7. Strategic Research Portfolio: Improved Management of Water Resources in Major Agricultural River Basins

Our vision: equitable sharing of water for agricultural and environmental purposes

Our vision is better and more equitable sharing of water and land resources worldwide. We see river basins in which flows are managed to minimize the impacts of rainfall variability; where agricultural productivity, livelihoods, water quality and ecosystem services are protected through reduced land degradation, control of erosion and pollution. Similarly, we see governance and institutional arrangements that protect access to land and water resources for the poor and which recognize the importance of ecosystem services to agriculture, other water consumers and the environment.

7.1. The compelling need for this research

As populations grow and incomes rise, resulting in more demand for staple foods and water-intensive high-value food products, the demand for water increases. Non-agricultural water needs increase similarly, while some water must be reserved to maintain essential freshwater ecosystem services. Approximately 3 billion people experience various forms of water scarcity already (CA, 2007), and in the 2050 world of 9 billion people, water scarcity may become the unpleasant ‘norm.’ The magnitude, type and extent of scarcity vary across river basins. Some basins are closed and water is over-allocated (physical water scarcity). Others are open with relatively abundant water resources that can be (but are not yet) harnessed through improved infrastructure (economic water scarcity). In some, institutions limit access to certain groups and exclude others (institutional water scarcity).

Land degradation reduces agricultural system productivity, threatens livelihoods, jeopardizes ecosystem services and reduces water quality – exacerbating the effects of water scarcity. Climate change, combined with land degradation and water scarcity, causes greater spatial and temporal variability in water availability, thereby increasing risk and reducing resilience. This variability of an already scarce resource is the major natural issue for agricultural water and overall water resources management in all areas with physical water scarcity (Figure 1.4 on page 19).

7.2. Building on a solid research foundation

Previous basins-related research has been significant. Examples of previous research on river basins are given below (see Appendix 1b for details on the research foundation of water scarcity).

Open and closed basins
Seckler (1996) introduced the ‘basin view’ into agricultural water management. Subsequent studies examined various stages of basin water resources development up to water ‘rereallocation’ at the time of ‘basin closure,’ introduced basin water accounting procedures and the use of remote
sensing and modeling tools for integrated assessment of water availability and access (Keller et al., 1996; Seckler et al., 1998; Molden, 1997; Kite and Droogers 2000; Molle, 2003). The concepts of closed basins and global water scarcity had significant impact worldwide and were further illustrated in individual basins globally: diagnosing cases of physical and economic water scarcity, exploring the societal factors leading to basin closure, examining future scenarios of water availability with in-built environmental water allocations, and exploring both drivers of change on basin water resources and the response options in the face of water scarcity (Amarasinghe et al., 2004, 2008; Biggs et al., 2007; Giordano and Vilholth 2007; McCartney and Arranz 2007; Venot et al, (2008); CA, 2007; Smakhtin et al., 2004; Molle and Wester, 2009).

**Water storage**
Keller et al., (2000) formulated the main principles of sustainable water storage development. IWMI has subsequently recommended that all forms of water storage including – large dams, through small reservoirs, rainwater harvesting, groundwater and conjunctive use of wetlands – should be considered in the development of locally appropriate solutions to provide insurance against drought and rainfall variability (McCartney and Smakhtin, 2010).

**Tradeoffs at basin level**
Molle (2003), Molle et al. (2005); Ringler (2001), Cai et al. (2003), Smakhtin et al. (2007) and many others have explored tradeoffs and water-allocation scenarios among various basin water users.

**Adaptive river basin management**
Lankford et al. (2007) formulated an adaptive framework for river basin management in developing countries, and Sadoff and Grey (2002) developed the concept of benefit-sharing in river basin management.

**Water and development challenges**
Recent CPWF research, through a number of basin focal projects (Cook et al., 2009), identified a range of development challenges in several of the world's largest river basins. They found that improved water productivity was often the basis of economic development, but analysis of basin conditions shows a complex dynamic between development processes and the natural resources they consume. This dynamic can push river basins, or parts of them, beyond the level at which ecosystem services of water provision, food production, energy and others can be delivered sustainably. This raises problems of potential conflict over limited resources among communities within river basins. An alternative situation occurs when resources are effectively underdeveloped. In such cases, poverty is associated with low productivity of land and water.

7.3. The compelling role for the CGIAR

River basin management in developing countries is generally in its infancy. The CGIAR can muster the range of disciplinary approaches and has the ability to integrate these in a way that has not yet been achieved by national institutions that tend to focus on individual issues. The CGIAR can also help fledgling river basin authorities compile data and information vital to evidence-based
decision-making and water allocation procedures. This is regionally critical given the significant number of transboundary river basins.

The CGIAR has experience in basin-, sub-basin- and landscape-level innovations in land and water management (not just plot- and farm-level innovations); in the introduction of benefit-sharing mechanisms that feature negotiations among upstream and downstream water users; and in anticipating and measuring the whole-basin, cross-scale consequences – including consequences for ecosystem services – of modifications in water allocation and landscape management.

Furthermore, the CGIAR can draw lessons from governance and management approaches in basins in developed and emerging economies (e.g. the Colorado in the United States and Mexico, the Yellow River in China, and the Murray-Darling in Australia) and contribute knowledge of what elements might be successfully transferred to our target basins. Finally, the strong linkages developing between CRP5 and the CRP7 (Climate change for agriculture and food security) gives the CGIAR a critical ability to link climate change predictions to estimations of water availability, variability and how these will affect basin water resources and their allocation.

This SRP will build on the work of the CPWF and its partners. We aim to further develop the paradigms for river basin management and explore how improved and better integrated information will provide policymakers with compelling evidence on which to base basin development and management decisions. We recognize the political issues associated in land- and water-use planning and the tradeoffs that come in to play when power development is pitted against agriculture and the environment. However, we also recognize, based on previous IWMI and CPWF work, that clever solutions can be found to optimize resource use, and that water also has to be viewed in the context of general development issues rather than in isolation. Successful examples of previous work include ‘water banking’ in the Ferghana Valley in Central Asia (capturing of hydropower water releases in winter and storing them in aquifers for subsequent summer irrigation), multiple use systems in southern Africa, payment for environmental services in South American Andes group of basins, and innovative rice–shrimp systems to cope with increasing salinity in parts of the Mekong Delta in Vietnam. Similarly, CRP5 will begin to address some of the basin development challenges described by Cook et al. (2009).

7.4. The scope and depth of the opportunity

Given the increasing pressure on water and land resources some significant problems must be overcome. For example:

- **Water scarcity**
  The often preferred response to water scarcity is to improve or increase water supply. The development of new supply sources (both conventional and unconventional) is often constrained by the cost and a range of hydrological, social and political risks, which negatively affect the livelihoods of the poor (World Commission on Dams, 2000). These risks are not always well understood and quantified. Negative consequences of investments in water supply
infrastructure are all too often transferred to the poorest and most vulnerable groups, to the environment, and to the next generations.

- **Water resources variability**
  Water resources variability – in time and space – remains a critical problem in water management, and hence sustainable agriculture and food production worldwide. This problem is increasing with climate change. Socially and ecologically responsible approaches to managing this variability are required. These will include developing, managing and diversifying supply, water-storage infrastructure and distribution networks.

- **Coordinating water and land management**
  Water and land management are inherently linked. Land-use change and loss of agricultural biodiversity, driven by population and economic growth, has pronounced impacts on water. Issues of sedimentation due to soil erosion, soil and water salinization, and pollution strongly link this SRP with the Rainfed Systems, Irrigated Systems, and Resource Recovery and Reuse SRPs. This SRP can help assess the consequences for ecosystem services of land and water management innovations introduced by other SRPs – and possibly other CRPs. Managing land, water and agricultural biodiversity in ways that benefit the poor and maintain or reduce impacts on ecosystems services remains one of the main basin development challenges.

- **Dwindling resources**
  Another common response to water scarcity is to produce more with fewer resources. Land and water productivity remain lower than they could be. Cases where improvements in both are possible, and means of improvement need to be identified and pursued. There is a clear lack of up-scaling of promising interventions – e.g. from irrigated or rain fed agriculture – to the basin scale. Agricultural intensification in an ideal world should aim to double production on half the area. The impacts of intensification on water resources and human health need to be understood, as does the role of diversity and diversification in increasing water-use efficiency.

- **Competition for water resources**
  One challenge for river basin management comes from the de facto reallocation of water out of agriculture to urban and industrial uses. While this is in general administered centrally with little transparency, there is a need to better identify the impacts of such reallocation, and how these can be mitigated.

- **Environmental water allocations**
  Global interest in environmental water allocations is growing rapidly. Examples include the Murray-Darling Basin in Australia, and the European Union, where the Water Framework Directive attempts to restore “good ecological status” of European rivers. However, this 'new' issue exerts pressure on conventional uses of water, particularly agriculture, and particularly in the developing world, where food production is the number one priority. No ecologically relevant thresholds for surface or groundwater use exist or are implemented in developing countries. This SRP will look at how environmental flows can coexist with other water uses.
• **Lack of good data**
  Measured reliable data (that reflect natural variability) on any water component remain lacking. Good policy and management must be based on sound scientific data. The maxim of ‘if you can’t measure it, you can’t manage it’ is never truer than for water resources management. This SRP will consider data needs in target basins, and will also link strongly with the Information Systems SRP to deliver regional-scale generic assessments of water availability and variability, and factors such as drought and flood risks.

• **Transboundary basins**
  Transboundary basins are dominant features of the water landscape in both Asia and Africa (Wolf et al., 1999). These basins are home to significant numbers of the world’s poor, and are sources of international and interstate cooperation as well as conflict. Developing effective governance structures and understanding and managing river flow variability in these basins will be keys to peace as well as agricultural and economic development and thus poverty reduction.

The above are just a few problem areas and research hypotheses that need to be addressed. Testing these in a selection of target geographical areas, as well as globally, will demonstrate how and where we can prove the overarching theses that 1) agricultural production can be intensified, diversified and expanded without further degradation of the natural resource base and supporting ecosystems, and 2) it is possible to improve water governance, institutions and management so that the impact of water scarcity and variability are reduced.

7.5. **Our Theory of Change for improved management of water resources**

There are several entry points (all having both land and water dimensions) that can be used to increase the magnitude, value and equitable sharing of ecosystem services and benefits in and from river basins.

1. **Understand and consider resource variability in basin management**
   Most, if not all, water management interventions are triggered not only by limited water availability in general, but also by fluctuations over time (which are increasing globally with climate change). This SRP will highlight the issue of variability for policymakers and land and water managers. Research can provide information to characterize variability of land and water resources in time and space, as well as recommendations of how best to deal with variability at the basin scale (in particular through storage and combined use of surface and groundwater).

2. **Invest in water infrastructure**
   This issue is closely related to 1), above. Where economic water scarcity prevails, this can improve water availability for many users. Complementary land and ecosystem management practices are needed to take full advantage of infrastructure investment and to avoid land degradation, one consequence of which can be infrastructure deterioration. This SRP aims to
influence how these investments are made, by direct advice to key investors or policymakers, or by developing decision support tools that highlight the tradeoffs and complementarities among land, water, ecosystem services and outcomes for rural livelihoods. A related strategy is to inform and thereby influence the discourse on investments. Research can provide information on: 1) alternative investments covering a range of infrastructure practices and storage options; 2) magnitude and distribution of benefits and costs from infrastructure investments (of special interest to investors concerned with their reputational risks); and 3) the extent to which infrastructure can help mitigate the effects of hydrological extremes (e.g. floods and droughts) while maintaining or enhancing social and environmental goals.

3. Allocate and manage basin water and land to raise productivity, improve equity and safeguard ecosystem services

Water in a basin can be reallocated from less productive to more productive uses with appropriate attention to water rights, including compensation. The productivity of water in different uses is affected by land management practices. This SRP will inform and influence the discourse about water rights and water allocation. Research can provide science-backed information on water productivity for different uses (and how productivity is affected by land management decisions) and indicators for suitable levels of compensation for those who cede water rights. Water resources can be reserved for environmental flows and research can examine the consequences of that for other water users. The recent introduction of these concepts into discourse on the National River Linking Plan in India was the result of good science and the ‘right’ relationships that jointly ensured a positive impact.

4. Introduce and consistently follow the principles of benefit-sharing

Upstream land and water management practices affect the quantity, quality and reliability of water available to downstream users (e.g. urban communities, fisheries, and hydropower and irrigation facilities). Institutional innovations can be introduced whereby downstream users invest in suitable upstream land and water management practices, thus improving the livelihoods of upstream communities and maintaining essential environmental services (e.g. reducing sediment flow, and stabilizing downstream water availability). Research can quantify upstream–downstream interactions and inform the design of related institutional innovations, which can then be tested with stakeholders and their achievements measured.

5. Pay attention to the political economy of policy selection

Decision-making must be understood within the existing governance framework, including both state and non-state actors, their respective political power, worldviews and interests. Hydrological and economic approaches may identify the costs, benefits and risks associated with particular courses of action, but they may also be confronted with the existing players and coalitions endowed with their own resources and logics. This opens the way for research that facilitates the development and use of tools such as multi-stakeholder platforms and other social learning techniques.
7.6. Where we will work

Target areas will include basins and basin groups with both physical and economic water scarcity. The original set will comprise such eight basins/groups: Mekong in South East Asia, Indus and Ganges in South Asia, the Aral Sea Basins of the Syr Darya and Amu Darya in Central Asia, Tigris and Euphrates in the Middle East, Nile in East and North Africa, Limpopo and Zambezi in Southern Africa, Volta and Niger in West Africa, and the Andes group of basins in Latin America.

These target areas have high potential for poverty alleviation, established partnerships, solid track records of previous CPWF and CGIAR research, and good potential for one or more levers of change to be applied. This SRP will however not limit itself entirely to these basins/target areas, but will keep a global outlook commensurate with its vision.

7.7. Links to other CRPs and SRPs

This SRP will link closely with the Irrigated Systems SRP given the strong connection between irrigation, water availability and water allocation. The SRP will also have major linkages with work in CRP7 (climate change) given the need for information on the impacts of climate change on hydrology. The availability of down-scaled climate predictions will be very important for basin modeling. Similarly the SRP will build linkages with the Rainfed Systems and Information Systems SRPs to link terrestrial changes in land cover to hydrological impacts via sentinel sites. From a policy perspective, this SRP will link to CRP2 (Policies, institutions, and markets to strengthen food security and incomes for the rural poor). We will also link with relevant parts of CRP1 (agricultural systems in dry, humid and aquatic environments) to coordinate on-farm NRM and basin responses.

7.8. What we will achieve in the first five years

In the next five years, this SRP will develop a much better understanding of how best, in different settings, to deal with water resources availability and variability in time and space – the primary issues in water resources management globally. How land and water are used in specific locations can have profound impacts on people and environment. This SRP aims to quantify the impacts of different land uses and management practices on water processes, flows and quality, on livelihoods, and on ecosystem services. This information will be used to help water authorities adopt new policies for land and water planning and management that will assist in poverty reduction and positive environmental outcomes in major target areas. We will integrate into other SRPs and relevant CRPs the cumulative impacts of and changes to agricultural activities at basin scale. Below are a few examples of the key problem sets and associated research directions that we will pursue in some of our target areas.
Andes Group of basins – Latin America

*Benefit-sharing mechanisms as a water management tool.*

Previous CPWF research suggested that the socio-political environment is ripe for pushing the full-scale adoption of payment for environmental services in this region. The idea is that rich(er) downstream water users co-invest in improved upstream land and water management so that all users benefit. Benefits include higher water productivity (upstream), improved livelihoods, reduced land degradation and a more stable supply of higher quality water downstream – hence reduced siltation and pollution, improved irrigation, etc. The impact pathway for this work is described in Table 7.1.

Ganges and Indus – South Asia

*Integrating environmental water allocations and climate change impacts with water resources development*

Climate change impact on glaciers and snow in the Asian Tower are amongst the hottest topics debated at present, but the impacts remain largely unclear in both basins. In parallel, IWMI’s previous work in India in the field of environmental flow management has stirred the national interest to the topic and has a high potential for impact in the near future. This research will include a mix of assessments of glacier and snow impacts on water availability downstream, optimal water allocation scenarios for the future, new models for conjunctive use of surface water and groundwater, and assessments of environmental flow impacts from increased groundwater use on rivers and flood in particular. The work will link closely with CRP7, under which the probable impacts of climate change are assessed. The impact pathway for this work is described in Table 7.2.

Mekong – Southeast Asia

*Harmonizing the water–energy-environment nexus*

The Mekong is one of a few major river basins in Asia that remain relatively unregulated. A hot issue in the Mekong is, however, planned hydropower development. This output will include the tools to assist with managing future reservoirs and their cascades with inclusion of ecological and livelihood considerations, quantified impacts of possible hydropower development scenarios on livelihoods, and quantified alternative scenarios for large-scale irrigation development and alternative energy sources. The impact pathway for this work is described in Table 7.3.

Nile – East and North Africa

*Managing water resources to reduce poverty and improve wetland management in upstream countries*

Upstream Nile countries generate most of the Nile flow, but receive the smallest share of benefits from it. Work here will include science-backed plans for optimal water storage development (currently almost non-existent), up-scaled information for water productivity improvement in rainfed areas, and quantified services of basin wetland ecosystems – all in the context of a complex transboundary perspective. The impact pathway for this work is described in Table 7.4.
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<th>Issue</th>
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<td>• In many small basins in the Andes, conflicts among water users are increasingly common. Downstream communities, lowland commercial farmers and highland irrigated farmers want year-round availability of clean water. Highland urban areas need, and highland mines want water for ore processing with the freedom to discharge polluted water back into rivers. Highland rainfed farmers and herders want to expand and intensify production systems, although this may lead to overgrazing and erosion with implications downstream. Hydropower operators need the flexibility to rapidly change the volume of water flowing through turbines to meet power demand. However, alpine communities and those who value biodiversity want alpine lake levels to remain stable and highland nature reserves properly maintained.</td>
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<th>Levers of change</th>
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<td>Improved energy, food and environmental security in the Andes can be achieved through (1) rewarding for positive and penalizing for negative incentives, (2) investments in water storage and water treatment, and (3) broker ‘benefit-sharing mechanisms’. The latter are when downstream water users co-invest in highland management focusing on practices that improve highland community livelihoods and stabilize water availability for downstream consumers. All three levers require strategies that integrate policies, institutional arrangements, technologies and stakeholder engagement.</td>
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<th>Research outputs</th>
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| **Information and tools**  
• A good understanding of land and water management practices by different stakeholders, and negative and positive externalities of such practices for downstream water users and the overall production of ecosystem services  
• A good understanding of the distributional and cross-scale consequences, including costs and benefits, of alternative strategies  
• Datasets and tools to support all of the above. |

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<th>Outcomes</th>
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| **Range of solutions**  
Strategies for investing in water infrastructure, treatment and benefit-sharing, with an understanding of the performance of different strategies under various conditions.  
**Improved capacity**  
A good understanding of how to encourage stakeholders to define problems, target solutions, understand their consequences, and negotiate evidence-based benefit-sharing agreements. |

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<th>Potential impact</th>
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| • National and provincial governments establish and implement policies favorable to the introduction of evidence-based negotiations to develop suitable benefit-sharing mechanisms  
• Institutional arrangements to share water, or water-related benefits  
• Investments made in water storage, management and treatment, with costs shared equitably by stakeholders  
• Improvements made in land and water management by farmers and herders that improve livelihoods, stabilize water flow, reduce sediment flow, and produce and support a wide range of ecosystem services. |

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<th>Contribution to SRF outcomes</th>
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| • Livelihoods of poor highland communities improved  
• Greater and more stable availability of water to downstream communities  
• Increased and more flexible power generation  
• Reduced water pollution from mines and urban areas  
• Improved preservation of alpine nature reserves including lakes  
• Reduced water-related conflict. |

| Sustainable NRM; poverty reduction |
Table 7.2. Impact Pathway: Integrating environmental water allocations and climate change impacts with water resources development in the Ganges and Indus River Basins

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<th>Issue</th>
<th>Levers of change</th>
<th>Research outputs</th>
<th>Outcomes</th>
<th>Potential impact</th>
<th>Contribution to SRF outcomes</th>
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| • The environmental and spiritual significance of Ganges for India is very high, as is the desire to keep it healthy, despite massive development plans. Climate change impact on glaciers and snow in the Asian Tower, coupled with projected changes in monsoon pattern are among the hottest topics debated at present, but the impacts remain largely unclear in both Indus and Ganges. Both basins are home to some 600 million people. Water productivity improvement in both basins is high on the agenda. Water resources planning and management is carried out in conditions of limited or no access to limited or no data on virtually any component of water balance. Transboundary cooperation between India and Pakistan, and India and Bangladesh, needs significant improvement. | • No matter how uncertain the projections are, the general biophysical trend in both basins seems to be towards the significant increase in water resources variability. Understanding this trend and communicating it to responsible authorities is imperative, as both basins will become much more vulnerable, and both may not be able to support their populations in 20 years’ time. | **Water resources:**  
• Impact of climate change on river flows and groundwater recharge in the Indus and the Ganges; availability of surface/groundwater resources in different parts of both basins  
• Quantification of disastrous events (e.g. flooding), their impacts on agricultural production, and formulation of preventive strategies.  
**Food security:**  
• Role of changed/improved water resources in continued intensification of food production.  
• Assessment of regional hotspots and ways to improve low water productivity.  
• Basin-wide, interstate hydro-economic models that allow the simulation of optimal water-allocation scenarios to meet future water demands.  
• Standard datasets and institutional arrangements accepted by all basin states, on which transparent decisions on water and benefits-sharing can be made  
**Environment:**  
• Environmental flows for both basins included into development planning;  
• Thresholds for groundwater development in underused parts of both basins established. | • Individual riparian countries and regional bodies use knowledge and recommendations to create policy.  
• National planning bodies and development banks support proposed strategies.  
• New water-sharing arrangements concerning the Himalayan region  
• Increased donor coordination and improved use of resources | • Enhanced food security for over 170 million rural inhabitants in both basins  
• Reduced vulnerability to climate-induced water extremes in the basin.  
• Better cooperation and reduced water conflict in the region.  
• Improved health of two of the major endangered rivers (Indus and Ganges) of the world. | • Food security  
• Poverty reduction  
• Sustainable NRM |
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<td>The Mekong hosts a range of biophysical and socioeconomic attributes, reflecting the degree of economic development of countries. Economic growth triggers the development of water resources for hydropower production and associated related areas. The Mekong however remains yet one of the few unregulated large river basins in the world, but for how long? Changes in the flow regime due to water infrastructure development will have both positive (water for irrigation, flood control) and negative (decline in fisheries, potential salt-water intrusion) impacts. Balancing these competing uses is an imperative in influencing the basin development trajectory that ensure equity and sustainability.</td>
<td>The recent push for mainstream dams at Xaybury and Don Sahong adds a new level of urgency to understanding impacts of water infrastructure development. Improved understanding of basin hydrology over the last 10 years provides the basis to – to incorporate ecological, social and economic consequences and tradeoffs of basin development. Structures for transboundary cooperation, such as the Mekong River Commission (MRC), provide pathways for putting new knowledge into practice.</td>
<td><strong>Transboundary cooperation</strong>&lt;br&gt; New tools for land and water resources monitoring using space technologies and public domain data to demonstrate data-sharing benefits for transboundary management</td>
<td><strong>Livelihoods</strong>&lt;br&gt; • Development and assessment of livelihood strategies for communities affected by large water resources development&lt;br&gt; • Practices to enhance productivity of seasonal floodwaters for the benefits of the poor (rice-fish systems, recession agriculture, maintenance of wild capture and harvest)&lt;br&gt; • Management of saline/fresh water to enhance livelihoods in Mekong delta</td>
<td><strong>Environment</strong>&lt;br&gt; • Improved watershed management to reduce sediment generation through 'smart' incentives to enhance adoption of conserving practices&lt;br&gt; • Quantification of the impact of water resources infrastructure on fisheries and aquatic resources and potential mitigation strategies</td>
<td><strong>Trade-offs</strong>&lt;br&gt; Economic and environmental evaluation of multipurpose dams in meeting energy, livelihood and environmental targets</td>
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Table 7.4. Impact Pathway: Managing water resources to reduce poverty and improve wetland management in the Nile River Basin

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<th>Issue</th>
<th>Levers of change</th>
<th>Research outputs</th>
<th>Outcomes</th>
<th>Potential impact</th>
<th>Contribution to SRF outcomes</th>
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| • Upstream Nile countries generate most of the Nile flow, but receive the lowest share of benefits from it. They are very poor and very vulnerable to climate change. Ethiopia’s agricultural GDP, for example, fluctuates almost in perfect correlation with annual precipitation. Agricultural intensification, irrigation and hydropower development in Sudan and Ethiopia – which are needed urgently for poverty alleviation – will affect downstream flows and wetland systems (e.g. Sudd) that are critical to local livelihoods. Strategies are needed to optimize upstream development and water access while minimizing downstream impacts. All of this must occur in a complex transboundary context | Current and proposed investments (e.g. Tekeze and Merowe dams) and population growth mean that rapid change is already underway; the challenge and opportunity is to influence development through better understanding of where benefits from water accrue. The major change lever is investment in water storage, but how will this, if it happens, affect wetland ecosystems, for example? | **Hydrology and Water Resources:**
  • Science-backed plans for optimal water management and storage in upstream Nile countries, including groundwater options – all with implications to downstream wetland systems
  • Management strategies for major wetland systems of southern Sudan (Sudd, Machar, Bahr el Ghazal)
| **Livelihoods**
  • Strategies to improve water productivity and decrease drought risk in rainfed agricultural and pastoral systems
  • High-potential water and land interventions for poverty reduction in the Blue Nile Basin – based on analysis of water availability, access and productivity in Ethiopian Highlands;
| **Ecosystem services**
  Quantification of relative importance of ecosystem services from the river and wetlands as the basis for negotiating tradeoffs among sectors and countries | **Outcomes**
  • Sustainable production systems in rainfed areas and major wetland areas of southern Sudan and the Equatorial Lakes region
  • Reduction of vulnerability to drought in the upper basin through improved water storage and access to groundwater
  • Basin-wide cooperation in identifying development projects with transboundary benefits
| **Potential impact**
  • Significant increases in food production from rainfed agricultural and pastoral systems, and reduced incidence of famine in Ethiopia and Sudan
  • Reduction in tension between upper basin and Egypt by identifying upstream development options with minimum downstream impacts
| **Contribution to SRF outcomes**
  • More equitable distribution of benefits from Nile basin water
  • Protection of key wetland sites | • Wetland protection leading to sustainable management of natural resources
  • Poverty alleviation through benefit-sharing
  • Food security via increased productivity
Amu Darya and Syr Darya – Central Asia

*Transboundary water management solutions in transition economies*

Syr Darya and Amu Darya are the only two major water sources in Central Asia. Political relations between the countries in Central Asia are driven by access to the water in these two rivers. Key here will be analyses of past and current water-related benefit-sharing agreements, and changes in them (before and after independence); assessments of possible options for water reallocation with environmental consequences; transparent decision support tools for basin-wide assessment of these options; possible data-sharing agreements; illustration of the benefits of an as-yet completely underused resource – groundwater – in agriculture; and analysis of the wider costs and benefits of sharing the water in the Syr Darya / Amy Darya, including potential new players such Afghanistan. The impact pathway for this work is described in Table 7.5.

Volta and Niger – West Africa

*Water storage to reduce regional drought risk*

Previous IWMI and CPWF research in the region demonstrated the potential of shallow groundwater and small reservoirs for agricultural production and poverty alleviation. The subsequent research will deliver guidelines on best possible combination of storage options (e.g. various size reservoirs and groundwater) to alleviate drought impacts – the major climatic factor hampering agricultural development in the region. Close collaboration with CRP7 (climate change), and CRP1.1. (drylands) is envisaged. The impact pathway for this work is described in Table 7.6.

Zambezi and Limpopo – Southern Africa

*Harvesting transboundary aquifers*

Southern Africa is characterized by high level of surface-water resources development, and, ironically, rather limited amounts of surface water. A push for regional agriculture may be expected from groundwater development in large transboundary aquifers. This research will include assessment of groundwater availability in these aquifers, establishing ecological thresholds for groundwater use (still possible prior to major harvesting of groundwater), and relevant governance models.
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</thead>
</table>
| • Soviet era cooperation in Central Asia (Amu and Syr Darya Basins) | • Coordinated management can improve energy, food and environmental security in the basins. But for it to happen, all parties need to benefit. One way to change is to learn from natural and social environments in which bright spots of cooperation (if any) occurred. Yet, considering the transitional nature of regional economies, identifying ‘second best’ solutions for immediate implementation is another strategy. This two-tier approach may provide the breakthrough that the region has been missing for over 20 years. | Transboundary cooperation: Inventory and analysis of past and current water related agreements  
Irrigation/livelihoods  
• Analysis of regional changes/variations in water control, and their impact on possible cooperation, poverty alleviation, equity and gender  
• Demonstration of benefits of groundwater use in agriculture for immediate water scarcity relief  
Environment  
Assessments of environmental flow impacts (with or without cooperation) including those on the Aral Sea, and of industrial/urban effluents and agricultural return flow on drinking water  
Overall cost and benefits  
Analysis of the wider costs and benefits of sharing the water including: agriculture, energy, environment, and drinking supply | • Regional states and organizations use knowledge and recommendations to create policy  
• Development banks support proposed strategies  
• Increased Donor coordination/decreased aid fragmentation  
• Institutionalization of enforceable transboundary cooperation | • Livelihood security of the Fergana Valley’s 10 million inhabitants increased  
• Water and electricity supply improved for the region  
• Environmental damage to basins reduced  
• Lessons applied to other basins in the region and beyond | • Significant contributions to livelihood and sustainable NRM SLOs |

# Table 7.5. Impact Pathway: Transboundary water management solutions in transition economies: Amu Dary and Syr Daria Basins
Table 7.6. Impact Pathway: Water storage to reduce regional drought risk in the Volta and Niger River Basins *(applicable to most of Africa)*

<table>
<thead>
<tr>
<th>Issue</th>
<th>Levers of change</th>
<th>Research outputs</th>
<th>Outcomes</th>
<th>Potential impact</th>
<th>Contribution to SRF outcomes</th>
</tr>
</thead>
</table>
| Inability to predict and manage climate and hence water variability lies behind much of the prevailing poverty and food insecurity in West Africa. Declining rainfall since the mid-1970s, has exacerbated the problem and it is anticipated that climate change, which will most likely increase the frequency and severity of droughts, will do so further. Previous IWMI and CPWF research has shown that access to groundwater and a range of water storage options can contribute to increased food security and better livelihoods. However, as a rule, past storage interventions have failed for a variety of reasons. Past water storage development has occurred in a piecemeal fashion, largely through local initiatives and with minimal planning. | Investment into various forms of storage is the main path to sustainability and food security in the region. It will be imperative to develop and test structured and science-backed and tested short- and long-term basin-wide storage plans, taking into account all possible and socioeconomically acceptable and feasible plans, rather than follow an ad-hoc path. **Improved understanding of storage efficacy:**  
  - Insights into the need, suitability and effectiveness of different water storage options, under different agro-ecological and socioeconomic conditions (i.e. what works where, when does it work and why does it work).  
  - Better understanding of synergies and tradeoffs associated with combinations of different storage types.  
  - Insights into how different groundwater and surface storage options are managed in terms of access, institutions and the distribution of benefits. **Livelihoods:**  
  Gendered evaluation of the direct and indirect impacts of different water storage options on livelihood strategies, poverty alleviation and equity. **Improved planning and management:**  
  Tools and approaches for better integrated planning and management of surface storage and groundwater | • West African states and organizations like the Volta Basin Authority use knowledge and recommendations to inform water resource policy.  
• West African states and river basin authorities develop water storage strategies to better plan and manage the full range of water storage options, in an integrated fashion, factoring in climate change too.  
• WB and AfDB support proposed water storage strategies and imbed them firmly in their investment policies  
• Increased coordination between NGOs, governments and basin planners in storage development, and awareness at all levels | • Livelihood security and resilience of around 120 million (mostly rural) inhabitants in the Volta and Niger River Basins increased.  
• Lessons applied to other basins in the region and beyond | • Poverty reduction  
• Food security |
7.9. What we will achieve in the second five years

In years 6 to 10, lessons from the above impact pathways will be used to extend sustainable land, water and ecosystem management practices into other water-stressed basins. Significant attention will be given to monitoring the impact on ecosystem services from diversified management practices, and to cooperation with the SRP on Information Systems to develop regional analyses and information products on drought risk, soil-water storage, environmental flow recommendations and groundwater recharge possibilities.

7.10. Examples of research questions

We will test several hypotheses in this SRP. The following are examples of those hypotheses, along with associated research questions.

Guiding hypothesis
Water scarcity can be alleviated by improved water supply, by management of water demand and, in particular, by reducing water resources variability.

Research questions
• To what extent is water physically/economically scarce in a basin?
• How is scarcity the result of past policy decisions and how can it be prevented from becoming worse?
• How is water used in a basin? How much recycling is observed and what is the scope for 'real' water savings?
• What are the appropriate basin/regional strategies for improved water supply and demand management considering particular physical and socio-political contexts?
• What are the hydrological, socio-political and ecological risks associated with water resources developments, as well as other policy options, that negatively affect the livelihoods of the poor? How can they be best quantified?
• How can groundwater abstraction be controlled and how to integrate the combined uses of surface and groundwater at the basin level?
• How does water quality affect water availability for various uses?
• How can hydrological extremes (droughts and floods) be better predicted and managed to minimize their negative impacts on agriculture?
• What are the best water-storage options for managing water resources variability?
• How best to manage water resources variability in transboundary river basins (international or state boundaries)?

Guiding hypothesis
River Basins can be managed to maximize the value of ecosystem services and benefits.

Research questions
• How best to quantify and map various ecosystem services and the components that provide these services in basins/landscapes?
• How are water-related ecosystem services for different groups affected by land management?
• How can ecosystem services and benefits of land and water be best shared across sectors, improving the livelihoods of the poor, fostering gender equity, and minimizing environmental impacts?
• What water and land management practices enhance or create ecosystem services for current and future use to reduce poverty?
• What composite of research, rules, monitoring and governance is best suited to ensure that negative impacts of an intervention in one part of a basin are not transferred to another?
• How to ensure that international agreements contribute to the protection of ecosystem services and poverty alleviation?

Guiding hypothesis
Agricultural intensification is possible without detrimental impacts on water and land.

Research questions
• What are the limits of water productivity improvement in different geographical and socio-political settings, and how can they be achieved?
• How to best up-scale promising interventions from irrigated or rainfed agriculture to the basin?
• What are the impacts of agricultural intensification and diversification on water resources?
• What are the trade-offs between environmental water allocation and ‘conventional’ uses of water, particularly agriculture in the developing world, where food production is a first priority?
• How best to set and implement ecologically relevant thresholds for surface or groundwater use in developing countries?

Guiding hypothesis
Global drivers of change can be explicitly accounted for in basin management.

Research questions
• Which drivers of change are most pronounced in different geographical and socio-political settings?
• How do various external drivers affect the availability of land and water, and the magnitude, value and distribution of water- and land-related ecosystem services and benefits?
• How can macroeconomic, trade and agricultural sector policies be harnessed to support enhanced water, land and ecosystem outcomes for poverty alleviation?
• What are the hydrological and social dynamics of competing water uses and drivers of change within river basins/landscapes?
• What tools can be developed to predict and manage change?

7.11. Implementation plan
Research will be conducted in target basins that represent different poverty levels, hydrological conditions, levels and types of water scarcity, and development and closure, and where the CGIAR already has a strong presence. By conducting studies across a wide range of basins and landscapes there are multiple opportunities for:
• New partnerships with relevant international research institutes and academic institutions.
• Complementarities between other SRPs and CRPs. Examples may include scaling up the findings of the Irrigation Systems and Rainfed Systems SRPs to landscape/basin levels; use of Information Systems SRP outputs for better quantification of basin land and water availability and ecosystem services; how upstream developments will impact coastal areas (link with CRP1.3); what are the downstream impacts of upstream development in highlands (link with CRP1.1 and CRP1.2), or how to adapt water storage structures, groundwater use and basin governance to increasing water and climate variability under progressive climate change (CRP7).
• Action research mode for stimulating water- and land-related benefit-sharing arrangements.
• Comparative analysis to generate international public goods.

7.12. Research outputs and outcomes

Generic research outputs from cross-basin research

• **Institutional, policy and technical innovations** to i) increase water and land productivity ii) arrest land degradation; iii) alleviate adverse impacts of spatial and inter- and intra-annual water resources variability, iv) improve resource governance and benefits sharing

• **Information and guidelines** on i) value and productivity of water in different uses (including aquatic and terrestrial environment); ii) selection and evaluation of various water storage options and their combinations at basin scale; iii) planning and implementation of benefit-sharing mechanisms; and iv) best water and land allocation practices with socially and ecologically responsible goals.

• **Methods and techniques** to: i) analyze trade-offs between different water and land uses; ii) evaluate the distribution of land and water related benefits; iii) evaluate water availability, allocation and access

• **Improved capacity** in the form of i) non-specialists who are aware of and have access to advanced technologies and data resources for policy-making (remote sensing, modeling, GIS); ii) trained specialists including M.Sc. and Ph.D. students

**Outcomes**

In 10 years it is expected that:

• Current and future (under changing climates) water resources variability is mainstreamed into water resources planning in all target areas.

• Decisions on investments in water infrastructure and on the selection of water management policy options (notably allocation) in water-stressed river basins are informed by the research of this SRP in all major river basins, considering both physical and socio-political contexts.

• Water storage development becomes a structured process worldwide. Governments and development agencies pay attention to the variety of storage options (and their
combinations) available, as part of the ‘storage continuum,’ and consider economic, social and ecological implications of storage development.

- Benefit-sharing mechanisms and payments for ecosystem services, designed or influenced by this SRP, are in place in target river basins (where proved feasible and relevant), and are considered for adoption in other major agricultural river basins/regions of the world.
- All water-related data and information (including ground observations from all national archives) required for informed water and land management in all world river basins (including all transboundary ones) are freely shared with all national and international stakeholders. This outcome is anticipated through work with the Information Systems SRP.
- Allocation of water for environmental and social needs is firmly included in national water policies in all countries that share the target basins, and has become the internationally accepted water management practice.
- A shift to combined surface-groundwater management and use is practiced in regions where groundwater is currently underused. Agricultural groundwater use has increased by an anticipated 30% in sub-Saharan Africa, Central Asia and East India/Nepal. Policies specifying environmental thresholds of groundwater use are in place in all above river basins whether closed or open. Managed aquifer recharge has become a viable alternative to the National River Linking Program (NRLP) in India. This outcome is anticipated through work with the Irrigated Systems SRP.
- The quantified impacts of land-use change on water availability are considered in all basin management decision in the target areas.
- The number of people experiencing various forms of water scarcity globally is substantially and clearly reduced – directly or indirectly influenced by the results of the work of this SRP.
- Improved research capacity to quantify ecosystem services, analyze land and water-related benefits, improve water and land monitoring, and mitigate negative impacts of human interventions is in place and doubled in all target areas.

7.13. Research partners

Table 7.7 indicates the types of partners we are currently working with, or plan to work with. More detailed partnership arrangements by basin, country or region will be developed during the implementation phase of the program. Apart from already existing strong partnerships in regions with individual organizations, one intention is to develop links with networks of organizations on one hand (to broaden the overall partnership web and increase visibility), and with new partners – to address specific technical needs of the new projects under this SRP. As this is an integrating SRP, additional partnerships will also naturally be established through four other SRPs. Many partnerships (e.g. with FAO, IUCN, the UN Conventions, UNESCO-HELP Program, and ARIs) will deal with sustainable NRM in world basins, regions and globally.
<table>
<thead>
<tr>
<th>Region/basin</th>
<th>Core research</th>
<th>Implementation</th>
<th>Outreach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limpopo–Zambezi</td>
<td>Agricultural Research Council (ARC) and Council for Scientific and Industrial Research (CSIR, South Africa); WRC (South Africa); Texas A&amp;M University, USA; DHI and Geological Survey of Denmark (GEUS)</td>
<td>Southern African Development Community (SADC); Ministry of Agriculture and Food Security, Malawi; LimCom (Limpopo Basin Commission); Department of Water Affairs (South Africa)</td>
<td>FANRPAN (Food, Agriculture and Natural Resources Policy Analysis Network), South Africa; UNEP; IUCN,</td>
</tr>
<tr>
<td>Nile</td>
<td>Bahir Dar and Arba Minch Universities (Ethiopia), WaterWatch and IHE (Netherlands), Cornell and Utah State Universities, USA; Stockholm Environment Institute (SEI); Ethiopian Economic Policy Research Institute; Ethiopian Institute of Agricultural Research; ARC and NWRC in Egypt</td>
<td>Nile Basin Initiative (NBI); Alliance for a Green Revolution in Africa (AGRA); Eastern Nile Technical Regional Organization (ENTRO); Ethiopian Rain Water Harvesting Association (EWRHA) network; Ministries of Water Resources and Agriculture in Sudan, Ethiopia and Egypt;</td>
<td>Ramsar; IUCN, UN Economic Commission for Africa; Alliance for a Green Revolution in Africa (AGRA);</td>
</tr>
<tr>
<td>Volta–Niger</td>
<td>AGRHYMET, West Africa- Niger; Council for Scientific and Industrial Research (CSIR), GHANA; Institute for Environment and Agricultural Research (INERA), Burkina Faso; ZEF-Bonn; WASCAL Project located in Ghana-Burkina Faso, engaging multiple East Africa and German Universities; CIRAD and IRD (France)</td>
<td>Volta Basin Authority (VBA); Water Research Commission (WRC)- Ghana; Alliance for a Green Revolution in Africa (AGRA); Bill &amp; Melinda Gates Foundation, USA; Water Resources Commission (WRC, Ghana), IDE</td>
<td>UN Economic Commission for Africa; Alliance for a Green Revolution in Africa (AGRA);</td>
</tr>
<tr>
<td>Mekong</td>
<td>CSIRO- Australia; Chinese Academy of Agricultural Sciences (CAAS), China; National Agricultural and forestry Research Institute (NAFRI)- Laos; Stockholm Environment Institute (SEI); Soils and Fertilizer Research Institute (SFRI), Vietnam; National Agriculture and Forestry Research Institute (NAFRI), Lao PDR; Utah State University, USA; IRD (France)</td>
<td>MRC, FAO, Ministry of Water Resources and Meteorology-Cambodia; Ministry of Agriculture, Forestry and Fisheries (MAFF -Cambodia; Ministry of Natural Resources and Environment (Vietnam) Water Resources and Environment Administration (WREA), Lao PDR</td>
<td>MPOWER, MRC</td>
</tr>
<tr>
<td>Indus–Ganges</td>
<td>ICIMOD, ICAR, Pakistan Agricultural Research Council, IITM- Pune, India, IWM (Bangladesh); WWF-India; San – Diego University</td>
<td>Ministry of Water Resources, India; Ganga Water Authority (GWA India), WAPDA (Pakistan); WARPO (Bangladesh); Nestle</td>
<td>WWF-India, IUCN, Water Footprint Network, GWP, International Water Stewardship Network</td>
</tr>
<tr>
<td>Aral Sea Basins</td>
<td>SIC-IWC, National Hydrometeorological Service, Uzbekistan; The Institute of Hydrogeology and Engineering Geology, Tashkent</td>
<td>GTZ, WUAs in Fergana Valley; SIC</td>
<td></td>
</tr>
<tr>
<td>Andean Basins' group</td>
<td>COSUAN (network of 16 Andean country universities); Consortium for the Sustainable Development of the Andean Ecoregion (CONDESAN), Peru;</td>
<td>FUNDESOT (Foundation for Sustainable Development), Andes; RIMISP (Latin American Center for Rural Development)</td>
<td></td>
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