby providing information to stakeholders to help them take decision as to which option is most appropriate.

<u>What kinds of governance systems and enabling policies and institutions foster equitable and sustainable management of aquatic ecosystems?</u>

Equitable management of aquatic ecosystems is of special interest to the poor. A "state-of-the-art" review paper[20] commissioned by Theme 3 has set out a detailed list of research questions on governance systems. Answers to these questions can help improve our understanding of the effect of different governance systems on the poor.

One such questions is as follows, "Is the existence of traditional authorities a good foundation for pro-poor (or improved) governance, and if so how can traditional leaders be incorporated as a third key actor in such a way that the new arrangement will benefit the poor and/or most marginalized sector of the population?" In other words how important is pre-existing "political architecture" in determining the extent to which the poor benefit from alternative approaches to fisheries management?

Issues of governance and policies in equitable and sustainable management of aquatic ecosystems were the subject of a discussion session at the International Forum on Water and Food (IFWF), held in Vientiane in November, 2006. Session participants concluded that "command and control management and governance will not deliver the benefits to the poor that could be achieved through appropriate participation in policy development and implementation. With such approaches must come devolved accountability".

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[20] Béné and Neiland, 2006

How can capacity be built within national and local institutions to understand the livelihoods of poor people and their use of aquatic ecosystems and take account of their needs in policy development and governance processes?

Theme 3 research on the inter-relationships among poverty, livelihoods, aquatic ecosystems, policy and governance has emphasized adaptive learning, partner participation, and partner capacity-building.

Project 35, for example, has adopted an adaptive learning approach, promoting learning as an integral part of the management process. The process not only seeks to develop effective management options for meeting the needs and addressing the uncertainties of the stakeholders engaged in the activity with regard to resource management. It also aims to build the capacity of stakeholders at all levels in the management of community-based fish culture approaches. Partners are encouraged to work with stakeholders to evaluate their interventions, and identify strategies for improving previous outcomes. Through this iterative process, stakeholders increase confidence in their capacity to identify problems and propose and test management options. This process also aims to facilitate dialogue and information exchange between community and government stakeholders to support decision-making.

Valuation of ecosystem goods and services

The Comprehensive Assessment of Water Management in Agriculture (CA) has recognized that, "Fish and other living aquatic resources of inland water ecosystems provide important services that are seriously undervalued." But by how much? As long there is limited capacity to estimate the value of water used to provide ecosystem services, such uses are likely to be ignored in public debate. As the CA itself states, "Improving the consideration of fisheries in water management decisions requires better valuation methods [as well as] improved governance."

The key might lie in whether "valuation" methods are restricted to economic and monetary considerations. This issue was addressed by one of the discussion groups at the IFWF. Their conclusion was that, "Aquatic resources are poorly valued and under-represented in broader water allocation and development policy. Tools are available and should be more widely used, but the current focus on economic valuation misses the crucial role in livelihoods, biodiversity and ecosystem function."

What are the monetary and non-monetary values of goods and services provided by different types of aquatic ecosystems, and what proportion of the household/community economy do they comprise?

Within the CPWF portfolio, Project 30 ("*Wetlands-Based Livelihoods in the Limpopo Basin: Balancing Social Welfare and Environmental Security*") specifically focuses on analyzing trade-offs among different uses of wetlands in dry environments. Specifically, the project aims to assess trade-offs among crop, livestock and fisheries water use strategies in *dambos* and riverine swamps in upper and lower catchments in the Limpopo River basin. The intention is to develop a tool, rooted in trade-off analysis, which can help inform decisions on wetland use and conservation. Among other things, this tool should be capable of determining the extent to which it is possible to increase the use of wetlands to support people's livelihoods without compromising environmental security.

A methodology for valuing wetland goods and services has been developed and is being tested in the South African site, beginning by valuing provisioning services directly benefiting the local community (harvesting of various plants, animals and water; wetland cropping). So far, valuation methods only cover direct provisioning services used by local people and not the "regulating" ecosystem services that are of benefit to downstream users. For the latter, better understanding of the impacts of wetland use on the hydrology of the catchment is needed before. If these impacts are judged to be important, an economic valuation will take place in 2007. A dynamic model integrating socio-economic aspects with the biophysical functioning of the wetland system is being developed to build a trade-off analysis tool.

Environmental water requirements

Theme 3 participants perceive as very important the issue of environmental water requirements – that amount of water needed to preserve and sustain environmental and ecological services, and riverine fisheries. As it happens, Theme 3 does not yet have in its portfolio any projects devoted to this issue. Future opportunities may enable the CPWF to more active in this area. Here are some examples of questions on environmental flows that are of interest to Theme 3 researchers

- What are the quantitative relationship between hydrological changes (including water quality) and the goods and services of aquatic ecosystems that are of high priority for food security and livelihoods?
- What appropriate methodologies exist or need to be developed for the determination, management and monitoring of environmental flow requirements in different aquatic ecosystems? What are the specific freshwater requirements for coastal ecosystems?
- What quantity (and quality) of water is needed to sustain riverine fisheries?

Improving water productivity in aquatic ecosystems

Within the CPWF, the concept of water productivity – defined as the amount or value of output per unit of water depleted – plays a fundamental role. Estimating crop water productivity is relatively uncomplicated: it is the amount or value of crops produced per unit of water depleted, or made unavailable for re-use, e.g., through evaporation, transpiration, contamination, or flow to a saline sink. Estimating livestock water productivity more challenging.

However, the question of how one goes about estimating water productivity in fisheries and aquatic systems is infinitely more puzzling. How is water productivity best defined and measured in the context of aquatic ecosystems?

When and how can water productivity and livelihoods be improved by integrating fish production and harvest of other aquatic animals and plants into farming and irrigation/flood prone systems?

In the state-of-the-art review commissioned by Theme 3, there was some discussion of the productivity of aquatic resources (interpreted in terms of the productivity of fisheries in rivers, floodplains, reservoirs, and lakes) but little discussion of water productivity *per se*. Project 35 continues to work on a conceptual framework for "aquatic ecosystem water productivity", but this work remains at a fairly rudimentary stage. The notion of water productivity applied to fisheries and aquatic ecosystems was also featured in a discussion session of the IFWF, but little progress was made.

One project, Project 34 ("*Improved Fisheries Productivity and Management in Tropical Reservoirs*"), working in the Indus-Ganges, Nile and Volta basins, focuses on fisheries in tropical reservoirs, naturally-occurring or artificially-created bodies of water fed by rivers or streams, whose primary use is to produce fish. As noted in the CPWF 2005 synthesis:

"A sustainable increase in fish production from these tropical reservoirs would be highly desirable, especially if this contributes to improved food security for the poor and to improvements in water productivity. Fortunately, it appears that there are substantial opportunities for increasing fish harvests in these reservoirs through a combination of better harvesting strategies, stock enhancement, and related aquaculture activities. [Project] activities include characterizing a wide variety of tropical reservoirs, assessing and diagnosing issues related to fisheries in the selected reservoirs, working with local fishing communities to develop tools and strategies for enhancing fish harvests, designing co-management arrangements, evaluating markets, disseminating results, and engaging in training and capacity building. Complementary research is to be done on assessing water quality in reservoirs as affected by fisheries management strategies."

During the course of 2006, project participants engaged in socio-institutional assessments of fisher communities (data collection and analysis still continuing); surveys of the physical environment (e.g., variables affecting water quality); evaluations of biological productivity and ecosystem services (different approaches used in different basins); assessments of fish stocks (data collection in process or completed from secondary data and supplementary surveys); analysis of the potential for enhancing fish productivity; and a study of local markets to ascertain the extent to which increased fish production can serve as a source of increased cash income.

<u>What new technologies can be designed to further improve the integration of fisheries into farming systems?</u>

The Comprehensive Assessment notes that, "There are two broad challenges for fisheries production. The first is to sustain the current levels of fisheries production and other ecosystem services through the provision of target-directed environmental flows that sustain or restore the aquatic environment, including its diversity, and improved management of capture fisheries. The second is to increase current levels of fisheries production through the wider adoption of methods for enhancing and intensifying production, such as stocking and aquaculture." This clearly includes the integration of fisheries into farming systems.

The key is to have simple and rapid tools for estimating seasonal water requirements needed to sustain aquatic ecosystems, fish communities and fisheries. Once such tools are available, implications for water management technologies (e.g. sluice designs, barrages, weirs, and other in-river structures) and conservation practices (water requirements for different designs of rice ecosystems; farming practices; fish pond management regimes) become apparent. In this way, fisheries requirements can be taken into account when irrigation systems are designed or operated, and when in-river structures are built and utilized.

Several projects are contributing to the development of needed tools, among them Project 35 and Project 10 on water requirements; Project 35 on in-river structures; and Project 46 and Project 10 on irrigation system design and management.

Progress made by Project 10 ("*Managing Water and Land Resources for Sustainable Livelihoods at the Interface between Fresh and Saline Water Environments in Vietnam and Bangladesh*") is particularly interesting.[21] Millions of people living in tidal ecosystem in South and Southeast Asia are poor and food insecure because agricultural production is hindered by seawater intrusion during the dry season, and because of the lack of fresh water for

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[21] Liz Humphries, Leader for Theme 1, provided this detailed analysis of Project 10

irrigation. In the Mekong delta of Vietnam and the Gangetic delta of Bangladesh, moving from rice culture (a single wet season crop) to double rice cropping, rice (wet season) – shrimp (dry season) culture, or shrimp monoculture, has created economic wealth for some and national export earnings. However this has been at the expense of livelihoods and food security and/or the environment for many small farmers and landless laborers, and has become a source of serious social tension and conflict.

The rivers in the coastal areas in Vietnam and Bangladesh are tidal. During the wet season the river water is fresh, but during the dry season, salinity increases. As the tide rises saline water flows upstream, then returns downstream as the tide ebbs. Agricultural lands are protected from flooding by levee banks and sluice gates which are opened to allow fresh water into the polders, and closed to prevent flooding or entry of saline water during the dry season. Availability of fresh water to grow rice during the dry season is a major limitation to food security and livelihoods.

Interventions include new varieties, changes in water management and irrigation practices, and new production systems.

Varieties: In both countries, new high yielding varieties with better tolerance to salinity have been introduced to project areas in coastal regions. Such varieties, however, must also be compatible with selected farming systems. In Vietnam, for example, rice varieties OM4498, OM4872 and MTL384 have been found attractive for "(rice/ upland crop) – rice" and "rice – (rice + fish)" systems. In contrast, the rice variety Mot Dui Do is preferred for "shrimp – (rice + fish)" systems. In Bangladesh, some farmers have been trained in quality seed production of modern varieties and there are plans for further training, especially of women. Surveys have shown that in the Bangladesh project area more farmers with medium and large holdings are now growing modern varieties.

Water management: In Bangladesh, the project has shown that river salinity increases during the dry season reaching the maximum salinity for rice culture (~4 dS/m) by mid-February. However at this stage the crop is not yet mature, and yields are poor unless supplemental irrigation is used. There is an opportunity to grow dry season (boro) rice using groundwater, and/or using the river water up until about mid-February and finishing the crop on (low salinity) river water stored in the natural river channels in the polders before the river water gets too saline. The amount of water which can be stored in the channels will determine the area of boro rice that can be grown in areas where suitable groundwater is not available or affordable.

The area of boro rice can be maximized by (i) increasing the storage capacity of the channels, e.g., desilting, and (ii) reducing the boro rice demand for water by reducing the duration of the rice crop beyond mid-February.

Cropping system: The project has developed systems for diversifying the rice-based system in both Vietnam and Bangladesh, including rice grown in combination with fish, prawns or both, and in rotation with vegetables during the dry season in Vietnam. Depending on the location/zone (salinity of the available water during the dry season), shrimp or shrimp/crab can be grown in rotation with the rice-fish/prawn.

How should water productivity be measured in order to facilitate inter-sectoral comparisons and support water management decisions?

Research managed by Theme 3 has focused on increased aquatic resource productivity in a range of water bodies (lakes, rivers, floodplains, ponds). Evaluations of water productivity for these systems have not, however, provided measures appropriate for use in making inter-sectoral comparisons or supporting water resource management decisions. These experiences generally reflect the difficulty in interpreting the concept of water productivity in a field that has traditionally focused on the level of output (principally fish) rather than linkages with ecosystems services.

Discussion on this topic at the IFWF confirmed that water productivity remains a difficult concept to apply to fisheries. Most thinking on this topic appears to have taken place largely within the CPWF and some CG centers, the Comprehensive Assessment and CPWF having been major triggers in this process.

In conclusion, while attractive as a standard concept for assessing and managing water across sectors, the concept of water productivity has proven difficult to apply to fisheries or aquaculture. Further work is needed to clarify the definition of water productivity in fisheries and aquaculture, and test its relevance and applicability. Further research has been planned in the 2007-08 research agenda of Theme 3, and a scientific publication will aim to fill this gap.

Reflections and observations

- Aquaculture and reservoirs in dryland environments. Several CPWF projects are focused on the establishment or management of ponds or small reservoirs in dryland environments. These are usually intended to have multiple uses, aquaculture among them. Theme 3, in collaboration with other themes and with BFPs, might wish to more closely examine the productivity of these reservoirs in aquaculture, the extent to which they accelerate water depletion through evaporation, how much they improve livelihoods and reduce poverty, and whether they cause decreased water availability for downstream communities.

- Water quality and aquatic resources. Theme 3 researchers clearly place a high priority on developing methods to value ecosystem services – so that these values can be taken into account in decision-making on water allocation and use. Within this broader issue of valuing ecosystem services, there might be some merit in a much more specific focus on water quality and its effect on aquaculture and fisheries. Upstream water management, including upstream investments in water resource development and land management practices in agriculture, can have large effects on the quantity and quality of water available for fish culture. Through research on the effects of water quality change on fisheries productivity and people's livelihoods, Theme 3 could more effectively form an alliance with Theme 2 on ways to influence upstream water and land management to benefit downstream populations.

- Enabling change and scaling out. One objective of Theme 3 (and for all other themes) is to enable change. In the context of Theme 3, this includes activities such as those described above that are aimed at fostering changes in governance and property rights to facilitate community-level collective action and investment in aquaculture. But what about scaling out? How does one go about fostering the generalized use of such institutional innovations so that they affect large numbers of people, thereby making a perceptible contribution to achieving developmental goals? How do you go from two communities to 200,000?

- Catchment vs. basin scales. Related to the above, but in a more general sense, most CPWF projects have adopted a local and/or catchment perspective. How such results translate at river basin scale is not clear and this requires further research to identify adequate diagnostic and assessment tools and frameworks. That is one reason why the new Theme leadership has decided to strengthen linkages other themes as well as Basin Focal Projects (BFPs). The Theme 3 leader has already increased this interaction and the team has planned to provide direct inputs to the BFPs, and joint visits to field sites with other Theme Leaders. A continuous interaction through an interactive process is planned to ensure progress towards integration of local and catchments results into a basin scale perspective. In turn, BFPs and other themes have shown an interest in enhancing the consideration of fisheries and aquatic ecosystems into their research agenda.

Theme 4 – Integrated basin water management systems

"The focus of attention [now] shifts to the basin as a whole, and to the integrated management of its water resources. Within a river basin, water resources become available and are used for a succession of purposes. These may include the production of plants, animals and fish; rural and urban direct consumption; industrial use and power generation; river transport; and the preservation of wildlife habitat and ecological processes. There are therefore many competing uses and users of water.

There may also be sizeable opportunities for enhancing water productivity through multiple and sequential uses of water as it cascades through the basin. Effective water resource management at the basin scale takes account, to the extent possible, of medium- to long-term processes of change, e.g., population growth, migration, urbanization, economic growth, opportunities for water development, water quality change . . ."

(2005 CPWF synthesis report)

The CPWF recognizes the global magnitude and severity of hunger, poverty, and disease. The Program further recognizes the many obstacles to overcoming these problems, among them climate change, resource degradation, and impaired ecosystems. Central to all of these is a rapidly unfolding crisis of water scarcity. Growing and urbanizing populations will need more water for direct consumption, power generation, industrial production, and increased food production. This must be achieved without excessive damage to ecosystems. [22]

Yet disturbing trends are apparent. Groundwater depletion proceeds apace in the Indus and western Ganges. Lake Chad is drying. The Yellow River at times no longer reaches the sea. In many developing countries, agricultural growth has not kept pace with population growth. Addressing such challenges is complicated by temporal and spatial variability in water availability, risks of floods and droughts, and multiple and diverse uses for/ users of water. Basin level research is needed to improve our understanding of these issues and to facilitate suitable decision making processes. In this context, "suitable" means using multiple criteria, involving multiple stakeholders, and taking account of multiple sectors and scales.

Theme 4 helps address these challenges by seeking answers to key questions, among them: What kinds of agricultural development strategies are most effective in reducing poverty? How might these strategies affect water and land resources at the basin level? By how much does basin-level water productivity need to increase so that adequate water is left for the environment? How can this level of increase be attained?

Goal and objectives

Theme 4 projects and activities share the goal of " . . . *[contributing] to poverty alleviation and to enhancing food, health and environment securities through the generation of the knowledge base needed to better manage water, land and agricultural production systems in ways that lead to increasing agricultural output and water productivity in agriculture.*" [23]

Participants and partners in Theme 4 aim to reach this goal by realizing three objectives:

[22] This paragraph is partly drawn from the Vientiane Statement issued by the IFWF.
[23] Theme 4 goal and objective statements are from the CPWF Medium-Term Plan 2006-2008. pp. 42-43.

- Innovative technologies and management strategies developed, tested and disseminated
- Effective policies and institutional arrangements identified and disseminated
- Decision support tools and information developed and effectively utilized

Innovative technologies and management strategies [24]

"Efforts to [increase] agricultural production and water productivity are constrained by lack of a good understanding of location specific (a) potential, attainable and actual yield; (b) technological and management practices that would enable resource poor agricultural producers tap this potential; (c) the cost and benefits of tapping such a potential and (d) implications of [tapping] the potential in one location on other agricultural producers and other water users including the ecosystem." (MTP 2006-8)

The CPWF invests substantial resources in the development of innovative farm-level technologies and management strategies. Earlier sections described the work of Theme 1 on increasing crop water productivity, and the work of Theme 2 on improving water allocation in catchments through institutional innovations (payment for environmental services, water systems designed for multiple uses, gaming to foster collective action and social learning). The work of Theme 4 seeks to complement these efforts in several ways:

- identifying scaling out opportunities for innovations, and helping evaluate the downstream and cross-scale consequences of widespread adoption
- evaluating livestock water productivity as well as crop water productivity
- assessing strategies to increase water availability through safe re-use of wastewater
- taking a closer look at the special role of small reservoirs in dry environments

<u>Basin-level water productivity and crop technologies</u>

In the <u>Volta</u> basin, Project <u>5</u> ("*Enhancing Rainwater and Nutrient Use Efficiency for Improved Crop Productivity, Farm Income and Rural Livelihoods in the Volta Basin*") conducts research to identify on-farm technologies and management strategies that lead to sustainable and profitable improvements in crop yields and crop water productivity. Theme 4 builds on this by focusing on the following two "value-added" questions:

- In which areas of the basin can these technologies and management practices be applied (scaling out)?
- What would be the hydrologic, social, economic and environmental impacts of basin wide application of these technologies and management practices (downstream and cross-scale consequences)?

Project 5 is evaluating the following technologies and practices: "*Soil fertility management practices (e.g., cereal-legume crop rotations, fertilizer micro-dosing, mulching with the leaves of Acacia); Soil and water conservation practices (regularly spaced ridges across the slope, Zai pits, mulching with Acacia); Diversification to tree crops (e.g. Ziziphus mauritania) planted in regularly spaced half-moons along the ridges; Boundaries and wind breaks of Acacia (to reduce evaporation and provide firewood and seeds for chicken feed as well as leaves for mulch).*" (From the earlier section on Theme 1.)

[24] This and following sections on Theme 4 draw on the 2006 Synthesis Report on Integrated Basin Water Management Systems (IBWMS), drafted by Francis Gichuki.

At the farm-level, adoption of some of these technologies in the Volta basin are observed to have had positive localized hydrologic and ecological benefits: reduced runoff and soil loss, increased infiltration, more rapid groundwater recharge, and increased dry season flow in nearby streams. The overall hydrological impacts, however, are difficult to assess because of patchy technology adoption patterns and lack of data. Soil water balance assessment using DSSAT models indicate that some technologies reduce runoff by up to 35% and increase deep percolation by up to 25%. Increased deep percolation is expected to have a positive impact on groundwater recharge – at least in the near term, until tree densities and root zones grow to take advantage of increased soil water availability.

If the adoption of new farm-level technologies were to become truly widespread, the downstream and cross-scale consequences could be considerable. Urbanization in the Volta basin is accelerating, resulting in increases in urban water demand and electric power consumption (thereby increasing the demand for hydropower). Most towns have inadequate water and sanitation facilities. Ouagadougou with a population of 1.2 million people experiences water shortages during the dry season and, despite new dam construction that provides an additional storage capacity of $200Mm^3$, water scarcity persists. There has also been some expansion in irrigated area. The adoption of best-bet technologies in rainfed areas could help increase household food security and avert the need for further development of small reservoir based irrigation, while benefiting hydropower generation by reducing siltation rates in reservoirs.

Future plans for Theme 4 call for an assessment of processes such as those described above. A first step will be to evaluate changes in run-off coefficients, using the SWAT model. Impacts of technology adoption on soil carbon levels will also be estimated.

<u>Basin-level water productivity and livestock technologies</u>

Livestock production is a major component of global agriculture. Its importance is expected to continue to grow, driven by population growth, urbanization, higher incomes and changes in dietary preferences. To be sustainable, livestock production will need to address environmental concerns: Over-grazing and soil erosion, water pollution, water depletion in areas where livestock are feed with irrigated grain, global warming related to methane emitted by livestock, and loss in biodiversity associated with conversion of wetlands and forests into grazing lands.

Project <u>37</u> ("*Increasing Water-Use Efficiency for Food Production through Better Livestock Management - The Nile River Basin*") explores how technical interventions can, at the basin-level, enhance positive and reduce negative impacts of livestock production. In-depth studies on livestock production in Ethiopia, Uganda and Sudan are complemented by case studies drawn other parts of the <u>Nile</u> basin.

The livestock water productivity framework developed by Project 37 has identified pathways for enhancing livestock output, profitability and productivity through appropriate water, feed and livestock management. Livestock water productivity is conceptualized as benefits per unit of water depleted. Benefits can be expressed in physical or monetary units. Five strategies have been identified for improving livestock water productivity:

- Use high water productivity feed sources. There are huge differences in water productivity among alternative feeds, e.g., natural pasture, improved pasture, crop residues, or rainfed/irrigated grain or fodder
- Further improve water productivity in feed production

- Increase the efficiency of feed utilization by reducing waste
- Select management strategies (livestock type, variety, health status, feeding habits) which increase livestock production per unit of feed and per unit of water
- Introduce livestock processing and marketing strategies that add value and increase "shelf-life"

The above strategies focus on livestock management and feed production. There are other strategies utilizing farm system interactions that can be just as powerful and effective. The following case study illustrates this.

A case study from the Gezira irrigation scheme in Sudan shows how integrating livestock with irrigated crop production can enhance the productivity of both systems. The Gezira scheme has an irrigated area of 800,000 hectares, most of which is under cotton. Livestock were originally prohibited because of anticipated damage to irrigation infrastructure. Nonetheless, livestock were gradually introduced because of three factors: (a) a huge demand for livestock products, (b) a lack of natural grazing lands, and (c) the availability of abundant livestock feed from crop residues, weeds and agro-industry byproducts. At first, animals were only brought in to be fattened before slaughter. Soon, however, livestock became an important source of income. This gradually led to the introduction of fodder production within the irrigated crop rotation. The introduced legume crops enhanced soil fertility, benefiting subsequent crops. Areas that occasionally receive excess water now divert this to forage plots. The outcome: a win-win situation for irrigators and livestock keepers.

Basin-level water productivity and wastewater technologies

One way around water scarcity is to develop "new" sources of water. The most simple way of doing this is to invest in large-scale water resource development. There are more subtle ways, however, such as fostering the safe, productive use of wastewater.

Rapid urbanization in developing countries is accompanied by an equally rapid growth in urban and peri-urban agriculture (UPA) systems. These systems produce vegetables, milk and meat for local markets. UPA is most important when: (a) demand for such products is large, (b) plots of unutilized land are available, (c) solid waste and wastewater rich in nutrients is abundant, and (d) many urban residents are unemployed or under-employed.

UPA can effectively contribute to poverty alleviation through employment creation, higher incomes and lower food costs. However, it also poses health problems. Vegetables produced in urban and peri-urban areas are generally contaminated with bacteria and protozoa. Irrigated vegetable plots also create breeding sites for the mosquito that causes malaria.

Theme 4 Projects 38 ("*Safeguarding Public Health Concerns, Livelihoods and Productivity in Wastewater Irrigated Urban and Peri-Urban Vegetable Farming in Ghana*") and Project 51 ("*The impact of waste water irrigation on human health and food safety among urban communities in the Volta Basin – opportunities and risks*") build on past work aimed at understanding the nature and extent of the problem, and then finding and applying solutions. Both projects work in the Volta basin.

These projects have established that vegetables generally contain high levels of faecal coliforms and helminth eggs. Sources of contamination include soils, irrigation water, animal (poultry) manure, "cleaning" activities, and even display in open-air markets. High levels of contamination, for example, were found in lettuce grown during the rainy season, or irrigated with wastewater from drains, water from urban streams and shallow wells, or piped water from urban supply systems. Contamination was highest for stream and lowest for piped water. Irrigation water from streams and shallow wells had coliform counts that exceeded WHO recommended levels. These counts were highest during March to June, because of runoff contamination of urban streams during the first two months of the rainfall season and percolation of these pollutants to shallow groundwater tables. And even lettuce produced with piped water was not free from faecal coliform, having been contaminated by immature poultry manure application or grown in contaminated soils.

The study challenges the conventional wisdom that only lettuce grown using waste water has unacceptable levels of pathogen contamination. Because there are multiple sources of contaminants, risk can be high regardless of water source. For this reason, an integrated approach may be essential. Some elements considered by the projects include:

- Increase public awareness of contamination pathways and attendant risks
- Use irrigation methods that reduce direct contact of crops with contaminated water
- Wash vegetables with clean water before marketing
- Reduce soil contaminants by decreasing surface runoff inflows from areas with high levels of pollutants, and by using composted, not fresh, animal manure
- Promote the production of alternative crops with lower health risks.
- Build the capacity of producers to produce more safely.

In spite of health hazards, urban and peri-urban agriculture will continue to expand within the limits of available land resources. In principle, health risks can be managed so that UPA producers can continue to use waste-water resources. Widespread use of safe UPA practices could have basin-level effects on water allocation by reducing the amount of water diverted from agriculture for urban use (other things being equal). Evaluation of such basin-level consequences, however, still lies in the future.

Basin-level water productivity and ensembles of small reservoirs

In relatively dry rainfed environments, small multi-purpose reservoirs are often an important source of water. They provide water for domestic use, livestock watering, small scale irrigation, fisheries, brick making, and the largely undocumented environmental function of supporting wild life. In the Volta and Limpopo basins, the number of small reservoirs is continuously growing. For example, Burkina Faso, Ghana and Zimbabwe have 1500, 500 and 7000 small reservoirs respectively. These reservoirs were constructed in a series of projects funded by different agencies, at different times, with little or no coordination among the implementing partners.

Where there are many small reservoirs in a sub-basin, they should be considered as an "ensemble", with synergies and tradeoffs determined with their number and density. Ensembles of reservoirs are hydrologically linked by the streams that have been dammed. A large ensemble of reservoirs could store a substantial quantity of water and have a significant effect on downstream flows. Such effects typically are poorly understood and rarely considered when additional reservoirs are built.

Within Theme 4, this topic is studied by Project 46 ("*Planning and Evaluating Ensembles of Small, Multi-purpose Reservoirs for the Improvement of Smallholder Livelihoods and Food Security: Tools and Procedures*"), working in the Limpopo, Sao Francisco and Volta basins. In the Limpopo basin, a study of four dams in the Mzingwane catchment was used to estimate the volume of water abstracted, its different uses (livestock watering, domestic use, irrigation, fishing, brick making, and collection of reeds used for roofing) and its productivity in each use. Livestock were found to consume on average over 70% of water for consumptive uses.

The water productivity of a reservoir is influenced by how water is used. Different uses have different sets of consequences, some of them negative. Harmful algal blooms (HAB) have been found useful as an indicator of aquatic stress. Their presence typical reveals a dysfunction related to excessive nutrient loading or pollution. In a context of elevated population density, the anthropogenic pressure exerted on watersheds and on the reservoirs themselves is likely to enhance the probability of HAB occurrences. Cyanobacterial blooms are of particular concern because of their potential harmful impacts on human health.

Future plans call for increased attention by Project 46 to the downstream and cross-scale consequences of continued investment in small reservoirs construction.

Effective policies and institutional arrangements

"Water productivity is constrained by lack of effective policies and institutional arrangements (good governance, legal framework and organizational structures) that create a conducive environment that facilitates the behavioral changes towards sustainable water resources management and agricultural production. Effective institutional arrangements are urgently needed to minimize conflicts, improve water access for the poor, and enhance investments in water development and management and the adoption of integrated water resource management principles." (MTP 2006-8)

Often there are opportunities to increase basin level water productivity through policy and institutional innovations that encourage good governance, and foster sustainable water resource management and agricultural production. Effective institutional arrangements are needed to manage conflicts, improve water access for the poor, and enhance water-related investments – and to do so in ways compatible with the principles of integrated water resource management. Theme 5 conducts complementary research on conflict management, while Theme 2 also works in the area of encouraging water access for the poor. Theme 4 makes sure that questions of basin-level water productivity are not forgotten in the process.

<u>Institutional interventions and the development and effective use of reservoirs</u>

The issue of basin-level water productivity and how it can be influenced by ensembles of small reservoirs was introduced above. Water productivity of reservoirs is influenced by the range of uses to which they are put, and the positive and negative consequences of these uses. As a rule, small reservoirs are treated as common property. Their planning, development and management should be guided by institutions that facilitate the attainment of societal objectives, e.g., reduced mismatch between water demand and supply, equitable distribution of benefits and sharing of the water resource, and productive use of stored water. The fact that many small reservoirs are functioning sub-optimally and/or are falling into disrepair suggests problems of institutional failure.

Project 46 reports that the past poor performance of water management institutions in the Volta and Limpopo basin have been the main drivers for creating new and more responsive institutions. Some countries in these basins have revised their water policies and have undertaken major reforms. These reforms bring with them a number of new institutions, processes, and procedures that will impact upon planning and management of small reservoirs. Supra-national agencies (Volta Basin Authority and Limpopo River Basin Commission) have been created to address transboundary water issues. In Ghana, the Water Resources Commission (WRC) oversees allocation of all water resources in the country and is creating sub-basin organizations to oversee water allocation and development. The White Volta sub-basin board has been set up to determine how district authorities, water users, and civil society can collaborate to manage water.

Many important water management institutions, however, are informal. The management of small dams is influenced by traditional leadership structures, which in turn may receive technical and financial assistance from various organizations. Small dam management needs to be coordinated with involvement by communities, NGOs and government, if the full benefits of these natural resources are to continue to flow on into the future.

Collective action and water governance

One way to improve water productivity at the basin level might be through the voluntary reallocation of water resources from low- to high-productivity uses. There may be win-win opportunities for reallocating water resources among the entire range of possible uses in a basin: rainfed agriculture in upper catchments, irrigated agriculture downstream, rural and urban direct use, industrial use, hydropower generation, riparian navigation, fisheries and aquatic systems, and even ecosystem services. At the whole-basin level, of course, there are likely to be an enormous number of stakeholders, each with their own interests. Understanding possible trade-offs and fostering a fully inclusive stakeholder dialogue is necessarily complex and difficult.

Project 40 ("*Integrating Knowledge from Computational Modeling with Multi-Stakeholder Governance: Towards More Secure Livelihoods through Improved Tools for Integrated River Basin Management*") working in the Andean and Volta basins aims to strengthen multi-stakeholder governance structures in two project sites, one in Ghana and one in Chile. Governance structures are thought to be important because they are the venue where negotiations occur at the sub-basin level on questions of water allocation. These structures are to be strengthened by identifying problems, shaping policy options, and establishing criteria for their evaluation by stakeholders. As described in the 2005 CPWF synthesis report,

"Initial project activities feature an analysis [and mapping] of the existing multi-stakeholder governance structures . . . The purpose of this analysis is to identify relevant stakeholders/ decision makers and the flow of water-related information amongst them, and then to integrate this information into model development and a corresponding research and learning framework . . . Stakeholder evaluation of policy options is to be assisted by a simulation model capable of "predicting agent-agent and agent-environment interactions". The simulation model in question integrates a climate model, a hydrological model and an agent-based socio-economic model. Decision support tools are to be designed that will allow stakeholders to better visualize the outcomes of different simulation scenarios. The intent is to use these decision support tools during actual processes of negotiation and planning within the governance structures in question."

The Chile case study focuses on market-oriented policy instruments associated with trade in water user rights, and the development of small-scale and large-scale irrigation infrastructure. Several critical issues have been identified. These include variation in individual incentives to participate in collective action; transaction costs associated with collective action; the effect of changes in institutional rules on individual incentive structures; and links among different stakeholders, e.g., between water users associations and irrigation system officials, between current rights holders and those who will gain from changes in water rights, and between stakeholders representing different interests, such as irrigators, hydropower and recreation.

Collective action problems in water trade were identified as (a) supply guarantees, (b) enforcement of water rights and (c) adequate and credible information. Collective action problems associated with small scale irrigation infrastructure development include (a) purchase and installation of water distribution monitoring equipment; (b) overnight water storage facilities, (c) canal operation and maintenance. The study noted that monitoring flows provides information on actual quantities of water used by each member and that such information provides a pure public good even in the absence of water trading. One major concern is that of free-riders. Collective action problems associated with large scale infrastructure affect a much larger group of users and can have substantial positive and negative externalities. Reconciling competing water interests and managing externalities requires institutional structures within which negotiations and bargaining can take place.

The Ghana case study focuses on major constraints/problems/conflicts associated with water governance. Issues vary by community and include declining water availability, deteriorating water quality, deficient infrastructure, inequitable allocation, and inadequate enforcement of the rules and regulations. The study also presents the negative social, economic and environmental impacts and the coping strategies of different communities.

Groundwater governance

Groundwater problems emerge slowly and incrementally as a result of the cumulative effects of abstractions, contamination and changes in groundwater recharge. Timescales for remediation are also long, and impacts noticed today will persist for some time, even after the reversal of the original stresses. Problems related to groundwater include:

- Continuously dropping groundwater tables
- Increased costs of groundwater pumping
- Inequitable access (when access to water depends on affordability of pumping)
- Drying out of groundwater-dependent water bodies and ecosystems
- Increased problems with salinity or salt-water intrusion into groundwater
- Groundwater contamination

When groundwater is treated as a common property and is readily available over large areas it becomes vulnerable to over-exploitation. This occurs when large numbers of users individually choose to tap it for their own purposes. Groundwater science can help assess the status of the resource, understand aquifer vulnerability, and anticipate surface water – groundwater interactions. Wise management of groundwater requires that decision-makers understand the effect of policies on water use; the limitations of regulatory provisions in groundwater conservation; the role of different stakeholders in decision making; and the need for integrated approaches that balance productivity, equity and environmental goals.

Unfortunately, there is often a disconnect between groundwater technical specialists and decision makers charged with its sustainable use and management. There is a strong need to close the gap in perceptions and understanding between these two groups.

Within Theme 4, work on this issue is done by Project 42 ("*Groundwater Governance in Asia: Capacity Building through Action Research in Indo-Gangetic (IGB) and Yellow River (YRB)*

Basins"). Project 42 builds on a substantial body of past work on groundwater and its management in East and South Asia and uses it in a research-based capacity-building program to strengthen groundwater governance. The project aims to develop teams of well-rounded, inter-disciplinary, problem-solving groundwater researchers and managers.

The project works with functionaries from government, civil society, media and academia in an inter-disciplinary inter-regional program of training and applied policy research. Training is organized around five modules:

- Resource characterization - hydraulics, hydrology, hydrogeology, soil physics, water lifting, irrigation systems, databases and GIS, etc.
- Agricultural water use –ecological principles, crop and livestock production, soil and water conservation, soil-water-plant relationships, irrigation practices, etc.
- Social science – economics, social processes, institutions, stratification and change, sociology, political systems, economics and human nature
- Governance and policies – the energy x irrigation nexus, property rights, institutions for water allocation, negotiating water rights, conflict management,
- Research methods

The first training of 40 practitioners took place in November 2006 in India and the trainees identified research topics that address a groundwater management challenge they face. Activities include literature reviews, sensitization trips to different countries, development of a knowledge base, pilot studies, and synthesis research. Formal training was followed by an intensive program of pre-designed action research supervised by renowned professional. Of particular interest have been the sensitization trips, in which participants have learned to understand groundwater issues, existing approaches to dealing with them, and further options for action

Some generic lessons learned include the following:

- Groundwater problems vary spatially and temporally. Well-targeted technical and institutional intervention packages are needed to address them.
- Even well targeted policies are difficult to implement because of the large number of groundwater users and the unpredictable outcomes of policy implementation.
- Under predictable market conditions, farmers generally adapt to changes in groundwater tables, pumping costs and water pollution by changing cropping systems and adopting water saving technologies.
- Groundwater use declines as groundwater depth and pumping costs increase.
- Groundwater scarcity and related high water costs differentially affect the poor.

Decision support tools and information

"Basin level decision support tools and information are needed to generate the credible knowledge base needed to address contentious issues such as: (a) transboundary water allocation; (b) application of the "user-pays" and "polluter-pays" principles of integrated water resources management; (c) facilitating integration of different sources and uses of water and management organizations and levels; (d) enhancing participation of the poor and marginalized by packaging information on the issues that affect them in ways that they can understand and relate to; (e)

facilitating wide-spread adoption of appropriate technologies and management strategies; and (f) for analyzing trade-offs between food and environmental security, equity versus economic efficiency, and allocating resources among competing users and users." (MTP 2006-8)

Decision support and information systems (DSS) cut across all other Theme 4 objectives. They are fundamental to Theme 4 efforts to better understand the consequences for basin-level water productivity of activities described above, e.g.,

- Scaling out different kinds of new farm-level technologies featuring crops, livestock and/or the use of wastewater
- Investing in ensembles of small reservoirs in dry environments
- Implementing institutional and policy innovations to improved water resource governance, especially that touching on groundwater

In addition, DSS are central to other aspects of water management, e.g., the management of large dams. Issues here include operation decision-making, benefits sharing and environmental flows.

<u>Dam DSS and environmental flows</u>

Typically, decisions on releasing reservoir water are based on economic and safety considerations, with relatively little consideration of environmental consequences.

Natural water systems can tolerate a range of flow conditions. Their resilience allows them to recover from some degree of human use and abuse. However, there is a level of flow modification beyond which the river losses its ability to recover, and begins to lose its capacity to produce ecosystem services. Understanding what these limits are and implications for decisions on reservoir releases calls for the development of a DSS for managing environmental flows from reservoirs.

There has been some work done in the past on environmental flows. It has had limited application, however, because it has usually not been integrated into decision support systems used by decision-makers to absorb, process and use information. This is particularly true for the semi-structured or unstructured decision context in which environmental flow issues are often addressed. Under this context, it is important to make sure that decision makers understand the importance of the decisions they are taking, have access to understandable data and operate within a decision framework that makes explicit both the implications of different decisions and the trade-offs involved.

Theme 4 work on DSS for large dams is carried out through Project <u>36</u> ("*Improved Planning of Large Dam Operation: Using Decision Support Systems to Optimize Livelihood Benefits, Safeguard Health and Protect the Environment*"), operating in the <u>Nile</u> basin.

Lessons learned by this project include the following:

- When faced with the challenge posed by water scarcity, environmental requirements are usually the first to be sacrificed.
- A suitable legal framework is a necessary but not sufficient condition to ensure proper design and implementation of environmental flow targets.
- Where dams are operated to meet the environmental flow requirements, a perception often persists that the dam created hardship for downstream people.

- Good science is needed to estimate the patterns of flow that could be expected to achieve targets for river health conditions, and allow the calculation of losses to downstream communities to determine appropriate compensation.
- Data continues to be a major constraint to generating information needed to manage environmental flows.
- There is a general perception that incorporating environmental flow considerations can make investments in dams unprofitable.
- Different people often attach different importance to different issues. As a consequence, negotiations on environmental flows can be difficult and contentious.

Dam DSS and benefit sharing

DSS is important when designing and implementing mechanisms for sharing benefits from large dams and other water resource development projects with project-affected communities. The rationale for do so includes the following:

- Dams generally generate significant rent that can be shared with communities
- There are ethical reasons for sharing benefits with project-affected population.
- Dam projects can be conceived as part of a strategy to foster regional and local development and to re-establish those displaced.

Project 36 conducted a review of benefit sharing mechanisms used in 11 dam projects. The feasibility of a mechanism depends on having a suitable DSS. Mechanisms have included:

- Redistribution of part of the dams revenue to local or regional authorities in the form of royalties tied to power generation or water charges
- Establishment of development funds financed from hydropower sales
- Part or full ownership of the project by project-affected population (equity sharing)
- Levying revenue generating property taxes by local authorities
- Granting preferential electricity rates and fees for other water related services to local companies and project-affected population.

DSS and ensembles of small reservoirs

The opportunities and problems associated with investment in ensembles of small reservoirs in dry environments were discussed above. It should be clear that DSS is essential in order to seize the opportunities and address the problems. Tools have been developed by Project 46 to estimate the spatial coverage and capacity of reservoirs. Work continues in order on such topics as measuring evaporative losses, assessing health aspects, evaluating impacts on water quality, etc. The following approach to assessing reservoir spatial distribution gives a sense of approaches being used:

" . . . the technique for automatic delineation of small reservoirs . . . utilizes Synthetic Aperture Radar images, high resolution images taken at radar frequencies from space. A statistical active contour model, developed for segmenting synthetic aperture radar (SAR) images into regions of homogeneous speckle statistics, is used for delineation of water reservoirs. The water boundaries are detected based on a technique that measures both the local tone and texture along the contour.

To improve the accuracy, the density slicing and physical constraints such as position of dam wall, maximum area of reservoir are specified. The main drawback with the SAR images is the noise present in the SAR imagery." [25]

Reflections and observations

Within the CPWF, Theme 4 scientists play a dual role. They conduct their own field- and catchment-level research on livestock water productivity, wastewater use, ensembles of small reservoirs, and large dam management. At the same time, they seek to add value to the work of other themes by identifying scaling out opportunities for new crop technologies, helping evaluate the downstream and cross-scale impacts of technical and institutional innovations, and helping develop decision-support systems based on the quantification and modeling of biophysical and socioeconomic processes.

- Downstream consequences of farm-level interventions and cross-theme integration. It was noted earlier that Theme 1 projects typically take little account of downstream and cross-scale consequences of field-level interventions aimed at increasing crop water productivity. Theme 2 does conduct some research on catchment hydrology and how it is affected by land use. However, it is only in Theme 4 where a whole-basin perspective really begins to take hold. It might be advisable if Theme 4 research to evaluate the downstream/ cross-scale consequences of innovations were more systematically integrated into the work of other themes, and coordinated with the work of BFPs.

- Enabling change and scaling out. Theme 4 deals with several topics not touched on by other themes, e.g., livestock water productivity and wastewater use in urban and peri-urban agriculture. As results in study areas begin to accumulate, questions begin to emerge about innovation systems, social processes for scaling out, and spatial targeting – in essence, the same questions being faced by other themes engaged in developing technical and institutional innovations.

- Basin Focal Projects. Theme 4 and the Basin Focal Projects are natural allies. Both claim to be active in using quantitative datasets and models to examine at the basin-level the likely impacts of different kinds of interventions on water allocation, water and land productivity, and poverty and livelihoods. How might they combine forces to perform this role more systematically over larger areas?

[25] 2006 Synthesis Report on Integrated Basin Water Management Systems (IBWMS), Gichuki

Theme 5 – The global and national food and water system

"The world is in the midst of unprecedented change. One dimension of this is globalization, characterized by the increased mobility of goods, services, capital, labor, information and technology throughout the world, largely driven by trade liberalization. Over the long term, globalization may generate significant economic benefits for developing countries. However, in the short term it can create economic and political instability, exacerbate inequities, and make the poor more vulnerable. Another dimension emerges from population growth, economic development and land use change. Processes of urbanization, the elimination of wetlands, and land and water degradation may undermine the world's capacity to feed a larger and wealthier population while also maintaining the [ecosystem] services derived from water resources . . .

"[Finally] the world is undergoing significant global warming and, with it, perturbations in regional and global water cycles. These shifts may undermine the capacity of agroecosystems to meet food needs and could trigger severe water shortages . . . These processes of global change will profoundly affect almost everything related to water and its management: the use of water in food production; the livelihoods of water users; rights and access to water especially by poor and marginalized people; the health of aquatic ecosystems; and the incidence and severity of conflicts over water use. The largest impacts from these changes will be on poor rural farmers, herders, and fishermen and women in developing countries."

(2005 CPWF synthesis report)

Goal and research areas

CPWF Theme 5 is concerned with those international, national and regional policies and institutions that directly or indirectly influence water and food – and how these policies and institutions can be shaped so that the poor benefit from, rather than being harmed by, the powerful and ubiquitous processes of global change. Theme 5 research covers two kinds of policies and the links between them: policies specific to the water sector, such as water institutions, economic incentives, and investment strategies; and policies that lie outside the water sector but indirectly affect water availability and quality, such as those on trade, climate, and macroeconomic issues.

Taken together, Theme 5 projects and activities share the common goal of ". . . *[supporting] policymaking both within and outside the water sector to enhance food security and human health, to promote the production of more food with less water, to help alleviate poverty, and to protect ecosystems."* [26]

Theme 5 participants seek to reach this goal by engaging in four distinct research areas:

- The role of globalization, trade, macroeconomic, and sectoral policies in achieving water and food security
- Incentives, investment and financing of agricultural water development and water supply
- Transboundary water policy and institutions
- Adapting to changes in the global water cycle

[26] Theme 5 goals and research areas are drawn from the CPWF Medium-Term Plan 2006-2008. pp. 49-50.

By and large, these four research areas are of immense interest to the global community. Theme 5 makes a distinct and unique contribution to the global debate on these issues by highlighting interactions among water, food, hunger, poverty, access, governance and technology. Moreover, Theme 5 helps provide the "big picture" context within which other CPWF activities can be interpreted and understood.

Globalization, trade, macroeconomic, and sectoral policies

"Globalization refers to the increased mobility of goods, services, capital, labor, information and technology throughout the world. A major engine of this trend is trade liberalization. Over the long term, globalization may generate significant economic benefits for developing countries. However, in the short term it can create economic and political instability, exacerbate inequities, make the poor more vulnerable and, in countries where agriculture is subsidized, reduce production and income. Moreover, trade and macroeconomic policies can have profound effects on the allocation and use of water and other natural resources such as land and forests. A better understanding of the impact of global and national policies on water resources and food systems is therefore essential to mitigate the adjustment process and avoid long-term harm." (MTP 2006-8).

This research area covers a broad range of issues including: ensuring rights to water for the poor under global change; harnessing globalization for improved water use efficiency; enhancing environmental policy, water quality and water-related ecosystems; assessing the role of virtual water for water and food security; and examining the role of economic incentives for improved livelihoods of the poor under increased trade and liberalization.

Discussion of Theme 5 in the 2005 synthesis document focused on the development of analytical frameworks. In contrast, this 2006 synthesis attempts to describe progress by Theme 5 researchers in answering key questions framed under the various sub-themes.

The key question for globalization focuses on water and its management as a means of helping achieve equitable development in the midst of global change and transformation: "*How can the participation, rights and access to water of the poor, women, and socially excluded groups be established and safeguarded in the processes of global and national demographic, economic and political change that are shaping the developing regions*?"

Important answers to this question are being developed by Project 50 ("*Multi-scale Mekong Water Governance: Inter-disciplinary Research to Enhance Participatory Water Governance from Local Watershed to Regional Scales*"), which operates in the Mekong as well as smaller, neighboring river basins in Thailand.

Multiple-stakeholder platforms, governance, and policy formulation

Project 50 focuses on multi-stakeholder governance in the Mekong basin and ". . . aims at developing workable effective adaptive institutional arrangements for communities, stakeholder groups, and societies to cope with and adapt to the complex and dynamic changes in the Mekong River basin and other basins in the region."

The principle vehicle of Project 50 is called "The Mekong Program on Water, Environment and Resilience (M-POWER)" which seeks to, " . . . democratize water governance and support sustainable livelihoods in the Mekong Region through action research . . . [where] water governance involves negotiating decisions about how water resources are used . . . .[and] democratization encompasses public participation and deliberation, separation of powers, trust in public institutions, social justice, protection of rights, representation, decentralization, and accountability."

M-POWER, among other things, engages in comparative studies of action research projects, drawing lessons through critical appraisal and sharing of experiences. Comparative studies are being conducted with regard to fisheries (for food security); flood management (to reduce the risk of disaster); irrigation (managing water supply and demand); hydropower (meeting energy needs fairly and sustainably); upper watersheds (securing resilience in livelihoods), and waterworks (providing water for households and industry). Synthesis research that cuts across these comparative studies aims to draw attention to critical principles and practices essential to the democratization of water governance: social justice, dialogue, appropriate policies, and knowledge sharing.

For each of these, a multi-organization research team organizes events for interaction and debate. Workshops have been held on cooperation in management of upland watershed development; flood risks; institutional dimensions of global environmental change; and informed and fair water and trade futures. Some highlights are listed below:

- The research group focusing on floods observed that flood-related disaster management has normally been understood by governments in the Mekong region as a technical problem – but that it requires attention to institutional and political issues as well.
- The research group on hydropower felt compelled to go beyond considerations of water and hydropower to scrutinize more carefully the whole system of energy planning and provision. While it is true that energy is needed for development, findings show that (large-scale) hydropower is not always the optimal strategy to meet these needs.
- The research group focusing on upper watersheds worked on achieving a better understanding of the characteristics and similarities and across northern Lao PDR, Yunnan province of China, northern Vietnam and northern Thailand. Striking parallels were found regarding land-use systems, property rights, and livelihood needs. There are also many shared equity and welfare concerns, given that many people in these landscapes are from ethnic minority cultures that historically have been left out of key decision-making processes that affect their lives.

One major event co-organized by M-POWER (with the World Conservation Union, the Thailand Environment Institute, and IWMI) was the Mekong Region Waters Dialogue (6-7 July 2006, Vientiane). This dialogue brought together the Mekong River Commission (MRC); key government officials from Mekong basin countries; local and external university students and staff; international and local NGOs; major development assistance agencies (Asian Development Bank, AusAID, the World Bank,); and private companies working in water infrastructure development (Italian-Thai Company).

The Mekong Region Waters Dialogue was an example of a "multi-stakeholder platform". Participants gave a very realistic assessment of what can be expected from such an event:

"Multi-stakeholder processes do not necessarily solve problems, but they do help disputing parties to understand at least partly other stakeholders' views and interests. Those involved have stressed repeatedly the crucial importance of the process itself as a communication and visioning process [sic]. People may not necessarily come to the table to learn or to bargain, but they find it very valuable to hear about what is going on. However, providing only political space to different stakeholders is usually not enough. Training, empowerment and working towards quick wins are necessary to keep people motivated. "Third parties" such as local and external knowledge brokers

can play an important role in this effort . . . Multi-stakeholder platforms do not cut out politics; they are an integral part of it!"[27]

The CPWF and Theme 5, through Project 50, played an important role in fostering this dialogue. Dialogue conveners are regularly and actively following up agreements made in Vientiane and are providing periodic updates and reports to participants and stakeholders. As a result of the Mekong Region Waters Dialogue in Vientiane, there has been greater recognition by Mekong country states and multilaterals that they must improve their level of engagement with other sectors in Mekong societies. Some immediate outcomes include:

- The Ministry of Foreign Affairs (Denmark) and the IUCN have recommended to the Mekong River Commission (MRC) that a multi-stakeholder consultation be held for inception report of the MRC's Basin Development Program.
- The World Bank has included a new component into the next phase of the GEF-funded Water Utilization Program of the MRC, "Component 4: Multi-Stakeholder Water Governance: Sharing Different Visions, Building Partnerships, Knowledge Brokering."
- The MWRAS (Mekong Water Resources Assistance Strategy) process, a collaborative product of the World Bank and ADB, was publicly evaluated and formally critiqued in follow-up correspondence from the Dialogue conveners. MWRAS has now been put to rest, and a reframed Mekong-IWRM is being developed in which the process and content are taking on board many Dialogue recommendations.
- Thailand's Energy Minister, who attended the Dialogue, has invited a sub-group to join smaller meetings to focus on Thailand-Myanmar energy projects that may re-think a policy shift in the proposed construction of dams in the Salween River.

A further challenge is to bring this experience to bear in other river basins, to examine how multiple-stakeholder platforms can be used more widely, and to apply the lessons learned in Project 50 to inform future CPWF research investments and approaches.

Further insights on multi-stakeholder platforms and their role in ensuring rights for the poor under global change processes were provided by a Theme 5 synthesis product, titled "Water Rights Reform: Lessons for Institutional Design" (Bruns et al. (eds.), 2005) Based on case studies in six continents and drawing on additional practical experience and research in multiple countries and regions, the book editors find that the following three steps can be important for enhanced water rights and access by the poor:

1. Redesigning governance—forming more inclusive forums to negotiate agreements and rules—including multi-stakeholder platforms;

Redesigning basin water governance often requires a "constitutional" level process of collective action to include new stakeholders and a wider scope for water management, (both geographically and across sectors), restructuring who will be involved and how decisions will be made. In such a process, stakeholder participation may be an essential means to incorporate different views and interests. Integrating environmental considerations, or for that matter, agricultural and irrigation concerns, into water

[27] IUCN, TEI, IWMI, and M-POWER, 2007. Exploring Water Futures Together: Mekong Region Waters Dialogue. Vientiane, July, 2006.

allocation illustrates some of the constitutional level complications of including different stakeholders and issues.

2. Resolving tenure—establishing rules and other institutional arrangements to clarify rights and provide recourse for settling disputes;

Resolving water tenure requires determining the scope of rights to access, withdraw, manage, exclude, and transfer. Resolving tenure focuses on distributional issues of who gets what, security of access to resources, with major implications for social equity. At the operational level, rules are then put into practice: recognizing rights, allocating water, and dealing with disputes. One subset of rules may well concern transfers (see point 3.), in which case reallocation could become primarily an operational level process of transactions among users, or between users and those agencies mediating voluntary or involuntary transfers. Administrative agencies usually play a major role in formulating rules, formally recognizing tenure rights, and resolving conflicts. Resolving tenure usually relies on delegating duties to agencies to formulate more detailed regulations and put them into operation, so the problems of aligning agents' incentives and monitoring their behavior are crucial. There are also technical complications in revising rules to include additional resource attributes and management objectives, such as environmental concerns with water quality and low flows, and in putting such rules into operation.

3. Regulating transfers—implementing routine mechanisms for temporary and permanent transfers, including relevant safeguards.

Transfers can only occur where rights holders can make credible commitments, based on rights that can be defended against infringement, and enforceable agreements for temporary or permanent transfers between users. Similarly, compensation for involuntary reallocation depends upon the state's commitment to respect existing rights. Transfers can contribute to economic gains from greater efficiency, so that the productivity of water increases in value, while safeguards may help mitigate adverse impacts on equity and the environment. Market exchange relationships become more prominent with transfers, as voluntary trading forms prices, or in negotiating possible compensation for losing access to water (involuntary water reallocation).

For governance, consensus about legitimacy and norms is an objective, while resolving tenure requires effective enforcement, and transfers need more detailed monitoring and accounting.

While these overall messages are important, no country starts with a blank slate when undertaking water rights reform. Participants at the African Water Laws Workshop (2005), which was held together with Project 47 ("*Transboundary Water Governance for Agricultural and Economic Growth and Improved Livelihoods in the Limpopo and Volta Basins: Towards African Indigenous Models of Governance*") called for research and capacity building to record and understand community-based water arrangements and the interface with other legal frameworks, including the gender dynamics of how water is used for multiple purposes. This "baseline" is critical for identifying the range of stakeholders and assessing how different types of reforms are likely to affect each group, with particular emphasis on poor and marginalized groups.

Revisiting the notion of "global water policies" and implications for the CPWF

Theme 5 research in the area of "globalization and water" has not been restricted to its participation in Project 50. During 2005, the Theme 5 team held a workshop in Costa Rica focusing on "Globalization and Trade: Implications for Water and Food Security". This workshop (described in more detail in the 2005 CPWF synthesis document) aimed to identify avenues for policy reform, research gaps and opportunities for collaboration among disciplines.

In 2006, Theme 5 partners and participants organized a session on "Global Water Policies" at the International Forum on Water and Food (Vientiane, November 2006). The focus of this session was to more accurately (and more broadly) define the notion of "global water policy" and the implications of this broader definition for the CPWF research agenda. Session participants identified five categories of global water policies:

- Strictly global water policies, e.g., the Convention on the Law of the Non-navigational Uses of International Watercourses
- Global policies that include water, e.g., GATS [General Agreement on Trade and Services] policies on opening up water services to competition from other member countries, or water-related trade sanctions and restrictions
- Non-water global policies that impact water, e.g., the Codex Alimentarius on food safety, or energy policies dealing with bio-fuels
- Water non-global policies with global, regional and basin-scale impacts, e.g., policies regarding water and sewage treatment plants, hydropower development, water pricing and cost recovery, irrigation management, etc.
- Non-water non-global policies with global, regional and basin-scale impacts, [sic] e.g., policies affecting agricultural input use, or the development of new crop varieties.

The bottom line is that both water and non-water policies are important for water and food outcomes at a larger scale. To date the CPWF has invested relatively few resources in examining links among global water and non-water policies and water and food outcomes. According to session participants, priorities include research on climate change, uncertainty and risk; research on policy processes, including frameworks for human rights, conflict resolution, water sharing, and determinants for their adoption; and research on biofuels, trade impacts, and disasters.[28]

Whether the above represent priorities for research by the CPWF itself, or by other concerned stakeholders, remains to be determined.

Incentives, investment and financing of agricultural water development

"*In much of the world, low water prices and high subsidies for capital investment and water infrastructure maintenance are counterproductive. They threaten effective and equitable water allocation and siphon off financial resources needed for further development of agricultural and urban water supplies. What makes the problem particularly serious is that future water development will require huge investments. New sources of water, for example, are increasingly difficult and expensive to exploit. At the same time, construction of traditional dams and reservoirs involves enormous environmental and social costs, especially the dislocation and*

[28] Session 18 Summary Report, Global Water Policies, International Forum on Water and Food, drafted by Claudia Ringer.

resettlement of people. Wise planning of new water projects demands more accurate estimates of the costs and benefits of alternative investments in supply and demand management strategies, by country and region. .. ..research will develop methods and tools to help policymakers to identify viable financing and incentive schemes and allocate resources more effectively." (MTP 2006-8)

When water is scarce, it can make sense to develop new sources of water. CPWF projects focus on three ways to increase the amount of available water. Two of these – fostering the safe and productive use of waste water, and developing ensembles of small, multi-purpose reservoirs – were discussed in the context of Theme 4.

Another way of increasing water supplies, of course, is through large-scale investment in water supply, including large dams. Other research areas under Theme 5 include public vs. private sector roles in water investment; pricing/use rights/institutions for cost recovery; distributional and poverty consequences of alternative cost recovery policies; and optimal investment allocation within agriculture [rainfed versus irrigation, research versus extension, etc.] and between agriculture and complementary service sectors [education, health, rural roads, etc.].

For the 2006 synthesis, Theme 5 partners and participants have framed the following key question, anticipating that answers can help disentangle some of the issues relating to poverty reduction and water resource development: "*How should investments be allocated to reduce poverty, directly for water development, or in water-related or water-supporting sectors, including agricultural research and other kinds of physical infrastructure and social investments such as education, health and nutrition*?"

Two points should be noted here: First, the question goes well beyond mere "water resource development". In essence, it is about how to reduce poverty, and the extent to which investments in water resource development are more effective in this regard than other kinds of public expenditure. Second, in examining investments in water resource development, it deals with large-scale infrastructure – large dams or water systems rather than small reservoirs at the village level. While Theme 5 will continue to pursue this question, few answers can be provided in 2006.

Of the various approved CPWF projects, only one is directly focused on this research area. This is project 48 ("*Strategic Analysis of India's National River-Linking Project (NRLP)*") focusing on all of India, including the benchmark basins of Indus and Ganges. The project seeks to conduct a strategic analysis of India's National River Linking Project, arguably one of the largest proposed water development projects in the history of humanity – and one of the most controversial.

The National River Linking Project (NRLP) is designed to ease water shortages in western and southern India while mitigating the impacts of recurrent floods in the eastern parts of the Ganges basin. At first glance, the logic is simple: western and southern India is dry and drought-prone; it needs more water. Eastern India is wet and flood-prone; it has too much water. Why not convey surplus water in the east to deficit areas in the west?

Many have argued that additional water resources are needed for western and southern India. Rural populations are growing, food demand increasing, cities expanding, and urban and industrial water requirements rising – even while water is becoming increasingly scarce. Others have argued that rural population will soon plateau and begin to fall, that food security can be achieved through more efficient use of rainfall, that demand management can take care of urban and industrial needs, and that alternative approaches to poverty reduction are more cost-effective. Proponents describe the immense benefits to the nation; critics point out the financial, environmental and social costs. The financial costs alone are said to be on the order of $100-200 billion.

Arguments in favor or against the NRLP often go to extremes, perhaps because the dialogue lacks a sound informational base. Project 48 is designed to promote a balanced, analytical, national discourse on NRLP proposals. During Phase I, Project 48 published several working papers and reports on such diverse topics as: the future of irrigation; agriculture and the WTO; environmental flow requirements of rivers; demographic projections; the future of food grain production; urban population growth; water productivity and water savings; consumption patterns and changes in the structure of food demand; groundwater management; labor migration; and water harvesting and rainwater management. The range of topics studied is indeed impressive.

The project is comprised of three phases: (1) research on drivers of water supply and demand, projected to 2025/2050; (2) research on the adequacy and cost-effectiveness of the NRLP in matching water supply and demand at the national level, and how the social benefits from any such investment can be maximized; (3) development of suggestions for a "Plan B" – what to do if the NRLP fails to take off. The project is now entering into Phase II and is beginning to look at the picture as a whole, including transboundary issues and the roles of Nepal and Bangladesh in making such a project viable. More importantly, the project is becoming more active in engaging with stakeholders within the political process. [29]

Project 48 is in many ways unique in the CPWF portfolio. It is engaged in assessing what might be viewed as the quintessential water development project. There is great uncertainty regarding the benefits and costs of the NRLP, though both are undoubtedly enormous. Project 48 will foster an improved understanding of the likely magnitude and social distribution of different categories of costs and benefits. By engaging in this project, Theme 5 strengthens the capacity of the CP and its partners and stakeholders to examine water development projects, and their utility in poverty reduction, at the national scale, for one of only two countries whose water and food situation will directly impact all other countries as a result of increased integration of world economies as well as their sheer size and economic power.

An analysis of the relative benefits of investments in roads versus irrigation was one of the research areas for a Theme 5 synthesis activity entitled "An Assessment of Investments in Agricultural and Transportation Infrastructure, Energy, and Hydroclimatic Forecasting to Mitigate the Effects of Hydrologic Variability in Ethiopia". Block (2006) [30] uses a dynamic climate agro-economic model of Ethiopia to assess irrigation and road construction investment strategies in comparison to a baseline scenario over a 12-year time horizon. Although both investments create positive economic boosts, the irrigation investment, on average, slightly outperforms the road investment, producing an average GDP growth rate of 0.95% versus 0.75% over the baseline scenario, along with lower associated poverty and malnutrition rates. The benefit-cost (b-c) ratios for the projects also favor the irrigation investment.

[29] The above paragraphs draw on two sources: the "Project 48 First Annual Progress Report April 2005 to March 2006"; and an unpublished draft paper by Tushaar Shah, Upali Amrasinghe and Peter McCornick entitled "India's River Linking Project: The State of the Debate"

[30] Currently a draft CPWF research paper developed by Paul Block for Theme 5.

Transboundary water policy and institutions

"River basins and groundwater aquifers that cross national, state, provincial or regional boundaries present major hurdles to effective water management. In many parts of the world, water is a major source of tension or conflict—between countries, between states or provinces within countries, and between groups of water users with differing interests. The main challenge is to build the institutional capacity and culture of cooperation needed to prevent economic, political or environmental crises before they happen. This research will investigate arrangements for sharing transboundary waters and processes for resolving or avoiding conflicts." (MTP 2006-08)

This research area thus covers the following issues: the role of alternative institutions in transboundary conflict prevention; the potential for market-oriented approaches in transboundary water sharing; and the integration of agriculture, rural livelihoods, food security and other social concerns into transboundary river basin agreements.

For the 2006 synthesis, Theme 5 partners and participants have framed the following key question: "*To what degree do different methods for conflict resolution or negotiation provide access and protection to the poor, women or other disadvantaged groups?"*

This question relates back to safeguarding water rights under global change as water rights are the foundation upon which negotiations and conflict resolution can take place. Theme 5's focus on negotiation across boundaries is reflected in Project 47 ("*Transboundary Water Governance for Agricultural and Economic Growth and Improved Livelihoods in the Limpopo and Volta Basins: Towards African Indigenous Models of Governance*"), which reviews transboundary water management in sub-Saharan Africa, particularly the Limpopo and Volta basins. With over 60 international river basins in Africa and virtually every African country sharing at least one of them, this is becomes a crucial issue. Implementation of basin-level integrated water resources management in Africa requires international cooperation among riparian countries.

Interventions that aim to shape transboundary water management in Africa must take account of following factors: poverty in Africa is widespread; overcoming rural poverty often depends on reliable access to water; the interests of the poor are rarely considered during international negotiations on water rights; and indigenous arrangements in land and water management continue to be very important in Africa.

The approach taken by Project 47 is to develop both "top-down" and "bottom-up" profiles of water governance issues in two case study basins, the Volta and the Limpopo. Local partners have formed a network to develop recommendations for incorporating indigenous principles into transboundary water management agreements and institutions. During 2005, Project 47 researchers and partners developed the top-down basin profiles, and created and made public a database of African water laws (www.africanwaterlaws.com).

This database has been influential in several ways. The Council on Foreign Relations, a prominent foreign policy think tank in the US, used the results to draw conclusions in their policy brief on transboundary waters in Africa. From that, the Asia Society contacted the project leader to elicit ideas on how they might set up a water program. The South African government commissioned a study on the extent of their transboundary water agreements, and used this database (and related papers) to inform that effort. Two papers based on the database have provided input to the IUCN book SHARE, a guide for negotiators and others involved in creating transboundary water law.

During 2006, the project made public the top-down hydro-political profiles for the Limpopo and Volta basins. These profiles present water management institutional histories from pre-colonial times through present day. They are structured such that issues and significant events involving the use and control of water in riparian countries are recognized and explored. The top-down assessment is being complemented by national level case studies based on data collected during a year-long field study of local level, indigenous water governance arrangements.

In general, it was found that under customary law, riparian (contiguous, neighboring) communities recognized the right of use by all. That is, a basic water use principle among riparian communities was that each user may use available water provided sufficient water is left for other users. "In essence, the water resource was viewed as community property and a free good. In practice the water resource was shared during periods of scarcity while other sources of water were explored such as digging shallow wells near river banks." Ownership of water resources was typically vested in traditional authorities who "acted as guardians and regulators of water and land resources for and on behalf of the gods and ancestors ensuring the protection and sustainable use of these resources".

During the colonial and later periods, these customary laws were in part over-ridden by a variety of statutes and regulatory agencies that changed and evolved over time. Some of these "commodified" what had been a basic right and/ or divorced water from land management. More recently, water governance has come to feature decentralization away from bureaucracies, greater participation of stakeholders in planning, an increase in decision making by water users, and attention to integrated water management principles.

Some early findings from Project 47 are unexpected and provocative. Three of these are:

- The very nature of indigenous water management practices and institutions is dynamic and flexible, with adaptive capacity to respond to even sudden changes in environmental, social or economic factors.
- Leaders establishing multiple-partner, multiple objective water management institutions would be well-served to keep in mind a series of customary principles in use:
    - Shared interest in protecting water resources for sustained use
    - Common vision and understanding of use rights and principles
    - Transparency in decision making and accumulation of benefits
    - Clear procedures for individual participation in institutional functions
    - Confidence that all will participate and all will follow the rules
    - Shared or common language(s) of understanding.
- "Integrated water resource management" (IWRM) generally promotes hydrological units of analysis rather than those pertaining to national, political, cultural, or linguistic boundaries. This raises the question of how customary water arrangements and IWRM can complement each other. [31] The multi-stakeholder platforms used by Project 50 might be helpful.

[31] This material is largely based on A. Sullivan, D. Malzbender, J. Lautze, and D. Merrey. 2006. Transboundary Water Governance: Origins and Nature of Institutional Arrangements in the Limpopo and Volta River Basins (unpublished).

Adapting to changes in the global water cycle

"*Water is not only vital for direct human consumption; it also contributes to the quantity and quality of ecosystem services such as food production, filtering of environmental pollutants, and the maintenance of healthy natural habitats for fauna and flora. But the world now faces the likely prospect of significant climate change and, with it, perturbations in global water cycles. These shifts may undermine the capacity of agroecosystems to meet food needs and could trigger severe water shortages especially for vulnerable populations. Higher temperatures and the associated changes in hydrological regimes may, for example, shorten growing seasons and increase the frequency of extreme and destructive weather events. They may also have indirect effects on social and economic systems. In the short term, human influences, such as altered land-use patterns, urbanization, elimination of wetlands, and high nutrient loads of water systems, may further undermine the global water cycle's capacity to support food production. Research is required to investigate international and national policies that can help the rural poor to adapt to climate variability and climate change.*"
(MTP 2006-08)

This research area focuses on understanding the impact of global/national, structural changes on the global water cycle; the prevention and mitigation of adverse human effects on global water cycles; understanding the impact of changes in the global water cycle on ecosystem services and human well-being; and the development of adaptation strategies to reduce potentially adverse impacts of global change for the poor.

For the 2006 synthesis, Theme 5 partners and participants have framed the following key questions: "*How will changes in global water cycles affect food production and change the ways in which the poor, women and disadvantaged groups access ecosystem services? How can global and national policies and institutions prevent or mitigate the negative impacts of changes in global water cycles on water and food security and on the livelihoods of the poor, women and the socially excluded*?"

Theme 5 addresses this supremely important issue through Project 53 ("*Food and water security under global change: developing adaptive capacity with a focus on rural Africa*"), which concentrates on sub-Saharan Africa, particularly the countries of Ethiopia (Nile basin) and South Africa (Limpopo basin). This project aims to provide policymakers and stakeholders in Ethiopia and South Africa (particularly farmers and others who will feel the effects of global change) with tools to better understand, analyze, and form policy decisions leading to better adaptation. It is anticipated that the least affluent stakeholders will benefit most from the results and insights gained. Impacts on women, and poor farmers, and other groups who are often overlooked will be accounted for explicitly in the assessment of global change impacts and adaptation strategies.

The project uses the following approach:

- Understanding the challenge: Appreciating the likely impacts of global change on rural Africa in general and on Ethiopia and South Africa, in particular; characterizing rural people's vulnerability and assessing their adaptive capacity
- Finding solutions: Identifying a range of adaptation and mitigation strategies for rural Africa and specifically for Ethiopia and South Africa; analysis of alternative strategies using an integrated policy analysis tool
- Building local scientific capacity: Enhancing national and international capacity for climate change and economic policy analysis through training of students

During 2005, progress was made in consulting with stakeholders; forging partnerships in Ethiopia and South Africa; developing and adapting suitable general equilibrium and other models (e.g., IMPACT); and collecting data. Progress continued in 2006 with the publishing of review papers on vulnerability and adaptation strategies in South Africa and Ethiopia; completion of household surveys in both countries; climate change downscaling activities; and further advances in model adaptation.

Early results from the household surveys conducted in the two countries indicate that most farmers in the Limpopo (South Africa – 90%) and the Nile (Ethiopia – 60%) claim to perceive long-term changes in precipitation (reduced) and temperature (increased). They report having developed several adaptive strategies. These include changes in crop variety, adjustments in crop selection, shifts in planting dates, investment in water harvesting practices, increased use of irrigation and – in some instances – abandonment of farming (sometimes accompanied by a shift to livestock grazing). A full 40% of farmers, however, indicated no change in farming practices. In Ethiopia this was attributed to lack of information about options, whereas in South Africa it was explained by lack of access to credit, markets, or water, or insecure or inadequate property rights. [32]

Theme 5 also actively engaged research and analysis with other global change research systems, including GWSP (Global Water Systems Project) – which led to the publication of a book.[33] Theme 5 also participated in the CGIAR Inter-Center Working Group on Climate Change and will remain engaged with a potential future climate change CP.

Reflections and observations

In its breadth of scope and range of interests, Theme 5 is unique within the CPWF. It deals with high profile issues of immense interest to the global community: globalization and trade; investment and financing of water resource development and water supply; transboundary water policies and conflict management; and threats to water resources and livelihoods posed by climate change.

Theme 5 has a role in contributing to the global debate on these questions. It does this through knowledge generation and sharing, with an emphasis on international public goods. However, it also has a role within the CPWF. The overall efficiency and effectiveness of the Program in part depends on systematically integrating Theme 5 activities and endeavors with those of other themes.

The policy and institutional context analyzed by Theme 5 projects may in some instances pre-determine the extent to which farm-level technical or institutional innovations, topics of research by Themes 1-4, have a chance of becoming widely adopted. It might be useful to have a mechanism whereby such information is systematically shared and applied. Similarly, Theme 5 research may detect trends which call for new directions in research on crop water productivity or aquatic ecosystems. One obvious example is the work of Theme 5 on "changes in the global water cycle". Lessons learned should be of immense interest to Theme 1 researchers working on drought tolerance and drought-related risk management in rainfed ecosystems – and vice-versa.

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[32] Information in this section was drawn from the First and Second Annual Project 53 Project Reports, and from a Most Significant Change story entitled, "Importance of Complementary policies in Farm-Level Climate Change Adaptation Strategies" presented at the International Forum on Water and Food, Vientiane, November 2006.

[33] Craswell, E., Bonell, M., and D. Bossio. 2007. Integrated Assessment of Water Resources and Global Change: A North-south Analysis. Springer.

Themes 1 – 4 all face common challenge of "scaling up and out". What is the social process whereby prototype technologies or successful case studies are transformed into something that affects huge human populations over large areas? This question applies to drought tolerant varieties and water harvesting technologies – but also to wastewater management practices, PES schemes, MUS systems, social learning processes to foster collective action, governance mechanisms for water allocation, and many more.

Theme 5 is not exempt. Similar challenges for scaling up and out exist for such institutional innovations as multi-stakeholder platforms – how to "bring this experience to bear in other river basins, to examine how multiple-stakeholder platforms can be used more widely, and to apply the lessons learned in Project 50 to inform future CPWF research investments and approaches". Scaling up and out questions even apply to the application of principles of indigenous water rights to transboundary contexts.

Some of the research questions posed by Theme 5 are critically important – and at the same time breathtaking in their audacity. One example is the following: "*How should investments be allocated to reduce poverty, directly for water development, or in water-related or water-supporting sectors, including agricultural research and other kinds of physical infrastructure and social investments such as education, health and nutrition?*" The question is a good one – to what extent are investments in water resource development more effective in reducing poverty than other kinds of public expenditure? While it may be relatively easy to conduct a few case studies on this question, how does one systematically come to closure on this question at a global level?

Theme 5 researchers might wish to reflect on their own relative advantage in a world populated with think tanks, international institutes, universities and other centers of expertise. Theme 5 can't do it all. Having said that, what is the peculiar, distinct role of Theme 5 in relation to collaborators and allies on the one hand, and companions within the CPWF on the other? There is no single answer – the task of Theme 5, like that of the CP itself, will continue to evolve and adapt.

Beyond Themes

First call competitive grant research projects with a thematic orientation are the principal but not the only means that the CPWF employs in pursuit of its goals. The Program also engages in activities that intentionally cross thematic boundaries. This section discusses three of them: Basin Focal Projects; major international conferences (in 2006, the International Forum on Water and Food); and capacity-building. The section ends with a summary of "reflections and observations" on how it might be possible to increase even further the efficiency and effectiveness of the CPWF by fostering increased integration of research activities across themes.

Basin Focal Projects

"*All CPWF projects work in one or more benchmark basins and focus on issues associated with one or more Themes. In fact, all projects can be placed in a basin by Theme matrix. The above sections have focused on the contributions of projects to Themes. However, the basin side of the matrix is also important. To what extent do approved and funded CPWF projects within a basin contribute to a coherent and systematic effort to improve water productivity and reduce poverty in that basin?*

There are at least two reasons why perfect coherence is not be expected. First, there is no benchmark basin in which CPWF projects are solely responsible for conducting research on water, food and poverty. Coherence of effort at the basin level is more likely to be found in a combination of CPWF and non-CPWF projects and activities. Second, CPWF projects were selected through a competitive grant system in which proposal quality was an important factor. When funding is limited, it may not be possible to attain coherence within basins (not to mention balance across basins) while also selecting projects with the strongest proposals." (2005 CPWF synthesis report)

Discussion in previous sections has focused rather narrowly on the 30+ projects approved, financed and implemented as part of the CPWF's first round competitive grant process. Regardless of their individual qualities, however, and when taken as a group for a particular basin, these projects do not necessarily add up to a coherent and systematic approach to addressing problems of water and food. From its very earliest days, the CP has recognized this. One response has been investment in synthesis research, for example, the present report.

Another, more comprehensive response has been the establishment of Basin Focal Projects (BFPs). These are designed to complement other CP projects in three ways:

- By assembling and utilizing datasets that systematically cover entire basins
- By systematically analyzing inter-relationships among poverty, food security and livelihoods; water availability and water access; water productivity in different uses; and the institutional and policy environment in a particular basin
- By predicting the likely outcomes of different (technical, policy or institutional) interventions on development outcomes in that basin.

BFPs help translate the CPWF's global goals into specific research objectives for each basin, while maintaining Program coherence through the sharing and use of common methodologies. Through whole-basin analysis of hydrology, poverty and livelihood support systems, each BFP defines specific problems of water and agriculture, the people they affect, and the areas they cover. Further analysis identifies opportunities to address these problems through research from existing (and future) projects. An essential role of BFPs is to help partner institutions identify project-specific impact pathways.[34]

All BFPs share the following basic processes:

Forming teams: International advanced research institutes (ARIs) assemble multi-disciplinary teams comprising national research partners and NGOs. BFP teams provide world-class skills of hydrology, socio-economics, aquatic biologists and agronomy.

Defining issues: Through consultation before, during and after basin tours, teams determine the broad issues that relate agricultural water use and poverty alleviation.

Marshaling data: Analysis must adapt to a highly variable availability of data. Each team reviews review availability of biophysical and social data for analysis.

Developing analytical frameworks: Teams develop coherent analytical frameworks for the study of the inter-relationships among agriculture, water, poverty and livelihoods. Frameworks are designed for detailed basin-wide analysis at multiple scales.

Linking cause and effect: Teams develop methodologies to determine causal factors at the basin scale. More detailed analysis will identify variation of such relationships with sufficient resolution to target interventions and enable basin-wide estimation of impacts.

Creating outputs: Each team develops an inventory of outputs. These will include maps of water productivity, water poverty, expansion of analytical method, data-bases, etc.

Predicting impacts: Detailed analysis of anticipated impact pathways, extrapolation domains for scaling-up and most-significant change. Impact assessment defines the changes that can reasonably be expected within the lifetime of the CP.

Sharing knowledge: Each basin focal project will contribute to the IDIS global data-base that will manage common-source data used in analysis.

Activities in 2006 included commissioning Phase I BFPs (for the Karkheh, Mekong, Sao Francisco, and Volta basins); convening methodological workshops; and developing impact assessment methodologies. Three Working Papers on issues relating to water productivity and poverty were made available: "Agricultural Water Productivity: Issues, Concepts and Approaches"; "Water Productivity: Estimation at Plot, Farm and Basin Scale"; and "Analyzing Water Poverty: Water, Agriculture and Poverty in Basins".

Of particular interest is the BFP work on impact assessment.

"Most people think of impact assessment as something carried out by economists several years after the end of the project . . . The Basin Focal Project (BFP) Impact Assessment Project is attempting to change all this. The project has begun running workshops to help CPWF projects clarify what sorts of impacts they expect to have, and how these changes will come about. In other words, we are helping projects define their impact pathways and in doing so workshop participants are carrying out ex ante impact assessment . . .

"We define an impact pathway as: (i) the causal chains of activities, outputs and outcomes . . . that show how a project achieves its purpose and goal; and (ii) network maps that show the evolving relationships between project implementing organizations, project partners and the ultimate beneficiaries that are necessary to achieve the goal. Developing an impact pathway helps

[34] This description of BFPs is largely drawn from information available on the CPWF web site www.waterandfood.org

a project better understand and communicate what it is doing, whom it is doing it with, and why . . . It can help the project focus on high priority activities and relationships. Moreover, constructing impact pathways for the projects in a basin helps the respective project leaders, basin coordinator and the CPWF Secretariat better identify complementarities and synergies between projects, thus contributing to basin research program development." [35]

Because BFPs are relatively new, a full description of their activities and accomplishments will be left for the future.

The International Forum on Water and Food

Each year, the CPWF organizes and participates in numerous seminars and workshops. In 2006, the Program organized one particularly high profile event that merits separate mention. This was the International Forum on Water and Food (IFWF), held in Vientiane, Lao PDR, from November 12 – 17, 2006. The event was co-hosted by the Mekong River Commission (MRC).

The Forum took place about half-way through the first phase of the CPWF and provided an opportunity to take stock of what the Program has learned, where it is heading, and which future directions might be particularly fruitful. As such, it was another example of CPWF investment in synthesis.

The overall objective of the Forum was to " . . . highlight research achievements in the field of water productivity in agriculture, expand on this knowledge, and recommend future areas for research and development investment." Specific objectives were:

- "To add value to water productivity research advances carried out under the CPWF, and complemented by other (non-CPWF) sources.
- To use CPWF benchmark basins, especially the Mekong, as case studies of the issues covered by the CPWF.
- To showcase the CPWF and its partnership structure as a means to identifying problems and delivering solutions to improving water productivity in agriculture, including the cooperation between the CPWF and the MRC.
- To recommend areas for research and development investment in the field of water productivity in agriculture, and to show how water-productivity research results can be better translated into positive development impact.
- To provide information about the CPWF as the leading research for development program in the field of water productivity in agriculture."

In brief, the Forum aimed to showcase ideas; share research results; identify promising interventions; open up new areas for discourse, policy and research; and define ways for moving forward. The assumption behind Forum organization was that creativity is most effectively unleashed through dialogue, interaction and debate, in which ideas are honed; arguments refined, and innovative areas for research, development and policy identified.

Technical papers as such were not presented at the Forum. Rather, contributors submitted drafts for consideration by the organizers. Accepted submissions (some of to be special journal editions) were made available to Forum participants. Authors were also

[35] http://www.waterandfood.org/index.php?id=133

asked to submit "briefing note" which were used to inform debate in 18 professionally-facilitated discussion sessions. These sessions covered the following topics:

- *Session 1: The future of irrigation*
- *Session 2: Water productivity at the basin level*
- *Session 3: Matching land-use ecologies*
- *Session 4: Greening upper catchments*
- *Session 5: Gender, resources managements and local institutions*
- *Session 6: Multiple-use systems (MUST)*
- *Session 7: Integrating fishing and farming*
- *Session 8: Positive management of dam reservoirs*
- *Session 9: Upland agriculture as a provider of ecosystem services*
- *Session 10: Integrating the unusual*
- *Session 11: Landscapes and land uses*
- *Session 12: Water poverty at the basin scale*
- *Session 13: Water as a source for international cooperation*
- *Session 14: The political ecologies of water management*
- *Session 15: The capacity to manage water and agricultural productivity*
- *Session 16: Up and out: scaling up and across basins*
- *Session 17: The global economy and water outcomes*
- *Session 18: Global water policies: inert or inspiring?*

Some sessions had a clear thematic focus. For example, sessions 3, 4, 5, 6, and 9 were closely allied to the topics covered by CPWF Theme 2, while sessions 17 and 18 dealt with topics of special interest to Theme 5. Other sessions had a cross-Theme focus, for example sessions 2, 12 and 16. Because some sessions were simultaneous, plenary events allowed feedback and discussion of key findings. A detailed report on Forum technical findings and conclusions is in preparation. This report will provide opportunities to take a fresh look at Program activities and priorities, past and future.

One key Forum output, however, has already been released – "The Vientiane Statement". This Statement represents a consensus view from Forum participants on what is needed from research, development investment, and policy to come to grips with the global water crisis and the water-poverty nexus. The first few paragraphs were used to introduce the CPWF itself in the very first section of this synthesis document. The full text of the Statement is found in Annex 3.

Capacity-building [36]

The Challenge Program on Water and Food (CPWF) provides opportunities for scientific mentorship and capacity building for understanding and measuring water flows, use, governance, and needs within multiple agricultural and ecological systems and at different spatial scales. The capacity building/training activities of special interest are those which build unique skills linked to CPWF themes.

All first call projects have identified the primary CPWF themes they intend to address and – when a project is relevant to more than one theme – the proportion of effort devoted to each. To ascertain how the thematic focus of the program compares with the thematic focus of capacity building, projects were classified into groups based on a single "predominant theme". Projects devoting over 50% of resources to a particular theme were uniquely assigned to that theme. Projects with activities addressing approximately equal representation of different themes were categorized as "cross theme".

These categories were compared with a second set of categories reflecting different kinds of investment in capacity-building:

- Training activities recorded in project annual reports
- Capacity building through students and universities
- Projects designed with notable capacity building components

<u>Scope and distribution of training activities reported in project annual reports</u>

Project leaders provide annual reports that summarize activities involving training of project collaborators, stakeholders, and beneficiaries. The assessment of capacity-building featured in this section is based on reports submitted by 24 projects that each had completed a year's worth of work. These represent 73% of the first call research portfolio. The reporting period covers June 2004 – May 2006.

In these annual reports, project leaders were asked to describe capacity building activities within nine different beneficiary categories: PhD, MSC, and Bachelors students; "post-doctoral fellows"; "NARES", "Scientists"; "NGOs"; "Farmers"; and "Others". In general, 50% of projects engaged in capacity building across all beneficiary categories. Over 75% of projects engaged in capacity-building involving "Farmers"; "NARES"; Masters, and PhD students. In other words, the CPWF builds capacity across a broad stakeholder base. The main focus group may be researchers, but because research is conducted in a participatory way, many others also learn and benefit.

CPWF capacity building within research projects aims to adapt, apply and disseminate research methodologies which build integrative skills linking research approaches for investigating water management, agricultural production, and ecosystem and livelihood resilience. Capacity building activities in projects fall into three major sub-categories: scientific mentorship; specialized skills development; and action research methodologies (see Table 1 for the distribution of these training activities by project number and basin).

"Scientific mentorship" includes informal activities such as advising; network building; attendance and/or opportunities to present at conferences or seminars; interdisciplinary exposure; and research planning and management. These activities are primarily targeted toward NARES scientists, but also include NGOs as beneficiaries.

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[36] This section draws on a 2006 report entitled "Capacity-building in CPWF Research Projects", drafted by Marcia Macomber, CPWF Capacity-Building Officer.

"Specialized skills" are targeted primarily for researchers to improve technical skills associated with a particular analytical task related to the research project. Specialized skills are built through short term and long term training, including research support to university students at undergraduate, post graduate, and post doctoral levels.

"Action research methodologies" belong to a family of research tools which simultaneously pursue action (or change) and research (or understanding). Action research has been applied by the CPWF on a range of topics, including measuring water productivity and participatory technology development and assessment. Action research methodologies include training across a broad range of stakeholders, including farmers.

<u>Capacity-building through students and universities</u>

Project Leaders from the CPWF first competitive calls provided information on the: nationality; research topic; degree pursued; academic department; area of specialization; and name of university for all students working in their project. The reporting period covers September 2005 – February 2007, and includes information from 22 projects. The CPWF was found to be supporting 163 students from 24 countries, attending 44 different institutions of higher education.[37]

Table 1: Capacity building activities across the entire CPWF First Call Projects, 2004 - 2006

Skill Categories		Basin	Comments	Project #	TARGET
SCIENTIFIC MENTORSHIP	informal contact	Limpopo, Nile, Volta; IGB, Karkheh, Mekong, Yellow, Nile	partnering, networking, planning, consultation; fisheries ecology & management, livestock water productivity, interdisciplinary research (health experts schistosomiasis, geohelminthes & malaria - participating in a water project)	16, 28, 37, 38, 46	NGOS, SCIENTISTS
	seminars, conferences	IGB/Mekong, Yellow, Karkheh, Nile	Managing agriculture-Fishery-Aquaculture Conflicts (International Conference on Environment and Livelihoods in Coastal Zones), aerobic rice, water saving technologies, INRM, livelihood resilience, watershed management, livestock water productivity, mixed cropping systems, Crop mixtures of barley and wheat	2, 10, 24, 28, 34, 37, 38, 47	NARES, SCIENTISTS
	research planning & management	Nile, Volta, IGB, Kharkeh, Mekong, (Lempira),	project management workshop; skills to validate methodologies and principles derived from the project; Impact Pathway, Most significant change	7, 15, 24 34	NARES, SCIENTISTS
SPECIALISED TECHNIQUES	statistics	Nile, Volta	GENSTAT, biometry, INSTAT (climate data)	2, 6, 38	SCIENTISTS
	language skills	Karkheh, Mekong	English	8, 24, 52	NARES
	breeding	Nile , IGB, Mekong	MAS - Marker Assisted Selection; phenotyping protocols,	7, 37	NARES
	modeling	Limpopo, Volta, Andean, Sao Francisco	SWAT, hydrological modeling; hydrologic (MIKE-SHE, SEBAL, WEAP; empirical parameterization of multi-agent models	17, 22, 40, 46	NGOS, NARES, SCIENTISTS
	DSS.	Volta, Andean	DSSAT (Decision-support system for agro-technology transfer); economics games, experimental economics tools	5, 22	NGOs, NARES

[37] In most cases, "support" refers to financial support. Occasionally, however, it refers to CPWF supervision of degree research in CPWF projects. Students from developed countries are not included.

	analysis methodologies	Limpopo, Nile, IGB, Karkheh, Mekong	poverty assessment, water productivity; biophysical characterization of QSMAS, interviews, socioeconomic surveys, crop water productivity, GIS	1, 7, 8, 15, 24, 37, 52	NARES, SCIENTISTS
ACTION RESEARCH METHODOLOGIES	field techniques (data collection, technology transfer, participatory methods)	Limpopo, Nile, Volta, IGB, Karkheh, Mekong, Yellow River, Andean, (Lempira, Philippines)	on farm experimentation; soil micro fauna, soil fertility, tree biodiversity, tree biomass, simple paired plot demonstrations, market linkages; land degradation analysis, establishment and evaluation of field experiments, participatory research; participatory diagnosis, farmer's innovation, participatory technology development; water savings, aerobic rice water productivity technology; erosion surveying, GIS/GPS	1, 5, 8, 10, 15, 16, 17, 20, 24, 34, 38, 52	FARMERS, NGOs, NARES, SCIENTISTS
	water management	Limpopo, Volta	ecological, health, irrigation	6, 17, 38	FARMERS, NGOS
	conservation agriculture	Limpopo, Andean	(soil and or water)	17, 22,	FARMERS
	crop management	Limpopo, IGB, Mekong	(seed handling, nutrient management, seeding, IPM etc)	7, 10, 16, 17	FARMERS, NGOs
	fish culture	Volta		6, 34	FARMERS
	income generation	Volta		5	FARMERS

Most students live in African countries. Student distribution by region and basin is shown in Table 2. A total of 44 universities are hosting students working on CPWF projects. These are well-distributed across Africa (17), Asia (11), Latin America (4), and Europe, North America and Australia (12).

Table 2: Distribution of students receiving CPWF support across regions and basins

Region	Andes	Indus Ganges	Karkheh	Limpopo	Nile	Mekong	Nile	Sao Francisco	Volta	Yellow	Total
Africa				54			18		26		98
Asia		21	5			9				9	44
Latin America	16							4			20

Despite the research emphasis of first call projects on Theme 1, "Crop Water Productivity", the largest proportion of students across the "first call" portfolio are working on cross-theme projects. This is particularly pronounced in the African basins, where over 56% of students are working on cross-theme projects (Table 3).

Table 3: Distribution of CPWF projects and CPWF students by theme

	Percent for CPWF Projects	% all students	% African students	% Asian students	% Latin American students
Theme 1	33%	17%	5%	43%	20%
Theme 2	18%	15%	10%	9%	55%
Theme 3	9%	6%	2%	18%	0%
Theme 4	21%	17%	23%	0%	25%
Theme 5	6%	3%	3%	5%	0%
Cross Theme	12%	41%	56%	25%	0%

Information on students in degree programs was categorized by research emphasis ("water" and "non-water") and disciplinary approach ("biophysical science" and "social science"). Categorization criteria are listed in Table 4. Results are only available for Africa and Asia, as they had the largest number of students, and the best response from project leaders. Across the program, the bulk of students are studying water-related fields. This water emphasis is not equally distributed across the program basins however. A large number of students in Africa (75 percent) are emphasizing water related-topics compared to the Asian students, who are more engaged in research emphasizing non-water related topics. In both regions, students utilizing methodologies from the biophysical sciences are more represented than those utilizing the social sciences.

Table 4: Distribution of CPWF students across regions and research topics

Topic	Africa	Asia	n
Non-water	25%	56%	n = 75 (Africa) n = 41 (Asia)
Water [38]	75%	44%	
Biophysical sciences [39]	71%	75%	n = 49 (Africa) n = 40 (Asia)
Social sciences [40]	29%	25%	

<u>Projects designed with notable and distinct capacity building components</u>

"Notable projects" are those with large numbers of people brought into CPWF research project through training activities, and where the activities of students or research fellows underpin the research of the project as a whole. They also tend to be very participatory research methodologies that the students are using and require substantial field work.

1. Large numbers of students from many fields in the Limpopo

- Project 17: IWRM for Improved Rural Livelihoods – 22 Masters Students, 5 PhD's , includes 17 partners (13 NARES, 1 ARI, 2 CGIAR Centers, and 1 NGO).
- Project 30: Wetlands, Social welfare & Environmental Security – 11 students

2. Linking students across disciplines and across basins in Africa: Limpopo and Volta

- Project 47: African Models of Transboundary Governance – 22 Students from a range of backgrounds and disciplines, to conduct field work in the six study countries. Targets building competence in the social sciences

3. Research Fellowship Programs in Asia – In both of these projects, the research fellows are collecting the information that feeds into a broader research goal.

- Project 42: Groundwater Governance in Asia: Capacity Building through Action Research in Indo-Gangetic (IGB) and Yellow River (YRB) Basins – 80 research fellows (40 per year) from India, Pakistan, Bangladesh, Nepal, and China
- Project 50: Multi-scale Mekong Water Governance: The project supports a multi-disciplinary Research Fellowship program (about 12 fellows per year, posted to work in institutions outside of their own countries) A key component of this action research program is social learning, which is envisioned to drive the process of multi-stakeholder governance and its formation.

Cross-Theme integration

Problems of poverty, food security and livelihoods are infinitely complex. So are the multifaceted ways in which they are interrelated with water scarcity and lack of access to or development of water. In any given river basin, these problems are likely to affect different groups of people in different ways. Adding on environmental and ecological

[38] Water topics incorporated the following: water science, water management, water sociology. "Other" topics included crops, crop water productivity, ecosystem, fisheries management, livestock.
[39] Biophysical research included methodologies from the biological sciences, agronomy, natural resources management, physical sciences; and geographic information science.
[40] Social science research included topics related to governance, sociology, and economics.

considerations does not simplify matters. Nonetheless, the main threads are not impossible to disentangle.

People's well-being is in part influenced by access to water (and other resources) and the productivity with which these resources are used. In any particular location in a basin, water access and availability are influenced by how water is managed by upstream users, and by water-related policies and institutions (including investments in water resource development). Downstream users can provide incentives to upstream users to manage water more parsimoniously. Environmental flows and ecosystem services are "users" of water, just like crop production or urban consumption.

When water is scarce, increased productivity can help enhance food production while making more water available for downstream users. Water productivity – whether measured with respect to crops, livestock, fish, or ecosystem services – can be increased through innovative technologies and institutional arrangements, and policies that encourage such innovation. All of this unfolds in an evolving and dynamic global environment of policy, institutional (and climate) change that sets the limits to what is feasible and what is not.

Taken as a group, the five CPWF themes touch on all of these areas. Theme 1 works to increase crop water productivity, while Themes 3 and 4 work on fisheries and livestock water productivity, respectively. Theme 3 also looks out for environmental flows and ecosystem services as water uses to be protected. Themes 2 and 4 work on measuring – and even anticipating – how downstream water availability changes in response to adjustments in upstream water management. All themes keep track of policies and institutions, with Theme 2 specializing in catchment-level institutional innovations and Theme 5 keeping track of global policies that influence what everyone else is doing. Several themes are committed to understanding and improving governance – the process whereby decisions affecting water allocation and water management are made.

Themes must specialize. Everyone can't be always trying to do everything. Theme 2, for example, concentrates on understanding poverty and how it is affected by water-related issues and practices. This does not mean that Theme 1 or Theme 4 consider poverty to be irrelevant or uninteresting. Theme 1, in contrast, concentrates on boosting farm-level crop water productivity. Other themes do not find this meaningless – in fact, such increases can be critically important in reducing poverty (Theme 2), in making more water available for ecosystem services (Theme 3) or in increasing water availability for urban centers and thereby avoiding a need to invest in expensive water infrastructure (Theme 5). And because all themes are part of the CP, and the CP has an impact orientation, all themes are deeply interested in innovations systems – the social process whereby innovations come to benefit vast numbers of people over large areas.

People from different themes and projects within themes are willing to work together. Perhaps what is lacking is a way to systematize the process for doing so. This can be achieved – without major changes in theme composition or focus – by improved cross-theme integration. Here are a few suggestions:

<u>Innovation systems and scaling out</u>

All themes working in a specific basin might wish to more closely integrate their efforts to foster and encourage innovation systems.

As noted above for Theme 1, "The challenge is to facilitate the creation of dynamic innovation systems for tailoring prototypes to local environmental and socio-economic circumstances. Innovation systems are an organic, dynamic, self-directed social process, a co-evolution of interventions and stakeholders. At its best, this process grows and gathers speed, with increasing involvement by more stakeholders – until, at some point (the 'tipping point'), a technology begins to be spontaneously and widely adopted, a suitable policy is shaped and implemented, or an institutional innovation takes hold."

Innovation can be facilitated and encouraged, and networks, properly managed, are the right tool for the job.

Note that the relevance of innovation systems and scaling out is not restricted to new technologies. "This question [of innovation systems and scaling out] applies to drought tolerant varieties and water harvesting technologies – but also to wastewater management practices, PES schemes, MUS systems, social learning processes to foster collective action, governance mechanisms for water allocation, and many more . . . Theme 5 is not exempt. Similar challenges for scaling up and out exist for such institutional innovations as multi-stakeholder platforms . . . Scaling up and out questions even apply to the application of principles of indigenous water rights to transboundary contexts."

Understanding and managing downstream and cross-scale consequences of innovation

All themes working in a specific basin might wish to more closely integrate their efforts to understand and manage the downstream and cross-scale consequences of innovation.

It would be highly desirable to develop systematic links between projects developing new farm-level technologies or catchment-level institutional innovations, and projects with the capacity to model the basin-level consequences of such technologies and innovations. Both kinds of projects are distributed across several themes.

As one example, a question was raised in the section on Theme 1, " . . . if aerobic rice practices were to be adopted on 5m ha in China, what might be the effects on the quantity and quality of water for downstream users? If more water were to become available, how might this most effectively be used?"

Similar questions were raised for Theme 2, "One of Theme 2's three objectives is to achieve a better 'Understanding [of] biophysical and social processes in catchments', including 'Understanding catchment hydrology and the impacts of land use' . . . Improved cross-Theme integration could facilitate the use by all themes of the modeling tools being developed by Theme 2, thereby facilitating the consistent assessment of downstream consequences for a far larger set of land use options."

Theme 4 needs to be part of this. It was also pointed out that it is . . . "only in Theme 4 where a whole-basin perspective begins to take hold. It might be best if Theme 4 research to track and evaluate the downstream/ cross-scale consequences of innovations were not confined to a few model projects. This may be an area where a more systematic effort might pay off. This would require some synchronization of effort among the five themes, and the Basin Focal Projects." An even better option might be to concentrate all whole-basin modeling, and evaluation of the downstream/ cross-scale consequences of innovations, in the BFPs.

Water, technical change and poverty

All themes working in a specific basin might wish to more closely integrate their efforts to assess the relative capacity of water-related interventions to address questions of poverty and food security.

Theme 2 researchers recognized that, "Sometimes poverty can be reduced by improving access to water, or by improving the productivity with which water is used. Other times, however, the real opportunities to reduce poverty lie elsewhere. It is even possible to envision occasions in which effective poverty reduction strategies result in water degradation, with trade-offs between peoples' livelihoods and environmental conservation." Understanding the links between water and poverty is indeed central to CP program planning and priority setting.

This issue is relevant to all themes. In the above section on Theme 1, the following question was posed: "If your project is entirely successful in developing and fostering widespread adoption of new technologies, policies and institutions to improve crop water productivity, how far does this take you towards meeting developmental goals? . . . To what extent does complete success in improving crop water productivity help solve problems of poverty and food insecurity?"

It was Theme 5 that raised this question at the broadest possible level. They asked, "How should investments be allocated to reduce poverty, directly for water development, or in water-related or water-supporting sectors, including agricultural research and other kinds of physical infrastructure and social investments such as education, health and nutrition?" In other words, to what extent are investments in water resource development more effective in reducing poverty than other kinds of public expenditure? And, going beyond *ad hoc* case studies, how does one systematically come to closure on this question at a global level?

Global policy and local innovation

There is likely to be value in considering a more systematic integration of the work of Theme 5 with that of other themes.

Earlier in this report, the possibility was raised that "The policy and institutional context analyzed by Theme 5 projects may in some instances pre-determine the extent to which farm-level technical or institutional innovations, topics of research by Themes 1-4, will ever have a chance of becoming widely adopted. It might be useful to have a mechanism whereby such information is systematically shared."

The sustainability of institutional innovations

Several Theme 1 projects intend to foster the development of local institutions for seed multiplication and dissemination. In doing so, these projects might wish to examine the lessons learned by others who have taken this path. Institutional innovation in seed systems is notorious for problems with institutional sustainability.

Theme 2 has a particularly heavy emphasis on institutional innovations, e.g., PES and MUS schemes. Several themes also work on fostering (institutional) mechanisms for improving water resource governance. Issues of institutional sustainability are just as relevant here.

Thematic research and Basin Focal Projects

Reasons for fostering closer integration of effort across themes are also valid for encouraging greater integration of effort between thematic research and that conducted by Basin Focal Projects. BFPs are designed to have the capacity for systematic and comprehensive analysis at the whole basin level of issues touching on water and livelihoods. In particular, Theme 4 and the Basin Focal Projects would seem to be natural allies. Both claim to be active in using quantitative datasets and models to examine at the basin-level the likely impacts of different kinds of interventions on water allocation, water and land productivity, and poverty and livelihoods. How might they combine forces to perform this role more systematically over larger areas?

Final words

The Challenge Program on Water and Food (CPWF) represents the response of the CGIAR system to a problem of global significance: water scarcity. It recognizes that competition for water is an important part of a larger set of problems involving poverty, food insecurity, and environmental degradation, and that increased water productivity in agriculture is a critically important factor in overcoming these problems.

For the past two and a half years, the CPWF has planned and carried out an aggressive and innovative program of research, development and capacity-building. In this brief period of time, it has identified innumerable ways in which water productivity can be increased through technical change, institutional innovations, and appropriate policies. It is developing methods that show how the adoption of innovations affects different water users and uses (including the environment) across scales. In effect, it is showing what can be done when innovative partnerships fully harness their creativity and experience to address enormously complex but supremely important problems.

Annex 1: Index of project numbers, names, basins and Themes

Project Number (PN)	Project name	Basins
PN1	Increased Food Security and Income in the Limpopo Basin through Integrated Crop, Water and Soil Fertility Options and Public-Private Partnerships	Limpopo
PN2	Improving Water Productivity of Cereals and Food Legumes in the Atbara River Basin of Eritrea	Nile
PN5	Enhancing Rainwater and Nutrient Use Efficiency for Improved Crop Productivity, Farm Income and Rural Livelihoods in the Volta Basin	Volta
PN6	Empowering Farming Communities in Northern Ghana with Strategic Innovations and Productive Resources in Dryland Farming	Volta
PN7	Development of Technologies to Harness the Productivity Potential of Salt-Affected Areas of the Indo-Gangetic, Mekong, and Nile River Basins	Indus-Ganges, Mekong, Nile
PN8	Improving On-farm Agricultural Water Productivity in the Karkheh River Basin	Karkheh
PN10	Managing Water and Land Resources for Sustainable Livelihoods at the Interface between Fresh and Saline Water Environments in Vietnam and Bangladesh	Indus-Ganges, Mekong
PN11	Rice Landscape Management for Raising Water Productivity, Conserving Resources and Improving Livelihoods in Upper Catchments of the Mekong and Red River Basins	Mekong
PN12	Conservation Agriculture for the Dryland Areas of the Yellow River Basin: Increasing the Productivity, Sustainability, Equity and Water Use Efficiency of Dryland Agriculture, while Protecting Downstream Water Users	Yellow
PN15	Quesungual Slash-and-Mulch Agroforestry System (QSMAS): Improving Crop Water Productivity, Food Security and Resource Quality in the Sub-humid Tropics	(outside of bench-mark basin frame-work)
PN16	Developing a System of Temperate and Tropical Aerobic Rice (STAR) in Asia	Indus-Ganges, Mekong, Yellow
PN17	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
PN20	Sustaining Inclusive Collective Action That Links across Economic and Ecological Scales in Upper Watersheds (SCALES)	Andes, Nile
PN22	Payment for Environmental Services as a Mechanism for Promoting Rural Development in the Upper Watersheds of the Tropics	Andes, Nile
PN23	Linking Community-Based Water and Forest Management for Sustainable Livelihoods of the Poor in Fragile Upper Catchments of the Indo-Gangetic Basin	Indus-Ganges

Project Number (PN)	Project name	Basins
PN24	Strengthening Livelihood Resilience in Upper Catchments of Dry Areas by Integrated Natural Resources Management	Karkheh
PN25	Companion Modeling for Resilient Water Management: Stakeholder's Perceptions of Water Dynamics and Collective Learning at the Catchment Scale	Mekong
PN28	Models for Implementing Multiple-Use Water Supply Systems for Enhanced Land and Water Productivity, Rural Livelihoods and Gender Equity	Andes, Indus-Ganges, Limpopo, Mekong, Nile
PN30	Wetlands-Based Livelihoods in the Limpopo Basin: Balancing Social Welfare and Environmental Security	Limpopo
PN34	Improved Fisheries Productivity and Management in Tropical Reservoirs	Indus-Ganges, Nile, Volta
PN35	Community-Based Fish Culture in Irrigation Systems and Seasonal Floodplains	Indus-Ganges, Mekong
PN36	Improved Planning of Large Dam Operation: Using Decision Support Systems to Optimize Livelihood Benefits, Safeguard Health and Protect the Environment	Nile
PN37	Increasing Water-Use Efficiency for Food Production through Better Livestock Management - The Nile River Basin	Nile
PN38	Safeguarding Public Health Concerns, Livelihoods and Productivity in Wastewater Irrigated Urban and Peri-Urban Vegetable Farming in Ghana	Volta
PN40	Integrating Knowledge from Computational Modeling with Multi-Stakeholder Governance: Towards More Secure Livelihoods through Improved Tools for Integrated River Basin Management	Andes, Volta
PN42	Groundwater Governance in Asia: Capacity Building through Action Research in Indo-Gangetic (IGB) and Yellow River (YRB) Basins	Indus-Ganges, Yellow
PN46	Planning and Evaluating Ensembles of Small, Multi-purpose Reservoirs for the Improvement of Smallholder Livelihoods and Food Security: Tools and Procedures	Limpopo, Sao Francisco, Volta
PN47	Transboundary Water Governance for Agricultural and Economic Growth and Improved Livelihoods in the Limpopo and Volta Basins: Towards African Indigenous Models of Governance	Limpopo, Volta
PN48	Strategic Analysis of India's National River-Linking Project (NRLP)	Indus-Ganges
PN50	Multi-scale Mekong Water Governance: Inter-disciplinary Research to Enhance Participatory Water Governance from Local Watershed to Regional Scales	Mekong
PN51	The impact of waste water irrigation on human health and food safety among urban communities in the Volta Basin – opportunities and risks	Volta

Project Number (PN)	Project name	Basins
PN52	Strengthening Fisheries Management Institutions in the Lower Mekong River Basin through Collaborative Research and Data Synthesis across Multiple Scales	Mekong
PN53	Food and water security under global change: developing adaptive capacity with a focus on rural Africa	Nile, Limpopo

Annex 2: List of acronyms and abbreviations

ACIAR	Australian Council for International Agricultural Research
ADB	Asian Development Bank
APSIM	Agricultural Production Systems sIMulator [sic]
BFP	Basin Focal Project
CA	Comprehensive Assessment of Water Management in Agriculture
CGIAR	Consultative Group on International Agricultural Research
CPWF	Challenge Program on Water and Food
CRS	Catholic Relief Services
CURE	Consortium for Unfavorable Rice Environments
DFID	Department for International Development (UK)
DSS	Decision support and information systems
DSSAT	Decision Support System for Agro technology Transfer
EPIC	Erosion Productivity Indicator
FAO	Food and Agriculture Organization
FDC	Flow duration curves
GATS	General Agreement on Trade in Services
GCM	Global circulation model
GEF	Global Environmental Fund
GIS	Geographic information system
GPS	Global positioning system
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Agency for Technical Cooperation)
GWSP	Global Water Systems Project
HAB	Harmful algal blooms
HRU	Hydrological response unit
IBWMS	Integrated basin water management systems
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFWF	International Forum on Water and Food (November, 2006, Vientiane)
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INGER	International Network for Genetic Evaluation of Rice
INRM	Integrated natural resource management
IPCC (SRES)	Intergovernmental Panel on Climate Change Special Report on Emission Scenarios
IPG	International public goods
IRRI	International Rice Research Institute
IRSSTON	International Rice Soil Stress Tolerance Nursery

IUCN	The World Conservation Union
IWMI	International Water Management Institute
IWRM	Integrated water resource management
LA	Learning alliance
M-POWER	The Mekong Program on Water, Environment and Resilience
MIKE SHE	(An integrated hydrological modeling system, acronym source unknown)
MRC	Mekong River Commission
MTP	Medium-Term Plan
MUS	Multiple-use systems
MWRAS	Mekong Water Resources Assistance Strategy
NARES	National agricultural research and extension systems
NGO	Non-governmental organization
NIA	National Irrigation Administration (Philippines)
NRLP	National River-Linking Project
PES	Payment for environmental services
PPB	Participatory plant breeding
PVS	Participatory varietal selection
QSMAS	Quesungual slash-and-mulch agroforestry system
QTL	Quantitative trait loci
RWS	Relative water supply
SAR	Synthetic aperture radar
STAR	System of temperate and tropical aerobic rice
UPA	Urban and peri-urban agriculture
VBSE	Village based seed enterprises
WEAP	Water Evaluation and Planning
WHO	World Health Organization
WHS	Water harvesting systems
WRC	Water Resources Commission (Ghana)
WTO	World Trade Organization

Annex 3: The Vientiane Statement

WE, the scientists, development workers, and representatives of civil society gathered together in Vientiane, at the CPWF "International Forum on Water and Food", agree to and state the following:

The challenge – We recognize the huge global problems posed by hunger, poverty, and disease. These same problems inspired the adoption of the Millennium Declaration by the United Nations. We recognize the many obstacles to overcoming these problems, among them climate change, resource degradation, and impaired ecosystems. We perceive, however, the presence of a further issue of paramount importance, one that must be addressed if the Millennium Development Goals are to be achieved: the rapidly unfolding and unprecedented crisis of global water scarcity.

Growing and urbanizing populations will need more water for household consumption, power generation, and industrial production – and for increased food production and the provision of important ecological services. Over the next 20 years, food production must increase by over 30%, much of it in poor, water-scarce developing countries. This must be achieved without excessive damage to ecosystems.

The vision – We seek a more water and food secure world, one where wise water management, innovative technologies and effective institutional arrangements work together towards eliminating hunger, poverty and disease, and where ecological services and resource quality are preserved. Such a world is within our reach.

The strategy – The best place to start is with food production as agriculture is by far the largest single water user. By using less water to produce more food, more water can be made available for nonagricultural purposes. Poverty can be reduced and food security improved when smallholder farmers and subsistence fishers achieve higher levels of sustainable productivity. A suitable strategy must also embrace more holistic and equitable water allocation and use in communities, catchments and river basins. Concrete actions are needed at multiple scales by multiple actors . . .

On farms and agro ecosystems – Develop farming practices that sustainably improve land and water productivity. In rainfed areas these include water harvesting, small-scale irrigation, conservation agriculture, and stress-tolerant crop varieties. In grazing areas, better rangeland management can improve livestock productivity while reducing soil loss. In irrigated areas, new technologies can sustainably increase crop yields while reducing water withdrawals. Risk and disaster management strategies are needed, especially in drought or flood-prone areas. In all areas, diversification can increase the value of output per unit of water depleted, while improving resilience. Diversification may feature integration of livestock, fishing, crops and trees.

Widespread adoption of sustainable, productive, water-wise farming practices emerges from dynamic innovation systems. These must be encouraged. Experience shows that innovation can be accelerated during crises. These opportunities must be seized – in ways that help the poor and vulnerable.

In local communities – Involve local stakeholders in water management decision-making. Participatory technology development that makes use of traditional knowledge and the capacity of farmers and fishers to find solutions to their problems is indispensable. Educational initiatives are needed to build this capacity.

Introduce multiple-use water systems. Most people use water for a multiplicity of domestic and productive purposes. Unfortunately, water supply systems are usually designed for a single use, e.g., irrigation. Such systems are often unable to cope with additional demands. Where appropriate, water systems that are multiple-use by design should be introduced. Diverse water sources should also be explored—such as waste water. Attention must be paid at all times to the ways that water effects human health.

Improve gender equity and introduce gendered research agendas. Women play a central role in food production, natural resource management, and communities and the livelihoods of rural families. Improved gender equity is a means of achieving food security and poverty-reduction goals, as well as a goal in itself.

Reduce groundwater depletion. In several major regions, e.g. the western Ganges, and Yellow River, groundwater depletion threatens the food security and livelihoods of hundreds of millions of people. A combination of new water management practices and policies for common property management are needed.

In watersheds and river basins – Improve communication and collaboration among water users. Water is often a source of conflict, e.g., between upstream and downstream users or across national borders. Raw power often determines who has access to water resources. Dialogue among stakeholders can, however, foster awareness of each others' interconnected needs, leading to more efficient, equitable water allocations and, where appropriate, a shift from sharing water to sharing benefits derived from water use.

Encourage payments for environmental services. Inappropriate upstream land and water use can damage downstream ecologies and people's health. Downstream stakeholders may need to provide incentives to upstream people to allow greater flows of higher quality water. This can be done in ways that build on existing policies and institutions, foster social cohesion and create awareness among stakeholders.

Recognize the value of ecological services and environmental flows. Within a basin, aquatic and land management systems produce ecological services such as clean water, fresh air and the preservation of biodiversity. The services are difficult to value, whereby their importance is often not fully appreciated. The same is true for environmental water flows – the water required to maintain downstream ecologies.

For national and global policies and institutions – Improve water use governance at all scales. Questions of governance are most challenging at higher scales of analysis, e.g., entire river basins. Here, 'command and control' governance systems are less suitable than those based on stakeholder participation. For the latter to work, however, innovative legislative frameworks are needed. Transboundary water policies are most likely to be acceptable, effective, and equitable when they focus on benefit sharing, not water sharing. Transboundary cooperation in water use is a question for governments, the private sector and civil organizations.

Introduce policies and develop institutions that encourage equitable and efficient water use in ways that reduce poverty and improve food security. Water management is often influenced by national- and global level policies that are outside the water sector, e.g., trade or energy policy, crop price support or input subsidies. Policies also play a pro-active role, e.g., by fostering the use of conservation agriculture or by giving priority to rehabilitating degraded lands. Harmonizing national and international water polices helps, as does the integration of sectoral policies, e.g., energy, hydrology, transport and agriculture.

A call for action –

We call for more research on:

- Sustainable, productivity-enhancing, water-saving farming practices adapted to local conditions.
- Risk management for vulnerable communities (e.g. rain-fed farmers and subsistence fishers).
- Ways to sustainably increase water productivity in aquaculture and livestock production.
- Ways to manage conflicts among alternative water uses and users; along with decision-support systems and scenario analysis to backstop dialogue among stakeholders.
- Links between gender and resource management and land and water productivity issues.
- Methods for valuing ecological services and for estimating environmental flows.
- The consequences of climate change on land and water productivity, food security, and poverty.

We call for greater investment in:

- Capacity-building in multidisciplinary and integrative approaches for researchers, development workers, and water management stakeholders.
- Programs for participatory technology development; aquaculture development in large and small reservoirs; and programs of payments for environmental services.
- Programs for fostering widespread adoption of successful farm level interventions

We call for policies that:

- Encourage the use of farm-level practices that sustainably improve land and water productivity; encourage wise use of groundwater; and foster land use congruent with ecological reality.
- Establish regulatory frameworks that recognize multiple uses and users and empower local and indigenous water management systems.
- Foster a greater and more systematic sensitivity to gender issues.
- Establish legislative frameworks for river basin governance systems based on stakeholder participation and supported by adequate information and decision-support.