2. A truly interdisciplinary research program

The research questions we have posed are substantial and comprehensive. We seek a better understanding of interactions involving land, water and ecosystems in agricultural settings, with the goal of increasing productivity and enhancing ecosystem services. This work will require substantial interdisciplinary collaboration, involving biophysical and social scientists. It will also require new ways of developing and delivering results that go beyond traditional research programs. In addition, we must consider the off-farm, basin-level and longer-term implications of agricultural practices. This larger-scale approach, unique to CRP5, will increase the chance of our results and recommendations achieving sustainable improvements in agriculture and ecosystems.

We have crafted a set of five SRPs (described in detail in chapters 4–8; see Box 2.1 for terminology) that encompass our primary research questions, and describe where and how technical and policy interventions will be most likely to achieve the productivity gains and ecosystem enhancements that constitute our vision of success. We have also developed a system for delivering those results that allows learning, focuses on core issues of poverty alleviation, and holds us accountable for results we can monitor. Finally, we have developed a framework and process for ensuring that the results and insights from each research portfolio feed back into our broader program and build synergies for achieving our overall goal.

Box 2.1. Notes on terminology
Regions: CRP5 works in these regions: Latin America; East, West and Southern Africa; the Middle East and North Africa; and Asia.

Research sites and scales: Research takes place at specific geographic locations within regions called research sites. Research at a site might address issues at one or more scales (e.g. farm, watershed, landscape, basin, country and region) and investigate implications across scales. For example, research on groundwater recharge at a site might address local issues defined by the extent of the aquifer (a landscape), but have implications for the basin (upstream or downstream trade-offs), the country (food security), and the region (transboundary conflict resolution).

Strategic Research Portfolios (SRPs): A research portfolio describes a set of investments in research aimed at tackling challenges related to irrigation, rainfed agriculture, pastoral systems, groundwater, resource recovery, river basin management, ecosystems, the social and cultural practices that lead to gender and other forms of inequity, information, and governance. Portfolios are 'strategic' because their five research domains were identified by partners and other stakeholders as offering the most promising pathways to achieving development goals.

2.1. Establishing priorities – creating research portfolios

While the need to address global issues regarding water land and ecosystems is clear, the scope and nature of the issues require that we organize our research program into easily managed components, each with its own set of clear priorities. To this end, we engaged in a three-fold process of regional consulting, global visioning and strategic reasoning (described below).

2.1.1. Regional consulting

We conducted a series of regional workshops and e-consultations involving hundreds of natural resource specialists, investors and farmer representatives (see Appendix 2b). Participants described the need for new research regarding water, land and ecosystems, both in general and within their regional contexts. Participants brought attention also to pressing and long-term issues, and described in detail the agronomic, hydrologic and socioeconomic aspects of each issue.

2.1.2. Global visioning

We placed the regional needs in global perspective, considering:

- the scope for direct and indirect poverty impacts
- potential positive impacts on global food systems, agricultural prices and ecosystem services
- the ability to scale solutions up or out.

2.1.3. Strategic reasoning

We considered whether the problems fit within the mandate of the CGIAR, and whether solutions would contribute to achieving the CRP5 vision of success. In particular, we considered:

- the need to enhance global knowledge, rather than closing site-specific knowledge gaps
- the potential for insights gained to be applicable beyond a given region or outside the scope of a single problem
- the opportunity to develop international public goods from the proposed research
- the need to bring together a wide range of national and international partners who can help cross the divide between agriculture and environment in conducting the research.

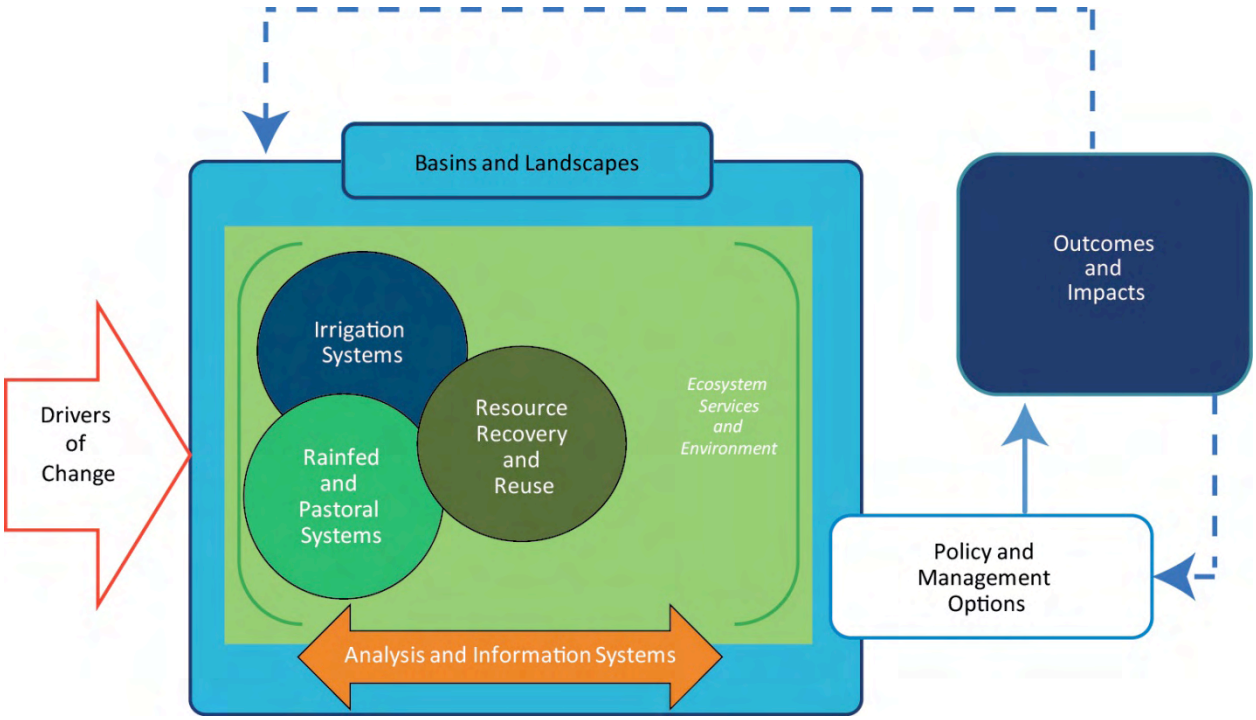
Each part of the process was helpful in formulating a conceptual framework for the research we will conduct in CRP5, crafting a practical set of SRPs, and determining the geographic scope of the research program. Input received from reviewers of initial drafts of our proposal has also been helpful in refining the scope and nature of our research program.

2.2. Conceptual framework

Agriculture and ecosystem services are influenced by external drivers that exert pressure on production systems that, in turn, affect the natural resource base and environment (see Figure 2.1 and Box 2.2). Currently, many agricultural practices contribute to land degradation and loss of ecosystem services, resulting in lower productivity and less resilience, equity and food and livelihood security. These practices are driven by many factors within and outside the agricultural system, including policies, information and knowledge asymmetries, and energy flows. Scarcity, degradation and other negative outcomes of inappropriate agricultural management practices are in themselves major drivers. Feedback loops exist whereby water scarcity, for example, triggers policy change and infrastructure development, and reduced productivity alters farming practices. Often the feedback loops are negative, resulting in increased degradation and downward spirals. Natural systems have both resilience and thresholds that must be understood and considered when making decisions.

However, a key entry point for CRP5 is that we can influence our impact on natural resources and ecosystems by modifying the governance and management of agriculture. A major question is whether we are able to measure changes to ecosystem services and whether we can use the nature of those changes to further influence governance and management. If changes can be observed and measured at basin and landscape scales in terms of processes (e.g. water flow, erosion rates and vegetation change), we can use this information to provide policy advice and further adapt management practices. Given that different management practices may act independently, we also need to determine the cumulative impacts of different management practices via modeling and mapping tools. Hence the need for a strong analytical and information base to support the CRP5 research program.

Figure 2.1. The conceptual framework for CRP5



Our view is that we can manage rainfed and irrigated systems better, to enhance interactions with the environment. Similarly, we can recover and reuse nutrients from wastes to improve fertility and minimize pollution. Consequently, these three areas – irrigation systems, rainfed systems, and resource recovery and reuse – are important research foci for CRP5.

We view the relationships involving drivers and responses of the production system and its underpinning natural resources through a nested approach, which includes fields, basins, and regions. Our research will complement the plot-scale work in other CRPs (e.g. conservation tillage trials). We will extrapolate plot-scale results across larger spatial units.

With regard to system dynamics, our basic analytical framework is a river basin or landscape unit. Using basins enables us to quantify water and nutrient flows and uses within the system, and thus we can examine upstream–downstream environmental changes and socioeconomic

trade-offs. We will use basic tools of water accounting and new land health surveillance tools to quantify the impacts of agriculture on the environment and vice versa.

Box 2.2. Factors influencing NRM and agricultural production

- External drivers such as climate change processes, existing agricultural and natural resource policies, trends in trade, and socioeconomic and cultural contexts.
- Actions that stem from our research, such as the use of new technologies; policy, governance and institutional reform; and uptake of integrated management strategies.
- Consequences of the above actions for, e.g. equity, environment and ecosystem services.
- Feedback, which involves understanding consequences and drivers, to help to redesign actions.

Agricultural and natural ecosystems function within basins and landscapes. Where ecosystems occur across basins or landscapes, we will use models to partition the area into similar environments and thus consider how the overall landscape pattern influences basin-level responses. Given that ecosystem work will cut across landscapes and themes, we have developed guiding principles for ecosystem services research in CRP5 (Box 2.3).

Box 2.3. Guiding principles for cross-cutting ecosystems work in CRP5

- Examine supporting, regulating and provisioning services, including evaluating on- and off-site effects of farming systems and management practices on ecosystem services.
- Work at landscape scales, incorporating social and biophysical functions and interactions, such as analyzing how the interaction of diverse land uses, social networks and institutions across landscapes influence the ecosystem services that sustain agriculture and ecosystems.
- Examine how ecosystem services help alleviate poverty and vulnerability, including understanding the scales at which ecosystems provide services to people.
- Examine transformation and change by evaluating trajectories, tipping points and thresholds in agricultural landscapes.

Sometimes a basin approach will not be necessary; for example, when change (e.g. biomass production) can be detected at landscape level and within administrative and regional or country boundaries, although such changes may affect the water balance of the landscape and associated basins. However, we will also have the option of using analytical approaches that enable the intersection of administrative and basin boundaries to differentiate approaches and policies across borders. We believe that this spatial approach combined with the differentiation of management practices that influence natural resources and ecosystems, and the integration of this change across landscapes and basins, will be extremely effective in helping us scale up outputs.

At the broadest level we focus on major regions. Where possible, broader agroecological characterization and development of information and other products (e.g. international public goods on nutrient cycling, soil fertility and water scarcity) will be targeted at these regions, and tailored to the different environments within them.

2.3. Five Strategic Research Portfolios

The defining feature of our research program is a set of five SRPs that resulted reflect the input of many scholars and practitioners, careful consideration of regional and global perspectives, and the conceptual framework. The five portfolios are:

1. Irrigated Systems
2. Rainfed Systems
3. Resource Recovery and Reuse
4. River Basins
5. Information Systems

While seemingly distinct, we view the five portfolios as comprising an exciting opportunity to conduct research across a wide range of critical topics within a single research program. CRP5 researchers will work collaboratively within and across the portfolios through well-defined processes as they seek answers to research questions that will enhance global knowledge regarding land, water, and ecosystems. We describe each portfolio below.

SRP1: Irrigated Systems

The first of our five SRPs targets irrigation. As noted above, 40% of the world's food is produced on the 20% of farm land under irrigation. Irrigation has improved livelihoods and enhanced food security for millions of rural and urban households. It has reduced poverty, and is expected to play an important role in climate change adaptation. However, irrigation has both positive and negative impacts on ecosystems. Gaining a better understanding of those impacts will enable us to determine why the rates of increase in productivity on irrigated lands are stagnant or declining in several important regions, such as the Indo-Gangetic plains. We will also improve understanding of constraints and opportunities for extending irrigation across Africa, and we will analyze issues relating to the use of surface water and groundwater, individually and in combination.

CRP5 researchers will examine opportunities to revitalize existing irrigation systems and invest in new systems to increase agricultural production and improve livelihoods. We will determine how to expand and improve irrigation with minimal impacts on supporting ecosystems. Water withdrawals from many important aquifers exceed the natural rates of recharge, making irrigation unsustainable. In areas where millions of smallholders depend on irrigation for their livelihoods, the potential impacts of losing access to irrigation water are enormous. We must develop strategies that restore sustainable rates of water withdrawals, while ensuring that all households can achieve and maintain food security.

Examples of the research we will conduct in this SRP include the following:

- Identify and characterize opportunities and options to develop irrigation in Africa, with the aim of increasing crop and livestock production;
- Work with partners to further experiment with new models for managing large pubic irrigation systems in Asia;
- Examine ways of improving groundwater management in South and Central Asia, where persistent overdraft of aquifers threatens agricultural sustainability.

SRP2: Rainfed Systems

Our second SRP targets the 80% of the world's farmland that is largely rainfed. Though many farmers in rainfed areas capture and store water for use as supplemental irrigation, millions more are entirely dependent on rainfall. The inherent uncertainty and extensive poverty that characterize rainfed systems generate research questions that are quite different from those pertaining to irrigated agriculture. We need to better understand the risks that households face in rainfed settings. We must explore the reasons why many methods for enhancing soil and water management are not adopted, while learning more about livestock production in water-scarce environments. Much of humanity earns its living in rainfed crop and livestock systems; this SRP will provide insight into issues that affect millions of households every day.

In many areas, increasing populations have placed substantial pressure on rainfed cropland and on the land and water resources used by livestock. As a result, the land and water resources in many areas are degraded and unproductive. Soils have inadequate amounts of essential nutrients and organic matter, and ecosystems have lost a portion of their inherent biodiversity. CRP5 researchers will determine ways to restore degraded resources using multifunctional landscape management approaches, and will develop integrated soil and water management techniques. We will endeavor to improve soil fertility and motivate better land and water management, with the goal of unlocking the inherent potential of rainfed agriculture while at the same time reversing the trend of ecosystem degradation.

In pastoral systems, extensive land degradation and the loss of access to water and land resources threaten the livelihoods of millions of pastoralists, leading to conflicts in some areas. CRP5 researchers will determine the changes in land and water management and the complementary policies needed to support pastoral livelihoods.

Examples of the research we will conduct in this SRP include the following:

- Develop recommendations for improving and extending water harvesting technology throughout rainfed regions of sub-Saharan Africa;
- Examine the financial and infrastructural constraints that limit farm-level access to commercial fertilizer;
- Study interactions involving crop and livestock production in regions with scarce water supplies, with the goal of improving productivity and enhancing the livelihood status of farmers and pastoralists.

We will examine how individual management changes at farm level affect landscape and basin processes and thus ecosystem services.

SRP3: Resource Recovery and Reuse

Land degradation and nutrient depletion characterize large areas of agricultural production, particularly in sub-Saharan Africa. Many farmers in Africa are unable to afford fertilizer, in part because the cost of transportation from ports or production centers to distant farms is high. Yet both human and animal wastes contain substantial amounts of nutrients that can be used in agriculture, such as nitrogen and phosphorus. Such use is very compelling in regions where the price and availability of commercial fertilizers do not match farm-level demands.

Enhanced recovery of water, nutrients and organic matter from otherwise wasted resources for use in agriculture will serve two critically important goals, as we endeavor to feed the world in 2050. First, more nutrients and water will be available for use in agriculture even as the natural stocks of nutrients, such as phosphorus, become more expensive to mine. Second, opportunities for generating revenue will support the provision of sanitation services.

We will determine through a business approach how to maximize the untapped potential for recovering water and essential nutrients. At the same time we will promote safer and healthier practices when reusing waste materials on farms and when processing crops for consumption in local markets. We will also examine affordable measures for improving land, water and environmental quality in areas where reuse occurs. Critically, we will contribute to notable gains in food security through the safe and effective recovery of nutrients from solid and liquid domestic and agro-industrial wastes.

CRP5 will explore scalable business models for blending compost with fertilizer, and developing alternative fertilizers from human and livestock waste as a byproduct of biogas production. Engaging the private sector might be the most effective approach to increasing the coverage of sanitation services and closing the nutrient cycle in agriculture by recovering and reusing elements such as nitrogen and phosphorus. We will also identify opportunities to develop scientific and policy recommendations to promote the safe reuse of wastewater and sludge by smallholder farmers in peri-urban areas (i.e., at the edges of cities and towns) to alleviate water scarcity and help restore nutrient losses on agricultural lands.

SRP4: River Basins

River basins will be used as a unifying unit of analysis to assess the impact of agricultural management on many ecosystem services given that hydrological processes naturally connect all water and land users. This connection greatly complicates decision-making on water, land and ecosystem issues, as decisions made in one location can have substantial and often unrecognized impacts in others. Salinization in the lower Indus, for example, is partly the result of farmer choices further upstream. In the Mekong, hydropower dam construction and monoculture plantation may have profound impacts on downstream flow. Countries in the lower Nile basin are concerned that their upstream neighbors may overuse water. Hydropower production and agricultural water use are in direct competition in the Aral Sea basins of Central Asia.

The interconnection in river basins also brings advantages. Cooperative development and use of water resources can generate benefits greater than those achieved through individual or sectoral actions. The opportunity for cooperation on water use, whether between two farmers or two countries, can provide a basis for even greater cooperation on other issues.

Making wise choices on water use, promoting cooperation and avoiding conflict require an understanding of how the physical unit of the basin intersects with the social and political spheres in which decisions are made and people organize their lives. In the richest countries this is not easy. In many of our target locations it can be even more complicated. CRP5 researchers will examine issues pertaining to competition for water, benefit-sharing

mechanisms and other forms of cooperation in river basins, where the sum of competing water demands is greater than available supplies.

Our research will produce both better and cheaper information sources for decision-making and, as importantly, on how cooperative solutions can be put into practice. Researchers will also develop recommendations for improving the allocation and management of water within river basins, with particular emphasis on key policy issues, such as efforts to improve livelihoods, increase drought resilience and reduce the potential damage from floods. While conducting this research, we will focus also on the implications of river basin policies and water allocations for people, livelihoods and ecosystems.

As an example of the research we will conduct in this SRP, we will demonstrate the potential benefits of collaborative investments in water storage and distribution networks, and cooperative management of water releases, in Central Asia.

SRP5: Information Systems

We complete our set of five SRPs with a portfolio designed to address a critical issue that can either constrain or enhance any research effort – the availability of accurate, reliable information. Our Information Systems SRP reflects the pressing need for much better data on hydrology, water management and agriculture. In many countries, data collection and reporting efforts are inadequate to support high-quality analysis of important research questions. These activities must be enhanced, taking advantage of modern methods such as remote sensing. Inadequate national data also constrain analysis of international and transboundary issues.

We will establish data collection and reporting systems that will provide the information needed to improve national and international research programs. We will work closely with national partners to design systems that can be managed and sustained within countries, and to build institutional capacity.

CRP5 researchers will work with NARES partners, universities and others to develop and implement global and regional agro-ecological information and assessment tools and make these available through user-friendly interfaces to stakeholders, including other SRPs in CRP5 and other CRPs. We will deploy novel spatio-temporal surveillance methods and standards to facilitate better, evidence-based planning and evaluation of agricultural interventions at multiple scales. Emphasis will be on strengthening stakeholder capacity in the development of information and surveillance systems in data-sparse regions.

We will endeavor to develop the highest-quality data collection protocols, while acknowledging the incremental costs and benefits, and the likelihood that new data collection activities can be sustained. It will not be sufficient to merely develop and implement new information systems – we must also ensure that national partners have the institutional capacity and legislative funding authority to maintain data-gathering activities. To this end, we will examine also the institutional and financial aspects of sustainable information systems.

As an example of the research we will conduct in this SRP, we will develop ways for countries participating in the Mekong River Commission to improve cooperation in collecting and reporting hydrologic data.

2.4. Cross-cutting themes

In addition to the five SRPs, we have established two cross-cutting themes that will influence and enhance our research: 1) Ecosystem Services, and 2) Institutions and Governance. Within each SRP, we will promote ecosystem resilience and work to minimize harmful impacts on ecosystem services. In addition we will determine methods of enhancing ecosystem services and providing farmers and pastoralists with production systems that can better adapt to environmental change. We will also seek to increase the value placed on ecosystem services. With regard to institutions and governance, we will examine measures for building capacity and enhancing policy and institutional effectiveness across the SRPs.

To systematize and institutionalize this approach, we will establish working groups on ecosystems (Box 2.3 on page 27) and institutions and governance (Box 2.4) to ensure that these cross-cutting themes are highlighted in research planning and reflected in our impact pathways. This work will be established and overseen by the Strategic Planning and Management Committee.

Box 2.4. Guiding principles for cross-cutting governance and institutions work in CRP5

- Governance is the process for joint decision-making. Institutions are the systems, mechanisms and traditions through which governance is implemented. We recognize the great difficulties faced around the world in designing governance and institutions to equitably and efficiently manage water, land and ecosystems. We thus know that governance and institutional issues, and how they relate to both poverty and productivity, must be at the core of our research.
- We will ask how current governance and institutions influence the way water, land and ecosystems are used and affected by agriculture
- We will ask how changes in governance or institutions may bring about positive impacts on agricultural productivity and resource sustainability and equity, and how changes may facilitate the technical and economic interventions we develop. We will not forget that existing institutions and bureaucracies are part of any change process.
- We will consider how governance and institutions can improve livelihood and poverty outcomes at different scales.
- We will learn from successes and failures around the world, but recognize that governance and institutions operate within larger social, environmental and political contexts and that successful interventions in one country or region cannot simply be transplanted to another.

2.5. Fertile fields, not isolated silos

We will work intently to ensure that the five SRPs operate as fertile fields of innovative, collaborative research, rather than silos of limited inquiry involving only one or two scholarly disciplines. We recognize that making such a statement is much easier than implementing the plan, but we have given substantial thought to this endeavor and offer the following perspective.

We will foster close collaboration between biophysical and social scientists within each of the five SRPs and also across selected combinations. For example, it is easy to imagine the need for hydrologists, agronomists and economists to together explore measures for reducing groundwater overdraft on the Indo-Gangetic plains. Political scientists and social scientists will also have important roles in seeking viable solutions to such problems. Similar collaborations will be important in examining opportunities for extending irrigation across Africa or improving rainfed systems in South and Southeast Asia.

The necessity of collaboration is equally evident in the Resource Recovery and Reuse SRP. Water quality specialists, agronomists, economists and business specialists must join together to develop viable business models for expanding sanitation services and promoting the reuse of plant nutrients in waste materials. Our work in developing data collection and reporting protocols will also be best informed by collaboration involving biophysical and social scientists.

The structure of CRP5, which involves a wealth of CGIAR centers and national partners, will also enable exciting interaction and collaboration across SRPs. We see great potential for sharing research ideas, data and implications across the portfolios. For example, researchers working to improve crop and livestock production in rainfed settings will gain value by interacting with researchers developing business models for resource recovery and reuse, which will likely benefit many rainfall-dependent farmers. Thus the interaction will enhance the efforts of researchers engaged in both the Resource Recovery and Reuse and Rainfed Systems SRPs.

Another example of cross-SRP collaboration will involve researchers in the Irrigated Systems and River Basins SRPs. Both groups will benefit from exchanging information on strategies for improving water allocation and use along rivers that cross international borders. The same is true for aquifers that underlie more than one country. Researchers in the Rainfed Systems and River Basins SRPs also will gain from collaboration, as many livestock herders move their animals across international borders and even across river basin boundaries.

Collaboration across SRPs will enhance our research in ways we cannot fully predict at the outset. Often, the most meaningful insights from collaborative research occur serendipitously, while colleagues are engaging in fieldwork together or reviewing information compiled by research partners. The best way to increase the likelihood of such unexpected benefits is to establish a research framework in which interdisciplinary specialists will have numerous and continuous opportunities to collaborate. By design, CRP5 provides precisely such a framework. Another key area where interdisciplinary specialization is given priority is on gender and equity issues. Gender equity has long been cited as an important indicator of the success of development interventions in poor agricultural communities. The core of our mandate is poverty reduction and we know that a pro-poor perspective takes into account social differentiation within communities. We also know that gender and equity issues in research often receive more consideration than action. CRP5 takes seriously the issue of gender and equity in the management of resources for agriculture. CRP5 incorporates a separate strategy to mainstream gender and equity issues across SRPs. Within SRPs we focus on specific issues that are strongly influenced by gender, such as the ownership of assets, access to markets and information, and vulnerability to risks and shocks.

We hold no illusions of the challenges and costs of engaging in truly interdisciplinary research. Yet we are eager to move forward in the collaborative spirit that has produced some of the CGIAR's best research in years past. We are ready to collaborate effectively, within and across the many centers participating in this research program, as we endeavor to enhance global understanding of water, land and ecosystems.

2.6. Research alone is not sufficient

The questions we must answer are of course the core reasons for the program. However, our goal is not simply to do research, but also to improve *how* we do research. We must aim to improve the cost effectiveness of producing results on the one hand, and to increase the value of those results through more effective pathways to impact on the other. Our approach is thus defined not only by the questions we address, but the way in which we address them. This involves 1) embracing the spirit of the CGIAR reform, 2) keeping partnership at the center, focusing on capacity, 3) keeping monitoring and evaluation as a cornerstone, 4) embracing capacity building, and 5) understanding that communication and uptake defines success.

Embracing the spirit of the reform*:* Work on water, land and ecosystems now occurs across the CGIAR. To rationalize that work, almost all centers have joined CRP5. This CRP seeks to gather the synergies from the existing skills, gain economies of scale, and focus our efforts to solve problems. We seek this collaboration not only for that reason, but also because we are running this CRP in the spirit of CGIAR reform.

Partners are key: CRP5's partners constitute an unconventional mix, ranging from traditional partners from agriculture such as NARES and ARIs, to strong international and local environmental NGOs. To capitalize and draw on the wide range of skills and capacities within our network, we have designed a *partner strategy* to engage our partners according to their specific skills and reach, and their proximity to communities and issues on the ground. Our partners, therefore, are the chief vehicles through which CRP5 interacts and engages with people and their day-to-day realities.

Monitoring and evaluation and impact assessment is a cornerstone: We understand the difficulties in evaluating NRM programs and impacts. CRP5 endeavors to use its *strategy for monitoring and evaluation and impact assessment* as the basis for continually improving and refining the program's research agenda, process of engagement and uptake strategies.

Good capacity building: The *capacity building strategy* of the program explicitly guides learning within and through the research agenda, however it fits within the ethos of the larger program. The strategy looks at enhancing the capabilities of researchers, partners and stakeholders through research projects, improving technical skills, building learning alliances and networks, and helping to build the institutional capacity of research management organizations. CRP5 will facilitate greater investment in capacity building activities ranging from training and scholarships to mentoring, driven by the demand and needs of stakeholders.

Communication and uptake is essential: The CGIAR has long been a source for valuable international public goods in NRM. Much of the impact of this work is attributed to clear

strategies that began with problem-focused research. It went beyond just making information and solutions available in the public domain by engaging with stakeholders or 'change agents' who could shape and affect policy change. CRP5's *marketing, communication and knowledge strategy* is the mechanism through which project and program results are communicated to its stakeholders and the general public. The strategy ensures that key messages that emerge out of projects are developed through collaborative processes between researchers, partners and other stakeholders. In linking with uptake strategies, information products and lessons learnt from SRP initiatives will not be made available only as international public goods, but key messages will be assimilated into plans and campaigns to influence policy and global agendas.

2.7. Where CRP5 will work

During the regional workshops we considered which regions and basins should be targeted, based on significance of the problems identified, logistics of access to specific regions and our capability to mount an effective program in such regions. Given these considerations, we have chosen to begin working in regions focused around eight sets of large river basins:

- **Southeast Asia** (Mekong Basin)
- **South Asia** (Ganges and Indus)
- **Central Asia** (Aral Sea)
- **Middle East** (Tigris and Euphrates)
- **East Africa** (Nile)
- **West Africa** (Volta and Niger)
- **Southern Africa** (Limpopo and Zambezi)
- **Latin America** (Andes Basins)

Each basin contains a mixture of agro-ecological zones, urban and rural landscapes, and social, economic and political entities. In each, the natural resource base supporting agriculture and livelihoods is under stress. By working in these basins, we will capture the regional dimension of interlinked issues, such as the development of hydropower and its impact on riparian countries. In addition, the Africa Soil Information Service (a component of the Information Systems SRP) will provide a focus for improving soil resource management in sub-Saharan Africa because of the imperative to increase food production in this region. Our long-term target is to have a positive impact on the livelihoods and food security of 50–60% of the agricultural population residing within these basins (Table 2.1). Details of the basins and key issues are described in section 2.5.

Table 2.1. Potential beneficiaries (in millions) of CRP5 R&D outcomes by river basins.

Region	Basin population	Rural population	Agricultural population	Expected numbers benefited by CRP5
East Africa (Nile)	200	128	102	61
West Africa (Volta and Niger)	126	80	80	48
Southern Africa (Limpopo and Zambezi)	45	24	23	12
Central Asia (Amu Darya and Syr Darya)	42	24	9	5
Middle East (Tigris and Euphrates),	45	30	25	12
South Asia (Indus and Ganges)	400	280	196	118
Southeast Asia (Mekong)	70	46	42	25
Latin America (Andes)	92	28	24	14

Source: these figures were compiled from FAO Aquastat and personal communication from partner organizations.

2.8. CRP5 basins and key issues

1. Mekong

Cambodia, China, Laos, Myanmar, Thailand, Vietnam

Potential impacts

- Basin population: 70 million
- Rural population: 46 million
- Agricultural population: 42 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 research

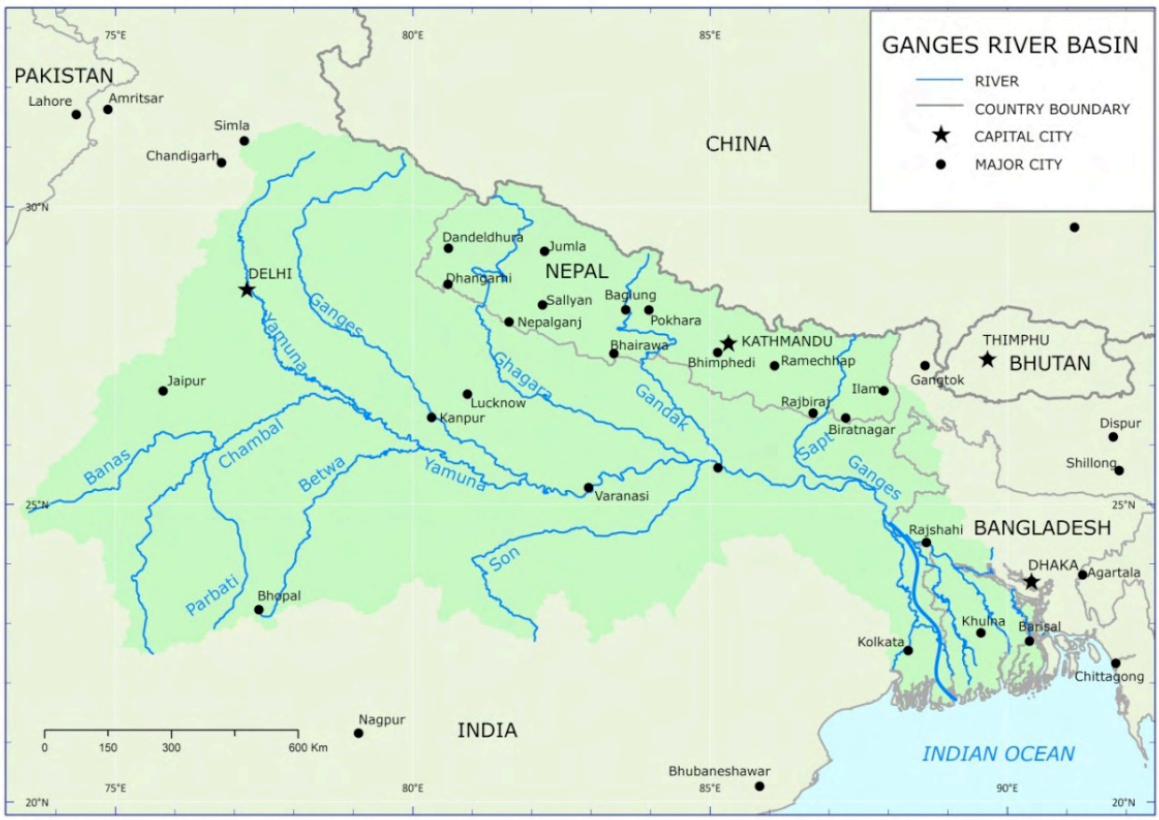
- Insecure property rights and inadequate access to natural resources contribute to the region's substantial poverty.
- Important fisheries are under pressure from hydropower development.
- Governments in the region are focused on economic development, yet there is inadequate cooperation and too little sharing of information along the Mekong River system.
- Agricultural productivity is low, particularly in northeast Thailand and Cambodia.

CRP5 research activities

- Develop policy recommendations for managing the expansion of hydropower production in a manner that protects and enhances the livelihoods of smallholder households located in or near hydropower watersheds.
- Develop a set of field-tested practices that demonstrate how to enhance the productivity of seasonal floodwaters to benefit the poor.
- Study informal and formal business models for the recovery of nutrients from domestic and agro-industrial waste for replication and application in other regions.
- Assess the extent, status and trends of terrestrial ecosystem degradation that are leading to low agricultural productivity
- Design and test location-based adaptive strategies for improved NRM.

2. Ganges

Bangladesh, India, Nepal



Potential impacts

- Basin population: 400 million
- Rural population: 280 million
- Agricultural population: 196 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 Research

- The Ganges basin is the most densely populated in the world with a population of about 400 million people. About 85% are poor and dependent on agriculture-based livelihoods.
- Shallow groundwater use is anarchic and widespread. Arsenic poisoning is a serious health problem affecting large numbers of the poor towards the eastern part of the basin.
- Floods in the Ganges delta affect Bangladesh in particular. Saltwater intrusion into upstream areas in Bangladesh affects agriculture and drinking water sources.
- The Ganges is one of the most polluted rivers in the world and downstream siltation caused by unsustainable land management on steep slopes upstream.

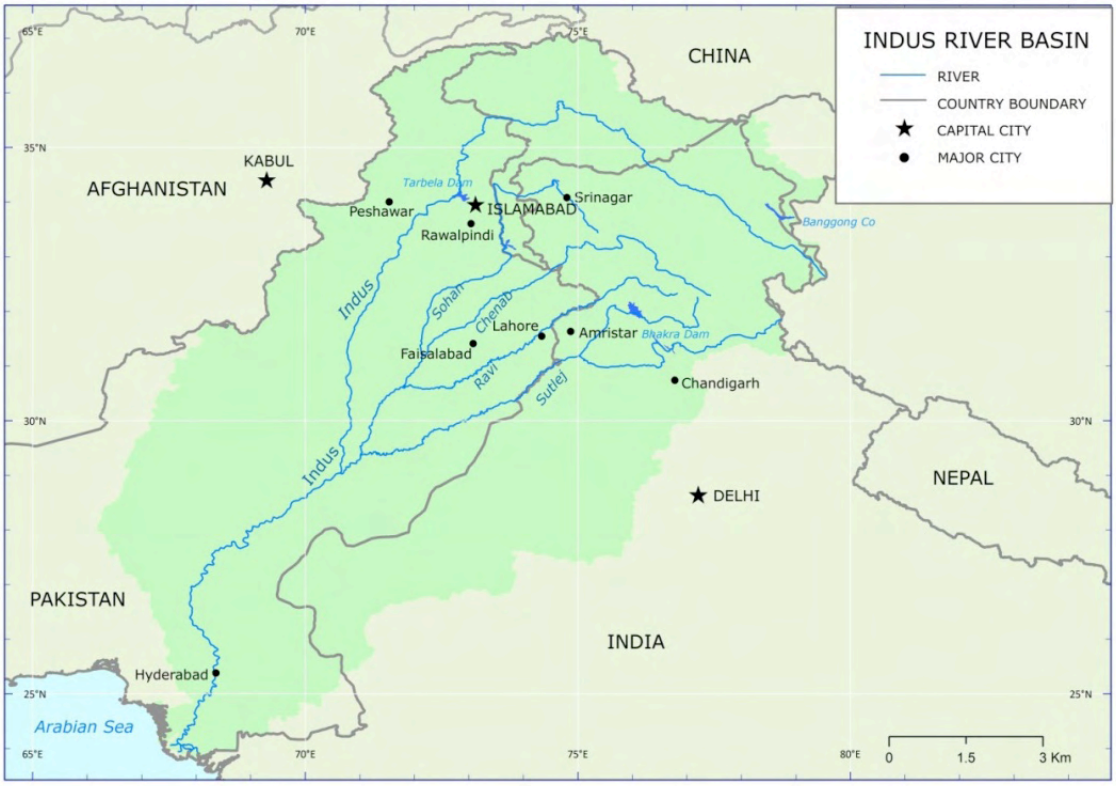
- In India, more than two thirds of farmers purchase agricultural groundwater through informal markets. Of the rest, 20% have their own pumps and 6% use canal water. In Nepal, most farmers depend on a single source of water, either from canals or groundwater.

CRP5 research activities

- Assess the extent, status and trends of land degradation to pinpoint sources of erosion and siltation in the basin, and design and test appropriate interventions.
- Develop better policy recommendations for modifying or eliminating the electricity subsidies that encourage excessive pumping of groundwater.
- Promote a better understanding of the role of energy policies (on rural electrification, renewable energy and diesel subsidies) in encouraging or impeding groundwater development.
- Examine opportunities for improving river water quality and the production of safe crops for consumers in close collaboration with the World Health Organization (WHO).
- Study the potential implications of water quality programs that will reduce the volume of irrigation water available to farmers along the downstream reaches of rivers that flow through or near urban centers.
- Examine opportunities for India and Bangladesh to cooperate in improving water quality in the Ganges River and managing the volume of water discharged from India to Bangladesh.
- Study informal and formal enterprises engaged in resource recovery from waste for the benefit of agriculture.

3. Indus

India, Pakistan



Potential impacts

- Basin population: 200 million
- Rural population: 168 million
- Agricultural population: 114 million

We expect to improve the livelihoods of 50% of the agricultural population and help Pakistan become a food supplier to the world.

Issues motivating CRP5 Research

- The Indus irrigation systems have the potential to be global agricultural engines.
- Rural poverty is endemic, particularly in Pakistan.
- There is vast potential to increase yields and produce more food with less water.
- Intensive irrigation has contributed to some of the world's most extensive salinity and waterlogging.
- In recent years damage from flooding has been substantial.

CRP5 research activities

- Establish a land health surveillance system to map and monitor salinity and waterlogging problems, and guide the design of land reclamation programs.
- Determine strategies for optimizing the collection and reuse of agricultural drainage water, while providing relief from saline high-water tables.
- Examine opportunities for reclaiming land and improving water quality in degraded areas, where reclamation would increase agricultural production and enhance livelihoods.
- Examine opportunities for constructing new water storage and transport facilities to provide better flood control, while increasing irrigation potential.

4. Amu Darya and Syr Darya

Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan

Potential impacts

- Basin population: 42 million
- Rural population: 24 million
- Agricultural population: 9 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 Research

- The breakup of the Soviet Union created fundamental challenges for agricultural water management that have yet to be resolved.
- Farm-level returns in agriculture are small because of inadequate market development and government policies that create disincentives for optimizing the use of farm inputs.
- Waterlogging and salinization reduce agricultural productivity in the region, particularly in lower reaches of the two rivers.

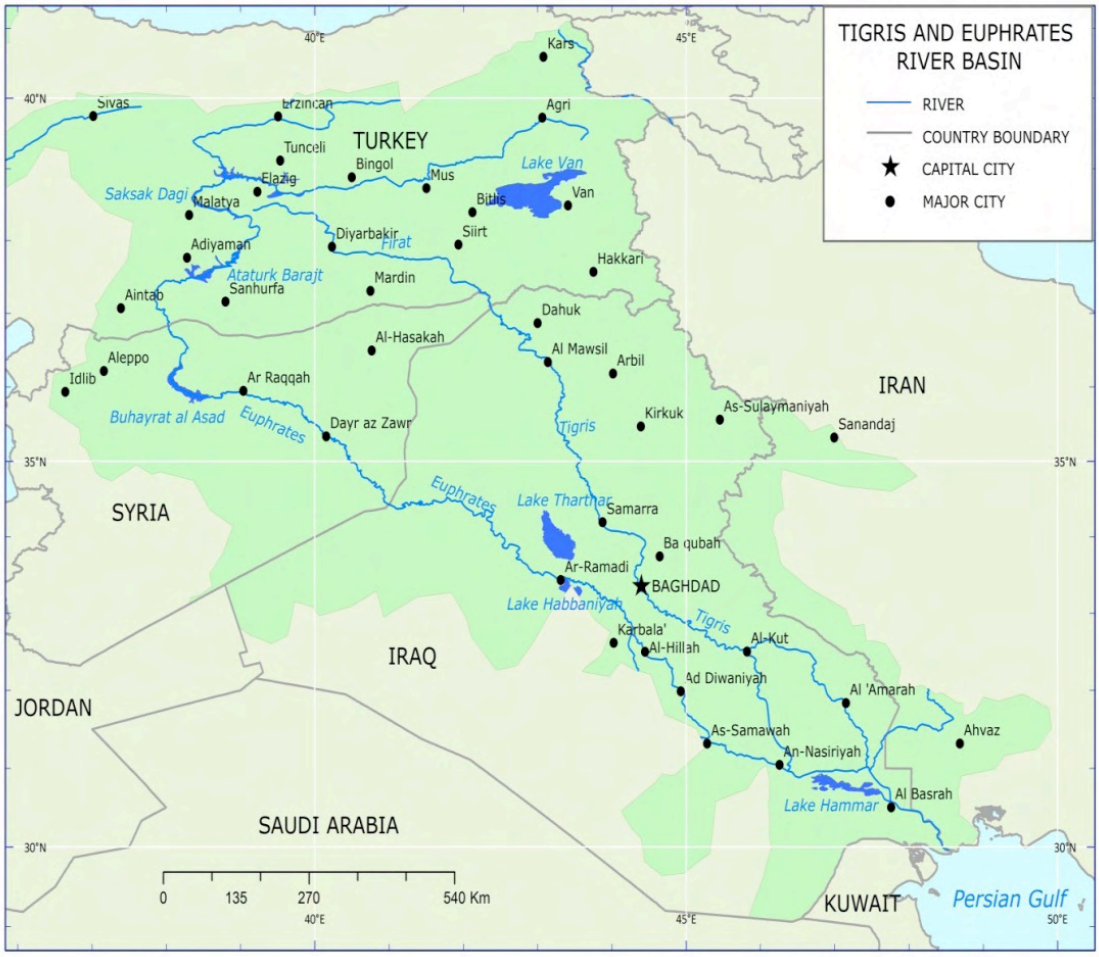
- Drinking water quality is degraded by salt and pesticide residues in lower reaches of the Amu Darya and Syr Darya.

CRP5 research activities

- Assess the extent, status and trends of unsustainable soil management and design preventive and rehabilitation strategies.
- Look at new models for governing a complex transboundary system and work with governments to implement viable approaches.
- Improve farm-level access to modern inputs, such as fertilizer, pesticides, tractors and other machinery used in cultivation and harvest.
- Examine strategies to benefit-sharing that leads to improved transborder management of water.
- Examine ways to boost farm-level incomes, with the dual objective of improving livelihoods and providing incentives for farmers to invest in the fixed and variable inputs that improve long-term productivity.
- Examine business options to make marginal quality water, including irrigation return flows, a valuable asset.

5. Tigris and Euphrates

Iraq, Syria, Turkey



Potential impacts

- Basin population: 45 million
- Rural population: 30 million
- Agricultural population: 25 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 research

- Agricultural policy has contributed to problems of desertification, driven by unsustainable dryland cropping and rangeland management, and to soil salinity as a result of unsustainable irrigation.
- The basin has a history of water disputes owing to the development of dams and hydropower plants along the Euphrates River, which rises in Turkey, and flows through Syria and Iraq.

- Information and data on annual flows, precipitation, evapotranspiration, salinity and other features are not shared and are often disputed.

CRP5 research activities

- Assess the extent, status and trends of terrestrial ecosystem degradation and design and test location-based adaptive strategies for improved management.
- Examine opportunities for increasing the sum of net benefits from water allocation and use along the Tigris and Euphrates, through international cooperation involving Turkey, Syria, Iraq and Iran.
- Study ways to increase the production of cereals and legumes, and improve the health and productivity of livestock in rainfed areas.
- Look at business options to make marginal quality water, including irrigation return flows, a valuable asset.
- Land health surveillance will focus on monitoring vegetation cover in agricultural areas and soil salinity in irrigated areas as a basis for designing interventions and assessing impacts.

6. Nile

Burundi, Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, Uganda

Potential impacts

- Basin population: 200 million
- Rural population: 128 million
- Agricultural population: 102 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 research

- Most of the poor live in rural areas (except in Egypt) and most make their living in agriculture.
- Egypt and Ethiopia have large populations and are growing at notable rates. Ethiopia's plans to develop hydropower and irrigation tend to meet resistance from Egypt.
- Unsustainable agricultural practices have inflicted upon Ethiopia some of the most severe land degradation problems in the world.
- Accelerated soil erosion from agricultural land poses a threat to the health of Lake Victoria.

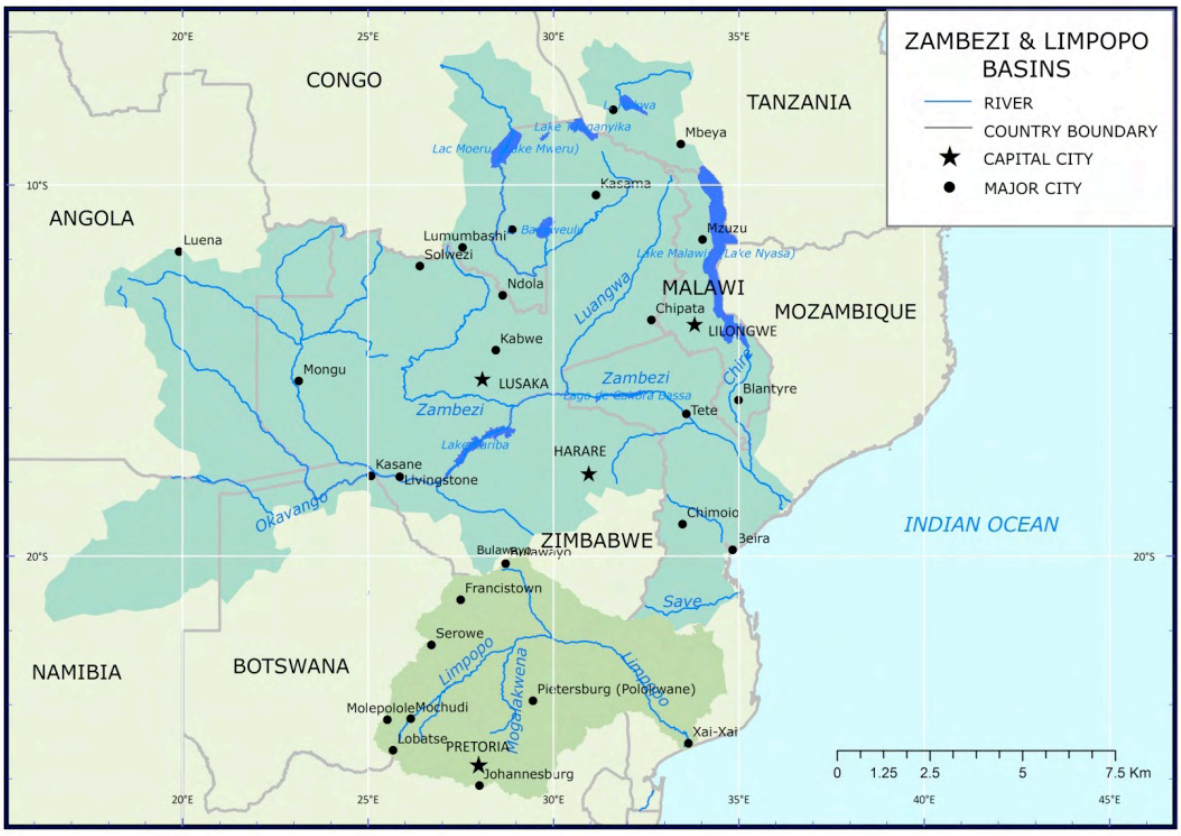
- There is substantial poverty in Sudan, despite notable agricultural potential, particularly in the Gezira region. There is very little information on the current state of land resources to guide development in South Sudan.

CRP5 research activities

- Examine opportunities for improving agricultural productivity in irrigated areas of the Nile Valley and Delta, given the likelihood of increasing pressure on water supplies in the region.
- Develop recommendations for investing in new irrigation schemes in Ethiopia and Sudan, while cognizant of international discourse regarding new water development in the Nile Basin.
- Develop strong technical capacity in the Nile countries in surface and groundwater resources assessment and management.
- Develop options for recovering water and nutrients from marginal quality water and other waste resources for agriculture and aquaculture.
- Establish a basin-wide land health surveillance system to provide a baseline on ecosystem services, a basis for prioritizing interventions, and mechanism for monitoring impacts. Ground sampling through sentinel sites will be a high priority in Ethiopia, Kenya, Uganda, Rwanda and South Sudan.

7. Limpopo and Zambezi

Angola, Botswana, Malawi, Mozambique, Namibia, South Africa, Tanzania, Zambia, Zimbabwe



Potential impacts

- Basin population: 45 million
- Rural population: 24 million
- Agricultural population: 23 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 research

Zambezi

- Over 31 million people reside within the boundaries of the Zambezi. Three countries – Malawi, Zambia and Zimbabwe – account for 86% of the cultivated land in the basin. Between 60% and 80% of the population in rural areas is poor.
- Rainfall is erratic and sometimes low. Almost 90 % of the streamflow in the basin occurs in the wet season.

- Extensive floodplain and wetland areas provide economic and social value to agriculture, fisheries, wildlife and tourism. Flood control in the estuary and delta areas is an important for sustainable livelihoods and ecosystems.
- In the Zambezi, although there is great potential to expand irrigation in the basin, lack of infrastructure for storage, diversion and delivery of water is a major constraint.

Limpopo

- Insecure tenure rights are a major obstacle to smallholder farmers improving their agriculture-based livelihoods in the semi-arid environment of the Limpopo basin.
- Over 14 million people live within the basin; around 1 million of these receive food aid.
- Heavy but unreliable rainfall, a characteristic of the climate in this region, seriously compromises food security.
- More than half the population falls below the poverty line and poverty is higher among female-headed households.

CRP5 research activities

- Characterize the binding constraints to improvements in agricultural productivity and sustainable ecosystem management, by agro-ecological zone, within the basin.
- Identify interventions to overcome the binding constraints in a manner that provides long-term gains in crop yields and livestock health and productivity.
- Describe and test affordable strategies for improving the management of land, water and nutrients in rainfed areas.
- Identify opportunities for investments in new irrigation potential, in both formal and informal settings.
- Examine opportunities for constructing new water storage facilities and water transport facilities to provide better flood control, while increasing irrigation potential.
- Study the potential gains from investments in hydropower generation, with particular emphasis on how a portion of the gains might be invested to increase agricultural productivity and improve livelihoods.

8. Volta and Niger

Benin, Burkina Faso, Ghana, Guinea, Mali, Niger, Nigeria

Potential impacts

- Basin population: 126 million
- Rural population: 80 million
- Agricultural population: 80 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 research

Volta

- Much of the population is very poor, has inadequate access to water supplies, and suffers from water-related diseases such as malaria, schistosomiasis and guinea worm.
- Poverty is caused by low agricultural productivity, limited access to markets, unstable prices and insecure land tenure.
- The scarcity of productive assets limits expansion of agriculture. Increasing demand for land will accelerate land degradation without preventive intervention.

- Rainfall is sparse and variable in much of the basin, thus limiting the productivity of rainfed agriculture.

Niger

- Much of the population suffers from extreme, chronic poverty and is vulnerable to droughts and malnutrition.
- Child mortality (deaths under the age of 5) is the highest in the region. Many deaths are due to malaria and diarrheal diseases.
- Agriculture and irrigation are not well developed. Most agriculture is for subsistence, and production is itinerant.
- Several dams are planned, generating potential conflicts between water users in several sectors: hydropower, irrigation, fisheries and ecosystems.

CRP5 research activities

- Identify and characterize opportunities to develop irrigation, with the aim of increasing crop and livestock production.
- Develop recommendations for improving and extending water-harvesting technology throughout rainfed areas of the basin.
- Explore opportunities for developing alternative energy sources (using byproducts and residues of crop and livestock production and processing) that could reduce the demand for forest products and thus reduce the rate of deforestation.
- Develop scientific and policy recommendations to promote the safe reuse of wastewater and sludge (which is common among smallholder farmers in peri-urban areas) to reduce water stress and help meet fertilizer needs.
- Describe opportunities to enhance cooperation in collecting and reporting hydrologic data, and demonstrate the benefits of collaborative investments in water storage and management facilities.
- Link with CRP4 (Agriculture for Improved Nutrition and Health) to ensure that any water related intervention is not increasing the risk of vector-borne diseases.
- Link with CRP1 (Integrated Agricultural Systems) to test the adoption and ensure the application of any recommended technology or change of practice at the household or farm level.
- Map areas vulnerable to land degradation and identify the main drivers as a basis for designing and testing preventive and rehabilitative intervention strategies.

9. Andes

Columbia, Ecuador, Peru

Potential impacts

- Basin population: 92 million
- Rural population: 28 million
- Agricultural population: 24 million

We expect to improve the livelihoods of 60% of the agricultural population.

Issues motivating CRP5 research

- Around 42 million people in Colombia, Ecuador, Peru and Bolivia are poor and depend on rural livelihoods.
- Water supply and availability vary considerably across the Andes, where rainfall gradients are quite large. Ecosystem degradation and climate change are primary concerns regarding water supply, while issues regarding water demands are gaining importance. Access to water in rural areas is limited and quality is often poor. Deforestation, unsustainable cultivation of slopes, and abandonment of land have accelerated soil erosion.
- The high mountain environment, with populations at both high and low altitudes, creates opportunities for benefit sharing between upstream and downstream stakeholders.

- Agriculture on steep lands is not very productive, yet reduces water quality, thus affecting communities downstream.

CRP5 research activities

- Improve the characterization of water supply from ecosystems.
- Fill rainfall gaps using remotely sensed data, especially at high altitudes, thus improving the knowledge of hydrological regulation processes and how they are degraded by land conversion.
- Jointly analyze water supply and uses at different spatial and temporal scales, including future scenarios. This also feeds into and CRP7 (Climate Change, Agriculture and Food Security).
- Assess the extent, status and trends of land-use change and unsustainable land-management practices as a basis for designing and testing interventions.
- Research benefit-sharing mechanisms that can help alleviate poverty by conserving fragile upland areas, reducing sediment flow and improving water availability. This work will provide valuable knowledge to other basins around the world.
- Examine agricultural practices at higher altitudes and on steep, sloping lands to determine their impacts on hydrological regulation processes, and develop interventions that can improve these processes.

2.9. Integration of CRP5 with other CRPs

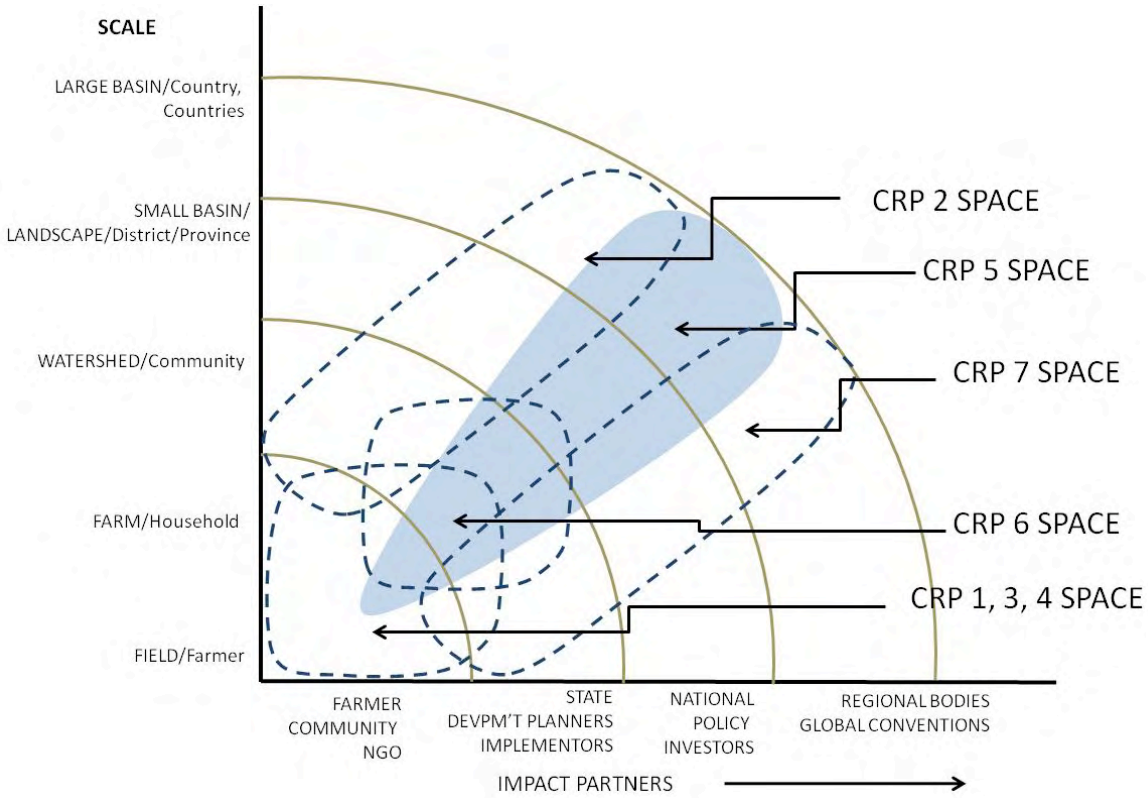
While other CRPs will conduct research at the commodity, field and farm levels, CRP5 researchers will work primarily at larger scales (landscapes and basins), with an emphasis on interventions that affect environmental quality and the natural resource base. We will also endeavor to understand what is happening at plot and farm, so as to predict the consequences of actions and interventions, and thus scale up results to the landscape and basin scales. The relationship between CRP5 and other CRPs is shown in Figure 2.2.

CRP5 researchers therefore have a unique opportunity to integrate the program's work at basin and landscape level, and also to investigate the spatial consequences of more site-specific work being undertaken in other CRPs. The nested strategy adopted in the conceptual framework will facilitate this. We will seek to work in locations where other CRPs are undertaking crop and field management trials. For example, drought-tolerant crop varieties may have beneficial impacts on the hydrological cycle. Conservation tillage can increase groundwater recharge while reducing runoff and erosion. Improved management of water in rainfed fields may increase crop production but reduce water flow in wetlands and streams, thus affecting biodiversity. To improve long-term analysis, we will work with researchers in other CRPs to select sentinel monitoring sites that monitor crop cover, soil properties and other factors.

To facilitate modeling of water flow, we will also work to improve the understanding of hydrological processes in key basins. Given that rainfed systems often coexist with irrigated systems, our work will view the landscape as a mosaic of interacting land uses in which changes in the management of one form of land use may affect another use or the environment. This is

important for assigning water allocations and developing water sharing plans. We will cooperate with CRP2 in this area, with respect to policy changes needed to facilitate better water governance. Such work will also be strongly linked with climate change predictions being developed in CRP7.

Figure 2.2. How CRP5 integrates with and complements the other CRPs



3. From research to impacts

A major challenge for CRP5 is to translate rigorous research into robust development outcomes that contribute to poverty reduction and food security while ensuring environmental sustainability.

Although the ultimate impacts of our research will depend upon a combination of political will, transparent systems of governance, and technical, financial and managerial capacity, there are many ways we can work to ensure that our technical and policy recommendations are implemented. Primarily, CRP5 researchers must work closely with strategic partners to ensure policy and management change. Poor and vulnerable groups have little choice when it comes to practices that degrade land, water and ecosystems. Consequently, we must give equal focus to the socioeconomic factors that overcome this lack of choice, including social support systems, in addition to proposing technical solutions.

A central feature of our approach will be to ensure that the exclusion of women and youth from decision-making processes in agriculture and NRM and the benefits derived is addressed more directly. We have therefore given considerable attention to what we term 'theories of change' and Impact Pathways, as described subsequently (see Box 3.1 for terminology). This chapter also examines how CRP5 will prioritize its work.

Box 3.1. Terminology
Theory of change: A theory of change describes how a project or program worked, or is expected to work (Weiss, 1995). In our case it explains how we speculate that CRP5 research will bring about developmental outcomes. Theories of change can be expressed in different ways (e.g. as logic models, LogFrames and impact pathways), and at several scales (e.g. project, SRP and Program).

Lever of change: an opportunity for research to lever developmental change together with a description of the strategy and tactics by which the opportunity might be realized.

Impact pathway: The research-to-development continuum; the connections between organizations that turn research into developmental outcomes and provide feedback on what is needed, working and not working.

Next users: the people and organizations that co-develop and use research knowledge for the benefit of the end users.

End users: our ultimate beneficiaries – the rural and urban poor whom the CGIAR seeks to benefit.

3.1. Theories of change

A generic theory of change (see Figure 3.1) was used to formulate the CRP5 SRPs. CRP5's theory of change describes the levers we can pull to bring about the changes we believe will foster sustainable agriculture and healthy environments, and alleviate poverty. Creating impact means changing behavior, be that policy change or farmer adoption. Hence our theories of