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Improving the resilience of small farm households through research partnership:

A review of evidence from CPWF projects

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Boru Douthwaite

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CPWF DONORS

DFID Department for International Development

IFAD Enabling poor rural people to overcome poverty

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Swiss Agency for Development and Cooperation SDC

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Acronyms

ARI	Advanced Research Institute
CBOs	Community-Based Organisations
CGIAR	Consultative Group on International Agriculture Research
ComMod	Companion Modeling
CPWF	CGIAR Challenge Program for Water and Food
CP	Challenge Program
CRESMIL	Coastal Resource Management for Improved Livelihoods
CSI	Central Source of Innovation
LWP	Livestock Water Productivity
MUS	Multiple-Use Water Systems
NARES	National Agricultural Research and Extension Systems
NGOs	Non-Governmental Organizations
SRP	Small Reservoir Management Project

Abstract

This paper explores the potential benefits of working to improve the resilience of complex adaptive systems in agriculture and aquaculture through engaging in diverse partnerships among different types of research and development institutions, and the people in those institutions. We use five case studies of CPWF research-for-development efforts to draw lessons about achieving effective results in system resilience. The paper gives concrete examples of effective partnerships and the positive changes that resulted for farmer and fisher communities.

According to the literature (e.g. Sayer and Campbell, 2001), one key to successful attainment of resilience is the interlinking of at least three system levels. Similarly, it appears from our study that projects need to intervene at three or more system levels, with their corresponding actors, to bring maximum benefit to small rural households. In the CPWF experience presented here, one level often provides the key opportunity to mobilizing the other levels. Hence, diverse partnerships increase the chance of innovation and success when that diversity covers at least three institutional scales, for example, farm households, community-based organizations and regional policy-making. We note that there is therefore likely to be a close link between resilient results and broad partnerships in research and development.

We find evidence that research products produced in this way contributed better to the resilience of rural livelihoods than those typically obtained from "business as usual", that is, using the science-driven Central Source of Innovation model, and that such contributions were often unexpected; this merits further study beyond the scope of this paper. In most of the cases, the "business as usual" research would not have produced any of the results. In others, some key results, but not the complete set of results, would have been obtained because not all levels of actors would have been present in the research.

The projects discussed in these case studies contributed to resilience of livelihoods because they sped up learning processes that were cognizant and inclusive of different system scales. This provided the checks and balances necessary to avoid promoting a change to the detriment of a long term trend, or of another system user. Involving actors from more system levels increased the ability to analyze, and generated more benefit for more people. By scoping the environment of diverse institutions for ideas, partners picked up good ones quickly. They understood "what is going on". A further key to success was leadership of the research-for-development teams by results-oriented, committed, well-connected people, accustomed to systems thinking, which was also a result of broader partnerships.

Key Words: research partnership; complex adaptive systems; research-for-development; resilience; diverse participation; system levels; agriculture; aquaculture.

Introduction

Changing models of innovation

One of the main drivers of change in human systems is innovation. Indeed the wealth of some countries relative to others is attributed to their differential ability to innovate (Mokyr 1990). The Consultative Group on International Agricultural Research (CGIAR) System is made up of 15 international research centers whose shared mission is to achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, forestry, fisheries, policy and environment. The CGIAR's key mechanism to achieve its vision is conducting research to catalyze innovation.

An innovation process is the means by which novelty—sometimes also called an invention—is developed, accepted and put to use by people. Innovation can lead to both incremental and radical change and is essentially a social process fashioned by the agents involved. Novelties can be new types of artifact (e.g., a machine, a seed, a database) or strategy (the ways an agent responds to its surroundings and pursues its goals) or more often new combinations of artifacts and strategies (i.e., technologies). These are put to use by agents in their interactions with other agents to achieve individual and group needs and ambitions. In the process, adaptations are made to technologies and further novelty is generated. The technologies themselves change and evolve as agents find some 'fitter for purpose' than others.

This view of how innovation happens is consistent with work by Axelrod and Cohen (1999) and Douthwaite (2002), amongst others, that see technological change as an evolution-like process controlled by three key factors: 1) the novelty and diversity of agents and technologies present; 2) interaction patterns among agents and technologies; and 3) how selection decisions are made that favor certain types of agent and technologies over others.

The first CGIAR centers were set up in the 1960s and early 1970s with a clear mission to help increase food production at a time when there was widespread concern about having sufficient food to feed the rapidly growing world population (e.g., Chandler 1992). The early CGIAR centers' main intervention was the introduction of novelty into rice and wheat systems in Asia through breeding high yielding varieties. The interaction pattern—later called the Central Source of Innovation (CSI) model or Transfer of Technology model (e.g., Biggs 1990)— involved CGIAR scientists inventing and transferring the novelties to colleagues in national institutions who in turn worked with their extension services.

The CSI Model helped spark the "Green Revolution" involving widespread changes to farmer practice particularly in Asia and increasing food production that kept pace with population growth (e.g., Hanson et al. 1982). The CSI model was, however, essentially science-led and its analyses were completely science-oriented. In the main it was a partnership of science and farmers, focused almost entirely on changes in farm level components of production.

The world has changed a great deal since then. Concerns about the environment, global warming, HIV/AIDS and a host of other factors, mean that agricultural research can no longer focus solely on increasing food production. Parts of research by CGIAR centers and others have focused on the sustainability of production systems, especially for small farmers who live in precarious circumstances. Much of this focus has evolved to achieve greater resilience of the systems that sustain small farmer livelihoods (Sayer and Campbell 2001, 2004).

Atwell et al. (2008) explain that resilience theory emphasizes how ecological and social systems are inextricably linked; their long-term health is dependent upon change, including periods of both organization and growth, as well as periods of collapse and reorganization (Gunderson and Holling 2002, Walker et al. 2006). Walker et al. (2004) describe resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity and feedbacks." Apparently, the complexity inherent in dynamic social-ecological systems often hinges upon the interaction of three to six critical variables and processes that operate over distinctly different spatial and temporal scales (Gunderson and Holling 2002).

The Internet and globalization have made it possible for scientists and farmers alike to 1) find and access much greater diversity of other agents and technologies; 2) interact in new ways through e-mail, web-pages, voice-over-internet, etc., and 3) evaluate and select among options available to them in many new ways. The iconic example of the change is seen in how the computer operating system Linux, developed by a volunteer and self-organized grouping of thousands of computer programmers, has been able to compete with, and beat in some areas, the world's biggest software company, Microsoft (Douthwaite 2002). A number of recently published books (e.g., Tapscott and Williams 2006) argue that to remain competitive companies need to find ways to harness this 'open source' innovation. The central source of innovation model has very definitely given way to a multiple-source one. The promise that a multiple-source innovation model offers to business also exists for agricultural research where the potential sources of innovation include millions of small farmers throughout the world. Indeed, they are part of an innovation system that has developed the world's crops for centuries.

There is a strong interest in developing approaches to support agricultural and watershed resilience that operate at a range of scales, linking decisions made at field, farm, community, local and regional levels. As Allen and Kilvington (2005) say, "while farm families may make decisions at the grassroots level, others play an active role in creating the context (both positive and negative) that supports efforts for sustainable development." There are clear trends in water management and other environmental management arenas towards a multi-scale, multi-partner approach (e.g., de Loe et al. 2009, Tropp 2007). We therefore see the need both for open source and multiple-source innovation, and for increased partnership.

Against the background of these needs, the CSI model has proved remarkably durable and has become what we shall describe here as "business as usual". It continues to focus on change in farm-level research only instead of responding to the need for research that acknowledges links with the wider agricultural system, and indeed with the wider social system.

The CGIAR System has been through a number of attempts over the last 40 years to adapt and maintain its relevance (Horton 2008). One of the most important was the launch of Global Challenge Programs (CPs) in 2001. Many key CGIAR donors saw CPs as a way to help the CGIAR centers work on key complex issues that require partnerships among a wide range of institutions in order to achieve impact. The justification for setting them up included the expectation that they would improve the CGIAR's relevance and impact, help better target and integrate existing activities, achieve greater efficiency and cohesion among CGIAR centers, widen and improve partnerships with non-CGIAR research partners and mobilize more stable and long term financing (CGIAR 2001). The CPs were a large-scale experiment in using the multiple-source innovation model in a system more used to the central model.

This paper examines the research-for-development efforts from one of the first three CPs, the Challenge Program on Water and Food (CPWF), using five case studies to draw lessons about achieving effective results in system resilience. The paper gives concrete examples of effective partnerships and the positive changes that resulted for farmer and fisher communities.

The Challenge Program on Water and Food

The Challenge Program on Water and Food (CPWF) (www.waterandfood.org) began its full implementation phase in January 2004. The CPWF was proposed as a three-phase, 15-year endeavor that is due to conclude at the end of 2018. The rationale for the CPWF is that water scarcity is one of the most pressing issues presently faced by humanity. Poverty, food insecurity, environmental degradation and disease are often interlinked and can be mutually reinforcing. How water is shared and managed for various purposes is therefore one of the key factors in resolving many other development-related challenges. The most extreme water shortages are often experienced by poor people in developing countries, where the agricultural sector accounts for even more than the world average of 70% of human water extraction from rivers and groundwater (Comprehensive Assessment of Water Management in Agriculture 2007 : 2). At the same time, demand for crop production for food and feed will nearly double over the next 50 years (op cit: 13), much of that demand being in those same water-scarce developing countries. Concurrently, growing and urbanizing populations will need more and more water for household consumption, power generation, industrial production and the maintenance of essential ecological services. Recently, the CPWF has explicitly placed emphasis on how its research contributes to more resilient water-for-food systems (Vidal et al. 2009). The CPWF and sister CPs have also considered how their experiences in using diverse partnerships have contributed to solving complex problems (Woolley et al. 2009).

Guided by an 18-member consortium, the CPWF worked in nine river basins in Africa, Asia and Latin America[1] and on five research themes[2] in its first Phase from 2004 to 2009. The program began with a large competitive call for projects of which it funded 31 with CPWF grants of USD 0.4 to 2.0 million for three to five years. Additional calls for competitive and commissioned research led to a total of 66 projects in Phase 1.

The first competitive call was the largest of its kind in the CGIAR system. More than six years after the first projects began operating it is timely to evaluate whether the Challenge Program's more networked and multiple-source-of-innovation approach has

1 Andes system of basins, Indus-Ganges, Karkheh, Limpopo, Mekong, Nile, São Francisco, Volta and Yellow river basins.

2 Crop Water Productivity Improvement, Water and People In Catchments, Aquatic Ecosystems and Fisheries, Integrated Basin Management Systems, and Global and National Water and Food Systems.

produced results different from what might have been expected from more traditional 'pipeline' central-source ways of working. The objective of this paper is to carry out that assessment from the CPWF's experience with five of its 31 first call projects, and draw out lessons and conclusions that may be valuable to other research-for-development programs striving to be relevant in an ever more connected and fast-changing world.

Thus, the paper explores the potential benefits of working to improve the resilience of complex adaptive systems through the use of broad partnerships among different types of research and development institutions, and the people in those institutions.

Case theory

Our analytical approach is based on case study methodology (Yin 1989). A number of commentators have recommended the use of case studies as useful for understanding complex processes (Sechrest et al. 1996, Yin 1989).

All case studies make an argument (Sechrest et al. 1996) and so to be effective a case study should make a persuasive argument. Sechrest et al. (1996) suggest that "a theory of the case" greatly aids the persuasiveness of the argument by helping provide understanding. The theory helps set boundaries on the amount of data presented.

The CPWF provides a particularly rich source of case studies because of the diversity among projects in its first phase – in geographical focus, subject material of the research, and type of institutional participation. Because one of the strengths of the CPWF in phase 1 as a "laboratory for change" was the rich diversity of its research, we draw here on five case studies, more than might typically be used in the case study method, and discuss each briefly.

Since contemporary efforts in agriculture and aquaculture research and development are moving towards diverse partnership approaches to improve the resilience of what are now seen as complex adaptive systems, we use these case studies to draw out valuable lessons of how to go about achieving this stated aim, and illustrating the benefits that flow through to the target communities by working in this way. Through this we intend to provide concrete examples from CPWF as a pioneer institution in this way of working. We intend these to inform the considerable rhetoric and occasionally theoretical debate that can be found in the references we have already cited here and elsewhere.

The hypotheses that we test through the CPWF experience are described below.

First, working at several interconnected system levels is important in order to resolve complex problems. According to this hypothesis, working at interconnected system levels should increase innovation and also the resilience of the outcomes and outputs by unlocking the potential at one or more levels. "Diversity" of partnerships has two potentially interrelated components:

(a) the number of system levels from which partners contribute and

(b) within reason, having more than one partner at each system level, so as to benefit from diversity;

we expect that both these components are likely to be important.

The second hypothesis is that the projects contributed to technological change by changing one or more of the following:

1) the novelty and diversity of agents and technologies available;

2) interaction patterns between agents and technologies; and
3) how selection decisions were made that favored certain agents and technologies over others.

We present and discuss the data from the case studies in various ways so as to examine these hypotheses. The sample of five projects taken for case studies includes some of the more successful CPWF projects, although by no means all. Thus the study examines factors that may have contributed to the success of projects. It does not aim to be an assessment of overall success of the CPWF approach, relative to "business as usual". That will be the subject of future analyses to which this paper contributes.

Source: CPWF

Case study context and descriptions

Each of the projects described was a major effort by many people and several institutions lasting 3-5 years and with budgets ranging from 0.5 to 1.5 million USD. Here we only have space to give a brief general description of each project and its achievements and to highlight interaction among system levels in achieving results.

Each case study is presented in terms of the background or context to the study, a description of the system levels of decision making involved, the changes from "the-business-as-usual" mode, and the key impacts or outcomes that flow from the partnership approach. The system levels are described in a continuum from system level 1 being the household or farm family level, through to system level 4 being a larger catchment, basin, regional or global perspective – depending on the case study context (Table 1, Appendix 1). Details of institutional leadership and participation are in Table 2, Appendix 1. This table highlights the range of partners in each project that went beyond CGIAR centers to include advanced research institutes, government research and extension, universities, NGOs, and local and national government.

Photo credit: C.T. Hoanh

Case 1. Coastal Resource Management for Improved Livelihoods (CRESMIL)

Background

Sustainable natural resource management in the coastal zones, where fresh and saline water interface, must take into account diverse stakeholder interests (e.g. agriculture, aquaculture, capture fishery) and complex multi-scale interactions among different resources (e.g. water, soil, land use).

The CPWF Coastal Resource Management for Improved Livelihoods (CRESMIL) Project (Tuong and Hoanh 2009) worked in the Mekong Delta in Vietnam and the Ganges Delta in Bangladesh from 2004 to 2007. The social conditions and technical opportunities in each of these are very different. In each case CRESMIL built on previous work that had been conducted by the lead institution with national and local partners, taking it much further in terms of partners at different institutional levels and, especially, linkages among researchers in the two countries, and beyond.

System changes

Different key changes took place in Vietnam and Bangladesh. We take as an example for the system analysis only those in Bac Lieu Province, Vietnam.

The key system level at which actors meet are the sluice gates which control water supply to zones and thence to farm households. The first attempt at zoning was the product of previous research from 1999 to 2003. It identified conflict between shrimp and rice farmers which came to a head in 2001 due to increased demand for shrimp export. Sluice gates had originally been designed to keep salty water completely out of zones designated by the provincial government for rice farming, to the detriment of those in the western region who needed brackish water to raise shrimp. That research therefore proposed a land zoning scheme that was adopted in 2002 to 2003 by the provincial government with corresponding sluice operation procedures to allow households to produce intensive

Source: CPWF - CRESMIL

rice, continuous shrimp culture, or wet season rice followed by dry season shrimp, depending on their location (Tuong and Hoanh, 2009).

When the CPWF project started in 2004, circumstances had already changed and included the rise in shrimp diseases, the availability of short-season rice varieties and the changing balance between fresh water river flows and salt water intrusion from the sea. Thus the project needed to implement a more sophisticated cycle of actions. Sluice operation was still the key (Table 1, Appendix 1) but, through availability of more sophisticated decision models, local government water management offices now had the capacity to monitor water quality in their zones (*system level 2*) and modify sluice operations to ensure suitable (salty or fresh) water quality for areas under their control.

A revised provincial zoning, based on CPWF research, and the supervision of the local offices, was still the responsibility of provincial government (*system level 3*). At *system level 1*, using a whole range of innovative components selected by researchers with farmers, individual farm households, in their turn, adopted and adapted new production systems with crops and aquatic organisms (shrimp, fish and crabs) to reduce production risks and increase income. Examples included maintaining specific plant species in the shrimp fields to regulate pond temperature and reduce shrimp disease; multi-culture with shrimp and crab instead of shrimp monoculture; planting upland crops after two rice crops instead of three in fresh water zones; and using new short-season rice varieties. Meanwhile, the success in Bac Lieu province led to the formation of a Water Management Alliance that coordinated sluice operation among provinces at sub-basin level (*system level 4*) that in its turn allowed provincial and zonal operations to be more effective.

Changes from business as usual

In this project, diversity in partners generated changes in who interacted with whom; those in turn led to selection of more suitable alternatives, as summarized in Table 3, Appendix 1. Diversity in types of research and development partners was key, with plant science, hydrology and development institutions working together in each country. Many of the experiences from Vietnam provided input into the work in Bangladesh. Ideas that were shared included institutional support for changed water management (in the Bangladesh case, to store wet-season water in canals for dry season use), adding fish to shrimp culture, and short season rice varieties to allow double-cropping. Beyond this, the CPWF project experiences provided the focal point for two Delta Conferences in Ho Chi Minh City and Bangkok in 2005 and 2007, with participation from 18 countries.

Key impacts

The key outputs were identified in a CPWF-commissioned external evaluation (MacDonald, 2011). In Vietnam, the Bac Lieu government changed its land-use policy from encouraging monoculture rice cultivation to a mixed farming system of agriculture and aquaculture. It also adopted the recommended sluice operation procedures. More than 8,700 farmers had adopted the intensive production practices by 2006, contributing to the 15.7% growth rate of the province from 2003-6 (MacDonald 2011). Meanwhile, in Bangladesh, the Water Development Board and the local government Engineering Department adopted the Project's water management strategies to increase cropping intensity; about 2,000 rice farmers adopted double cropping in 2006-7 increasing their annual economic returns by 50-100%, while rice-shrimp farmers at the study site began to diversify using salt tolerant rice varieties, fresh water prawn and genetically improved farmed tilapia (Tuong and Hoanh 2009).

Case 2. Companion Modeling (ComMod)

Background

Companion Modeling (ComMod, http://commod.org) is a novel process that helps stakeholders understand and resolve conflicts in the use of natural resources in an iterative manner. In stakeholder workshops, it usually combines role-playing games and computerized agent-based simulations so as to stimulate and inform group debates. These multi-agent systems based tools are used to understand how actors whose needs are in competition with each other can be mutually understood, so as to mediate the collective search for acceptable solutions facilitated by participatory simulations. In its infancy in 2003, Companion modeling was greatly expanded and tested in Asia under a CPWF project that included nine case studies with diverse natural and socioeconomic conditions and different water management problems in Bhutan, Thailand and Vietnam. This helped to develop creative thinking in applying the highly flexible companion modeling tools and provide lessons for their use in other situations (http://www.cpwf25.sc.chula.ac.th).

System changes

The companion modeling project produced a range of nine different experiences, most of them successful and each requiring several system levels of participation. We present here one typical case, described in more detail by Gurung et al. (2006, 2009). In the Lingmuteychu watershed, Punakha District, Bhutan, typical of small and remote Bhutanese villages, conflict over irrigation water has been going on for generations and flared up during each rice transplanting season. Traditional rules allowed upstream villages to control the release of water needed by downstream villages.

A diagnostic study in 1997 had noted how rigid traditional rules severely affected particular downstream villages. Companion modeling between two conflicting communities in 2003 gradually grew to include all seven communities in the catchment.

Three workshops were held that built a collective sense of responsibility for water management and sharing. The catchment (*system level 3*) was the key level (Table 1, Appendix 1) at which innovative agreement was reached for an upstream village to release irrigation water five days earlier to a downstream village to permit timely rice transplanting that allowed greater water availability and prosperity at household level (*system level 1*). This would not have been possible without the novel and carefully constructed process at catchment level, motivated by the desire for action by the downstream community (system level 2). In turn, the process at catchment level would not have been possible without diverse institutions, especially local government authorities (*system level 4*) whose presence had been requested by the communities themselves. The validation and support by the authorities led to the catchment workshop agreeing to establish a further innovation, that is, a watershed management committee, the first in Bhutan, which secured a grant from the Global Environment Fund and the United Nations Development Program and has been operating successfully since 2006. The workshops were seen as a breakthrough in the mediation process, which almost certainly would have been impossible to negotiate without companion modeling. Following this successful case, the Bhutan Ministry of Agriculture requested application of the same methodology in two problematic areas of eastern Bhutan.

Changes from business as usual

Of itself, the practice of companion modeling is very different in concept and actions from business as usual (Table 3, Appendix 1).

Diversity of partners, with initially conflicting needs and interests and using strategies that may harm each other's interests, are the circumstances in which companion modeling comes into its own.

Role-playing games, combined with computer simulations, initially place participants in a virtual world in which they can act and talk without concrete consequences, thereby helping mediate among different actors and fostering the development of generally-acceptable strategies for the real world.

Key impacts

Initial applications of companion modeling in communities have transformed the ability of poor and marginalized farmer groups, including female-headed households, to assert themselves and to communicate effectively with administrators, resource managers and more wealthy farmers at the local scale. The ComMod cases have resulted in diverse, real changes in land-use patterns and infrastructure investment decisions. In addition to the case above, these include communal water management in northern Thailand (Bousquet 2009), agreement between shrimp and rice producers in Vietnam on the timing of saline water intake at the sluice gate (part of Case 1 above), agreement between villagers and foresters on gathering of non-timber forest products in northern Thailand and coordinated use of seven storage tanks in eastern Bhutan.

In terms of a practical development methodology, thanks to this project, companion modeling has now expanded to a truly international approach in Asia with adherents from several different countries. In May 2009, the latest ComMod training course was held in Bangkok with participants from 12 different countries from Japan to Malaysia and Bhutan to the Philippines.

The resource management context

❒ Market oriented economy and decentralization in land management provides household autonomy in their land used decision making.

❒ Black tiger shrimp production become an attractive enterprise in coastal area of Vietnam due to high income.

❒ Shrimp production is still facing high risk due to disease outbreak frequently.

Figure 1: Study site in the Mekong Delta, Vietnam

Table 1: Rice & shrimp areas in Mekong Delta (MNRE, 2002)

Area (ha)	Year 2000	Year 2002
Shrimp	230,000	370,000
Rice	970,000	800,000

The study site: land use and water conflicts

❒ Rice and shrimp are co-practiced in Northern areas of Bac Lieu province, Mekong Delta, Vietnam.

❒ Shrimp producers can be competed with rice growers on land use due to their different water quality demands.

❒ Conflicts among shrimp producers would be happen due to co-existing different intensified levels of shrimp production.

❒ All rice and shrimp producers must seasonally decide their production based on (i) water quality, (ii) household capital availability, (iii) shrimp seed quality and other material inputs, (iv) market price of output products.

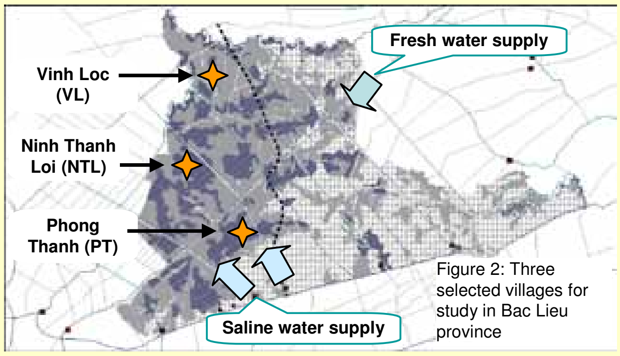

Figure 2: Three selected villages for study in Bac Lieu province

Research objectives

❒ To understand individual decision making on choosing between rice and shrimp production under complex biophysical and socio-economic conditions at farm level.

❒ To provide a supportive tool for promoting dialogue about water demanded from both rice and shrimp producers at different villages in different parts of the province.

Players get loans from the Banker

Players draw ball of risk before harvest their shrimp

Source: commod.org

Poster of 'Participatory Simulations of Competing Aquaculture and Agricultural Land Use' in Bac Lieu Province, Mekong Delta, Vietnam (ComMod, 2007).

Case 3. Small Reservoir Management (SRP)

Background

People living in arid areas with highly variable rainfall experience droughts and floods and often have insecure livelihoods. Small multi-purpose reservoirs are a widely-used form of infrastructure to provide reliable water supplies. Reservoirs are often constructed through a series of projects funded by different agencies, at different times, with little or no coordination among the implementing partners. Many small reservoirs function sub-optimally or are falling into disrepair, which indicates that there is room for improvement in their planning, operation, and maintenance.

In 2005 the CPWF small reservoirs project (SRP) began in the Volta, Limpopo and São Francisco basins, with the aim of developing tools to support use of small multi-purpose reservoirs that are properly located, well designed, well maintained and well operated. The project aimed to improve the livelihoods of the local households while at the same time maintaining water related ecosystem services, the long-term sustainability of local water supplies, and adequate downstream flows.

System changes

Key to the process was the sub-basin level (system level 3 in Table 1, Appendix 1). Project research results demonstrated that evaporation from small multi-use reservoirs in a savanna setting was half what had been assumed previously, based on analogy with oases in deserts, and was less than from cropped areas of similar size (Liebe 2009, Liebe et al. 2009). This unexpected finding opened up the exploration of the social and production advantages of storing water in community reservoirs (*system level 2*) nearer to where it is needed by individual households (*system level 1*) to improve their livelihoods. However, in order for community reservoirs to be effective for households, a range of management issues arise, hence the project focused on toolkits for use by extensionists working with communities. The toolkit consisted of diverse technical results, participatory methods and practical know-how that had been tested with diverse project partners.

At higher system levels, concerns are often expressed that proliferation of small reservoirs could harm downstream users. To answer this concern, other project research that combined satellite and field measurements to estimate water balances demonstrated that at basin scale (*system level 4*) the downstream impact of small reservoirs is minimal. For instance, in the Volta Basin, even quadrupling the number of small reservoirs would result in the consumption of less than one percent of the total available water.

Changes from business as usual

Project success was based on geographical, institutional and disciplinary diversity (Table 3, Appendix 1). The team worked in five countries across three river basins in Africa and Latin America. It considered the hydrologic, economic, ecological, health, and institutional dimensions of small reservoirs. Of particular importance to project inventiveness was that more than 60 students (60% from developing countries, 46% female) approached the project either inspired by the research partners or through on-line searches and then did their research with it. Project staff considered that the mix among different basins and among advanced research institutes from the North (ARIs), national agricultural research and extension systems from the South (NARES) and CGIAR centers, together with students from North and South, was a particular key to the success. This both built future professional capacity and mobilized a large research effort.

Key impacts

The primary impact achieved so far was the building of a future generation of professionals familiar with multidisciplinary approaches to integrated water resources. Additionally, an important outcome, well on the way to creating impact, was the first version of the Small Reservoirs Toolkit, which can be found at http://www.smallreservoirs.org. There are approximately 30 tools and techniques presented in four topic areas: i) intervention planning; ii) storage and hydrology; iii) ecosystems and health; and, iv) institutions and economics. This tool kit is intended for use by NGOs, research institutes, universities, donor agencies, multilateral organizations, and government agencies. While the project was still on-going, there was early adoption of some tools by a Ghanaian university and by extensionists in the Upper East region of Ghana.

Source: CPWF

Case 4. Multiple-use Water Systems (MUS)

Background

The Multiple Water Use approach recognizes that many poor rural households and communities use available water sources to meet all of their water needs, despite the authorities' intended single purpose for each source. CPWF's Multiple-Use Water Systems Project (MUS) synthesized ways to incorporate multiple use approaches to water management at community, intermediate and national scales, working across the Nile, Limpopo, Andes, Mekong and Ganges basins with policy makers, water management institutions, farmers, researchers and development professionals (van Koppen et al. 2009).

System changes

In our analysis, we have kept the three system levels used in the MUS concepts, even though each level is broader than those we use in the other case studies; for example, the MUS "local level" includes both households and communities. MUS project research built on the key observation at local level (*system level 1*) that poor rural households have multiple needs for water use and thus use water sources for multiple purposes. Thus, unlike technical agencies, they do not distinguish between "domestic water supply", "irrigation water supply" and "livestock water supply". The MUS project built its strength through systematizing and sharing information about widespread, but hitherto ignored, informal local level practices and opportunities for planning water services across a diverse range of communities in eight countries of the five river basins.

The local (household and community) level (*system level 1*) drove this system because it required support from higher levels so that support agencies' innovations in water use systems at the local level could function (Table 1, Appendix 1). To provide such support, changes were needed at what the MUS project denominates intermediate and national levels. At the intermediate level (*system level 2*), NGOs, line agencies and local government agencies learned how to strengthen their support through action research, leading to changes in: (a) including users in the design process through participatory adaptive management; (b) long-term technical support and coordination; and (c) finance. Support from the national level (*system level 3*) by government and financiers was also vital, especially to provide the innovative policy and legislative framework to allow and support the actions at intermediate and local levels that might otherwise have violated traditional and informal water arrangements. In order for the other levels, especially the national one, to perceive that MUS concepts were legitimate and broadly accepted, global advocacy through the MUS group (*system level 4*) played a key role.

Changes from business as usual

The diverse range of project partners across eight countries and five basins, and equal roles given to partners at all levels, is clearly a key change in this project (Table 3, Appendix 1). The cross-country, cross-basin approach provided everything from the wide range of local experiences in which commonalities could be seen, to global legitimacy for the approach that informed and supported all the work.

Key impacts

An impact evaluation (Merrey and Sibanda 2008) concluded that "the most important achievement of the MUS Project has been its contribution to conceptualizing, legitimizing and raising the profile of MUS both as a topic worthy of detailed scientific study, and as a potentially powerful tool for improving the livelihoods of poor people by providing a higher-level water service than is often the case in rural

water supply programs and irrigation projects."
An international thematic group has formed of organizations working on the topic (MUS Group; see http://www.musgroup.net). Additionally, groups of communities with which the MUS project worked in several countries, including Nepal, Thailand, Bolivia, Colombia and South Africa, have adopted novel MUS practices using ideas developed jointly with project staff. A number of national governments in project countries have taken steps towards national planning and implementation of MUS including Nepal, Ethiopia, Colombia, South Africa and Thailand (van Koppen et al. 2009).

Source: CPWF (R. Yoder, IDE)

Case 5. Livestock Water Productivity (LWP)

Background

The CPWF livestock water productivity project (LWP), which focused on three countries of the Nile basin, has found ways to increase livestock production while using less water. It found that feed sourcing strategies have a major effect on water use in livestock production, and that taking account of livestock when making investment decisions on water resource development can lead to large increases in returns to investment.

In the Nile basin, where livestock use as much water as crop production, crop-livestock systems are of increasing importance as population pressure rises and climatic variability increases. The project has concluded that, first, far from being a "drain" on the system resources, livestock are of vital importance to cropping, especially through animal traction and concentration of fertility in specific areas through manure. Second, as cropping intensity rises, there is a "crisis of biomass production" and both provision of animal feed and return of vegetative matter to the soil are compromised. Less land is available at any one time for livestock to graze fallow areas. Crop residues, as well as grain, are less plentiful when soil fertility drops due to intensive cropping without sufficient provision of nutrients and soil water management.

An extreme case of this is the completely degraded pasture land of Nakasongola District in Uganda's "cattle corridor" which is the subject of our analysis of key system levels in this case. This is an area where pastoralists are beginning to settle. The project found increases in water productivity following settlement because use of crops for food and feed makes the best use of water for agriculture not withstanding the need to return organic matter to the soil (Gitau et al. 2009).

System changes

Project experience in the Nakasongola District illustrates well the benefits of systems thinking in this project. Although ideally suited to livestock production, overgrazing aggravated by charcoal production led to loss of vegetative cover, high rates of soil erosion and siltation of small reservoirs. Repeated efforts to rehabilitate the vegetative cover had failed because of high termite populations that destroyed grass seedlings. The key observation (Table 1, Appendix 1) was at community level (*system level 2*) when university researchers corralled cattle at night to see whether it would help grass seedlings establish, as had been suggested anecdotally by their Ethiopian colleagues in the project. It appeared that termites preferred to eat the manure, thus allowing seedlings to grow to the point that termites could not destroy them. For the practice to work, community members needed to agree to corral their animals together to obtain sufficient manure concentration before moving to the next area; the animals of a single herder would have been insufficient. This key opportunity opened up actions by local organizations (*system level 3*), especially NGOs, local government offices and a bilateral agency, for promotion with farm households (*system level 1*). Just starting to open up are opportunities for improved livelihoods at catchment level (*system level 4*) since re-established grassland reduces runoff, increases infiltration and improves water quality to the likely benefit of other productive uses of water.

Changes from business as usual

The project worked across three countries and was particularly strong in giving national researchers equal status with international researchers (Table 3, Appendix 1). The progressive approach of the Animal Science Department at Makerere University was key to the system changes in Nakasongola, from the inclusion of hydrology teaching in university animal production courses to the close involvement in working with local communities. Firm efforts in communication were important to this project's success. A full page in the national Ugandan press for World Environment Day focused on the Nakasongola experience. It was also the CPWF project that had most papers accepted at the Second International Forum on Water and Food in November 2008, mostly prepared by students with support of the project leader and CPWF theme leaders (Humphreys et al. 2008: 57-114). Three students won national financing for doctoral studies in Nakasongola based on those Forum presentations.

Key impacts

The project has opened up opportunities for investment in both the Uganda cattle corridor and in the Lake Tana highlands of Ethiopia, where a bilateral donor plans to follow up project research by installing fodder banks to increase the biomass in the crop-livestock system. Equally important is the impact of the project in changing concepts – researchers, development specialists and government now begin to understand that livestock production is highly relevant to water management.

Source: CPWF

Analysis and discussion

We consider the practical lessons from the five case studies in several ways. First, we examine how these successful case studies had partnerships at several system levels. We observe how those partnerships contributed to interventions in complex adaptive systems in seven complementary steps that are shown in Figure 1 and were used in Table 3 (see Appendix 1). These are our adaptation of the three stages proposed by Axelrod and Cohen (1999) and presented earlier in this paper. The seven steps can be summarized as: changes in geographical scope; new types of partners; changed research priorities; novelty and diversity of outputs; deciding who assesses fitness for purpose; investment in the spread of knowledge, attitudes and practices; and outcomes and impact.

We then ask whether "business as usual" research with the CSI model could have produced those results. Finally we look at the contribution of broad partnerships to achieving resilience in agricultural and aquaculture systems.

Partnerships at several system levels

Analysis of this set of five case studies of projects that yielded positive results suggests that successful projects have partnerships at several system levels. As each study description has pointed out, a change in knowledge, attitudes or practice at one of the system levels unlocked or mobilized the improvement of system resilience at other levels. The level at which this key opportunity arose varied from case to case (Table 1, Appendix 1). Thus in multiple use systems research (MUS), it was new understanding at the lowest system level—of how households in eight different countries and five basins view water—that was the catalyst. For the potential to be "unlocked", this induced and required changes in attitudes and policies at intermediate and national level, thus permitting further development of multiple use systems at community and household level.

In two other cases, it was change at system level 2 (zones in CRESMIL and community in LWP) that was the key opportunity. In two other studies, it was change at system level 3 that was the key: catchment in ComMod and sub-basin in SRP. Four system levels were identified in each case, so the key level was never the highest level at which the project engaged. It would seem that successful system change requires intervention at least at one level above the level that we identified as "key" in each case. In contrast, it seems that the CSI model often focuses on only one systems level.

The presence of resources at several institutional scales in these cases worked as an enabling environment to unlock potential solutions. Working at a higher institutional scale often meant working at a larger geographical scale, because many institutions don't work at a local scale. In order to involve people and institutions from several scales, the research for development must, as a principle of multi-scale partnerships (Huxham and Vangen 2005) have information and results to offer to those who work at each scale. Bringing together people and institutions from different sectors and scales also implies action research at the local level, from which more general results and the "big picture" may be built up. We see that Reason and Bradbury's (2001) definition of "action research" clearly applied to each of these five case studies where participants

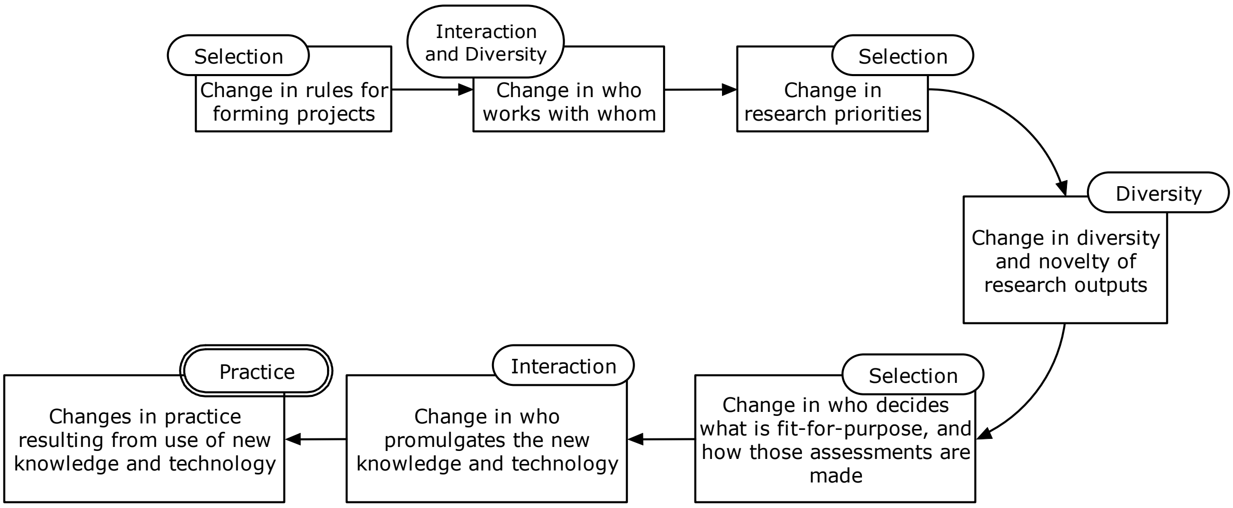

Figure 1: Changes from 'business-as-usual' resulting from changing the rules by which CPWF projects were initially selected

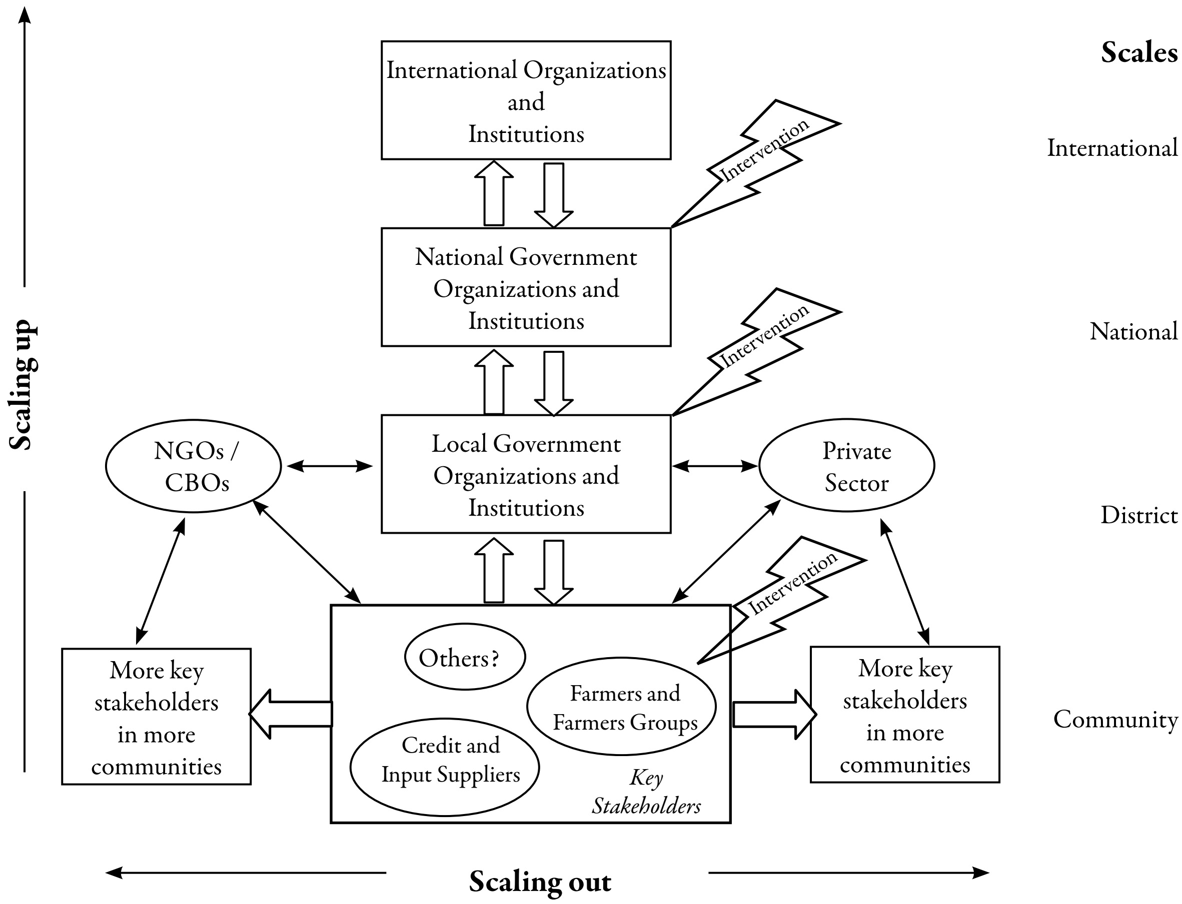

Figure 2: CPWF concepts of scaling-out and scaling-up (from Douthwaite et al. 2003)

both made problem solving actions and carried out data-driven collaborative analysis to understand the underlying causes of the changes that were achieved, thus enabling future predictions about technical and organizational change.

Our finding that work at several institutional scales is needed is consistent with the CPWF's working concept of scaling-up and scaling out (Douthwaite et al. 2003). Scaling-out is the increasing adoption of project outputs from farmer to farmer, community to community, within the same stakeholder groups. It is a horizontal spread, at the same scale, as shown in Figure 2. Scaling-up is a vertical institutional expansion, between scales, based largely on a desire or need to change the rules of the game. It can be driven by the influence of first-hand experience (e.g. from action research), word-of-mouth, and positive feedback, from adopters and their grassroots organizations on policy makers, donors, development institutions, and the other stakeholders who then have an interest in building a more enabling environment for the scaling-out process. Sometimes the process is reversed and driven by political conviction. Interventions at a higher scale—for example, policy research—can affect scaling-out processes at lower ones, as shown in Figure 2.

In all five cases, indeed in CPWF work in general, the international, cross-river-basin nature of the research and development is very important. This could in fact be considered as an additional higher system level that interacts with those we already discussed. MUS is the only case where we explicitly included the global level in Table 1, Appendix 1 as fundamental to the project since the sharing across countries legitimized and made possible the powerful development of the local-intermediate-national sequence in each country.

However, arguably we might have included international/global level as a fifth system level in the other four projects as well. Thus in CRESMIL, the input of experiences from Vietnam enabled innovation in Bangladesh; in ComMod, the cross-fertilization of novel methodology among the eight cases in three countries was vital. In the SRP, experiences in the Volta basin generally opened innovation in the other two basins. LWP was originally conceived as a multi-basin project but later focused on the Nile for reasons of cost and logistics. Despite this, its cross-basin influence was important: the project leader provided advice on livestock water productivity to CPWF projects in several other basins. Within the project itself in the Nile basin, the original suggestion that manure might control termite activity was given by Ethiopian to Ugandan researchers.

Contributions of partnerships to interventions in complex adaptive systems

The second theory of the case—that the five projects were operating in complex adaptive systems and making changes to diversity/novelty, interaction patterns and the way decisions were made—allows us to understand how changing the rules by which CPWF projects were selected led to other changes. The following is a summary description of the changes that are summarized for each project in Table 3, (see Appendix 1).

Change in geographical scope

In all five case studies, CPWF research had a much broader geographical scope than the projects that preceded it and, in many cases broader than what project leaders declare would have been possible without the CPWF. Thus four of five case-study projects were induced by CPWF rules to expand work to more basins while the fifth on livestock worked at higher scales and across more countries of the Nile basin than in early work outside the CPWF. Broader geographical scope not only increased the chance that there would be a breakthrough in innovation in at least one of the research locations or countries, but also made possible a "virtuous circle" of innovative ideas spreading from one country to another.

New types of partners

In each case too, new types of partners were added in the initial design, again encouraged by CPWF selection criteria that rewarded inclusion of diverse partners and also required at least one CGIAR center and two NARES in each project. Usually the expanded range of partners corresponded to the increased set of system levels. Many of these were planned from the start, but some, like the large number of MSc and PhD students who joined the SRP, were attracted and accepted after project inception. Partners in these successful projects fill from 4 to 6 of the institutional types we established (Table 2, Appendix 1). There is a partial correspondence to system levels, but not a complete one since some organizations work at more than one level. Note additionally that in all projects there are several representatives of one or more key types, whether CGIAR centers (CRESMIL), government research (CRESMIL, SRP, LWP, ComMod), universities (ComMod, MUS), ARIs (ComMod, SRP, MUS), NGOs (CRESMIL in Bangladesh, MUS). Analogous to increased geographical scope, greater scope in number and type of partners appeared to increase the chance of productive interaction from which a key opportunity was identified.

We have also observed that project leaders, and some other key participants of successful CPWF projects, including all the cases in this study, have a number of outstanding abilities not always found among researchers including systems thinking, people skills, interest in development outcomes and good personal connections with development institutions. Phillips et al. (2010) reference a number of similar findings by other reviewers while Woolley et al. (2009), working from the experiences of four CPs, including CPWF, present several practical conclusions about effective management of diverse partnerships.

Changed research priorities

If we return to the third row of Table 3 (see Appendix 1), changed research priorities are apparent in each case in our analysis; leaders of the projects featured here have all made similar comments. All such changes in research priorities represented a change in attitudes or beliefs at some level, whether by technical people (small reservoirs in the SRP; the importance of livestock for water management in the LWP), by community members (as in most cases in ComMod), or by the government authorities (in CRESMIL and MUS).

Novelty and diversity of outputs

All the five case-study examples of the novelty and diversity of outputs arise from systems thinking by project actors. This in turn can be seen to arise in each case from having representatives of different system levels present as well as benefiting from the change in key attitudes mentioned in the previous paragraph. Note the wide range of innovation, from development of toolkits, to termite control, to integrated diverse production systems to the conceptual breakthrough on MUS. Allied to this, the results of innovation from projects needs to be published in interdisciplinary journals such as *Ecology and Society*, which is also an example of those with another advantage for developing country readership, namely that it is available free on-line – although that results in a cost of publication for the publishing institution.

The number of such suitable journals is still limited, however, as is illustrated by the fact that many of our references to the recent successful projects in our case studies are from CPWF reports and working papers. We might add that one reason that this present paper is published as a CPWF Impact Assessment Paper is that its explanation and analysis of several case studies in the context of innovation models made it long, slow and expensive to publish by other means.

Who assesses fitness for purpose?

Even in research with beneficiary participation, assessment of fitness for purpose is often carried out by limited groups such as farmers and researchers working separately. In all the cases here, there is breadth of evaluators, with actors from at least three system levels usually involved, and always including the end users.

Investment in the spread of knowledge, attitudes and practices

Pay-off from all except one of the research cases can already be seen in terms of investment in future propagation and extrapolation of results. In the case of CRESMIL, this actually began while the project was still on-going.

In the only project where investment in scaling up has not yet taken place, the ComMod research group emphasizes the importance of scaling up the methodology to include district and regional institutions. This is the subject of a present CPWF research proposal to the European Commission and the International Fund for Agricultural Development.

Outcomes and impact

The main project outcomes were changes in practice of farmers through adoption of new technology, and changes of behavior of policy makers and other working at high institutional scales. The impact of two projects (CRESMIL and MUS) has already been evaluated by independent impact studies that each run to over 100 pages and was generally very positive (MacDonald 2011, Merrey and Sibanda 2008). Table 3 (Appendix 1) shows uptake by farmers in all four cases directed to them. We consider that the impact in all these cases, except SRP, clearly increases the resilience of small farm households. The fifth case (SRP) is aimed initially at researchers and extensionists; early uptake by professors of the Kwame Nkrumah University of Science and Technology already began, but is slower in Brazil because of translation needs and in Zimbabwe because of the present national situation.

Could "business as usual" research have produced the results?

In most of the cases, business as usual research, following a CSI model, would not have produced any of the results. In other cases, some key results might have been obtained, but not the complete set, because not all actors would have been present in the research. In the SRP, the key finding – that a series of small reservoirs does not, despite previous assumptions, evaporate more water than an equivalent amount in one large reservoir – might have been obtained anyway given the clear vision of a single hydrology researcher. However, the social and economic research context that made such a result so significant in stimulating other research and developing the small reservoirs toolkit was obtained thanks to the project.

Evidence that CPWF is other than business as usual—i.e., that it uses partnerships with a broader range of institutions and that these achieved a different level of scientific results, outcomes and impacts—also comes from a survey of project leaders in CPWF phase 1 (Sullivan and Alvarez 2009), see Figure 3. Approximately 70% agreed that their scientific results in CPWF were different from those expected from business as usual and that outcomes and impact were also different. Over 80% agreed that partnerships were different from business as usual, and most of those agreed that the partnerships contributed to outcomes different from business as usual. A separate piece of research (Barr et al. 2009) shows that CPWF has been successful in bringing together and improving bridging between institutions that concentrate more on water issues and those that concentrate more on food issues.

The contribution of broad partnerships to resilience

Resilience and breadth of partnerships are clearly closely connected. If our first case theory is correct, this result would be expected to follow, because resilience theory (Walker et al. 2004) states that it is necessary to take into account at least three system levels in order to improve the resilience of a particular system.

Contributions of the group of five case-study projects to resilience are summarized in Table 4, Appendix 1. The projects discussed in these case studies contribute to resilience because they speed up learning processes that are cognizant and inclusive of different system scales. This provides checks and balances so as to avoid promoting a change to the detriment of a long term trend, or of another system user. Having actors from more levels involved increases the ability to analyze, and to generate more benefit for more people. By scoping the environment of diverse institutions for ideas, partners pick up good ones quickly. They understand "what is going on". Ideally a diverse set of partners,

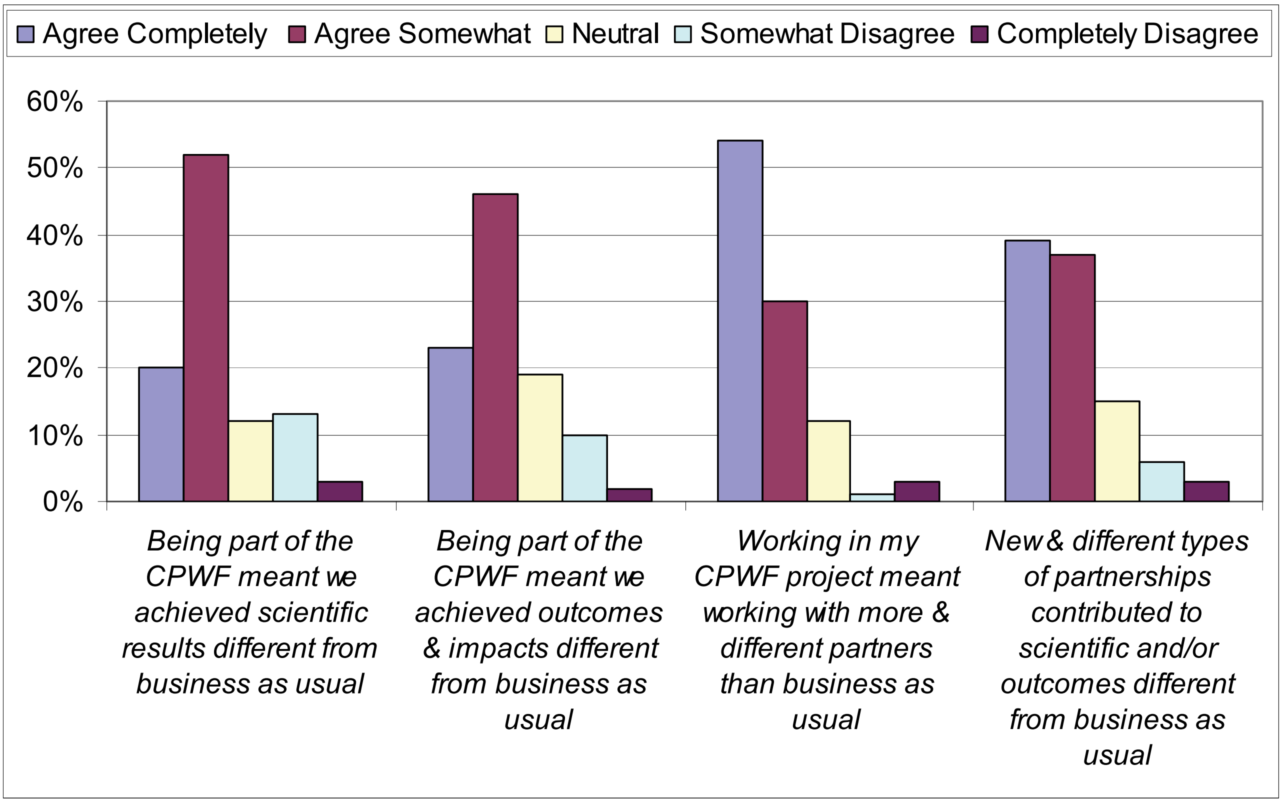

Figure 3: Selected results from survey of CPWF project leaders, January 2009 (Source: Sullivan and Alvarez 2009)

"from field plot to policy making" would be present in each project. In the case studies here, the set of partners was very effective in four of the projects but might usefully have been expanded in ComMod to include partners from regional and national levels within the new methodology.

All of the five case studies deal with overcoming thresholds—not just biophysical thresholds but also institutional, financial and social thresholds—through key system changes at one level that have effects at several levels. All take into account the long-term, and not just the immediate effects, of a change in practice and its connection to decision making. An example from part of the CRESMIL project in Bangladesh is storing water in the irrigation ditches so as to use it for dry season rice or vegetables (Sharifullah et al. 2008).

Another part of the CRESMIL project provides a good example of how policy change enables several levels of the system, starting from households, to be more resilient if they can make more sensible decisions. Prior to CPWF work, provincial government and rice farmers conducted conventional agriculture doing everything they could to keep the salt water out. However, other farmers were experimenting with improving their livelihoods through shrimp production but were thwarted by complete on/off control of salty water. The situation reached crisis point in 2001 when shrimp farmers broke down the sluice gates to the detriment of rice farmers. Then modeling identified a compromise that made the pot bigger for all; using the concept that water that was "salty some of the time" was a major resource and opened up a win-win situation (Tuong and Hoanh 2009).

Conclusions

The results from the case studies show that at least three system levels, with their corresponding actors, need to be considered to successfully intervene in complex adaptive systems; in fact four levels were identified in all the case studies reported here. It appears that one level often provides the key opportunity to mobilize a change in knowledge, attitudes and practices at the other levels; the level at which the key opportunity occurred varied from project to project but was never the highest at which project research was active. Hence, diverse partnerships increase the chance of innovation and success when that diversity covers at least three institutional scales, for example, farm households, community-based organizations and regional policy-making. There is likely to be a close link between more resilient results and broad partnerships in research and development.

We consider that in the four case studies that are already having impact on end-users, the results were more resilient than those typically obtained from business as usual under a Central Source of Innovation model and were often unexpected; this merits further study beyond the scope of this paper. In most of the cases business as usual research would not have produced any of the results. In others, some key results, but not the complete set of results would have been obtained because not all levels of actors would have been present in the research. Research with multiple, diverse partners changed interaction patterns, the diversity and novelty of the research conducted, the solutions obtained and the way decisions were made.

The projects discussed in these case studies contribute to resilience because they speed up learning processes that are cognizant and inclusive of different system scales. This provides checks and balances so as to avoid promoting a change to the detriment of a long term trend, or of another system user. Involving actors from more system levels increased projects' ability to analyze, and to generate more benefit for more people. By scoping the environment of diverse institutions for ideas, researchers identified good ones quickly and gained a better understanding of the complex adaptive system. Ideally a diverse set of partners, "from field plot to policy making" would be present in all research-for-development.

Having results-oriented, committed, well-connected people, accustomed to systems thinking, to lead and participate in research-for-development teams was key to success. Both of these were also a result of broader partnerships.

Work at a higher institutional scale also implies work at a broader geographical scale because many institutions don't work at a local scale. Participants at each scale need to see research or development content that is interesting to them. Action research is the key, followed by scaling up. Contact across countries and basins provided further important opportunities and insights in each case.

Source: CPWF

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Appendix 1

Tables

Table 1 Key levels of system change in each project (key opportunity shown in bold)

	Coastal management systems CRESMIL	***Companion modeling (Lingmuteychu case) ComMod***	***Small reservoirs SRP***	***Multiple water use systems MUS***	***Livestock water productivity (Nakasongola case) LWP***
System level 1	*Household* Farmers adopted and adapted new farming systems depending on their zone and time of year. Household income increased	*Household* Individual farmers needed water to be released earlier for transplanting rice	*Household* Greater water availability and better use through validation of community reservoirs	***Local (Household, community)*** **Research showed individual water use decisions don't separate domestic and productive water supply – wide range of innovation**	*Household* Ready to invest labour and change practice to re-establish degraded pastures once the technology was found.
System level 2	***Zone*** **Shrimp and rice farmers had different needs for water salinity; negotiation of sluice gate management led to modified operation regimes under local control**	*Downstream community* Identified need for action that wouldn't have been possible at household level	*Community reservoir* Social and practical advantages of having water near at hand. Major management guidelines available through toolkit	*Intermediate (Local government, private sector, NGOs and CBOs)* Action research showed how intermediate institutions could and should recognize and support co-existing multiple uses	***Community*** **Research showed that joint corralling of cattle at night provided concentrated manure that was attractive to termites, thus permitting reseeded pasture to survive.**
System level 3	*Province* Recognizing salty water as a resource led to more innovative zoning whose operation was managed by local irrigation officers	***Catchment*** **Companion modeling among communities led to agreement to release water five days earlier**	***Sub-basin*** **Research showed that small reservoirs are efficient hydrologically, thus validating their use which has major social advantages**	*National (Government, financiers)* Project showed that national policies, programs, laws and regulations could permit and stimulate multiple use at lower levels; they could also be influenced by practices at those levels	*Local organizations* Had investment and training commitments ready once solution was found
System level 4	*Sub-basin* Neighboring provinces formed a Water Management Alliance to cooperatively manage the salinity control sluices	*Local authorities* Present at request of communities in second and third workshop. Provided legitimacy "in the background"	*River basin* Modeling showed that a fourfold increase in small reservoirs would only have a 1% effect on downstream availability	*Global* Global advocacy in collaboration with the MUS Group provided legitimacy and support for innovations at the national and other levels	*Catchment* Reduced runoff and higher water quality likely to benefit water availability in general for other productive activities

Table 2 Institutional participation in case study projects

	Coastal management systems CRESMIL	***Companion modeling ComMod***	***Small reservoirs SRP***	***Multiple water use systems MUS***	***Livestock water productivity LWP***
Project leader	*Dr T.P. Tuong, IRRI*	*Dr F. Bousquet and Dr G Trébuil, CIRAD*	*Dr M. Andreini, IWMI*	*Dr B. van Koppen, IWMI*	*Dr D. Peden, ILRI*
CGIAR centers	IRRI, IWMI, WFC	IWMI	IWMI	IWMI	ILRI, IWMI
Advanced research institutes (North)		CIRAD, CEMAGREF	IRD, SEI, TUD	WAU, ODI, WRC	
International NGOs				IRC, IDE, CRS	CARE Ethiopia
National planning & development	BWDB, IRMC, NIAPP, SIWRP			South Africa, Colombia	
Non-university research (South)	BRRI, BFRI, BARD, RIA2, SIFR	Thailand, Bhutan, Vietnam	WRI, Embrapa		
National universities (South)	BAU, CTU, AGU, UAF	CMU, URU, CTU, CU, RUB	University of Zimbabwe	KKU, Mekelle, CNU, AAU	Makerere
National NGOs	HEED, Socio-Consult Ltd, BRAC	Royal Project Foundation (Thailand)		IWSD, MT, CA, PA, Dilasa, SSSP Nepal, LWN, AWARD, Mvuramanzi, FWN, WFM	Ethiopian Rainwater Harvesting Association
Government extension	Dept of Agriculture and Rural Dev't (Agriculture and Fisheries centers)	Thailand, Bhutan, Vietnam		Nepal, Zimbabwe, South Africa	National Agricultural Advisory Services Uganda
Local government	Bangladesh Local Gov't Engineering Department, Bac Lieu People's Committee	Sub-districts (Thailand), Districts (Bhutan), Bac Lieu People's Committee (Vietnam)		South Africa, Nepal, Colombia, Bolivia, India, Ethiopia	District Veterinary Officer

Notes to Table 2. Partner institutions included are those that continued as formal partners at project completion. In all five cases, local communities and organizations were partners. In Case 4, the MUS project learning alliances encompassed a total of 150 institutions (van Koppen et al. 2009).

Abbreviations:
CGIAR Centers: International Rice Research Institute (IRRI), International Water Management Institute (IWMI), World Fish Center (WFC), International Livestock Research Institute (ILRI).
Advanced Research Institutes (North): Centre International de Reseaux Agriculture and du Developpement (CIRAD), Institut de Recherche en Sciences et Technologies pour l'Environnement (CEMAGREF), Institut de la Recherche et du Developpement (IRD), Stockholm Environment Institute (SEI), Technical University Delft (TUD), Wageningen Agricultural University (WAU), Water Research Commission South Africa (WRC).
International NGOs: International Water and Sanitation Center (IRC), International Development Enterprises (IDE), Catholic Relief Services (CRS).
National planning and development: Bangladesh Water Development Board (BWDB), Integrated Resource Mapping Centre (IRMC), Vietnam National Institute for Agricultural Planning and Projection (NIAPP), Vietnam Sub-Institute for Water Resources Planning (SIWRP).
Non-university research (South): Bangladesh Rice Research Institute (BRRI), Bangladesh Fisheries Research Institute (BFRI), Bangladesh Academy for Rural Development (BARD), Vietnam Research Institute for Aquaculture No. 2 (RIA2), Vietnam Institute of Fisheries Economics and Planning (SIFR), Water Research Institute, Ghana (WRI).
National universities (South): Bangladesh Agricultural University (BAU), Can Tho University (CTU), An Giang University (AGU), Vietnam University of Agriculture and Forestry (UAF), Chiang Mai University (CMU), Ubon Ratchatani University (URU), Chulalongkorn University (CU), Royal University of Bhutan (RUB), Khon Kaen University (KKU), Colombian National University (CNU), Addis Ababa University (AAU).
National NGOs: Education & Economic Development Bangladesh (HEED), Bangladesh Rural Advancement Committee (BRAC), Centro Agua (CA), Programa Aguatuya (PA), Local Wisdom Networks (LWN), Association for Water and Rural Development, South Africa (AWARD), Farmer Wisdom Network (FWN), Water for Food Movement (WFM).

Table 3 Changes from business as usual in the case studies

Changes from business as usual	*Coastal management systems CRESMIL*	*Companion modeling ComMod*	*Small reservoirs SRP*	*Multiple water use systems MUS*	*Livestock water productivity LWP*
Change in geographical scope	Action in two deltas – Ganges not just Mekong. Further international expansion through Delta Conferences.	Work that originated in Thailand expanded to Vietnam and Bhutan	Researchers from three basins in two continents agreed common methodologies	Work in eight countries and five basins, instead of one or two basins	Added basin and sub-basin scales to work originally only done at field scale. Acted in three Nile countries
New types of partners *(see also Table 2, Appendix 1)*	National and provincial governments included. Fish and hydrology researchers included as well as agricultural research	Communities often sought inclusion of other communities and local government in new ways of doing business	Over 60 students approached the project to do their research.	In all eight countries NARES and NGOs played an equal role with IWMI and international NGOs	NARES had equal role. Ugandan researchers were key in finding solution to degraded rangelands
Changed research priorities	Diversification of production systems. Brackish water as a resource.	E.g., in Bhutan holistic management of renewable natural resources instead of previous sectoral topics	Research results on efficiency of cascades of small reservoirs (SR) focused research on toolkit for SR	In Nepal and Thailand, greater focus on multipurpose systems for productive uses	Changed widespread belief that livestock production is not relevant to water management, e.g., creation of new ILRI /IWMI program
Novelty and diversity of outputs	From models (zoning, sluice gate operation) to diversified cropping systems (income, reducing shrimp disease)	Different watershed resource management committees, coordinated use of tanks, change in dates of water release, agreement between foresters and villagers	Diverse range of options presented in toolkit, mobilized by novelty of original result about evaporation from SRs.	The original concept, that communities don't distinguish "potable" from "irrigation" water, was the basis for R&D innovation in several countries	The unexpected and effective result on termite control was obtained by systems, "out-of-the box" thinking by Ugandan researchers
Who assesses fitness for purpose	Local government, planning and development institutions are now all research partners and clients	All stakeholders: communities, NGOs and government, as part of methodology	Toolkit developed with extensionists, researchers and farmers; aimed at use by first two.	All stakeholders, depending on system level.	District officials, researchers, farmers and local NGOs
Who is investing in scaling-up the changes in knowledge, attitudes and practice	National and provincial policies and farmers organizations (Vietnam). NGOs (Bangladesh). IFAD through new project investments	Researchers developed simulations to out-scale case studies and communicate with decision-makers	Interest by African Development Bank in SR vs. large dam investment debate.	World Bank and other investors recognize publicly that multiple use is a reality	Local NGOs, local government and SIDA began rapid investment in termite control/ pasture reclamation
Outcomes and impact	Improved livelihoods for at least 10,000 farmers and contribution to rapid provincial growth rate in Vietnam; 30% early adoption in research area in BD	Specific changes in practice in seven of the nine community cases in Thailand, Vietnam, Bhutan.	Detailed toolkit available for practical use. Rapid early uptake of some tools through course at KNUST university.	Governments, esp. S Africa and Thailand, changed water use policies. Communities in several countries adopted improved MUS technologies.	Water use by livestock is understood by researchers as an integral part of water management. Novel termite control permits restoration of degraded lands in Uganda.

Table 4 Broad partnerships and their apparent effects on resilience

Changes from business as usual through working with broad partnerships	***Effects on resilience observed in CPWF case studies***
Change in geographical scope	More geographically diverse partners bring a wider range of solutions and ideas and may lead to more resilient solutions.
Greater range of partners	Diverse partners allow ideas, interaction and influence across more than one scale.
Changed research priorities	Research priorities can be designed to focus more on resilience; inclusion of more and diverse partners may strengthen this.
Novelty and diversity of outputs	Having more diverse outputs, organizational as well as technical, means a greater opportunity to assemble them to achieve resilience. Novel outputs can also be focused towards resilience.
Who assesses fitness for purpose	Having the opinion of more diverse stakeholders, both scientists and those closer-to-the-ground, each with their different ways of predicting and measuring resilience, is likely to lead to a more resilient result.
Who invests in scaling-up the changes in knowledge, attitudes and practices	Including those working closer to end-users in promulgation is likely to lead to more success in realizing the potential for resilience in the knowledge and technology. Should also provide good feedback about how to improve resilience as part of performance in general.
Outcomes and impacts	Results obtained in all the case studies are of types that will tend to increase resilience, especially ways to build on collective learning.

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About CPWF

The Challenge Program on Water and Food was launched in 2002 as a reform initiative of the CGIAR, the Consultative Group on International Agricultural Research. CPWF aims to increase the resilience of social and ecological systems through better water management for food production (crops, fisheries and livestock). CPWF does this through an innovative research and development approach that brings together a broad range of scientists, development specialists, policy makers and communities to address the challenges of food security, poverty and water scarcity. CPWF is currently working in six river basins globally: Andes, Ganges, Limpopo, Mekong, Nile and Volta.

About this Impact Assessment

This paper explores the potential benefits of working to improve the resilience of complex adaptive systems in agriculture and aquaculture through engaging in diverse partnerships among different types of research and development institutions, and the people in those institutions. We use five case studies of CPWF research-for-development efforts to draw lessons about achieving effective results in system resilience. The paper gives concrete examples of effective partnerships and the positive changes that resulted for farmer and fisher communities.

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