

1. Motivation for new research on water, land and ecosystems

Our vision: agriculture and ecosystems thrive

Our vision is of a world in which agriculture thrives alongside vibrant ecosystems, and those engaged in agriculture live in good health, enjoy food and nutritional security, and have access to the inputs and resources they need to continuously improve their livelihoods. We see a future in which the increasing numbers of urban residents, particularly in developing countries, have access to safe and affordable food and water, made possible by gains in agricultural productivity and public investments in food safety and water quality. We envision a world in which sustainable management of water, land and ecosystems is the norm, food security is ensured for most of humanity, and poverty has indeed become history.

To achieve this vision, we must redouble our efforts to increase agricultural productivity, while protecting the environment. Agriculture provides essential food and fiber, and generates employment for most residents of many poor countries. Hence, agriculture powers both the supply and demand components of household food and nutritional security. To achieve long-term growth and economic development, we must ensure that advances in agriculture do not degrade the natural resource base on which agriculture depends. To this end, we must build on past successes of the CGIAR in boosting agricultural growth through scientific inquiry and policy analysis. We must conduct new research on agricultural and ecosystem interactions.

1.1. Background – successful past, challenging future

In the late 1960s, the prospect of widespread famine threatened many areas of the developing world. In response, CGIAR scientists and their partners in national research centers developed new crop varieties that produced much higher yields. Fertilizers were made available to support the new seeds, and massive investments in irrigation provided reliable water supplies to nurture the crops and give farmers the confidence to invest in change. Millions of farmers became food secure, rural livelihoods were transformed and new food supplies drove down prices for urban consumers.

That early success of the CGIAR had a number of factors in its favor. Those making the changes benefited directly. Farmers saw the benefits of growing improved seed varieties that generated better yields and higher incomes. Feedback was direct and easy to measure and adoption increased quickly. Politicians could easily understand the issues and benefits. Thus, there was strong political support for policy changes that led to subsidies on fertilizer and energy, and construction of large irrigation schemes. The technical and engineering solutions were at hand.

Yet the improvements in productivity made possible by the technical innovations could not be fully sustainable, because the institutions and policies influencing farmer decisions did not always take into account the unintended impacts of change. Farmers had too little information or incentive to consider the off-farm or long-term impacts of their intensive use of fertilizer, pesticides or irrigation water. This situation resulted in land degradation, off-farm pollution and excessive use of water resources, all of which compromised the ecosystem services on which

farming depends. Working at the level of farm and plot provided the technology needed to quickly expand food production, but failed to focus on larger-scale, longer-term implications.

Looking forward, we must not only reverse the degradation and reduce the excessive use of scarce resources through the development of new technical interventions; we must also put in place the right institutions to ensure that new research contributions generate sustainable gains in resource productivity and livelihoods.

The CGIAR is well placed to conduct this research for two reasons: 1) NRM specialists within the CGIAR are uniquely placed in that they can work across national borders, form partnerships with advanced research institutes (ARIs) and work with NARES and the private sector to guide and implement the technical and institutional components of this truly interdisciplinary research program; 2) CGIAR NRM scientists while having a strong commitment to agriculture and food production, also have the experience of working with non-traditional partners including the Ramsar Convention on Wetlands and the larger environmental nongovernmental organizations (NGOs); and 3) The research outputs will serve as international public goods. Indeed, the CGIAR is precisely the organization that can take the larger-scale, longer-term view that is needed to achieve sustainable outcomes. The time is ripe for this initiative because of the magnitude of the problem and because a previous effort to integrate NRM across the CGIAR was only partially successful (see Box 1.1).

Box 1.1. Integrated NRM in the CGIAR

Between 1999 and 2003, the Interim Science Council of the CGIAR and the Center Directors Committee on Integrated Natural Resources Management undertook a process to define the Integrated NRM (INRM) concept; describe the history of INRM research in the CGIAR; portray the role of systemwide and ecoregional programs in operationalizing INRM; and illustrate successful INRM research through seven case studies. The process featured four workshops (Bilderberg 1999, Penang 2000, Cali 2001 and Aleppo 2002) and culminated in a summary publication (Harwood and Kassam, 2003). In the summary, INRM was defined as “a conscious process of incorporating multiple aspects of natural resource use into a system of sustainable management to meet explicit production goals of farmers and other uses (e.g. profitability and risk reduction) as well as goals of the wider community (sustainability).”

To some extent the Challenge Program on Water and Food followed up on these integrated approaches after 2002, but few systematic studies have examined agriculture, NRM and their environmental impacts in a comprehensive manner. CRP5 aims to fill this void.

1.2. The challenge – expand, intensify, restore and protect

The conditions that challenge agriculture today are quite different to those of the 1960s. Rivers are drying up, groundwater is being depleted, and ‘water crisis’ is now a commonly used term. Widespread land degradation is reducing productivity in many areas and more resources are needed to maintain output. Agricultural intensification is harming the ecosystems on which agriculture depends, resulting in salinity, waterlogging and other negative impacts. The expansion of agriculture is imposing unacceptable costs on others who rely on natural resources for their livelihood activities. Such problems arise through the ‘tragedy of the

commons,' or the fact that markets do not exist to deal with the basin-wide and long-term impacts of agriculture. Developing solutions to such problems requires research that goes beyond farm and plot-level analyses.

But our current challenge is not only to solve existing problems. With demands on agriculture increasing, we must contend with many new pressures (Chartres and Varma, 2010). Two billion people will be added to the global population by 2050. Higher incomes, changing diets, and urbanization will impose new demands on farming systems, and the resources that underpin them. With increasing energy demands, biofuel production will continue to compete with food production for available resources. Climate change will bring more frequent droughts and floods, and will influence temperature regimes in ways that will increase the challenges faced by farmers in many areas. Economic growth will deepen competition between agricultural and non-agricultural uses of resources. Although much of this can be resolved through political discourse, conflict will be an increasing worry.

We know also that we have not yet solved the rural poverty challenge in much of the world, and that large numbers of the rural poor will continue migrating to cities in search of employment. Increasing urbanization will place additional pressure on agriculture to produce sufficient food, in light of increasing competition for land and water. Affordable food is critical for the urban poor and to support economic development. Thus, efforts to improve agricultural productivity will benefit both the urban and rural poor in many developing countries.

The increasing global demands for food, fiber and energy will place new stresses on the land, water and ecosystems that support agriculture. It will not be possible to satisfy global demands in 2050 and beyond without increasing the land area devoted to agriculture and intensifying crop production on lands already farmed. Most of the needed increase in agricultural output will come from intensification, which can include increasing the use of fertilizer, greater use of genetically modified organisms (GMOs), using farm chemicals, providing irrigation, or increasing the amounts of labor and machinery used each season. Intensification will have impacts on supporting ecosystems, but those impacts can be moderated through policies and incentives informed by the research we propose in this portfolio.

1.3. Our objective – improve agriculture, protect ecosystems

We derive the objective for this CGIAR Research Program from the challenge we describe above. In brief, our objective is the following:

We must learn how to intensify farming activities, expand agricultural areas and restore degraded lands, while using natural resources wisely and minimizing harmful impacts on supporting ecosystems. Our goal is to achieve the sustainable improvements in agricultural productivity required to produce enough food for all and generate sufficient income to lift millions of smallholder households from poverty, while also ensuring their food and nutritional security.

In pursuing this objective, we will build upon previous successes of the CGIAR centers in improving agriculture and addressing NRM issues. We will enhance those earlier successes by

giving greater attention to the impacts of agriculture on ecosystems, and the importance of ecosystems in supporting agriculture. The science we conduct and the recommendations we produce will promote wise use of natural resources, in support of thriving agricultural sectors and healthy ecosystems. We consider addressing this objective will contribute significantly to the System Level Outcomes defined in the CGIAR Strategy and Results Framework (see Box 1.2) and Figures 1.1–1.3.

Box 1.2. Addressing the CGIAR’s Strategy and Results Framework
 CRP5 plays a critical role within the CGIAR to deliver on NRM objectives. The CGIAR Strategy and Results Framework has four System Level Outcomes:

- reducing rural poverty
- improving food security
- improving nutrition and health
- sustainable management of natural resources.

CRP5 focuses on the fourth of these outcomes, but improved NRM is central to all four and improving water quality also strongly relates to health and nutrition.

Figures 1.1–1.3. How CRP5 contributes to the strategic level outcomes of the CGIAR Strategy and Results Framework (detailed descriptions of the Strategic Research portfolios (SRPs) are given in subsequent chapters).

Figure 1.1.

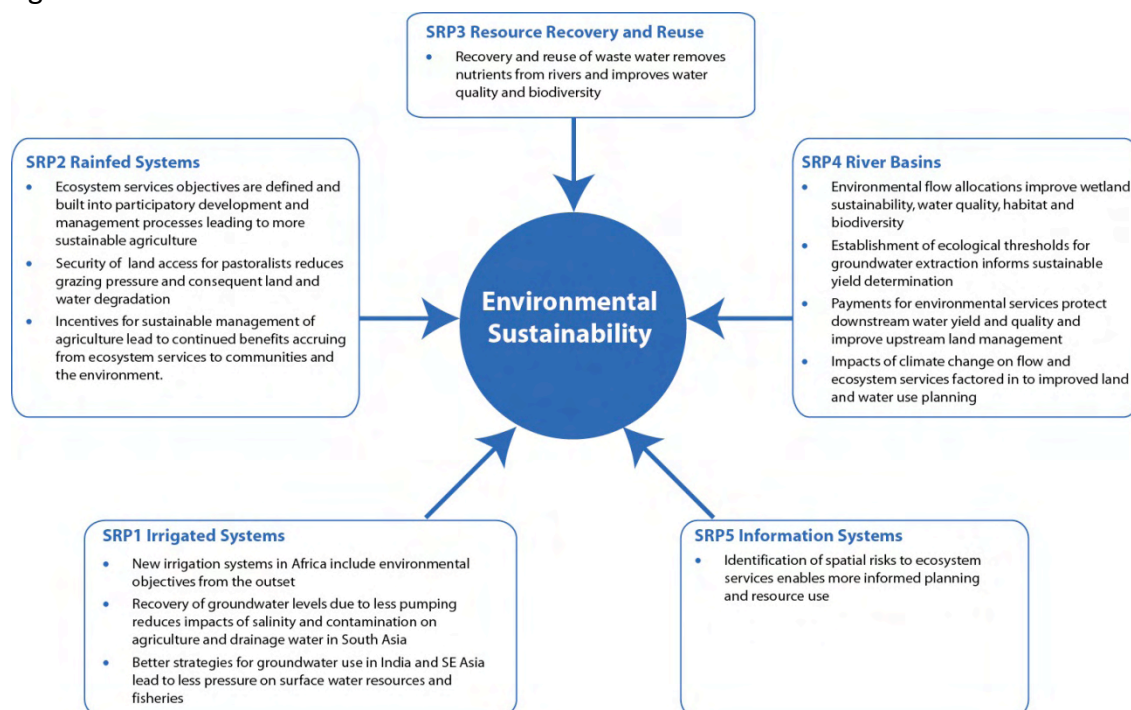


Figure 1.2.

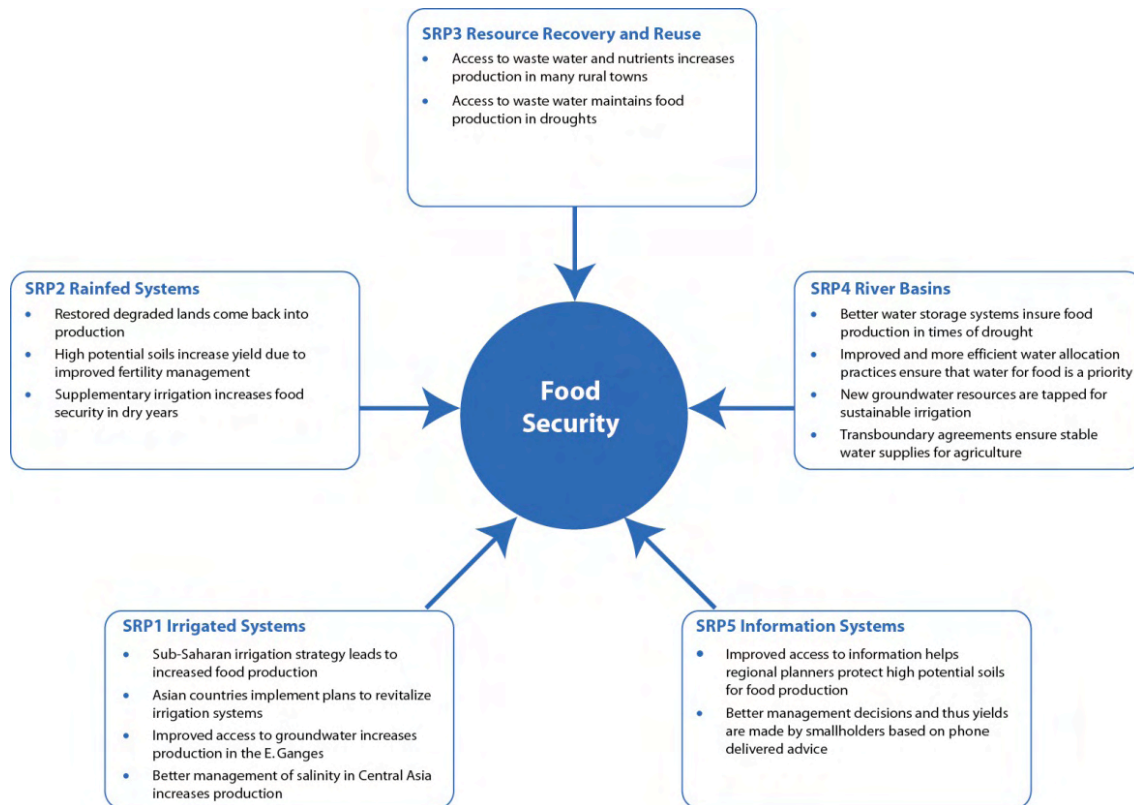
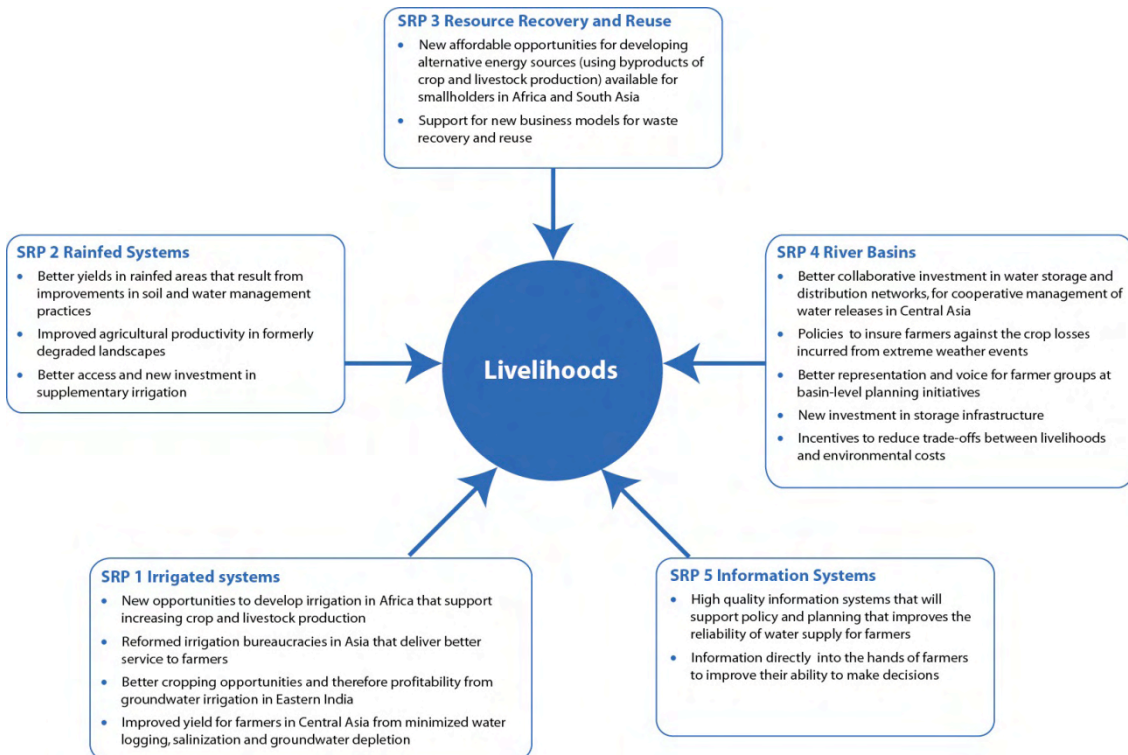


Figure 1.3.



1.4. Our perspective – water, land and ecosystems

Given the challenges ahead, we will focus our research efforts on improving global understanding of critical interactions involving water, land and ecosystems in agriculture. We will examine both technical and policy aspects of resource allocation and use, while studying also the many ways in which ecosystems support, enhance and are affected by agricultural production. To this end, we will address three overarching research questions:

1. In an era of increasing water scarcity and variability in water supplies, what improvements are needed in governance, institutions and management to achieve wiser use of water in agriculture, to ensure that we meet global food production targets and enhance household-level food and nutritional security in developing countries?
2. What are the most effective interventions for ending land degradation in many areas of Asia and Africa, and beginning the long process of restoring productivity to degraded lands?
3. What are the trade-offs between agricultural intensification and ecosystem services, and how can these be measured to facilitate the development of sustainable land and water management practices and sound rural policy?

These three topics – water scarcity and variability, land degradation and ecosystem support for agriculture – represent the current major threats to agricultural output in many developing countries. Yet they also represent opportunities: they are the areas of research that hold the greatest potential for increasing agricultural production and ensuring food security for millions of smallholder households across Asia and Africa. Below, we summarize our perspective regarding each of the three questions.

1.4.1. Water scarcity and variability

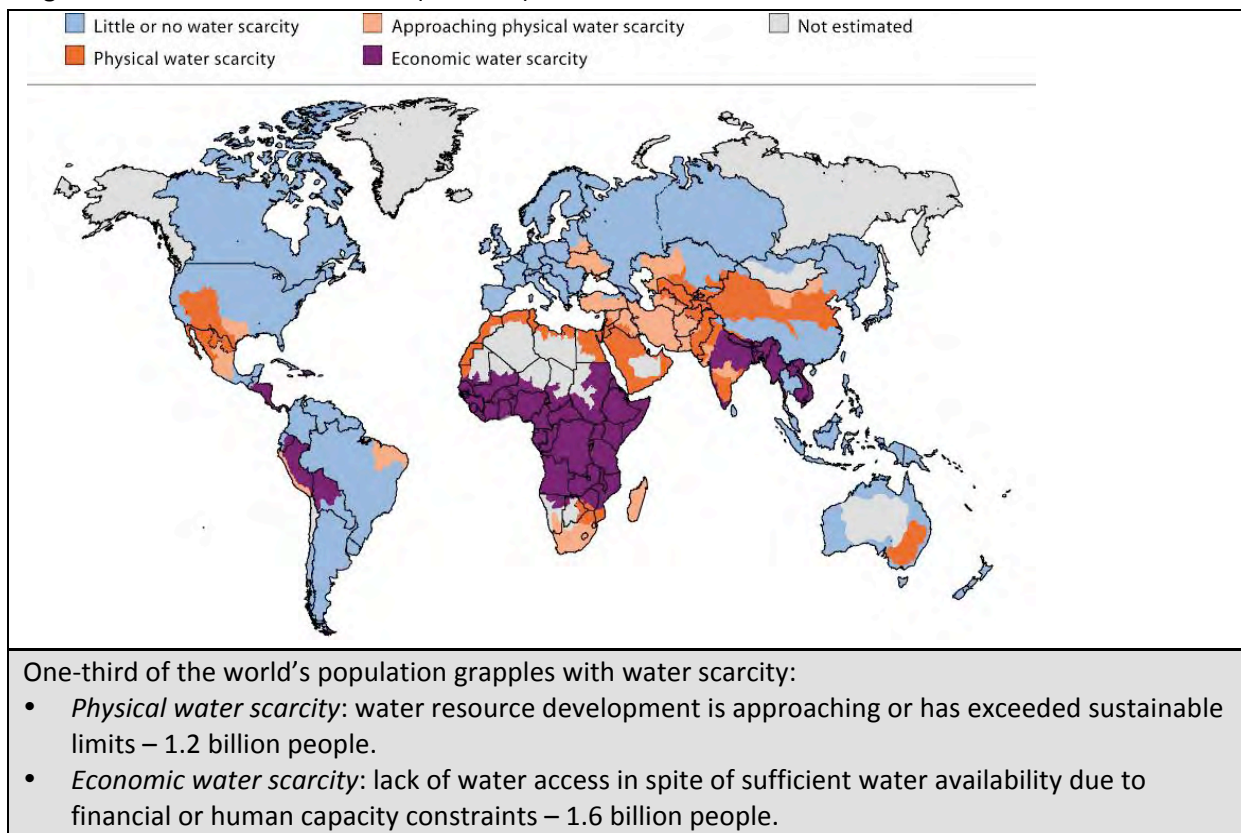
Globally, agriculture uses 70% of the world's extracted freshwater. In some developing countries the figure is as high as 90%. Already, several river basins have become essentially 'closed' – that is, all the water is being used and little or no water flows to the ocean. When this happens, ecosystem services, such as biodiversity and water quality, are compromised.

Water scarcity can be physical or economic (see Figure 1.4), and the types of solutions required to address each form of scarcity are quite different. Scarcer water and more nutrient-depleted soils, combined with rising populations, higher energy prices and other drivers, will contribute to rising food prices. Food crises and sudden spikes in food prices will become increasingly frequent in future, thus threatening the food security status of millions of poor households.

By 2025 it is estimated that water scarcity will affect the livelihoods of more than 1.8 billion poor people (Nelleman et al., 2009; WHO, 2007). The 2009 FAO Expert Panel on Food Security predicted that we must increase food production by 70% to meet demand in 2050 (Bruinsma, 2009). Achieving this will require more water, more land and more fertilizer, as well as the continued provision of a wide range of ecosystem services that underpin productive agriculture. Forecasts made in the Comprehensive Assessment of Water Management in Agriculture (CA, 2007) suggest that water demand from agriculture could double by 2050. Water demand in

India could exceed supply by 50% in 2050, with increasing demands for food, biofuels, and other uses (Mckinsey, 2009; 2030 WRG, 2009).

Figure 1.4. A water-scarce world (CA 2007)



Variability in water supply is already the greatest threat to production in many areas. Climate change predictions (Bates et al., 2008) for many tropical countries indicate that higher temperatures, increased evaporation and greater variability of rainfall will present new challenges and increase the complexity of management in both irrigated and rainfed agricultural systems. It will not only be the absolute changes in temperature and rainfall that will make agriculture more risky and the poor more vulnerable, but also the increased variability, which will require innovative adaptation strategies.

Coupled with the issues of water scarcity and supply variability is a third critical issue: equitable access to water. Lack of access is often a fundamental constraint to improving people's livelihoods. Although the relationship between poverty, livelihoods and access to water is complex, Lawrence et al. (2002) have shown that access to water and the level of development can be strongly linked.

In summary, as competition for water resources from cities, industry and the environment increases, agriculture faces the paradox of having to produce much more food using no more – or even less – water than it does at present. Solving this paradox presents a major challenge for CRP5 researchers.

1.4.2. Land degradation

Many forms of land degradation are found in the agricultural areas of both industrialized and developing countries: soil salinization, organic matter and carbon depletion, erosion, and nutrient exhaustion. The Global Assessment of Human-Induced Soil Degradation (GLASOD) was the first attempt to estimate the extent of soil degradation globally (Oldeman et al., 1991). It remains the main source of land degradation data, although new initiatives are under way (Sanchez, 2009; Vlek, 2010; Winslow et al., 2011).

According to GLASOD, degradation of croplands is most extensive in Africa, affecting almost two thirds of cropland areas, compared with just over half in Latin America and more than a third in Asia (CA, 2007). About 1 billion hectares of the world's agricultural land have been degraded by deforestation and inappropriate agricultural practices (Pinstrup Andersen and Pandya-Lorch, 1998). The Millennium Ecosystem Assessment (MA 2005) estimated that 10–20% of the world's drylands suffer from one or more forms of land degradation, but reliable data are limited. Dryland degradation is also responsible for a global decline in both the actual and potential ability of the earth to produce organic matter (Zika and Erb, 2009). Numerous studies (see Appendix 1c) have demonstrated links involving soil nutrient and structural decline, acidification, and low and declining crop and pasture yields.

Additionally, urbanization and industrialization consume increasing areas of often high-quality agricultural land every year. The soils in many areas of sub-Saharan Africa are old and intrinsically lower in nutrients than the relatively young and extensive alluvial soils that supported the Green Revolution in Asia (van der Zaag, 2010). Making the situation worse, productivity has declined significantly (up to 40%) in several sub-Saharan countries because of land degradation and nutrient exhaustion (Bai et al., 2008; Bai and Dent, 2006). The persistently high population growth rates in many African countries combined with the small proportion (only around one sixth) of land area in Africa with high agricultural potential (Eswaran, et al., 1997) will exacerbate these issues.

As agriculture expands and intensifies, we must end the persistent degradation of farmland that has reduced productivity and impaired the livelihoods of many poor households. Particularly in Africa, many smallholder farmers have not replaced the nutrients taken up from soils by crops each season. As a result, soil nutrients have been depleted across large areas of farmland, slashing the productive potential of crop and livestock agriculture. We must break the downward spiral of declining productivity by providing farmers with affordable access to plant nutrients, along with the technical assistance needed to apply them correctly.

Later in this proposal we describe opportunities to reverse land and water degradation and minimize environmental pollution through ecologically sound integrated land and water management practices, including recovering and reusing waste materials.

1.4.3. Supporting ecosystems

Ecosystems have sometimes been described as life support for the planet. Agricultural ecosystems have replaced natural ecosystems across much of the globe. Well managed agricultural systems improve soil fertility, encourage pollination, suppress pests and diseases, maintain healthy wetlands, provide clean water for healthy communities, and can enhance

biodiversity. By contrast, efforts to intensify agriculture, with too little concern for the environment, can impair supporting ecosystems.

The intensification of agriculture since the Green Revolution has seen the area under irrigation nearly double, and the use of nitrogen and phosphate fertilizers increase by more than seven times and three times, respectively (Green et al., 2005). Ecosystem services – which were dependent on adequate water, healthy soils and healthy biodiversity – have been replaced by external inputs that have damaged the agro-ecosystem.

Agricultural run-off has led to significant sedimentation, eutrophication, and algal blooms in numerous rivers, causing harm to water quality, aquatic habitat and fisheries. Water is used excessively, at the expense of the environment, particularly in closed river basins (Smakhtin et al., 2004). Prominent examples include the Murray–Darling River basin in Australia, the Krishna in India, and the Colorado in the United States and Mexico, where in many years nearly all the annual water supply is fully allocated to users, such that little or no water reaches the ocean. As a result, water quality is impaired by high levels of salinity and pollutants, and biodiversity is reduced.

With our increased knowledge has come a growing awareness that thresholds have been reached or exceeded for rivers, groundwater and soil resources in many parts of the world (Rockström et al., 2009). There is also a growing realization that we can no longer view water, land and the biodiversity that ensures ecosystem function as inexhaustible and free inputs to a global food production system. We can no longer assume that the environment will continue to provide the services that support agriculture. We cannot continue to pursue a vision of agricultural productivity based on yields at the expense of equity, resilience and sustainability, but must instead broaden the range of benefits to society as a whole.

CRP5 researchers will consider the individual issues of water scarcity, land degradation, biological diversity loss and ecosystem deterioration in an integrated manner designed to generate sustainable improvements in food security, livelihoods and the environment. This approach will contribute to global discussions and decision-making regarding agricultural development. Examples of key issues include the question of land conservation versus land transformation (Fischer et al., 2008); the role of agriculture in crossing critical environmental thresholds (Rockström et al., 2009); and the potential of sustainable, biodiverse systems and multifunctional landscapes to sustain ecosystem services and feed the planet while providing sustained livelihood options for rural populations (Pretty et al., 2006; Pretty et al., 2011; Scherr and McNeely, 2009).

1.5. CRP5 harnesses the power of integration

“It is not an eye-opening statement to suggest that natural resource management increasingly occurs in turbulent, contentious settings. These settings are often typified by contested or ambiguous goals and lack of scientific agreement on cause–effect relationships.” – McCool and Guthrie, 2001.

The above quote is apposite, in part, because NRM work in agriculture is often piecemeal and practiced only at the field and farm scales. CRP5 considers a more systematic approach that takes landscapes and river basins into account. There are a few examples of how the impacts of agriculture on natural resources and the environment have been managed at these scales. These include the success of the Murray–Darling Basin Commission’s Salinity and Drainage Strategy, which used land and groundwater management strategies to maintain low salinity levels in the Murray River in Australia; the LandCare movement, again initiated in Australia; and South Africa’s Water Policy.

The Challenge Program on Water and Food (CPWF) also has succeeded in bringing together researchers, policymakers, funders and the community to solve problems at the basin and sub-basin scales. These successes offer a guide to what CRP5 can achieve, given its more integrative nature and broader geographic coverage.

These examples succeeded because they looked at big-picture issues, used scientific evidence backed up by policy development to initiate change, and gained a degree of bipartisan political support. They indicate that if CRP5 is to succeed, it must catalyze sound land and water management practices – through government- and private-sector policies and strategies – in the regions in which it will operate. Furthermore, CRP5 must look at agriculture and NRM from an integrative perspective, which it has been designed to do. Part of this will be to see agriculture as part of the solution to environmental problems as opposed to the cause.

Above all else, CRP5 will bring critical mass and diverse skills to solve key problems via an integrated R&D value chain including farmers, environmental managers and policymakers

Currently, there are major gaps in NRM R&D programs in many countries. Institutionally, resource sectors are separated and few pay much attention to issues of impending scarcity, degradation and environmental management. Gender, age and caste/class inequities in NRM are widespread, and formal sectors often lack the capacity to bring in local-level knowledge and expertise. Specific examples of where CRP5 will address these gaps are given in Box 1.3.

We will also build a system of delivery via NARES, NGOs, government agencies and the private sector that few, if any, alternative suppliers can emulate. The CGIAR centers bring strength in physical and social sciences and agriculture on the scale necessary to address local, national, regional and global problems. To fulfill CRP5’s promise, the CGIAR needs new partners and new forms of partner networks to promote uptake and to expand its development work and capacity building.

Research links involving universities, national research institutes and global organizations (e.g. UN and World Bank) are poorly coordinated, and there are strong demands from the NGO community, the private sector and governments for credible scientific information and policy advice. Thus, the CGIAR and its partners have the opportunity, via the integration of CRP5’s NRM work, to lead international efforts to balance agricultural productivity objectives with environmental sustainability. This will happen through the nested regional-, basin- and issue-focused strategy detailed in the Conceptual Framework (Chapter 2) and subsequent sections.

Box 1.3. How CRP5 will improve natural resource management and the environment

- Involving, from the outset, key stakeholders via participation in research and development
- Achieving critical mass among the CGIAR and its partners to solve key problems
- Integrating biophysical solutions and socioeconomic drivers to develop a holistic view of possible beneficial changes
- Taking an evidence-based approach based on a logical pathway via hypotheses and methodologies to develop solutions and catalyze change at policy level
- Adopting an integrated landscape/basin approach, as opposed to focusing on single issues
- Viewing agriculture as part of the solution not the cause of the problem
- Harnessing the private sector and NGOs to help deliver solutions
- Using information systems and technology to ensure the message gets to farmers and land and water managers
- Being clear about the development outcomes we wish to achieve and using adaptive management approaches to achieve them
- Developing appropriate partnerships at science, policy and implementation levels, and clearly defining responsibilities and accountabilities

1.6. CRP5's comparative advantage

CRP5's international focus will assist the development of strong networks of ARIs, CGIAR centers, private-sector partners, NARES and other relevant government agencies. Many alternative suppliers conduct NRM research (e.g. universities, foundations, international NGOs, multinational corporations and think tanks), but few can bring together partnerships at the scale or scope that CRP5 can accomplish. Furthermore, few aim to transfer lessons learned in one part of the world to another, and few are dedicated to the creation of global public goods. Although there are other groups and universities working in complementary areas, these are usually project- or location-based. However, by developing strategic partnerships, we will access the high-quality work of these suppliers.

CRP5 also complements the NRM work of national researchers by exchanging lessons learned and bringing in ideas from the global community. The private sector, although showing increasing concern about the environment and solving problems related to their particular industry, generally does not offer international public goods. Our role will be to build private-sector partnerships where there is likely to be a market-based solution to a problem (for example, we are partnering with Jain Irrigation in South Asia to overcome technical issues that are limiting adoption of high-efficiency irrigation).

Lastly, CRP5 intends to build on the successes of its partners to deliver innovative information products to users of appropriate technology. Highlights of this new approach will include: a partnership with FAO to link and improve NRM databases and target information to their network; delivering NRM information directly to farmers by mobile phones (as being developed by IWMI and the International Fund for Agricultural Development); and further developing products that build on the successful African Soil Mapping technology of the World Agroforestry Centre (ICRAF) – including improved soil water and drought forecasting tools, flood prediction information, and population vulnerability mapping.