CRP 1.1 Dryland Systems

Integrated Agricultural Production Systems for Improved Food Security and Livelihoods in Dry Areas

CGIAR Proponents

International Center for Agricultural Research in the Dry Areas (ICARDA), Lead Center

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Bioversity International

Centro Internacional de Agricultura Tropical (CIAT)

Centro Internacional de la Papa (CIP)

International Livestock Research Institute (ILRI)

International Water Management Institute (IWMI)

World Agroforestry Centre (ICRAF)

WorldFish Center

Sub-Saharan Africa Challenge Program (SSA-CP)

Cover: Learning, growing, spiral impact pathway

The traditional, linear research-for-development impact pathway includes four steps: research, outputs, outcomes and impact. However, CRP1.1 views these steps not as a linear sequence, but as an upward spiral of learning and growing.

Information on technology performance, user perspectives and livelihood issues feeds back into research. This results in an iterative research cycle, with continuous improvement in technologies. Such an impact pathway (shown here as an upward spiral) is demand-driven, focused and results-oriented. With every ‘revolution’, learning improves and technologies become better targeted to users’ needs, leading to greater impacts on poverty and livelihoods.

THEMATIC AREA 1

INTEGRATED AGRICULTURAL SYSTEMS FOR THE POOR AND VULNERABLE

CGIAR Research Program 1.1
Dryland Systems

Integrated Agricultural Production Systems for Improved Food Security and Livelihoods in Dry Areas

A proposal submitted to the CGIAR Consortium Board

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Executive summary

The CGIAR Research Program (CRP) on "Integrated Agricultural Production Systems for Improved Food Security and Livelihoods in Dry Areas" (Dryland Systems, initially known as CRP 1.1) targets the poor and highly vulnerable populations of the dry areas. It aims to develop technology, policy, and institutional innovations to improve food security and livelihoods using an integrated systems approach. Developed from the CGIAR Strategy and Results Framework's (SRF) Thematic Area 1, "Integrated Agricultural Systems for the Poor and Vulnerable," CRP 1.1 addresses each of the CGIAR System Level Outcomes (SLOs), and builds on past achievements by CGIAR Centers and their partners.

The dry areas of the developing world occupy about 3 billion hectares, or 41% of the earth's land area, and are home to 2.5 billion people, or more than one-third of its population. About 16% of this population lives in chronic poverty. Dry areas face several demographic challenges, including rapid population growth, high urbanization, youth-skewed age distributions, and the world's highest unemployment rate. Dry areas also have limited natural resources and face serious environmental constraints that are likely to worsen as a result of climate change.

Dryland systems are found where precipitation tends to be low and erratic, and water supply is usually (but not always) the most limiting factor to agricultural production. They are characterized by persistent water scarcity, frequent drought, high climatic variability, and, especially in developing countries, various forms of land degradation, including desertification and loss of biodiversity. About two-thirds of the land under dryland systems consists of rangeland. Individual farms are typically smallholdings of only a few hectares. As with any agricultural system, dryland systems consist of a combination of plant and animal species and management practices selected by farmers to pursue livelihood goals that are based on several factors, including climate, soils, markets, capital, and tradition. However, risk is especially endemic in dryland systems. The Dryland Systems CRP is therefore about developing approaches that simultaneously mitigate risk and increase productivity to enhance food security and improve livelihoods.

In developing countries, there is little or nothing in the way of safety nets to manage risk in the event of system shocks such as drought, price rise, or pestilence. Livelihood goals of dryland farmers therefore tend more towards food security, stability, and risk avoidance, with profit often as a more secondary goal. Especially for poor small landholders in developing countries, an integrated and diverse approach is important to managing risk or increasing resilience. Dryland farmers (including pastoralists) need to understand and manage the many components of their particular production system, which may include various soils, landscapes and sources of water, and several plant and animal species. Often, they must add value to their products, e.g. through processing or marketing, to form viable businesses. And they must cope with spatial and temporal climatic variability, including complex facets of climate change. Therefore, traditional and improved plant and animal species, indigenous and introduced technologies, access to markets and financial resources, and communication of knowledge are all important parts of the mix. Management focus on any one system component or commodity in isolation from the others is unlikely to significantly improve livelihoods, and indeed may cause resource degradation, compromise food security, or otherwise increase risk.

The overarching challenge for the Dryland Systems CRP is to deliver food security and livelihood benefits to the poor and vulnerable of dryland systems, and especially to marginalized segments of society. The research program addresses a spectrum of production systems in the drylands that fall into

two broad categories: (i) those with the **deepest endemic poverty and most vulnerable people**; and (ii) those with the **greatest potential to contribute to food security and grow out of poverty** in the short to medium term. These categories are consistent with the CGIAR SRF, and allow us to identify **two basic but complementary approaches** to improving dryland systems:

1) **reducing vulnerability and increasing resilience** and mitigating risk from biophysical and socioeconomic shocks despite marginal conditions; and
2) **sustainable intensification** of production systems to improve livelihoods.

The overall objective of the Dryland Systems CRP is to improve food security and livelihoods in rural communities of the dry areas through:

- enhanced and equitable agricultural innovation systems that link interventions to policy and improve the impact of research and development;
- less vulnerable, more resilient rural communities that can better mitigate risk;
- productivity growth through sustainable intensification of dryland systems at the farm and landscape levels; and
- more resilient and productive dryland agroecosystems that can cope with increased land pressure, climate variation, and other forms of stress.

The **goal** is to improve the lives and livelihoods of 87 million people and mitigate land degradation in 1.1 million km^2 in six years: 20 million people and 600,000 km^2 in sub-Saharan Africa; 65 million people and 465,000 km^2 in South Asia; 1.1 million people and 18,600 km^2 in North Africa and West Asia; and 0.5 million people and 5000 km^2 in Central Asia and the Caucasus.

To reach this goal, **CRP 1.1 will follow** the SRF's general principles, and be **driven by a conceptual framework** in which **four Strategic Research Themes** (SRTs) are used to address risk mitigation and sustainable intensification in the two dryland-system categories identified**. The SRTs consist of steps in the impact pathway.** Within each SRT, problems and their underlying constraints are identified and addressed through a set of research hypotheses tailored to the two categories of dryland systems in various regions. Hypothesis-driven research is then subsequently designed to produce research **outputs** that contribute to the delivery of targeted development **outcomes** that in turn address identified problems and constraints. Outputs are produced through individual research-related **activities**. Succinct statements of the objectives of the four SRTs are as follows:

- SRT1: Approaches to strengthening innovation systems, building stakeholder innovation capacity, and linking knowledge to policy action
- SRT2: Reducing vulnerability and managing risk
- SRT3: Sustainable intensification for more productive, profitable and diversified dryland agriculture with well-established linkages to markets
- SRT4: Anticipating and measuring impacts and cross-regional synthesis.

Early program activities in the Dryland Systems CRP will be concerned primarily with:

1) forming partnerships as part of specific innovation platforms;
2) further characterization of the various dryland systems in each target region;
3) identification of technologies, institutions, and policies to manage risk or sustainably intensify systems; and
4) development of tools for monitoring and synthesis.

Scaling-up and scaling-out are longer-term goals.

To further develop the program activities, substantial investment was made into a **participatory consultation** process that included a series of meetings to identify and actively involve stakeholders in CRP planning. These meetings resulted in the selection of **five target regions** containing SRT2 and SRT3 target areas, in which "**action sites**" were selected as entry points. The five regions are:

1) The West African Sahel and dry savannas
2) East and Southern Africa
3) North Africa and West Asia
4) Central Asia
5) South Asia.

Regional inception workshops (RIWs) and characterization groundwork were conducted to refine selection and characterization of action sites; identify key problems and underlying constraints; agree on research hypotheses; and develop outputs and activities that would lead to CRP-specific outcomes as well as to the four CGIAR System Level Outputs. The RIWs were attended by several stakeholder representatives from the regions. Groundwork characterization and findings of the RIW were summarized for each region in reports submitted by the interim Interdisciplinary Research Team (iIRT).

A summary of the iIRT reports is included in the Inception Phase Report. Several more in-depth documents, including detailed site characterizations, problem and constraint identification, hypotheses, and logframes are available.

The Inception Phase Report, and especially the iIRT reports, contains a wealth of biophysical and socioeconomic characterization data for the various SRT2 and SRT3 dryland systems. They also provide the basis for a standardized logframe that starts with a specific problem identified with stakeholders during the consultative process and the desired outcome; hypotheses were then identified with a view to producing research and other types of outputs to bring about the desired outcome. These standardized logframes will be incorporated into a **Research and Performance Management System** that will track progress towards obtaining CRP outcomes and the four SLOs. The system, which is currently under development with the Statistical Services Center at Reading University, will be linked to data acquisition, flow, and utilization (especially within the context of SRT4), and will be used as a tool to prioritize and seek cost-effectiveness in budgeting by (i) tracking activity costs and outputs, and (ii) assessing performance through tracking and analyzing uploaded data.

In addition to the four SRTs, **four cross-cutting themes** will be mainstreamed throughout the Dryland Systems program. The first two, **gender** and **youth**, address social inequities. The third, **biodiversity**, is essential to food security, risk mitigation, sustainability, and identification of new sources of increased income. The fourth, **nutrition**, is increasingly important because of profound negative effects of rapidly changing food consumption patterns among different demographics, and specifically among rural poor populations. The four cross-cutting themes will be mainstreamed within Dryland Systems during the coming months as part of a consultative process with experts and stakeholders. As a systems research program, Dryland Systems views these four cross-cutting themes as integrally linked.

Partnerships are an explicit part of the impact pathway, and of SRT1 in particular. The CRP will include all major players as part of innovation platforms, which provide a forum for individuals and institutions from the public, private, and informal sectors to identify and promote needs of target groups, and for testing various options to address these needs. Innovation platforms typically include a mixture of farming communities, national research and extension systems, policy-makers, international and regional organizations, advanced research institutes, civil society and non-governmental organizations, the private sector, and development agencies. All of these are paramount to the identification and prioritization of the most relevant problems and constraints to be addressed, and to facilitating adoption of policy, technologies, and other innovations intended to improve food security and livelihoods in dryland systems. Furthermore, researchers will work directly with local communities to better understand and address the complex interactions between socioeconomic and biophysical components within dryland systems. CRP 1.1 must work closely with other CRPs as the natural integrator of their outputs into successful dryland systems. It will add value to other CRP outputs, and provide feedback on how their research products can combine synergistically to improve dryland systems. Some of the linkages, such as those with the commodity-oriented CRP 3s, are fairly evident. Identification of two broad categories of dryland systems further facilitates CRP integration because it allows better targeting of research and other outputs to risk-averse and production-oriented systems.

Capacity development will be another key component of CRP 1.1. Experience has shown that relentless capacity building is part of successful dryland systems. The aim of capacity building within CRP 1.1 is to help partners build a cadre of well-trained staff capable of leading change and innovation. Activities will therefore target the partners already described, with particular emphasis on gender and youth, and on capacities that are needed to achieve impact. Activities will include short- and medium-term training, training of graduate students, targeted workshops, farmer field schools, distance learning, and more.

The estimated total budget for the first three years of the CRP1.1 is US$ 122.725 million, starting with US$ 37.42 million in 2013 and climbing to US$ 44.5 million by 2015. The resources sought are the minimum needed for implementing this CGIAR Research Program under the CRP1 Theme on systems research, which “embodies the essence of the CGIAR reform and presents the newest and most challenging design issues.”

Because the Dryland Systems CRP’s approach to developing agricultural systems in complex and marginal production environments is novel, it will require interdisciplinary skills that have not traditionally been part of the training of agricultural scientists. Building this skill set within CRP 1.1 will likely require reaching out to new partners. For example, at the RIWs, most international and national scientists were quite comfortable proposing SRT2 and SRT3 hypotheses, outputs, and activities, but much less so when discussing SRT4 and especially SRT1.

The Dryland Systems CRP must evolve over time through an informed learning process towards the new vision of the CGIAR system, and this must be done within the larger context of CRP mandates while expanding stakeholder commitment to (and investment in) this shared vision.

This latest version of the proposal presents a transformation process in which the partners establish an agenda for action as a basis for knowledge-based development. It will serve to establish a research and development portfolio that pursues a common vision and will guide the CGIAR Centers in the activities that they will pursue in the future.

CRP1.1 Dryland Systems

Integrated Agricultural Production Systems for Improved Food Security and Livelihoods in Dry Areas

1. Justification and rationale

CRP 1.1, or "Dryland Systems," targets the poor and highly vulnerable populations farming the dry areas (Figure 1) in developing countries. It will develop technology, policy, and institutional innovations to improve livelihoods using an integrated systems approach that includes socioeconomic and biophysical components. CRP 1.1 was developed from Thematic Area 1: Integrated Agricultural Systems for the Poor and Vulnerable described in the SRF (CGIAR, 2011), which defines the target regions as "systems characterized by major constraints, such as drought or other agroclimatic challenges, poor infrastructure and underdeveloped markets, or weak institutions and governance."

Agricultural systems found in dry areas comprise a diverse and complex mix of pastoral, agropastoral, mixed rainfed and irrigated production systems. Figure 2 shows the population density in arid, semi-arid and dry subhumid areas. Currently about 800 million poor and vulnerable people depend on dryland agricultural systems for their food security and livelihoods. Population growth rates in the dry areas are among the highest in the world, and population distributions are heavily skewed towards the young. Dry areas also have very high rates of urbanization and the world's highest unemployment rate. A critical challenge for agriculture over the next 25 to 50 years is to increase food security and livelihoods of the poor and vulnerable rural populations in dry areas, who to date have not benefited significantly from agricultural research.

As with any agricultural system, dryland systems consist of a combination of plant and animal species and management practices selected by farmers and pastoralists to pursue livelihood goals that are based on several factors, including climate, soils, markets, capital, and tradition. About two-thirds of the land under dryland systems consists of rangeland. Individual farms are typically smallholdings of only a few hectares. Especially on smallholdings, dryland production systems are often based on complex combinations of crops, vegetables, livestock, rangelands, trees, fish, and other commodities that are adapted to the prevailing climatic conditions. Dryland agricultural systems have been developed over centuries and adapted by farmers to their limited resources and the variable climate. However, increasing pressure on natural resources and trends in climate change are leading to greater water scarcity and degradation of land, water, and vegetation. Dryland systems in developing countries are already over-stretched. Better management of risk and sustainably enhancing productivity are critical to ensure future livelihoods of rural communities.

Key biophysical constraints in dryland systems include natural resource limitations, particularly water scarcity, and land degradation. Water scarcity may be caused by low overall precipitation or distinct wet and dry seasons that result in moisture deficits for part of the year. Most dry areas suffer periodic drought within seasons and prolonged drought for an entire season or even consecutive seasons. Rainfall insufficiency and variability are expected to be amplified by climate change. Collection, storage, and efficient management of rainwater are therefore imperative.

There are also formidable socioeconomic constraints in the dry areas, with small-scale farmers often lacking political power, access to finance and markets, and supportive institutions and policies. Furthermore, much of the population in the dry areas is marginalized through various forms of social inequity, including gender discrimination and youth disenfranchisement.

Small-scale dryland farmers use a combination of natural, human, social, financial, and physical resources to pursue a set of socioeconomic and biophysical production and livelihood goals as part of a larger agricultural system. The interaction of the socioeconomic and biophysical components within the larger system and their role in the adoption of new technologies are complex and not well understood (Pretty and Ward, 2001). CRP 1.1 will use an integrated systems approach to better understand such interactions and identify the most suitable technological, institutional, and policy interventions. Interventions will also be monitored and evaluated from an integrated systems perspective.

The current goals of the Dryland Systems program are to improve the lives of 87 million people in dryland areas of the world, and to mitigate land degradation in over 1 million square kilometers of drylands. It will do so by sustainably increasing productivity by 10–20% in the most marginal and vulnerable dryland systems and by 20–30% in systems with the potential for intensification, while simultaneously increasing technology adoption rates through the use of partnerships involving innovation platforms—coalitions of actors (mostly informal), that promote and identify the knowledge needs of target groups and test various options to address these needs.

1.1 Drylands systems in the developing world

The major dryland systems of Africa, Asia and Latin America are listed in Table 1, along with numbers of poor in each system and the potential drought impact index (PDII), which indicates the scale of impact of crop failure as a result of drought. The greatest number of world's poor are found in mixed rainfed systems (260 million, mainly in Asia, Africa and the Andes), followed by irrigated arid and semi-arid systems (218 million, of whom 194 million are in the Indo-Gangetic Plains), and lastly pastoral or agropastoral systems (45 million, mostly in North Africa, West and Central Asia). Many of these areas are characterized by variable precipitation and temperatures, economic and physical water scarcity, low soil fertility, severe land degradation, and loss of biodiversity. They also face several important socioeconomic constraints, including weak institutions, poor policy environment, and lack of investment. Natural resources, and especially common property resources such as grazing lands, water resources, and trees, are essential to livelihoods and sometimes even survival in these areas. There are substantial technical and institutional barriers to sustainable management and use of these systems.

Drylands are generally economically and politically marginalized. National and international investment strategies tend to favor high potential or densely populated areas, despite evidence that the highest returns to investment in infrastructure are in less favored lands (Fan and Hazell, 2001). Many smallholder systems in dry areas have poor access to markets, inputs such as improved seeds and seedlings, fertilizers, livestock and fish breeds, and animal health services, and information on alternative production technologies. Gender differences in access to inputs, rural services, information, and technologies have been widely documented (World Bank et al., 2009). Improved market access and community institutional arrangements can be key to effective management of environmental risk.

Non-farm or off-farm income is also an important contributor to livelihoods of rural populations in dry areas, and may be the only source of income for landless, asset-less rural families. Smallholders—especially women—need to be empowered to take part in the development of livelihood strategies that cope with economic and environmental shocks, increase the value of their assets, and create new income opportunities. In most of the dry areas, society misses out on the huge contribution women could make in the development process. Women contribute substantially to farm labor and, with increasing migration of men, are often the de facto heads of the household. They are nonetheless frequently overlooked in decision-making processes, involved in only limited roles along the value chain, and insufficiently consulted during the design and implementation of policies, even in development programs.

Figure 1. The world's dry areas.

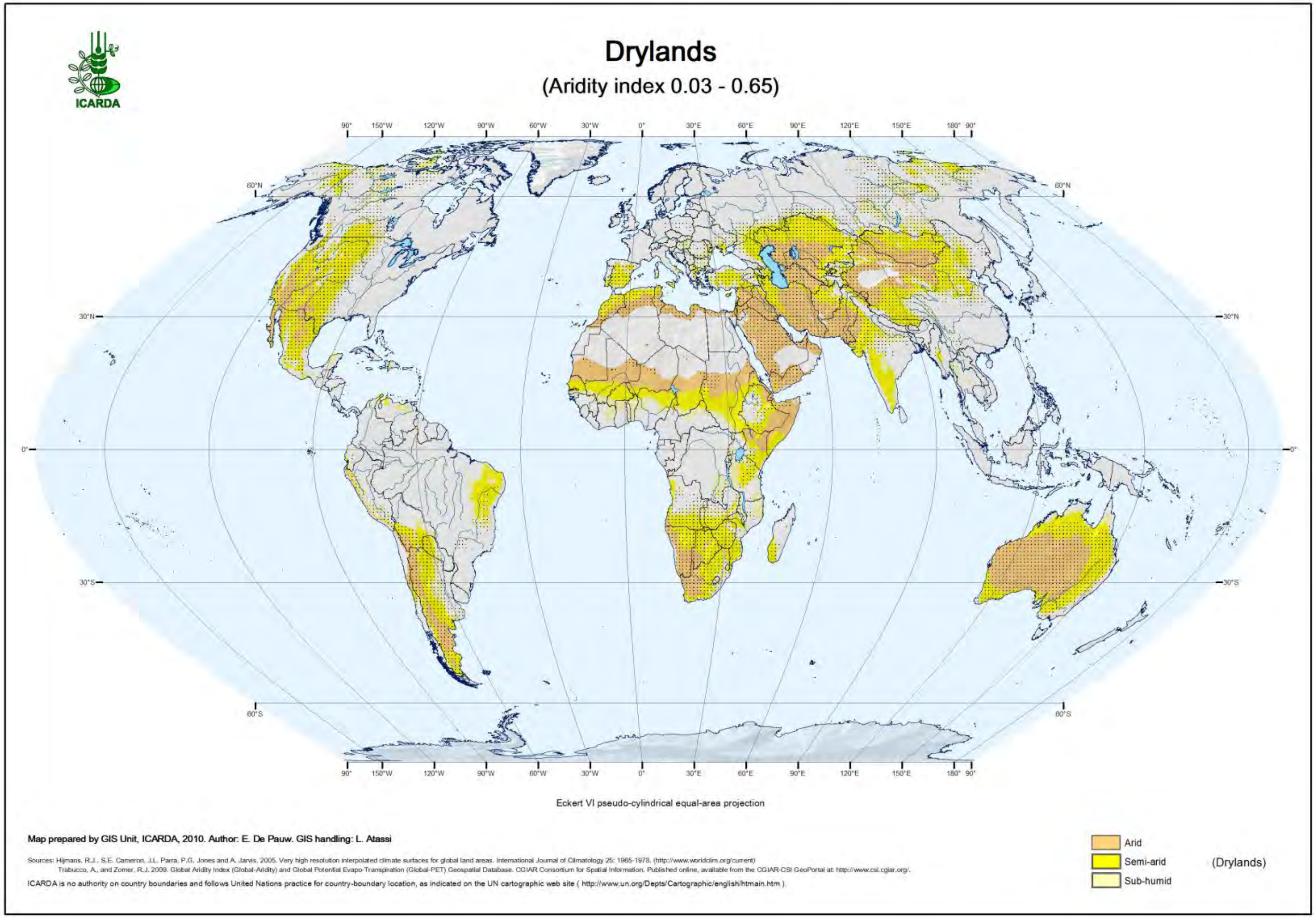


Figure 2. Population densities (persons per km²) in arid, semi-arid, and subhumid areas.

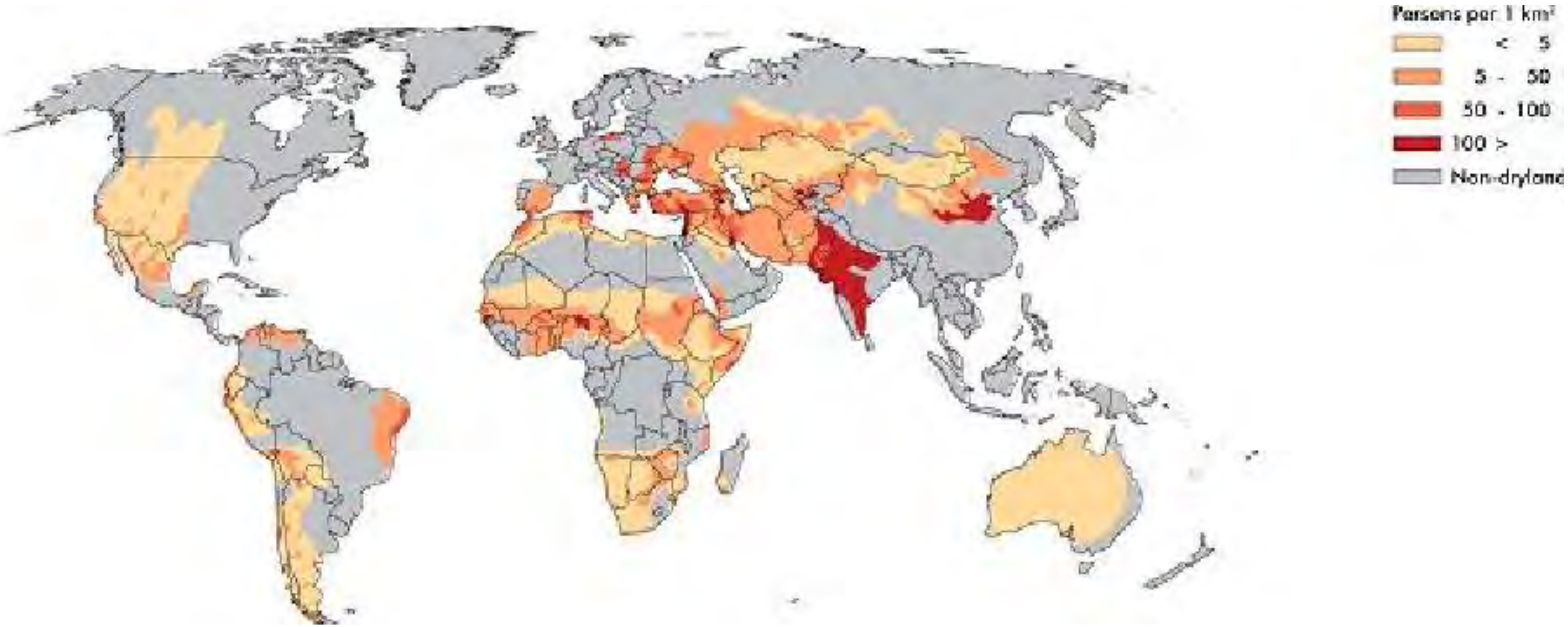


Table 1. Dryland farming systems, population, poverty and drought.

Area/ System	Total population (millions)	No. of poor (millions)	Drought probability[a]	PDII x 1000[b]	Main crops and trees	Main livestock	Example
Asia							
Mixed irrigated arid/semi-arid	716	194	0.35	4050	Rice, wheat, pulses, sugarcane, potato, mustard, vegetables, sunflower, sorghum, millet, tree fodder in dry periods	Buffalo, cattle, small ruminants, camels, chickens, pigs	India: Indo-Gangetic Plain, Krishna river basin. Pakistan: Indo-Gangetic Plain, Punjab
Rainfed mixed	357 E. Asia 9.9, S. Asia 106.5	107	0.17	8176	Rice, wheat, millet, sorghum, chickpea, bean, groundnut, brassicas, linseed, vegetables, maize, tree fodder throughout the year	Cattle, buffalo, small ruminants, chickens	India: parts of Madhya Pradesh, Uttar Pradesh, Orissa, Jharkhand, Bihar, and West Bengal Bangladesh: Barind tract
Dry rainfed	46	3.6	0.32	1446	Sorghum, millets, chickpea, groundnut, bean, vegetables, trees for fodder and fuel	Cattle, buffalo, small ruminants	India: Deccan plateau (Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Karnataka)
Agropastoral	23 S. Asia 18.6. S.E. Asia and islands of E. Indonesia: 8.5	S. Asia 6.9, E. Indonesia 2.5			Rangeland, millets, firewood, tree fodder	Camels, small ruminants, horses, pigs	India: Rajasthan and parts of Haryana SE Asia: Eastern Islands of Indonesia (East and West Nusa Tenggara)
Africa							
Mixed irrigated arid/semi-arid	4	1.8				Cattle, chickens, small ruminants, pigs	Parts of ESA
Agropastoral	55	ESA[c] 15.6, WCA[d] 4.8	0.53	2633	Millet, sorghum, pulses, groundnut, maize, trees for fuel, fodder, shade, fruits, and medicinals *19% of land area*	Cattle, small ruminants *15 million livestock*	ESA: N. Kenya, N.W. Uganda, Sudan, N. and C. Tanzania WCA: Sahel countries, northern parts of Nigeria, Cameroon, Ghana, Côte d'Ivoire
Pastoral	100	3.2			Rangeland species, fodder trees and shrubs *40% of land area*	Camels, cattle, small ruminants	Botswana, Namibia, S.W. South Africa ranching
Rainfed mixed	157	ESA 75.8, WCA 35.6	0.17	5331	Wheat (Ethiopia and Eritrea), sorghum, millet, pulses (cowpea, chickpea, lentil, faba bean), maize, groundnut, cassava, trees *16% of land area*	Cattle, small ruminants, chickens	WCA: Sahel/Sudan savannas ESA: large parts of Ethiopia, Eritrea, Kenya, Tanzania, S Zimbabwe, Zambia, N South Africa

Area/ System	Total population (millions)	No. of poor (millions)	Drought probability[a]	PDII x 1000[b]	Main crops and trees	Main livestock	Example
West Asia, North Africa, Central Asia and Caucasus							
Mixed irrigated arid/semi arid	99	24.0			Wheat, alfalfa and fodder-legume crops, chickpea, faba bean, bean, potato, lentil, vegetables, grape, pomegranate, citrus	Cattle, poultry, small ruminants	Tunisia, Algeria, Egypt (Nile delta), Iraq, Iran, Central Asia and Caucasus
Sparse arid/agropastoral	35	8.3			Barley, rangeland species	Small ruminants, camels	Syria, Jordan
Rainfed mixed	39	22.6	0.09	592	Durum wheat, bread wheat, barley, potato (highlands)	Small ruminants	Tunisia, Algeria, Morocco, Syria, Turkey, Iraq, Iran, Central Asia and Caucasus
Dryland mixed	47	0.8	0.19	413	Figs, date palm, prickly pear	Small ruminants, camels	Tunisia, Algeria, Morocco, Syria, Iraq, Oman, Central Asia and Caucasus
Small-scale cereal/livestock	20	0.4	0.03	205			Pakistan
Latin America							
Agropastoral	15	6.7				Cattle, small ruminants, camelids	N.E. Brazil; Yucatan in Mexico, Patagonia in Argentina
Rainfed mixed	39	15.1			Potato, quinoa, faba bean, lupin, Andean roots and tubers	Cattle, sheep, guinea pigs, camelids	Peruvian and Bolivian high plateau (Altiplano)

[a] Drought probability based on length of growing season/stress index using 100 years' data.
[b] Potential drought impact index (PDII) index from cropped area x drought probability.
[c] East and Southern Africa
[d] West and Central Africa.

Source: Adapted from Hyman et al. (2008) and other sources.

The dry areas encompass several globally important centers of origin and diversity for crops, vegetables, livestock, trees, and fish. Most traditional farming systems maintain local agrobiodiversity in the forms of crop landraces, local animal breeds, pastoral flora, and other native and wild species. However, biodiversity and related local knowledge in dry areas are threatened by land degradation and pressure on natural habitats, despite the opportunities that more-effective use of biodiversity's functional contributions could offer. Making more-effective use of agrobiodiversity offers opportunities for reducing vulnerability of those dependent on dryland systems and enabling system intensification while contributing to maintaining the natural resource base, of which agrobiodiversity is an important component. The same genetic resources can also provide plant breeders with the traits needed to adapt crops to heterogeneous and changing environments (Fowler and Hodgkin, 2004). With proper incentives to farmers and other users, drylands could also increase their contribution of ecosystem services. For example, payment for environmental services (PES), which has been practiced for decades in dryland systems of developed countries, is increasingly used in developing countries to enhance biodiversity and wildlife conservation and for watershed preservation. The vast dryland rangeland areas could potentially contribute to climate-change mitigation through carbon sequestration. But enhancing these ecosystem services requires improved knowledge and management of ecological systems that draws on both indigenous knowledge and modern science.

Although diverse, systems in dry areas differ from those in many other regions in facing higher levels of endemic risk. Many traditional production systems are finely adapted to historical agroecological conditions. Indeed, an important feature of these systems is that they are "local" in character, using indigenous knowledge, traditional cultivars, and natural-resource management (NRM) practices that are compatible with wider social and ecological systems. Some are largely closed systems, i.e. with little external input or influence. However, these systems have been increasingly exposed to increased demographic pressure, modern development, and integration into national and global economies. There are expectations that many dryland systems will increase food production in a more sustainable way, improve food and nutritional security, and increase agroecosystem resilience. Sub-Saharan Africa, South Asia, West Asia, North Africa and Central Asia in particular have large productivity gaps, where relatively quick wins have for decades been theoretically possible (Quiroz et al., 2003; Peterson et al., 2006; Cooper et al., 2009; Wani et al., 2009a).

Dryland systems often contain relatively small high-potential areas that can play a key role in the functioning of the entire system. Developing and managing the potential of these areas may have significant implications for the overall system. Increases in vulnerability are often driven by the fact that the management of high-potential areas has been decoupled from the broader system. One goal of this CRP is to create more of these high-potential areas while ensuring that they are better integrated into the broader system context. It will, for example, identify specific niches in the food chain that have been overlooked in the past because of their informal role in the food system and apparently low productivity and potential. These include minor or "orphan" crops or products that have fulfilled specific nutritional or cultural roles; post-harvest processing; informal marketing; and seed exchange. Women are involved in a range of such activities, which are essential to ensuring stability of food security and nutrition in households and communities (Jiggins, 2011).

1.2 Addressing the constraints facing dryland agricultural systems

Address the many constraints facing the dry areas requires innovative approaches that bring together all stakeholders, including local communities, to develop technologies, resource management strategies and policies, and institutional arrangements that build resilience into dryland systems in the face of water scarcity, climate change, and numerous other constraints. Agricultural development in these marginal environments must take into account their dynamic nature and complex scale dependencies. The development process must be driven by technical and institutional innovations that address hunger and poverty, but these innovations must respond and adapt to external and internal changes through rapid feed-forward and feedback mechanisms. This adaptive and dynamic approach is best pursued through appropriate partnerships that provide feed-forward and feedback mechanisms. The development process will also need a suite of socioeconomic and biophysical models that function at different scales to guide and inform learning and development, and to generate the information, communication, and knowledge transfer needed to up- and outscale innovations.

Thus, the aim of this CRP is to trigger sustainable agricultural development in the drylands. It will identify and address the key constraints to increased productivity, stability, and sustainability at technical, social, and institutional levels. On the technical level, it will aim at reducing demand for water per unit crop area, improving water capture and storage, increasing productivity per unit of water at farm and landscape levels, and changing land-use practices to better manage risk and sustainably enhance production and income. On the social level, it will enhance the capacity of communities, including marginalized sectors, to address constraints and respond to opportunities. At the institutional level, it will strengthen policies that empower small-scale farmers, provide them with better access to markets, and reduce their vulnerability.

To do so will require a non-traditional, iterative approach with strong involvement of stakeholders. In CRP 1.1, the process started with stakeholder consultation that culminated during the inception phase of the program with five stakeholder regional inception workshops (RIWs) corresponding to five targeted regions (see the Inception Phase Report). Participants in the RIWs included representatives of international and regional research institutions, extension services, the private sector, non-governmental organizations (NGOs), and farmer groups. As a first approximation, the RIWs followed the impact pathway "backwards." The participants first agreed what development outcomes were needed. Then, stakeholder teams defined what outputs (if adopted) would likely produce the desired outcomes. Finally, they suggested what research activities would lead to these outputs. This iterative approach will require additional cycles that maintain stakeholder involvement through the formation of innovation platforms to provide feedback. The hypothesis is that such an approach will produced appropriate, effective, demand-driven, and results-oriented research for development, which should result in greater adoption and impact of research outputs. Monitoring and evaluation will be integral to the iterative process as a means of informing stakeholders, including innovation platforms and donors, of overall progress along the impact pathway.

1.3 Social equity

The changes in policy, institutions, and technology must impact women and other socially disadvantaged groups, including youth, in order to deliver socially equitable development. Most published definitions of sustainability include social equity as an essential component (Payne et al., 2001). Without social equity, research impacts will be limited, and sustainability will not be achieved.

Social inequity can be the result of such factors as age, race, gender, ethnicity, and social status. Marginalized individuals and groups can be at a disadvantage in terms of restricted access to and control of productive resources and information, and limited capability to voice their needs and constraints, participate in decision-making, and benefit from new opportunities. Social inequities can reduce the effectiveness of development interventions, including how benefits are shared among stakeholders. Addressing the needs of marginalized groups and individuals therefore serves two purposes: (i) it increases the effectiveness of development interventions, and (ii) it ensures that R&D projects reduce rather than increase the social inequity.

Gender is one of the most common factors in inequity and intersects other socioeconomic factors that create differences between individuals. Although women play active roles as traders, processors, laborers, and entrepreneurs, they still face many more obstacles than their male counterparts in market access and decision-making. CRP 1.1 will address these issues. Various aspects of gender diversity will be emphasized, including participation of both women and men in research and in evaluation of technology and other interventions, which will be considered from various perspectives, preferences, and knowledge bases. Development of innovations will explicitly address the specific needs of rural women by ensuring that women participate in and contribute to generation and sharing of local knowledge and the development process. CRP 1.1 will also include capacity strengthening activities to empower women.

Throughout the developing world, but especially in drylands, young people are marginalized as a result of several megatrends: (i) youth-skewed population distribution; (ii) rural–urban migration and urbanization; (iii) disproportionately high unemployment and inadequate livelihood skills; and (iv) disempowerment with regard to decision-making and access to financial resources. These trends are ominous because they can lead to broader problems such as civil unrest, political stability, and conflict on local and regional scales. There are numerous recent incidents in the dry areas in which disenfranchised youth have expressed their frustration through civil unrest and violence. Despite the prevalence of these trends in developing countries and the unrest and instability that they portend, youth is seldom mentioned or stressed among the new CGIAR priorities. CRP 1.1 will address these trends as a priority through targeted research and capacity building that will focus specifically on rural youth. The approach will be analogous to that of the U.S. land grant university system, and will include training youth in farming skills that require technology use, and development of skills that lead to employment or business development. The overall goals are to: a) retain youth in rural communities to contribute to community vibrancy and to stem urbanization, and b) teach technical and financial skills that can be used to enhance rural economies.

There are obvious links among social inequities, e.g. those due to gender and youth. Roughly half of youth are women, who will have major responsibility for raising children. Unemployment among young men in particular is associated with migration, crime, and civil unrest. In CRP 1.1, socioeconomic analysis will disaggregate innovation impact on such vulnerable groups as part of *ex ante* impact assessment as well as monitoring and evaluation.

1.4 The need for a systems approach in dryland agriculture

Despite the inherent complexity of dryland systems, historically many research efforts have focused on single commodities or management practices rather than the system as a whole. This research approach has produced spectacular successes in high production environments (Hardin, 2006), although with some notable undesirable side effects (Payne and Ryan, 2006). It has, however, been less successful in marginal environments, and in dryland systems in particular (Runge, 2006). Moreover, agricultural systems today are being judged more and more by criteria other than yield per hectare, particularly within the context of broader public or ecosystem services to communities (Hubert et al., in press). Agricultural systems, after all, involve people—farmers and other members of the community—who seek to learn and apply new technologies and improved management practices to improve their lives (Giller et al., 2006; Pretty et al., 2006; López-Ridaura et al., 2007; Twomlow et al., 2008). Ultimately, the aim of sustainable development is to improve their ability to learn and make decisions based on adequately contextualized knowledge, with a view towards their leading better lives.

The specific combination of plant and animal species and management practices that farmers select to pursue their livelihood goals is based on several factors, including climate, soils, markets, capital, and tradition. Biophysical research has often tended to focus on specific production constraints without sufficiently taking into account social, economic, and institutional factors that drive the decisions of farmers, pastoralists, and other rural community members, and in particular whether they will adopt recommended technologies. Broad diagnostic assessments on underlying causes of unsustainable land management practices (Binswanger et al., 1987) have pointed to several socioeconomic factors including:

- property rights, including land and tree tenure and access to common property, and collective action in sedentary and pastoral systems (Wade, 1987; Ostrom, 1990; Place and Hazell, 1993; Behnke, 1995; Baland and Platteau, 1996; Platteau, 1996; Agrawal, 2001; Otsuka and Place, 2001; Deininger 2003);
- encroachment by external interests (Lane, 1998);
- population pressure and poverty (Tiffen et al., 1994; Grepperud, 1996; Templeton and Scherr, 1999; Pender et al., 2001);
- drought as a driver and trigger of desertification (Dregne, 2000);
- access to markets and infrastructure (Binswanger and McIntire, 1987; Pender et al., 2006);
- lack of economic returns to promoted practices (Cramb et al., 2000; Shiferaw and Holden 1998, 2001; Pender et al., 2006);
- ineffective extension approaches (Gautam and Anderson, 1999; Pender and Gebremedhin, 2006);
- market imperfections (Clay et al., 1998; Pender and Kerr, 1998; Holden et al., 1998, 2001);
- lack of social capital (Krishna, 2002); and
- the presence of irreversible thresholds (Antle et al., 2006).

Although the quality of much of this biophysical research was excellent, its disciplinary or topical isolation (among a great many other things) often rendered subsequent technological interventions ineffective, if indeed interventions were attempted at all. On the other hand, socioeconomic research outputs are often promoted by those with little real understanding of biophysical sciences or the technical aspects of farming. This may result in advocating biophysically unsound interventions that do not recognize or have little relevance to the practical challenges that farmers face. In general, research outputs produced without stakeholder support and involvement are seldom sufficient to influence policy or larger-scale development programs (Bauer and Stringer, 2008).

A major research disconnect still exists between the biophysical and socioeconomic domains. Even when research is conducted at the farm level, it is often done in disciplinary isolation. For example, outputs from crop improvement research may be applied in isolation, and not integrated with those from NRM, and without an understanding of wider system interactions. Likewise, crop/livestock interactions cannot be understood without studying food/feed considerations across the entire system. The situation can lead to technologies being pushed without understanding their role in the sociopolitical context, or within the biophysical context. There is a pressing need for research methods that can interrelate various system components and disciplines, and at a level of integration that reflects the reality of agricultural systems, which have both socioeconomic and biophysical aspects. The Millennium Ecosystem Assessment concluded in its Desertification Synthesis (MEA, 2005: p. 19) that "understanding the impacts of desertification on human well-being requires that we improve our knowledge of the interactions between socioeconomic factors and ecosystem conditions." There is growing recognition of the need for a new "science of complex systems" to better handle such integration challenges. In this regard the CRP will also build on lessons learned, for example, in the CGIAR Rice-Wheat Consortium (RWC, 2006).

A systems approach is a holistic way of addressing a complex and interactive set of problems within a set of boundary conditions. It aims to identify, quantify, and integrate the factors and processes that shape and constrain farming systems and their interactions (Lockeretz and Boehncke, 2000; Roetter et al., 2000). By doing so, it helps identify researchable issues, clarify relations, and generate testable hypotheses.

CRP 1.1 intends to use a systems approach to move dryland development science towards a concise set of principles that can help analyze causal patterns under diverse conditions, at a range of scales, and in various locations. This approach is consistent with the "Dryland Development Paradigm" advocated by Reynolds et al. (2007). The CRP 1.1 approach is based upon a conceptual framework designed to lead to the four CGIAR system level outcomes (SLOs) in the developing world:

1) Reducing rural poverty: Higher and more stable incomes; improved security of individual and household assets;
2) Improving food security : Improved crop and livestock productivity; variability in dryland farming systems productivity reduced in target systems
3) Improving nutrition and health: Improved nutrition, especially among women of child-bearing age and children
4) Sustainable management of natural resources: Productive quality of environmental resources improved and maintained; environmental degradation reduced

The relative importance of the SLOs will differ between agroecosystems.

Unlocking the potential of drylands will not be easy. Dryland systems are complex, with multiple, mutually-reinforcing or counteracting biophysical, economic, and social constraints. They have generally not been reached effectively by previous agricultural research and development (R&D) efforts for several reasons. To have impact in dry agroecosystems, research must not only generate new knowledge, but also catalyze innovation, investment, and changes in policy and institutions (including safety nets) that can make the adoption of new policies, interventions, technologies, and livelihood strategies feasible, attractive, and sustainable.

2. The systems approach and categorization of dryland systems

2.1 The systems approach

CRP 1.1 aims to identify and alleviate the constraints to productivity growth and the conditions that degrade the natural resource base and perpetuate poverty and vulnerability. Research on constraint alleviation (both within and from outside CRP 1.1) and on processes will be key elements of the program. But these have to be put into the wider context of R4D pathways. Needs include innovative technologies, economic incentives, and institutional approaches that will enhance the resilience of smallholder farmers, livestock keepers, tree growers, fishers, and rural communities to a range of external change drivers. The basic approach will be to work with end-users and beneficiaries to test a range of interventions, technologies, and research methods, using innovation platforms that also involve partners from the research, policy, development and civil-society sectors. Boxes 1–5 below give a few examples of how this integrated systems approach has been applied in specific scenarios.

1. Integrated research sites for sustainable agroecosystems: improving productivity and the sustainable use of water and land in the Middle East

The productivity and sustainability of production systems in dry areas are severely limited by water scarcity and land degradation. Both factors are being addressed by a regional project organized around integrated research benchmark sites in farmers´ fields. The project, implemented jointly with national research programs in ten countries, aims to help increase water productivity in irrigated systems, rainfed systems, and dry rangelands.

The project has established benchmark research sites in each agroecosystem, together with complementary "'satellite" sites in multiple countries. Research at these sites is conducted at the community level using participatory approaches. Water- and land-management technologies are integrated with appropriate cropping patterns, taking into account socioeconomic and policy issues relevant to the specific community and agroecosystem. This helps ensure that resources, inputs, and management are in synchrony, thereby helping to create more productive, sustainable, and diverse farming systems.

The project has developed "'packages" combining multiple technologies, such as rainwater harvesting, supplemental irrigation, optimized planting date/method, and improved irrigation scheduling together with supportive policies. For example, in Egypt the package included deficit irrigation (rather than traditional full irrigation), raised-bed planting, new wheat varieties, and integrated soil and water management methods. This has led to a 30% saving of irrigation water, lower fertilizer costs, and better control of salinity, weeds, pests, and diseases. Water productivity and farmers' income increased by 25% and 32%, respectively, in the project target areas. The package has been endorsed by the Egyptian Government, widely disseminated, and adopted by three development projects and more than 1000 farmers. It has also been recommended by the Ministry of Agriculture for implementation in a new project that will cover 40,000 hectares.

The use of integrated, context-specific packages of interventions that were developed in partnership with stakeholders and beneficiaries increases intuitive appeal to the users, resulting in greater adoption of the entire package and its synergies rather than individual components. Project results are being used by both scientists and policy-makers to improve water productivity and ecosystem resilience in target areas.

2. Index-based livestock insurance: reducing risk and vulnerability in pastoral dryland systems in Africa

Simple and highly innovative financial instruments are helping to protect small-scale livestock producers in Kenya from climate-related asset losses such as animal deaths caused by drought.

Index-based livestock insurance (IBLI) involves actuarial analyses of risk and economic and climate data. The underlying concept is that policy-holders (livestock owners) are compensated based on a clear, measurable outcome that neither insurer nor policy-holder can influence, such as amount and distribution of rainfall. It is therefore easier to administer and more cost-effective to develop than many other livelihood interventions aimed at supporting livelihoods or reducing risk. Several pilot programs in India and various countries in Africa and Latin America have proven the feasibility and affordability of such index-based products.

IBLI benefits livestock keepers in three ways. First, it can stabilize asset accumulation and enhance economic growth. Insurance addressed the high risk of investment in dry environments, improving incentives for households to build their asset base and climb out of poverty. Second, it can increase the availability of finance for investment more generally. For example, private creditors might be more willing to lend to households who insure their livestock assets. Third, because it provides indemnity payments after a shock, IBLI can help prevent vulnerable but currently non-poor households from falling into poverty following a crisis such as drought.

Following detailed field work and stakeholder consultation, an IBLI contract has been modeled, priced, and sold to the public on a pilot basis in Kenya's drought-prone Marsabit District in January 2010. Nearly 2000 contracts have been sold to poor pastoral households. Contracts are based on livestock mortality, which is modeled using an empirical relationship between mortality and the Normalized Difference Vegetation Index (NDVI) as a proxy for plant biomass and forage availability. Currently, monitoring and evaluation of the impact that IBLI has had on herders' livelihoods and livestock-management decisions, in particular on changes in herd size, is ongoing.

3. Integrated crop–agroforestry–livestock systems in North Africa

Crop–livestock systems in Morocco and Tunisia face problems caused by low rainfall, soil erosion, and declining soil fertility: severe shortages of livestock feed and poor crop productivity. An in-depth analysis with stakeholders identified alley-cropping of fodder shrubs (salt-bush and cactus) in barley-based systems as a potential solution to both problems. National and international research centers worked together to develop and promote alley-cropping technologies, and conducted adoption and impact studies that provide lessons for future efforts.

Salt-bush (*Atriplex* sp.) and spineless cactus (*Opuntia* sp.) alley-cropped between rows of barley provide a reliable supply of fodder, reduce erosion and rainfall run-off, and increase soil-moisture retention. The technology, once developed and proven, was outscaled by the International Fund for Agricultural Development (IFAD) within their development projects. Impact assessments, conducted through case studies show:

- 26% of farm area alley-cropped with salt-bush in target areas in Morocco
- 40% adoption of cactus alley-cropping in target areas in Tunisia
- Farmers were able to reduce purchases of feed concentrates by up to 72%
- Internal rate of return was 50–90% in Morocco (salt-bush) and 20–40% in Tunisia (cactus)
- Economic rate of return, after factoring in cost of subsidies and other government support, was 25–48% in Morocco and 7–15% in Tunisia.

The studies highlighted several issues relevant to policy-makers, including:

- Adoption depends on multiple factors including productivity, income and subsidies.
- Subsidies are important in encouraging adoption, especially for the resource-poor. Small-scale livestock keepers could not have adopted this technology without subsidies, as they have to remove animals from the field until the alley-crop is established.
- Benefits from a technology may be direct and immediate (e.g. increased household income), or indirect and long-term (e.g. reduced soil erosion).
- Poor producers will adopt a technology only if it provides direct, immediate benefits. In such situations there is a strong economic justification for providing subsidies or other incentives to encourage adoption and realize the substantial indirect or long-term benefits and for creating safety nets to manage risk.

4. Integrated watershed development in South Asia

The productivity and sustainability of a dryland agroecosystem depend on the quality and reliability of water resources—which in turn depend on the health of its watersheds. Research on watersheds in the 1970s and early 1980s produced a number of technologies for improved soil conservation and fertility management, but adoption of these technologies remained poor. This changed when the producer- and technology-oriented approach was replaced by a community-based, demand-driven approach—integrated watershed programs that address livelihoods, community empowerment, agricultural production, and natural-resource management.

The lessons learned are being successfully applied by policy-makers in Asia. Crucially, introduction of new technologies must be based on incentives. In India, higher groundwater levels have proved to be sufficient incentive for small-scale farmers to adopt improved watershed technologies. Other lessons are: (i) interventions are needed that enable specific target groups to diversify production and seek new markets; and (ii) community-based mechanisms should be used to improve resource allocation at various levels, from farm to landscape scale, depending on livelihood or natural-resource-management issues.

Using this approach, technologies that previously had low adoption rates are now being adopted and demand has been created for new technologies. These include new crops and varieties, more efficient irrigation methods, high-value products such as vegetables and milk, improved livestock breeds, and agroforestry techniques. With the new community-based, participatory approach, watersheds have become a growth engine for sustainable development of rainfed agriculture in Asia. Productivity, livelihoods and ecosystem services (e.g. groundwater recharge, reduced runoff and soil loss, improved water quality, increased carbon sequestration) have improved, while maintaining equity. The Government of India has now implemented policies to support integrated watershed management. Some state governments have gone further and put all crop production under watershed programs.

5. Biological control of the pearl millet head miner with NARS leadership and farmer participation

The pearl millet head miner became a major pest in the West African Sahel during the droughts of 1972–1974, and has since remained a threat to food security. Control through pesticides is unrealistic for subsistence farmers for a number of reasons. Furthermore, there are no cultural methods to control the head miner or genetic sources of resistance. Biological control was a possibility, but the required ecological knowledge did not exist in the 1970s. A biological-control program could have been rapidly developed through sustained and coordinated funding using existing knowledge and models from Asia. Instead, it took 25 years to lay the scientific groundwork through occasional bursts of uncoordinated short-term activity in large “development projects” that relied on international scientists funded by large public donors. There was little funding or leadership given to national scientists, who were especially isolated during the funding dearth for international agricultural research during the 1990s and early 2000s. In 2006, however, national scientists working on the head-miner problem were funded by the McKnight Foundation. As a result, an operational control system was quickly developed, tested, and deployed by national program entomologists in Burkina Faso, Niger, and Mali. Researchers trained extensionists, who in turn trained leading farmers, women and men, to rear and, at the proper time and location, release *Habrobracon hebetor*, a small indigenous parasitoid wasp. The release of this wasp effectively eliminates the head miner in granaries and nearby fields. Initial estimates were that *H. hebetor* populations affected head miner larvae within about a 5-km radius of the village of release and increased pearl millet yields by about 40%. As of 2010, it was estimated that the release program had impacted about 200,000 ha, but expansion to 3,000 additional villages was planned for 2012.

The national program scientists received public and governmental acclaim, and demonstrated admirably that, when trusted and adequately supported and empowered, national African researchers can deliver real and effective solutions that are scientifically sound, meet the needs of smallholder farmers, and contribute significantly to improved food security, community resilience, and reduced poverty.

It is difficult to spread technologies, particularly in West Africa, where historically rates of adoption have been low. Nonetheless prospects for out-scaling of this integrated-pest-management technology are fairly good because: (i) it has already started to spread through extension and farmer-to-farmer teaching; (ii) there is a need for the technology in other countries because of the presence of the head miner (and *H. hebator*); (iii) after decades of neglect, there seems to be a renaissance of donor support for agricultural research; and (iv) the national scientists have designed the project with a participatory and inclusive approach that includes international partnerships and community training at many levels, thereby developing the capacity to out-scale through community involvement rather than solely through external scientific and financial support. However, there remains a large need to out-scale the technology and approach to other countries in West, North, East, and southern Africa, where rural communities’ food security and livelihoods are threatened by the pearl millet head miner.

This integrated systems research approach is a reflection of the integration envisioned for all CGIAR CRPs, based on comparative advantages and complementarities among CGIAR Centers and other partners. It has a clear strategic focus, and builds on earlier CGIAR successes and current Centers’ mandates and programs. The CGIAR Centers have a role not only in research, but also as knowledge and partnership brokers, providing information and tools for decision-making, for information sharing, and for experimentation and joint learning among partners. CRP 1.1 will provide a process and learning framework within which all CRPs can contribute to equitably increase food security, reduce poverty, and enhance the sustainable use of environmental resources, while generating lessons for the broader R&D community.

In many dryland agroecosystems, e.g. those of sub-Saharan and North Africa, West, Central and South Asia, and the dry Andes, poverty and food insecurity remain endemic. Nonetheless, yield gap and other analyses suggest that there are also opportunities to increase food production and income in these dryland systems (Peterson et al., 2006; Cooper et al., 2009). A working hypothesis of CRP 1.1 is that research efforts have not had sufficient impact in these dryland systems because they have tended to focus on a limited set of commodities or management practices rather than integrated systems, that they were not done at sufficient scale, or that they failed to breach the historical disconnect between the biophysical and socioeconomic sciences. As such, research results have had relatively little meaning to farmers, communities, and policy-makers, who must operate routinely in complex systems that include both socioeconomic and biophysical variables, and at various temporal and spatial scales.

2.2 Categorization of dryland production systems in CRP1.1

In each targeted agroecosystem, CRP1.1 partners will develop a research portfolio based on a number of promising land-use, crop, vegetable, livestock, tree, and fish combinations, taking into account the specific contextual challenges that must be addressed in terms of natural resources, markets, policies, institutions, and social inequities.

Production systems have been classified into **two broad categories**: (i) those with the **deepest endemic poverty and most-vulnerable people**; and (ii) those with the **greatest potential to contribute to food security and grow out of poverty** in the short to medium term. The categories are admittedly somewhat arbitrary, and simplify inherent complexities and continuities within dryland systems. As with any classification of complex systems, e.g. climate or soils, it is difficult to devise rational categories, but one must nonetheless do so to provide a concise description that captures the truly active factors (Thornthwaite and Hare, 1955). The basis for this distinction between dryland systems is that the two will require somewhat different approaches, or “mixes” of technologies, institutions, and policies. The categories are also consistent with the CGIAR SRF, and allow us to identify **two basic but complementary approaches** to improving dryland systems:

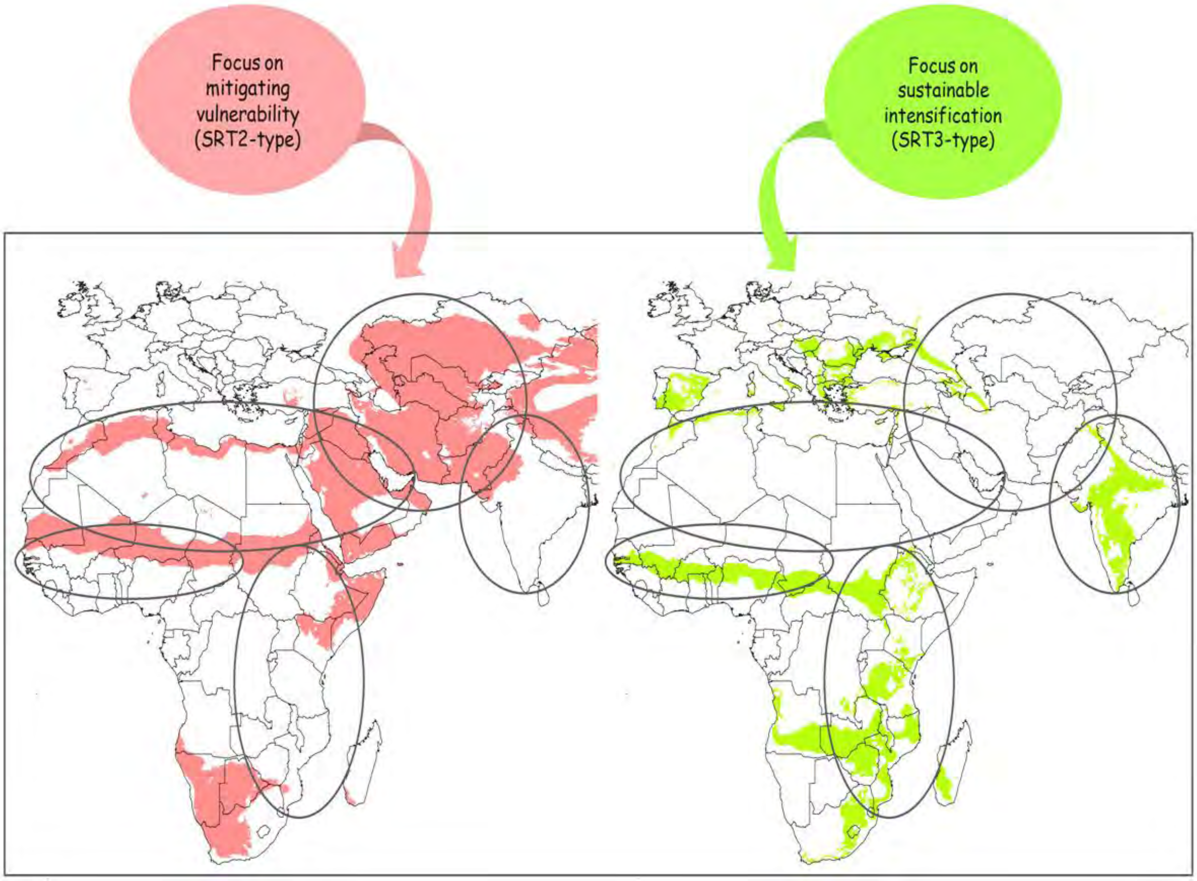
1) **Increasing resilience** and mitigating risk from biophysical and socioeconomic shocks despite marginal conditions
2) **Sustainable intensification** of production systems where possible to improve livelihoods.

Furthermore, the two categories are consistent with those used in other CRPs and allow more targeted direct links to other CRPs. For example, crop ideotypes from CRP 3 targeted to the first dryland system category might be selected for traits that reduce risk and increase stability, such as earliness, asynchronous tillering, and adaptation to low fertility, whereas those targeted to the second might be selected for high yield potential and input response, and uniform maturity to facilitate mechanized harvesting.

We recognize that the two systems are not mutually exclusive and that many dryland agricultural systems will contain areas or elements of both.

These two dryland system will be addressed, in each target region, through specific Strategic Research Themes (SRTs), SRT2 and SRT3 (see Section 5) and, therefore, for convenience, are referred to as SRT2- and SRT3-type systems. The extent of the respective systems is shown in Figure 3, and general descriptions of the two targeted categories of dryland systems follow:

Figure 3. Extent of SRT2- and SRT3-type dryland systems.



1) **SRT2-type systems with the deepest endemic poverty and most-vulnerable populations, often associated with severe natural-resource degradation and extreme environmental variability**. Pastoralists and agropastoralists or smallholder farmers with extensive systems are acutely vulnerable to risks associated with natural-resource degradation and variable rainfall. Their vulnerability will be further exacerbated by climate change, particularly in the Sahelian belt of sub-Saharan Africa, South and West Asia, North Africa, India, and parts of the dry Andes in Latin America. These systems, with chronic poverty and unsustainable natural-resource-management practices, have not benefited from or been amenable to R4D programs based on traditional technology-transfer models.

   In these agroecosystems, science-based approaches and technologies must be strongly linked through local institutions to development programs that address issues of social and financial capital, to institutional support programs, and to capacity strengthening. Development strategies in vulnerable systems will have entry points related primarily to livelihood strategies rather than productivity *per se*. These strategies may include risk management (especially for land degradation and rainfall variability), diversification into more market-oriented systems or other income sources—for example PES in specific cases—or even (partial) exit from agriculture. Strategies will also have to recognize that non-agricultural sources of livelihood and non-commercial agricultural activities (e.g. food processing and seed selection) are increasingly important sources of livelihoods and that social and institutional support networks and systems will be needed. It will be more difficult to lift people in these agroecosystems out of poverty, and it may take more concentrated time, effort, and innovation to reach them, though the huge payoffs in terms of poverty reduction fully justify the effort and investment needed.

SRT3-type systems with the greatest potential for impact on poverty in the short to medium term. Some agricultural systems in dry areas are in transition from primarily subsistence to more market-oriented forms (e.g. South Asia, parts of West, East and southern Africa, Central Asia, West Asia, North Africa, and some areas of the dry Andes). These include irrigated, rainfed, and steppe regions. Many countries are urbanizing rapidly, creating expanded markets and a demand for diverse and high-quality food. Research has shown that investment in infrastructure and improved access to markets can drive rural growth (Fan and Hazell, 2001), and there are substantial opportunities to improve livelihoods and food security through combinations of market linkages and enterprise diversification or specialization (e.g. peri-urban dairy systems, greenhouse fruit and vegetable production) that result in greater productivity (through intensification) and opportunities for income diversification. Development strategies for these areas will involve improved agricultural practices (including increased input use), combined with innovations around postharvest issues, market access and value chains, fodder production, and emerging markets for ecosystem services. Intensification should be associated with better soil- and land-management practices and hence greater sustainability. These systems are potential sources of major increases in productivity during the next 20 years (Peterson et al., 2006; Herrero et al., 2010).

The two target dryland systems are categorized firstly using the United Nations Environment Programme (UNEP) Aridity Index (UNEP, 1997), which is in effect an expression of Thornthwaite's (1948) water balance using mean annual precipitation divided by potential evapotranspiration (a term Thornthwaite coined). Other descriptors include the length of growing period; distributions of poverty, hunger, and malnutrition percentages; production risk and stability using rainfall variability and access to irrigation as proxies; land degradation (e.g. soil salinity, erosion, desertification, etc.); and market access. The criteria used to describe the two categories of dryland systems are summarized in Table 2.

Table 2. Criteria used to distinguish between two categories of dryland systems

Criterion	Dryland system category	
	Endemic poverty, vulnerable population, pronounced degradation, and extreme environmental variability	**Greatest potential to contribute to food security and grow out of poverty**
Aridity Index	0.03 to 0.35	0.35 to 0.65
Length of growing period	< 90 days	90 to 180 days
Environmental risk (as measured by rainfall variability and access to irrigation)	Coefficient of variation >25%	Coefficient of variation ≤ 25%
Land degradation	High	Low to medium
Market access	Travel time > 2 hours	Travel time ≤ 2 hours

The proposed approach to understanding, targeting, and defining the two dryland systems will lead to different priorities—with different starting points, trajectories, and partners—for developing innovations in terms of risk management and sustainable intensification with a view towards achieving the four SLOs. Indeed, one research issue is to understand the complementarities and forms of integration between the two target systems. Studies on interactions between the two zones (market innovation, resource management, employment/diversification, among others) can also lead to innovations with potentially widespread applicability. Because of the dynamic nature of both SRT2 and SRT3 systems and the interdependencies between those systems, an in-depth characterization that maps numerous defining factors of the dryland systems mosaic is essential. No single characteristic is sufficient to define the complexities of the livelihoods at work in these areas and therefore a more descriptive framework has been developed to delineate between systems, as captured in Table 2.

3. Conceptual framework for research and development in dryland systems

The **overall objective** of the Dryland Systems CRP is to improve food security and livelihoods in rural communities of the dry areas through:

- enhanced and equitable agricultural innovations systems that link interventions to policy and improve the impact of R&D;
- less vulnerable, more resilient rural communities that can better mitigate risk;
- productivity growth through sustainable intensification of dryland systems at the farm and landscape levels; and
- more resilient and productive dryland agroecosystems that can cope with increased land pressure, climate variation, and other forms of stress.

The objectives will be achieved by employing a conceptual framework that recognizes that dryland systems are heterogeneous, implying that development challenges and therefore the paths to address them differ (Figure 4). We view the spectrum of development challenges as a gradient. At one end of the spectrum are systems where the key challenges are to mitigate vulnerability and risk, and to increase resilience. At the other end of the spectrum are systems where, although risk is still a factor, there are opportunities for intensifying production in response to market opportunities. In general, the challenges or constraints in such systems relate to environmental sustainability, equity, and economic growth through improved agricultural productivity. Food security, poverty reduction, and NRM are important everywhere along the spectrum, but may be given different priority or addressed in different sequences depending not only on the starting point, but on the surrounding institutional, political, and environmental circumstances. Numerous interventions are or will be available that can be leveraged and combined. But, to achieve significant impacts on poverty, food security, and the environment, integrating these interventions and including a proper trade-off analysis will be paramount. In addition, capacity-strengthening mechanisms are also needed, targeting regional and local stakeholders—including both socially disadvantaged groups and those who influence policy—to ensure delivery of technologies, access to markets, equity, and economic balances. This underscores the need for an integrated approach, which is at the core of CRP 1.1.

The conceptual framework is used by CRP 1.1 to “get the mix right.” It also addresses the four CGIAR SLOs (reducing rural poverty, improving food security, improving nutrition and health, and sustainable management of natural resources), as well as the SRF view that a CGIAR research program should “identify and develop resilient, diversified and more productive combinations of mixed crop/livestock, rangeland, aquatic and agroforestry systems that have the potential to be deployed on a wider scale, especially in dry areas where water is scarce” (SRF, 2010).

Strategic Research Themes

The conceptual framework of CRP 1.1 was developed with stakeholder participation beginning with a framework development workshop held in January 2012. The framework consists of four **Strategic Research Themes (SRTs)**, each derived from a hypothesis:

1) CRP 1.1 assumes that the use of innovation systems will improve the effectiveness of agricultural research for development in contributing to, defining, and delivering target outcomes to complex dryland systems. It further assumes that innovation systems and partnerships will more effectively drive policy change and technology adoption in these often politically marginalized environments with limited technology access. This hypothesis has led to the establishment of **SRT1**.
2) CRP 1.1 further assumes that for a significant proportion of livelihood systems in the most vulnerable and degraded dryland areas, increased food security, reduced risk, and improved

resilience are fundamentally achievable through technical and institutional innovation, and can lead to more secure and improved livelihoods without land degradation and other forms of unsustainability. Those areas where this is not possible would be better targeted with alternative land-use and livelihood systems. This overarching hypothesis will be tested in **SRT2**.

3) CRP 1.1 considers that certain parts of the dry areas have potential to significantly contribute to economic growth. The overarching assumption is that substantial and sustainable production increases can be realized through innovations that will lead to intensification and diversification of production systems and the development of the necessary value chains. The extent to which this assumption holds will be studied in **SRT3**.

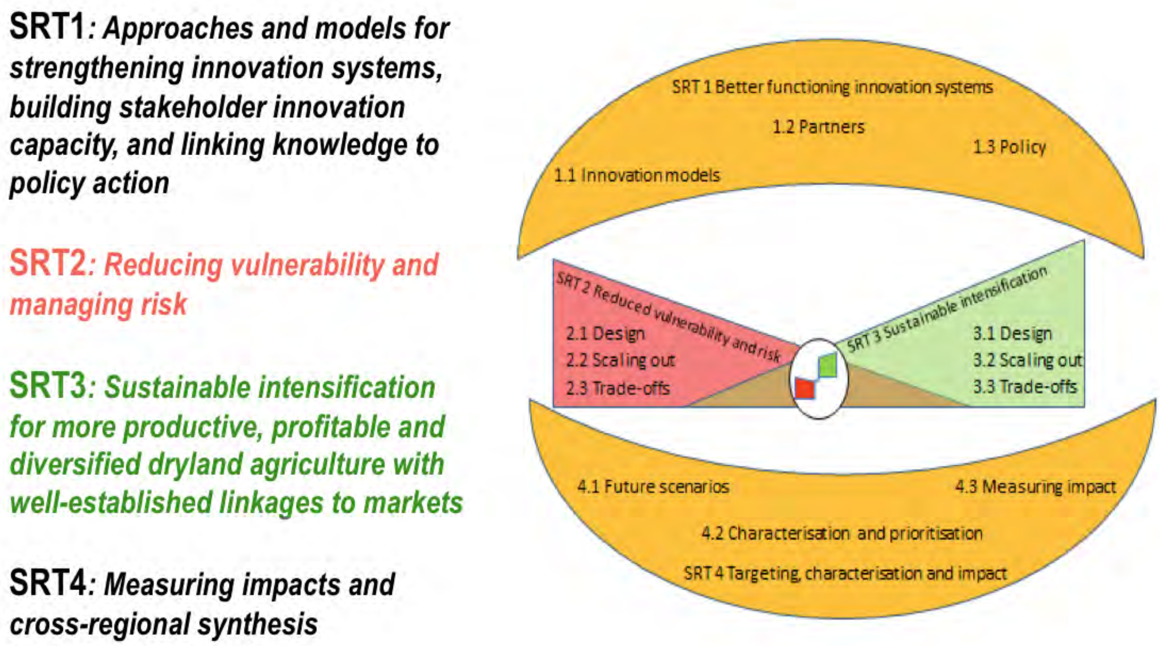
4) The complex nature of the pathway to generating outputs and outcomes in CRP 1.1 can be captured only with the help of biophysical and socioeconomic models that function at different scales. These can provide the necessary insights to inform the innovation system and to generate the information, communication, and knowledge-transfer needs for up- and out-scaling of the innovations and for measuring their potential impact. The system analysis platform needed to test this assumption and verify models with real-time information will be elaborated in **SRT4**.

The four SRTs constitute steps in the impact pathway and as such are targeted towards improving food security and livelihoods in dryland systems**. SRT1** recognizes growing evidence that innovation systems that actively involve relevant stakeholders as part of the development process offer rapid feed-forward, feedback, and scaling-up mechanisms needed to address development in agricultural systems with marginal resources and complex scale dependencies. Innovation platforms will be applied to addressing complex problems and constraints in the two broad categories of dryland systems, i.e. those with the deepest endemic poverty and most-vulnerable people (**SRT2**), and those with the greatest potential to contribute to food security and poverty reduction (**SRT3**). Capturing the process with a view towards knowledge synthesis and out-scaling either within or between regions is at the heart of **SRT4**, which will require the development and use of monitoring and evaluation tools, and various biophysical and socioeconomic models that function at different scales. SRT4 is meant to provide the insights needed to inform the innovation system and generate information, communication, and knowledge transfer for continued learning and up- and out-scaling. The way in which the four SRTs interact and reinforce each other is illustrated in Figure 4.

Within each SRT, problems and their underlying constraints are identified and addressed through a set of research hypotheses tailored to the two categories of dryland systems in different regions. Hypothesis-driven research is designed to produce research **outputs** that contribute to the delivery of targeted development **outcomes** that in turn address identified problems and constraints. Outputs will be produced through individual research-related **activities** that will be developed as part of the innovation platforms.

A brief summary of the four SRT's and their program level outputs follows.

Figure 4. The conceptual framework for CRP 1.1



SRT1. Approaches to strengthening innovation systems, building stakeholder innovation capacity, and linking knowledge to policy action

Action research to generate, use and share knowledge on cost-effective approaches for building innovation capacity and strategies for informing policy decisions and processes in support of equitable and sustainable development in drylands.

Output 1.1: Models and approaches for strengthening innovation systems in drylands
Output 1.2: Enhanced capacity for innovation and effective participation in collaborative R4D processes
Output 1.3: Strategies for effectively linking research to policy action in dryland context

SRT2. Reducing vulnerability and managing risk

Research on the most vulnerable production systems which is integrated, inter- and multi-disciplinary, and participatory. This theme will determine combinations of options for risk management, NRM, and livelihood diversification from interventions and technology introductions, including those from other CRPs.

Output 2.1: Combinations of institutional, biophysical, and management options for reducing vulnerability and mitigating risk
Output 2.2: Options for reducing vulnerability and mitigating risk scaled out
Output 2.3: Analysis, within target regions, of trade-offs among options for reducing vulnerability and mitigating risk, and knowledge-based systems for customizing options to sites and circumstances

SRT3. Sustainable intensification for more productive, profitable, and diversified dryland agriculture with well-established linkages to markets

Research that is integrated, participatory, and multi- and inter-disciplinary on combinations of improved agricultural technologies and practices for increasing production, adding value on-farm and along the value chain, and sustainably managing natural resources, using to the extent possible interventions and technology from other CRPs.

Output 3.1: Combinations of options for sustainable intensification and diversification of agricultural production systems
Output 3.2: Options for sustainable intensification and diversification scaled out
Output 3.3: Analysis, within target regions, of trade-offs among sustainable intensification and diversification options, and knowledge-based systems for customizing options to sites and circumstances

SRT4. Measuring impact and cross-regional synthesis

A system-analysis platform to capture and elucidate the path to generate outputs and outcomes, based on (i) biophysical and socioeconomic models that function at different scales and (ii) recurrent monitoring of key indicators of progress towards impacts. A variety of tools, such as simulation modeling, socioeconomic and livelihoods analyses, systems and geospatial analyses, and *ex ante* impact modeling will provide the necessary insights to inform the innovation system and generate the information, communication, and knowledge-transfer needs for scaling up and scaling out innovations.

Output 4.1: Analyses of future scenarios and priorities
Output 4.2: Baseline characterization of livelihoods and ecosystems, and synthesis across regions of lessons learned about the options developed in SRTs 2 and 3
Output 4.3: Assessments of program outcomes and impacts

Region-specific outputs for specific dryland agricultural systems have been captured in the logframes that have been developed for each Target Region during the Inception Phase.

Thus, the conceptual framework recognizes that technologies, interventions, approaches and partnerships required will differ among dryland systems. This is because households in livelihood systems where vulnerability is above a certain “threshold” level are more concerned in reducing risk and avoiding catastrophic losses in production or assets than in increasing average productivity over time. This does not mean that resilience and intensification are mutually exclusive. Both are important in all systems, but the primary research emphasis will depend on where the target population is situated on this vulnerable-to-higher-potential spectrum. Livelihood-system trajectories may improve or degrade and, at any geographical location, there may be systems both above and below the transition threshold, distinguished by differences in livelihood assets and strategies.

Dryland agroecosystems are heterogeneous and subject to change due to population increase, climate change, or other drivers. Both dryland ecology (Scheffer et al., 2001; Washington-Allen and Salo, 2007) and people’s livelihoods (Folke, 2006) respond to these drivers in complex ways, so that systems can be conceived as having multiple quasi-stable states, separated by thresholds. State and transition models (Stringham et al., 2003) are available that use this concept, and diagnostic tools for detecting such thresholds are constantly being updated and refined (e.g. Washington-Allen et al., 2008). In some dryland-system contexts, e.g. those of SRT3, concerned primarily with sustainable intensification, it is relatively easy to envisage livelihoods progressing over the transition threshold. In others, e.g. those of SRT2, concerned primarily with mitigating risk and increasing resilience, constraints may be so severe that a significant proportion of people may need to transition partially to non-agricultural livelihoods

(Ridolfi et al., 2008; Safriel and Adeel, 2008; Thomas, 2008). In worse cases still, entire populations may be forced to migrate.

Perhaps the best indicator of farmers' preference for resilience over production is the way that they deal with risk. One approach to risk mitigation is diversification, which will not necessarily allow an improvement in livelihood through an increase in production, but may ensure food security or protect against loss of livelihood by hedging risks. For example, farmers in the Sahel often cultivate both short- and long-season pearl millet to spread risks associated with unpredictable rainfall duration (Brock and Ngolo, 1999; Roncoli et al., 2001). Additionally, asynchronous tillering and photoperiod response, e.g. among landraces, can increase diversity and stability (Payne, 2010). Of course, farmers may also try to diversify means of making a living as well as diversifying their crops, animals, and other products. They often sell their labor, migrating large distances to find work. But many would prefer to find local opportunities for employment rather than migrating (Meze-Hausken, 2000).

4. Impact pathway

CRP1.1 Dryland Systems research will reduce the vulnerability of farming communities to drought and climate change and sustainably improve agricultural productivity, resulting in improved and more secure incomes for 87 million people in dryland systems, while improving the productive capacity of natural resources and reducing environmental degradation in some 1.1 million km^2 in dry areas.

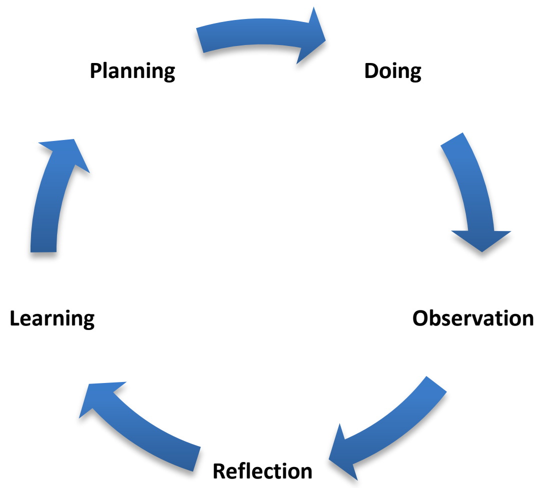
The following section defines the pathway from CRP1.1 research to achieving these impacts, together with the underlying theory of change.

4.1 Theory of change

The impact pathway is based on a general theory of change, which assumes three distinct kinds of change, namely emergent change, transformative change, and projectable change (Reeler, 2007).

> **Emergent change** is the inherent process by which individuals, households, entrepreneurs, communities, organizations, and societies adjust to shifting realities, trying to improve and enhance their knowledge, skills, and conditions through numerous ways of interactions, yielding both conscious (more predictable) and unconscious (less predictable and uncertain) changes. The explicit assumption here is that individuals and societies are not stagnant but are engaged in a process of change affected by internal and external factors. The first step is, therefore, to understand and harness this inherent process of change. The participatory approaches embraced in this program will help people to understand their own experiences (past and current), including their stories or biographies. The approach encourages people to appreciate their tacit knowledge and resources and thus help them to build self-confidence to learn their way forward. One way of doing this is the action–learning cycle, which involves doing, observing, reflecting, and learning and then planning for a second cycle and so on (see Figure 5). Methods associated with emergent change approaches include participatory action research, asset-based learning or indigenous knowledge-based approaches, appreciative inquiry, coaching, and mentoring (Reeler, 2007).

Figure 5. The action–learning cycle.



> The second type of social change that the program will foster is **transformative change**. This can occur when individuals, households, and organizations realize that the status quo is no longer functioning satisfactorily and generate sufficient willingness to consider transformation. This type of change is often associated with situations of crisis and stagnation. The conflicts over natural resources and the severe degradation in many dryland systems, as well as frequent droughts, represent crisis situations where this approach could be applied. There is always resistance to transformative change from a variety of sources based on tradition, culture, and potential threats to the interests of various groups. Transformative change also applies to the organizations implementing the program as much as the target communities and national institutions.
>
> The third type of social change is **projectable change**, which is based on the change agents' ability to identify and solve problems and imagine the outcomes of different possibilities. This approach forms the core of the program's problem-solving research and logical frameworks at the different action sites. This problem-solving research has a clear vision of expected outcomes and detailed plans are being formulated as to how it will bring about the expected change.

As noted by the Independent Science and Partnership Council (ISPC, 2012), "while the CRPs are accountable for their outputs and have some control over the near-term adoption and use of their research results, the development outcomes occur, particularly at scale, as a result of activities, policies and investments outside the CGIAR". In order to influence these actions, the CRP will actively engage with development organizations and policy makers in the five target regions. These partnerships will evolve over time as the necessary supporting policies and investments are identified. To achieve the envisaged outcomes and impacts, the program has developed clear mechanisms for linking researchers on the one side and development agents and policy-makers on the other.

An important result of such linkage will be the successful development and implementation of effective technology dissemination mechanisms to enhance the adoption and impact of the program beyond the action sites. These mechanisms will build on the concept and experiences of "boundary work" advanced by Clark et al. (2010, 2012). Boundary work is defined as the processes through which the research community interacts with the development and policy-making community (Hellstrom and Jacob, 2003) and with knowledge based on local experiences and practices (Clark at al., 2010, 2012). The concept makes a clear distinction between the business of producing science and science-based solutions and the business of development action and policy-making, and seeks effective ways for proactive interaction between the two. The distinction does not mean a total separation, but rather a well-structured process of engagement that promotes learning. CRP1.1 will develop such an interface by actively engaging relevant and influential stakeholders and policy-makers. The innovation platforms developed under SRT1 will form the main vehicle for implementing the boundary work. The innovation systems approach will bring together a variety of stakeholders, including policy-makers, and is aimed to lead to policy changes or to the development of new institutions (e.g. for marketing). The boundary work emphasizes two levels in this interface – the local community and policy-making:

- At the local-community and individual-farmer level it is critical that both scientists and farmers participate in key stages of research (setting priorities, research, interventions, and evaluation of activities and their results) at research sites through meetings facilitated by the innovation platform. These maybe largely informal but can also be organized in a semi-formal structure mediated by local community organizations or NGOs. If properly executed and all parties understand its purpose and function, participation can successfully develop trust and rapport and can ensure relatively rapid change. Participation must be based on mutual trust and two-way flow of information and knowledge; these will develop if the raised expectations that participation often generates are properly managed. Strengthening local institutions is crucial in enhancing community participation, a process that needs careful monitoring and documentation as invaluable lessons can be learned for other CRPs.
- At the policy-making level, senior scientists of the program should devote time to engage policy-makers and development partners in formal discussions about key priority decisions critical to the outcomes that the program seeks based on scientific evidence and practice. Identifying “national champions”—individuals, usually national scientists, who command respect of both the scientific and policy communities—at key intuitions can play a major role in facilitating this engagement. These interactions can take place at targeted events, meetings, and workshops. The program, under SRT1, will engage with policy makers and provide the necessary evidence to promote changes in policies and investment.

The integration of gender analysis to promote a greater understanding of gender roles and priorities, will lead to better selection and implementation of technologies that could have gendered benefits, e.g. reduction in women’s labor, or changes in women’s empowerment, management of income, and accumulation of assets, which are associated with better development outcomes, such as improved child nutrition. Livelihood approaches provide researchers with a more nuanced understanding of the realities faced by rural people, and greater attention to gender and power dynamics makes it more likely that both men’s and women’s voices will be heard. As a result, more people will have the opportunity to participate and be empowered to contribute to changing their social circumstances as well as their material circumstances. An analogous approach can be used to empower and create opportunities for youth.

By implementing such approaches, and by strengthening partnership facilitation skills and innovation systems capacity among researchers, development partners, and end users, CRP 1.1 will not only produce science-based solutions but will also ensure that development outcomes and impacts are achieved.

4.2 The impact pathway

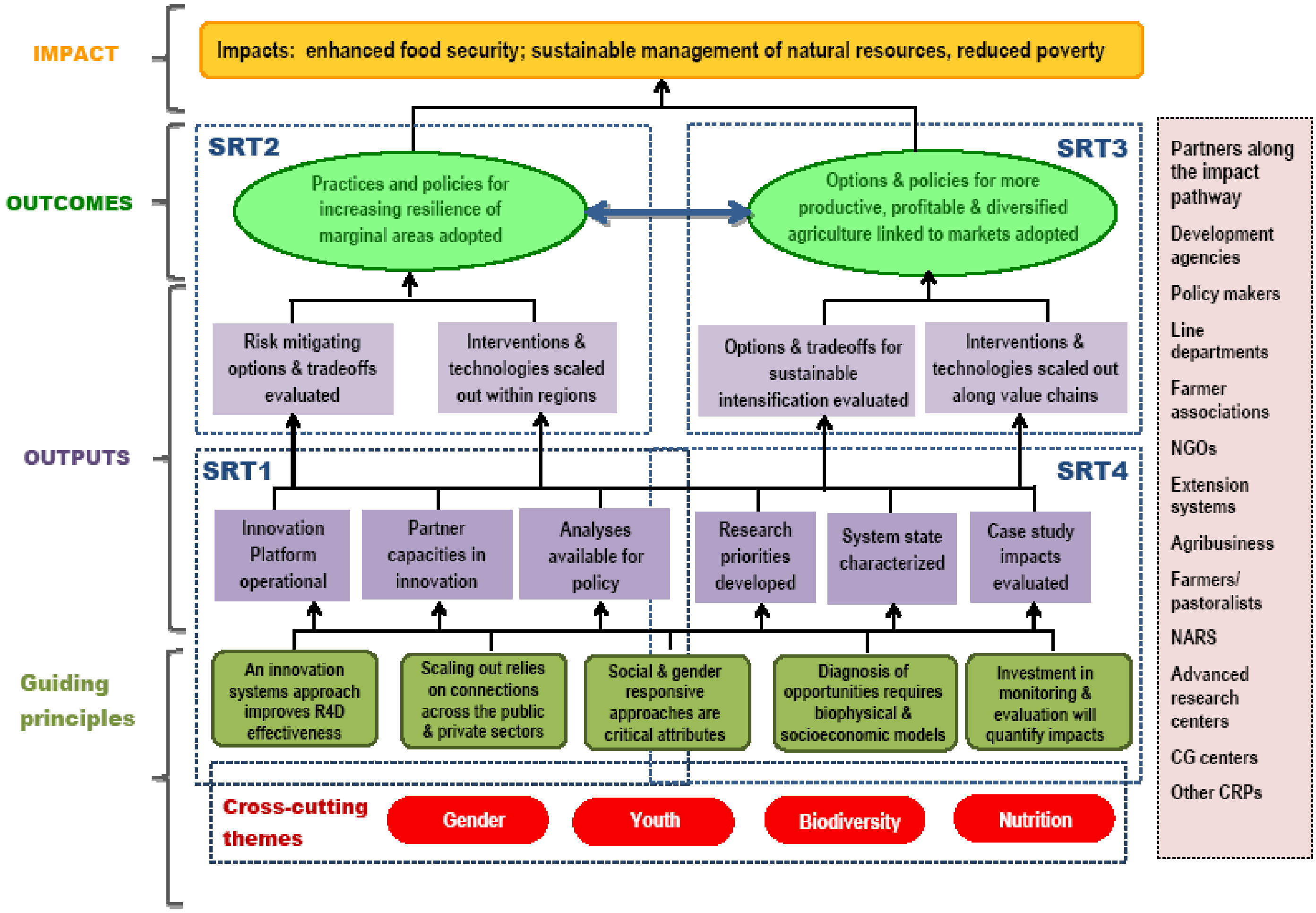
The CRP1.1 impact pathway, shown in Figure 6, encompasses a hierarchy of objectives – research outputs, outcomes and impacts:

- Outputs are the products delivered by the CRP research program, intended for utilization by end users, including other researchers (other CRPs, national agricultural research systems); farming and pastoralist communities; policy makers; development agencies and other investors; and others.
- As defined in the ISPC's white paper on *Strengthening Strategy and Results Framework through prioritization* (ISPC, 2012), "research outcomes are the adoption and use of research outputs by users….. They are generated as a result of research, technology demonstration and dissemination, capacity building and advocacy activities by the CRP, and monitored and documented as part of the CRP and Consortium monitoring".

  The ISPC distinguishes between research outcomes and intermediate development outcomes (IDOs). Given that CRP1.1 is designed to work directly with users (innovation platforms and engagement with policy makers) and at different scales, the distinction between research and development outcomes is blurred. Furthermore, as development of IDOs, at both CRP and system level, is an ongoing process within the Consortium, the CRP1.1 impact pathway has not developed this distinction further. In CRP1.1, outcomes are defined as the adoption and use of research outputs and are measured by the direct results from the use of the program's various research outputs by the target groups.

  Region-specific logframes have been developed during the Inception Phase that specify, for each production system in each region, the underlying problems to be addressed, associated research hypotheses, research outputs, activities and milestones, and research partners. These are too detailed to be included in the proposal, but are provided in the supporting Inception Phase reports. These will be further developed and integrated within the performance management system (Section 7), so that each links to program level outputs and outcomes, and include indicators that measure the uptake of outputs (numbers of farmers adopting, changes in policy, etc) and their direct benefits (changes in productivity, incomes, etc).
- Finally, the impacts are the ultimate benefits for the target populations and environments of the dry areas. The impact pathway embodies iterative steps involving research, capacity building, adaptation, up- and out-scaling. However, the progress toward achieving the eventual impacts are dependent on other developments and incentives outside of the control of the CRP such as policy changes, institutional changes, substantial additional investment in infrastructure and other rural development support. CRP1.1 has built in components that are intended to influence these "external" conditions, by involving development partners, policy makers, rural communities and other stakeholders in the various stages of the impact pathway, specifically:
  - SRT1 that will develop innovation systems that actively involve relevant stakeholders as part of the development process, and provide rapid feed-forward, feed-back, and scaling-up mechanisms
  - SRT4 that, by synthesizing knowledge within and between regions, will measure progress towards goals and inform those innovation systems, for continued learning and up- and out-scaling.

Figure 6. CRP 1.1 program impact pathway



CRP1.1 has a clear strategy for achieving outcomes and impacts. As shown in Figure 6, this impact pathway has three connected components:

- The first component embodies a number of critical principles that determine the potential for change (Douthwaite et al., 2007). The principles, which are independent of the specific research context or focus, include an integrated systems perspective; attention to social inequity to foster equitable outcomes; use of participatory approaches involving diverse farmers and pastoralists (e.g. gender, age, ethnicity) as well as other resource users and stakeholders (e.g. value-chain actors) to facilitate adaptation of technologies; effective partnerships with critical stakeholders (national agricultural research systems, development organizations, NGOs or policy-makers); and communication and information sharing within and between stakeholders, including support of policy processes. These principles, which are central to the impact pathway, are part of the R4D design of CRP 1.1, and are reflected in the description of the research framework. The application of these principles in the implementation of the research themes is a critical commitment of the program to the generation of outcomes and eventually impact. There will still be researchable issues around adoption phase of the impact pathway even when technology outcomes start to be more widely implemented in the target areas with local communities and during the scaling-up and scaling-out phases. This implies a continued and growing interaction by the CRP research partners with development agencies.

- The second component is the engagement of multiple partners along the impact pathway, particularly development partners, who will play a major role in research implementation, outputs delivery, and transforming research outputs into outcomes. At the farmer/pastoralist level, the emphasis is on the adoption of improved productive and more sustainable options, while at the policy level the focus is on the use of new policies, development strategies, institutional changes and investments. To realize outcomes at the production system level, effective scaling out and up approaches are an integral part of the impact pathway and are developed within the first Strategic Research Theme (SRT1), through the development of innovation platforms. An important factor in any technology adoption is to understand the constraints to adoption and some of these constraints could be institutional in nature. The partnership within the innovations platform will actively seek how these constraints can be removed and adoption enhanced and out scaled.
- The third component of the impact pathway is effective monitoring and measurement of the outcomes and impacts, including relevant performance indicators and their quantifications. The program has research activities within SRT4 dedicated to establishing baseline information for production systems and rural livelihoods, as well as methods for measuring the program's impacts and synthesizing the information across the action sites and target areas.

This impact pathway and its underlying processes will evolve as the program progresses and in response to emerging constraints, tradeoffs, and new partnership opportunities.

The principles of the impact pathway and the underlying theory of change have been applied successfully in a number of cases, including the "Alternative to Slash and Burn" program described by Clark et al. (2011), and the adaption of alley cropping in Tunisia described by Shideed et al (2007).

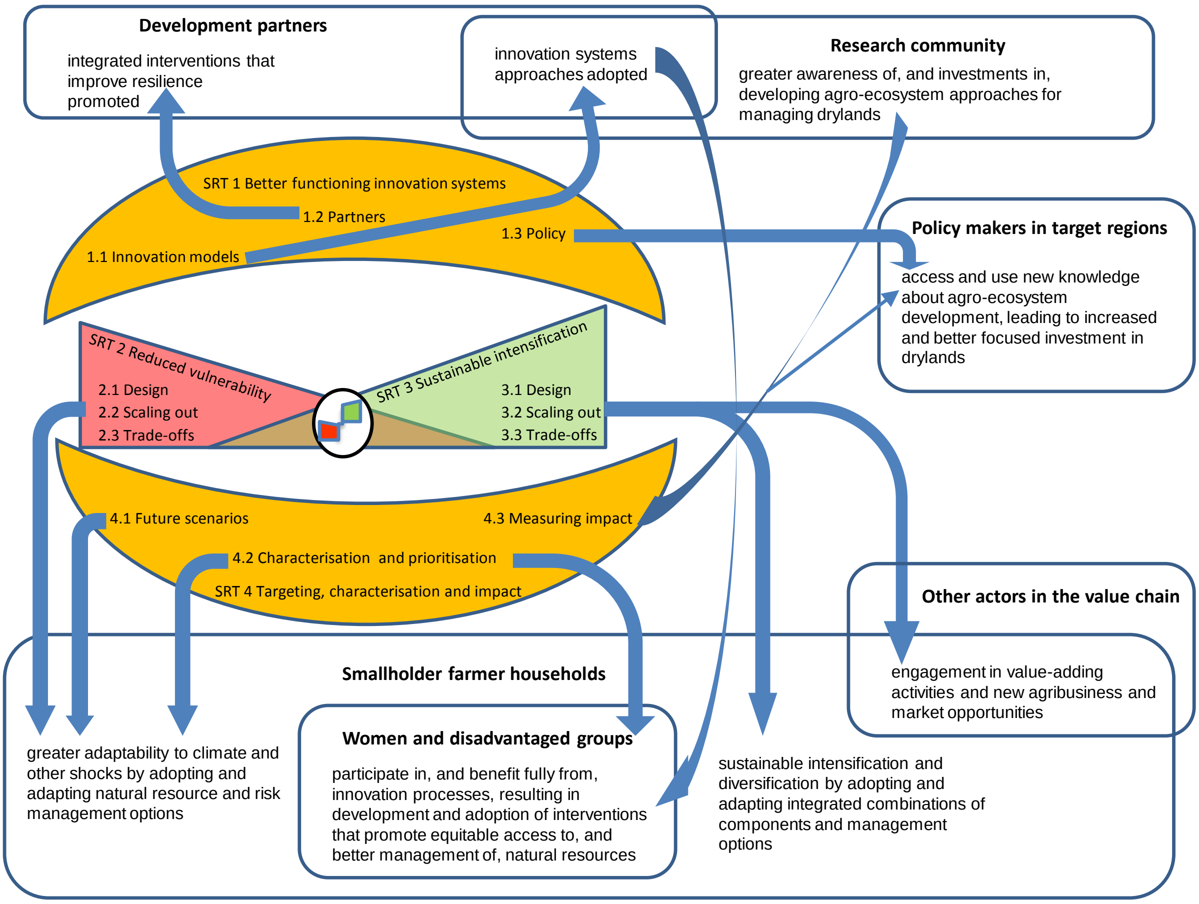
The various types of partners who will be engaged at different stages along the impact pathway are listed in Figure 6 and their engagement at various stages along the impact pathway is illustrated in Figure 7, which expands on the figurative presentation of CRP's conceptual framework in Section 3 above.

Outcomes

As depicted in Figure 6, the four Strategic Research Themes (SRTs 1 through 4) will generate outputs that, with effective scaling out and up approaches through targeted partnerships, will be adopted and used. These outputs contribute to multiple outcomes; likewise, outcomes derive from multiple outputs. Major expected outcomes are:

1) R&D organizations adopt and use innovation systems approaches co-developed in CRP 1.1.
2) Smallholder farmers in dryland systems
    (a) increase their capacity to adapt to climate and other shocks by adopting and adapting natural-resource-management options that increase the resilience of their livelihoods.
    (b) adopt and adapt integrated combinations of components and management options that sustainably intensify and diversify their production systems and livelihoods.
    (c) conserve and use agrobiodiversity more sustainably and effectively as a result of their adopting relevant options generated in CRP 1.1.
    (d) engage in value-adding activities and exploit new agribusiness and market opportunities
3) Women, youth, and other disadvantaged groups participate in and benefit fully from innovation processes, resulting in development and adoption of interventions that promote equitable access to, and better management of, natural resources.

Figure 7. Linkages among SRT outputs and outcomes, and the users and partners at each stage of the impact pathway.



4) Policy-makers in target regions have access to and use new knowledge on dryland system development, resulting in the introduction of supportive policies and increased and targeted investment in drylands.

5) Development partners promote interventions that integrate technologies, institutional and market innovations, community-based approaches, and support strategies that reduce vulnerability, manage risk, and improve resilience of rural livelihoods in dryland areas.

6) The international research for development community (including other CRPs) has access to and uses new knowledge about the opportunities for dryland systems development, and the added value of the systems approaches developed in CRP1.1

As the scale of the adoption increases, the program will contribute to the ultimate goals of enhanced food security, more productive and sustainable management of natural resources, and reduced poverty in dry areas that link with the four System Level Outcomes:

SLO1. Reduction in rural poverty

SLO2. Increase in food security

SLO3. Improving nutrition and health

SLO4. Sustainable management of natural resources.

Impacts

CRP1.1 Dryland Systems research will reduce the vulnerability of farming communities to drought and climate change and sustainably improve agricultural productivity, resulting in improved and more secure incomes for 87 million people in dryland systems, while improving the productive capacity of natural resources and reducing environmental degradation in some 1.1 million km^2 in dry areas.

Conservative estimates of changes in productivity, based on CGIAR experience in dry areas, in five to ten years are:

- In the marginal and highly vulnerable dry areas, 10-20% increase in productivity; and
- In the high potential production systems, with scope for sustainable intensification, 20–30% increase in productivity.

With the out-scaling of proven technologies, together with anticipated higher and more equitable adoption rates, it is estimated that these changes will:

- impact the livelihoods of 20 million people and 600,000 km^2 in sub-Saharan Africa;
- 65 million people and 465,000 km^2 in South Asia;
- 1.1 million people and 18,600 km^2 in North Africa and West Asia; and
- 0.5 million people and 5,000 km^2 in Central Asia and the Caucasus.

5. Strategic Research Themes

CRP 1.1 will be implemented across the five Target Regions using the conceptual framework shown in Figure 4. The research program will be based on clear regional priorities and productivity, sustainability, and efficiency targets. Iterative and participatory design and implementation will ensure that CRP 1.1 priorities match those of regional and national stakeholders and encourage buy-in and support from policy-makers and donors. This will lead to strong national support, sustainable activities, and high impact on livelihoods and the environment. Details of the four SRTs, their underpinning hypotheses, delivery methods, and component outputs are given in the following sections.

5.1 Strategic Research Theme 1: Approaches to strengthening innovation systems, building stakeholder innovation capacity, and linking knowledge to policy action

In a rapidly changing global environment, poor agriculturalists have to constantly respond to emerging challenges and opportunities despite limited resources. It is critical to improve their access to knowledge and information so that they can make the best use of their resources and available support. A significant percentage of dryland agricultural technologies have not been widely adopted by the resource poor. Whether intended users lack knowledge of or access to technologies or complementary inputs, or whether the technologies themselves were not appropriate for the target systems, it reflects a weakness in the research and extension system. Many believe that the classical approach, in which public-sector agricultural research and extension deliver new technology, needs to be replaced by a systems approach focused on demand-driven innovation, which is the result of a process of networking, interactive learning, adaptation, and negotiation among a heterogeneous set of actors (Leeuwis, 2004; World Bank, 2007).

An innovation system is a “network of organizations focused on bringing new processes and new forms of organization into social and economic use, together with the institutions and policies that affect their behavior and performance” (World Bank, 2007). The actors in these networks could be farmer or local civil-society organizations (CSOs), NGOs, advanced research institutes (ARIs), or individuals and firms along the value chain. Public policy and government agencies also participate in and shape the processes in a variety of ways. The innovation system approach recognizes that agricultural innovation is not just about adopting new technologies; it requires a balance among new technological practices and alternative ways of organizing, for example, markets, labor, land tenure, and distribution of benefits. Enhancing innovation capacity and creating an enabling environment are becoming common practice in many R&D interventions (Sanginga et al., 2009; Scoones and Thompson 2009).

Given that the innovation system approach is specifically promoted to improve the effectiveness and impact of agricultural research in challenging environments such as dryland systems, CRP1.1 will examine efficacy of the approach (Lynam et al., 2010) by generating evidence about which innovation system methodologies work best, and how they can be improved and integrated to enhance impact and sustainability. Answering these research questions will involve working closely with partners in other CRPs in an action-research mode and learning from non-CGIAR R4D organizations, many of whom are also using the innovation system approach in the development of the technological and institutional innovations that are potential components in the dryland agricultural systems being targeted by CRP 1.1.

Innovation systems can be strengthened by improving interactions between actors by strengthening existing linkages and/or forging new ones (SRT1.1) and enhancing the capacity of the actors to engage effectively in innovation processes (SRT1.2).

In some cases, the knowledge generated by research-for-development requires policy change to be used effectively. The policy challenge is especially critical in drylands because of their historical marginalization. Achieving development impacts will require overcoming challenges in infrastructure and embedded special interests, as well as misperceptions about the returns to investment in these “marginal” areas and their potential contribution to national and regional economies. Recent research has provided a better understanding of what is required to go from policy analysis to policy impact (Hooton and Omore, 2007; CGIAR Science Council, 2008; Joshi et al., 2008; Kristjanson et al., 2009; Clark et al., 2010), including embedding policy-makers in innovation processes. This research also challenges the belief that research can inform policy and remain outside of the political processes (Clark et al., 2010). A better understanding of what this means for the design and implementation of R4D interventions in drylands (SRT1) will contribute to the success of CRP 1.1 and also generate international public goods (IPGs) that add to the global knowledge base.

5.1.1 Hypotheses

SRT1 assumes that strengthening innovation systems will increase the effectiveness of agricultural research in contributing to system-level outcomes in drylands, and that policy constraints are especially important since dryland areas are often politically marginalized.

There are three overall hypotheses that drive more specific research at the regional level, related to the SRT1 program level outputs:

1) The first hypothesis (H1.1) is that the most effective approach for strengthening innovation systems will depend on the characteristics of the site, the type of issue being addressed, and the stakeholders being targeted (for example, resource-poor women). Evaluating this hypothesis will require well-specified and distinguishable approaches to strengthening innovation systems and well-characterized contexts, issues, and target groups. The level of rigor will depend on the number of replications. In practice, the problem will be disaggregated and simplified comparative analyses attempted, such as investigations of how well innovation platforms (a method that is now widely

used in CGIAR Centers for many purposes) work in different contexts (e.g. SRT2 vs. SRT3 or East Africa *vis-à-vis* West Africa), at different scales (local vs. national scale), for different problems (e.g. food production vs. income generation), or for different stakeholders (e.g. women vs. men). The Sub-Saharan Africa Challenge Program (SSA CP) is already attempting to address this question. We will build on this experience using qualitative as well as quantitative evaluation.

2) The second hypothesis (H1.2) is that improving collaboration and partnership skills (capacity strengthening) will improve sustained linkages between actors (women and men) thus strengthening innovation systems. Specific capacity-strengthening activities will be assessed using "knowledge, attitude, and practice" types of survey, combined with social-network analysis and other methods to measure impacts on relationships among actors. There is growing interest in improving methods to assess the impacts of capacity strengthening (Gordon and Chadwick, 2007) and going beyond application of skills and knowledge to measure influence within institutions (e.g. in African Women in Agricultural Research and Development) and linkage among organizations.

3) The third hypothesis (H1.3) is that research projects that engage with policy-makers and policy processes from the earliest stages and throughout the project cycle have a better chance of influencing policy than projects that only share their results at the end. This hypothesis can be tested by documenting and comparing the strategies used by different policy-oriented research projects (in CRP 1.1, other CRPs, and projects outside CRPs) working in CRP 1.1 areas. The evaluation methods will be qualitative rather than quantitative, seeking to chart policy change that results from research results and how research itself is modified by engagement with policy-makers and processes.

5.1.2 Methodology

While appropriate methods will be used to test specific, fine-scale hypotheses within regions, general methods will be applied across regions within SRT1. One view is that researchers need to move beyond problem identification to engagement with the development community in co-production of knowledge and solutions to problems (Clark and Dickson, 2003). Much of the work in SRT1 will use action-research approaches involving iterative processes of planning, action, reflection, and analysis conducted collaboratively between researchers and other stakeholders (O'Brien, 1998). The design of action research will benefit from recent advances in quantitative impact evaluation of agricultural technologies (de Janvry et al., 2010) and interventions, including institutional change (Duflo et al., 2008; de Janvry and Sadoulet, 2010). Recognizing both the opportunities and limitations of this approach (Deaton. 2009; Barahona, 2010), mixed-method approaches (Adato and Meinzen-Dick, 2007) will be used that consider multiple points of view when evaluating outcomes (Jupp et al., 2010). Research within SRT1 will also include production of systematic review and synthesis papers and the development of analytical frameworks to guide empirical work and facilitate comparative analyses. Existing methods for understanding and assessing policy impacts such as "Research and Policy in Development Outcome Assessment" (www.odi.org.uk/rapid) will be adapted for the drylands context.

5.1.3 What's new?

R4D and innovation-systems approaches are becoming increasingly common. However, there have been few attempts to assess experiences systematically across sectors, sites, or scales to determine what works where, what can be improved, and how. The fact that CRP 1.1 focuses on integration within and among entire agroecosystems is innovative and has implications for who the key stakeholders are and how they work together. On occasion, and as appropriate, finer focus may be targeted to a specific sector, value chain, or challenge. Another innovative aspect of SRT1 is that it looks at interventions in innovation systems at various scales (in conjunction with other CRPs and partners): from community-based research groups to regional value chains and networks to the national policy processes that are often critical to creating an enabling environment. This cross-scale approach will facilitate integration with other CRPs that will be working at different levels, and will explicitly look at how to deal with trade-offs as part of SRT4, including policy trade-offs and how to support negotiation rather than decision processes. Finally, SRT1 integrates capacity building explicitly into the R4D agenda, recognizing that lack of capacity related to innovation and partnership skills is often a major obstacle to effective collaboration, social learning, and access to information.

5.1.4 Outputs

Output 1.1: Models and approaches for strengthening innovation systems in drylands

The CGIAR has considerable experience with multi-stakeholder R4D processes. Work on farmer participatory research made a legitimate case for involving end-users in the research process, for efficiency and equity reasons, and provided models for engaging farmers effectively (Ashby, 1996; Lilja and Dixon, 2008a). Work on participatory watershed management addressed the integration of agriculture and NRM at a landscape scale, and generated lessons and models to facilitate pro-poor multi-stakeholder processes (Hinchcliffe et al., 1999; Swallow et al., 2001; Wani et al., 2008).

Within an R4D framework, the learning-alliance methodology (Lundy et al., 2008) expanded participatory-research concepts to value chains, and made joint learning a specific objective of the interaction between producers, other value chain actors, policy-makers, NGOs, and donors. This approach has also been applied to water management (Moriarty et al., 2005; Smits et al., 2007; Jackson et al., 2010). The Enabling Rural Innovation Initiative in East and southern Africa organized communities to conduct integrated, community-led research on productivity, NRM, and markets, with explicit focus on gender issues in both participation and distribution of benefits (Sanginga et al., 2004). Challenge Programs (CPs) such as the SSA CP and the CP on Water and Food (CPWF) explicitly target the strengthening of innovation systems and seek to generate global and regional IPGs through developing and validating methods and approaches in R4D processes. The SSA CP, a leader in this area, will be a strong partner of CRP 1.1. Experiments have taken place, involving several CGIAR Centers, with forming innovation platforms/networks, which are coalitions of actors (mostly informal), that promote and identify target group knowledge needs, and test various options to address these needs. For example, public–private -partnerships have been forged in numerous projects, including an index-based livestock insurance project in Kenya (http://www.ilri.org/ibli/; see Box 2), a fodder innovation project in India and Nigeria (www.fodderinnovation.org), a project promoting enhanced livestock services delivery in Southern Africa, and the widespread dissemination of a vaccine-based approach to prevent livestock deaths from East Coast Fever across East and southern Africa.

While there may be shortcomings regarding innovation system theory as an analytical framework (CGIAR Science Council, 2009), innovation system principles and methodologies are widely used tools for implementing R4D (Lynam et al., 2010). Many methodologies such as those mentioned above exist and have been shown to be effective, usually in case studies, though it is likely than many failures went undocumented and the lessons unlearned (Hall et al., 2001). Little systematic analysis has been done across methodologies and contexts that would enable potential users to make informed decisions about questions such as: Which methodology or combination of methodologies is most appropriate given the context, objectives, and budgets? What is the role for external facilitation initially and over time? What are the necessary conditions for sustainability or scaling up? How can approaches be improved to yield better gender and equity impacts?

Some research is underway to address some of these issues (e.g. SSA CP and CPWF); however, more is required and will likely include the adaptation or development of methods for assessing the impacts of innovation system approaches.

Output 1.2: Enhanced capacity for innovation and effective participation in collaborative R4D processes

Effective participation in agricultural innovation systems may require that actors acquire specific skills and competencies or change their existing attitudes and practices (World Bank, 2007). Effective engagement often requires knowledge, skills, and attitudes that are new not only to stakeholders such as farmers, resource users, or market agents, but also to research, extension, and development professionals. Scaling up and scaling out innovation system approaches will require cost-effective ways of building capacity for various types of actors, capabilities, and contexts. How this type of capacity strengthening links to more traditional, disciplinary training or to building capacity in multidisciplinary or systems approaches also needs to be better understood.

Achieving this will likely involve combining capacity-building opportunities with changes in incentive structures towards those that reward use of new knowledge and behaviors. It implies institutional arrangements that support and foster change. It also requires building and maintaining trust. This can be true at the individual and at the institutional levels.

This work will build on lessons learned from previous partnerships. Such partnerships have included public–private partnerships involving public universities, NARS, producer associations, and agribusinesses (Spielman and von Grebmer, 2004). They have also included farmer-participatory research, involving scientists from national and international research organizations, and farmers or resource users (Aw-Hassan, 2008; Lilja and Dixon, 2008b), and innovations systems, which involve a range of actors along the value chain (Hall et al., 2001).

Innovation capacity is determined by the ability to access knowledge and information on a continuous basis and by social learning opportunities. These are, in turn, determined by linkages/partnerships between various actors who have the knowledge and experience and the availability of spaces to support knowledge sharing. Social and gender-responsive approaches will be adopted to address issues of equity and exclusion in defining what and whose knowledge counts, in accessing new collaboration opportunities, in voicing needs, and participating in shaping innovations. To support partnerships, and to contribute to knowledge about how to facilitate individual and social learning, activities will focus on conducting needs assessments, implementing targeted capacity building, and carrying out research on the modalities and role of capacity building in partnerships and the impacts of increased capacity on the effectiveness of partnerships and on development impact.

Output 1.3: Strategies for effectively linking research to policy action in dryland context

Recently, theoretical advances in understanding impact pathways (Douthwaite et al., 2003a; Douthwaite et al., 2007) and in empirical analyses of successful cases of policy influence (Leksmono et al., 2006; Hooton and Omore, 2007; Joshi et al., 2008; Kristjanson et al., 2009; CGIAR Science Council, 2008; Clark et al., 2010) highlight the importance of engaging policy-makers, including involving them in the research process early on, when questions are still being defined, in order to enhance the relevance of the research and increase buy-in and the probability of uptake of policy recommendations that are generated from agricultural research.

These experiences need to be systematized and the lessons identified to develop and validate effective and efficient strategies for policy influence. There will be an opportunity to do this in CRP 1.1, working with partners inside and outside the CRP who are producing policy-relevant outputs for drylands. Doing this in a systems context offers both opportunities—various types of knowledge generated in a variety of ways and targeted at diverse types of policies at a number of levels—and challenges: there will inevitably be real trade-offs (winners and losers) associated with the various recommendations being promoted.

At the moment there is relatively little to guide researchers on how best to deal with the connections between innovation processes and political processes to provide knowledge to support policy negotiations rather than policy decisions (Clark et al., 2010). Working closely with CRP 2 and with the other system CRPs, provides an opportunity to contribute new knowledge and insights on this critical issue.

5.2 Strategic Research Theme 2: Reducing vulnerability and managing risk, leading to resilient dryland agroecosystems with less vulnerable and improved livelihoods of rural communities

In dryland agricultural systems, with severe water scarcity and fragile lands, productivity is not the primary driver of agroecosystem management. Yield stability sometimes has priority over high yield potential, productivity per unit of the most limiting factor (e.g. water, labor, or time) has priority over productivity per unit land, and input efficiency has priority over input responsiveness. Managing risk and vulnerability becomes a fundamental tool in building resilient and sustainable dryland systems, but can have many dimensions (Walker et al., 2002). System shocks, often influenced significantly by climate variability, resulting in a single failed crop or grazing season, a livestock disease epidemic, or a shift in market structure can have a catastrophic impact on vulnerable communities. Building adaptive capacity is therefore an integral part of reducing poverty and ensuring food security. The dominant production systems may include various crop, vegetable, livestock, rangeland, tree, and fish components that are often finely balanced to achieve positive synergies and spread risk, but they may also compete for the same resources. Whilst in the most marginal of these systems, pastoral management of rangeland resources has the potential to contribute positively to ecosystem services (Homewood et al., 2008), changing drivers means that such opportunities are at times missed—for example, increased cropping in marginal lands leads to higher stocking rates, increasing grazing pressure and resulting in rangeland degradation (Toutain et al., 2010). Despite these and many other constraints, agriculture has remained the basis of the local economy in such areas. Matching the environment and the food and feed crop/vegetable/livestock/trees/fish elements in a particular agroecosystem is the pre-eminent research need. “Getting the mix right” in terms of alleviating poverty, enhancing food security, and ensuring environmental sustainability is crucial under these conditions. This requires understanding the roles that these elements play in the livelihoods of rural communities and farming systems and how these roles change under different contexts and over time, as well as acting on this diversity of species. This understanding will be achieved by identifying, testing, and scaling up interventions that can enhance the value of the components and the system as a whole and generate new options for diverse groups of households. Maintaining these systems will also require the creation of incentives for on-farm conservation of agrobiodiversity.

Capturing, managing, and using limited water resources are major components of success under these environmentally and socioeconomically extreme conditions (Rockstrom et al., 2010). Research areas include water harvesting, vegetation- and soil-management options and their trade-offs, and exploring the use of marginal-quality water resources that include grey and saline water. Beyond these, opportunities for PES and incentives for environmental stewardship may be important starting points in areas where production activities are often too risky or would seriously damage the natural resource base. There is some controversy about recent large-scale agricultural developments in drylands, and the livelihood and environmental trade-offs warrant further study (Cotula and Vermeulen, 2009).

Degradation of water and land and its effects on agrobiodiversity are major threats to sustainable dryland agriculture, especially rangelands, which cover some 35 million km^2 of the earth’s surface and on which 180 million people depend for their natural resources (Thornton et al., 2002). Poor land, water, and agrobiodiversity management are the major causes of degradation. However, it is important to realize that once communities fall into the poverty trap, immediate food-security concerns may override long-term sustainability considerations, and a vicious cycle ensues that deepens poverty and leads to further resource degradation (Homewood et al., 2008; Little et al., 2008). Drylands are not homogeneous and are responding to a variety of drivers, meaning that determining where and how to break the cycle of resource degradation and poverty becomes a priority researchable issue. This will require working closely with SRT4 to identify the minimum biophysical and socioeconomic information required to make decisions to determine the most appropriate approaches in different circumstances, depending on possible development trajectories.

Vulnerability to poverty and food scarcity results from interaction between biophysical and socioeconomic factors. Therefore, this SRT will analyze the perceptions that various groups in diverse contexts have of vulnerability to risk, options available to them, and constraints they face to avert risk, and the impacts of shocks they might experience. This exploration will provide a solid ground to develop better technologies and institutional arrangements to reduce vulnerability to poverty and enhance rural livelihoods.

These fragile systems demand a variety of approaches to reducing risk that initially bring system stability, a prerequisite for building improved livelihood dimensions. Key approaches to risk reduction include early warning systems that are sophisticated but at the same time easy to use (Ericksen et al., 2011), crop and livestock insurance mechanisms, and greater recognition and rewards for environmental stewardship (Van Noordwijk and Leimona, 2010). In some instances (where natural resources can support this) a transition to new market opportunities may be part of the process; this might include, for instance, where access to information and delivery of novel approaches can build upon, for example, experiences in Africa and China on the use of mobile phones to provide agricultural advice (http://www.new-ag.info/focus/focusItem.php?a=1669). Such strategies will need to deal with complex situations, integrating multiple and variable inputs from agroecosystems, interactions among crop, vegetable, livestock, rangeland, tree, and fish enterprises, potential synergies, and livelihood welfare and stability aspects. There is already interest in how modern communication tools can be used to help guide movement of pastoralists to new grazing areas, coupled with incentives to maintain ecosystem balance.

Risk-reducing approaches might also require attention to previously overlooked orphan crops or activities. Women's multiple roles in post-harvest activities (e.g. food processing, seed selection and sharing, informal marketing, indigenous knowledge of wild plant species) have been shown to be vital for food security at household and community levels. These activities need attention despite their apparently low productivity and commercial potential. Also, women's knowledge and use of crops with limited commercial potential have been shown to support marginal rural livelihoods and preserve local food cultures (Howard, 2003).

Because of the fragility of these systems and the severe effects that unpredictable climate, global trade policy, or one or two poor seasons can have on local communities, a variety of societal and institutional mechanisms need to be added to natural-resource-based strategies. In this respect, utilizing and, to some extent, experimenting with the approaches described in SRT1 will be crucial to ensure not only the incorporation of indigenous and new knowledge but to address the variety of local, national, and regional policies that determine the success and sustainability of potential interventions. These may range from local engagement in land or water management to global policies that could have an influence on carbon payments. It is possible that some production systems will need to be dramatically altered and even that new agroecosystems will have to be adopted; in other cases, relatively minor but crucial adjustments may be sufficient to minimize risk and support more stable production. Given that rangelands are the biggest global land-use system, developing and learning lessons in target areas using innovation system approaches described in SRT1 and applying the priority setting and targeting strategies in SRT4 will foster the generation of regional and global public goods from the work in SRT2. Innumerable national and international research communities (including the CGIAR) and a host of development agencies have conducted biophysical and social research germane to dryland systems for decades and there are pockets of success. One of the aims of SRT2 is to provide an opportunity for "adding together" this vast body of knowledge responding to the biophysical and institutional challenges and taking the positive impacts of such strategies to scale.

5.2.1 Hypotheses

SRT2 starts with the overriding assumption that, for a significant proportion of livelihood systems in the most vulnerable and degraded dryland areas, reducing risk and improving stability and resilience is a fundamental priority, a significant livelihood gain, and a prerequisite for enhancing productivity. While specific hypotheses are developed and addressed within each region, there are several interacting generic hypotheses that drive regional research towards each of the outputs that SRT2 will produce.

There are three initial hypotheses underpinning SRT2 that relate to **system states for livelihoods**:

1) The first hypothesis (H2.1.1) is that vulnerable dryland livelihood systems typically involve complex interactions among a range of components so that change in the management of one will affect others.
2) The second hypothesis (H2.1.2) is that livelihood systems interact with one another so that changes in one affect others.
3) The third hypothesis (H2.1.3) is that while detailed local knowledge exists about how to manage natural resources within these livelihood systems, there are significant gaps in knowledge about to how to respond to new and intensifying drivers of change (e.g. climate change, declining water availability) and limits to observation (comparison is limited to options within a vicinity, knowledge is aggregated by observation, so, for example, knowledge of soil fertility is aggregated across crops grown and knowledge of fodder across type of livestock kept).

These hypotheses will be tested in conjunction with characterization in SRT4 through classical systems analysis and modeling with a focus on eco-efficiency (Keating et al., 2010) supplemented with systematic knowledge-based systems approaches to the acquisition and analysis of local knowledge (Sinclair and Walker, 1998).

These three system-state hypotheses lead to three hypotheses about **system dynamics**:

1) The first of these hypotheses (H2.1.4) is that options for improving whole-system performance are different from options for improvement of single components (as in commodity-focused CRPs).

   This helps to define where there is most value added by using integrated systems approaches. A commodity focus may work well for reasonably stable systems that are well linked to markets and involve only one or a few dominant crops or livestock, but we anticipate that whole-system approaches will yield different, more relevant, and more supportive guidelines for component and system improvement than commodity-orientated research for complex systems in vulnerable dryland contexts with critical resource constraints and trade-offs in the use of resources among components.

The second and third system-dynamics hypotheses relate to non-linear criticality.

2) The second hypothesis (H2.1.5) is that there are threshold levels of diversity required for stability and resilience.
3) The third hypothesis (H2.1.6) is that there are threshold levels of stability and resilience required before livelihood systems are robust enough for productivity enhancement to be a viable option.

These hypotheses will be tested using qualitative and quantitative comparative analyses (for example, evaluation of the value of recommendations for component improvement emanating from systems research compared with existing crop and livestock varieties and management options) and systems-dynamics-modeling approaches validated by testing model predictions against measured system performance.

Three key hypotheses underpinning SRT2 relate to **scaling**:

1) The first (H2.2.1) is the interlocking-livelihoods hypothesis: since different livelihood systems depend on one another (see H2.1.2), changes in one affect others, requiring considerations of interactions among as well as within livelihood systems when scaling out.

   This is partly the case because the definition of livelihood system boundaries is associated, for good reasons, with fundamental concepts of human organization (e.g. households). For tightly interacting livelihood systems, opportunities for certain types of households to change may lead to collapse of system properties at larger scales, affecting other livelihood systems. The critical issue is the need to consider interactions among as well as within livelihood systems.

2) The second hypothesis (H2.2.2) is that system interventions (see H2.1.4 above) can be generalized, that it is possible to understand the key system characteristics and contexts for which particular options are suited, and hence to match options to circumstances.

   In reality this will require continuous and iterative testing of what works, where, and for whom, implying co-learning during scaling up and out that will require a sufficiently rich range of options to be tested across a wide range of circumstances, coupled with monitoring of their performance.

3) The third scaling hypothesis (H2.2.3) is that some scale effects are only manifest at larger scales, and so may only be detected once system interventions are adopted by a sufficiently large number of people across a sufficiently large geographic scope.

   This most notably occurs with pest and disease incidence and spread, and feedback on market prices, but may also include many other issues, such as long-term impacts on aquifers of increasing tree density. Our knowledge of such scale effects creates a practical imperative to try to anticipate what may happen at scale, using modeling approaches.

Finally, there is one key hypothesis central to the SRT2 outputs: given complex trade-offs among co-limiting resources (inputs), local people are more likely to be able to integrate options for improvement within their complex livelihood systems than external scientists are to design whole-system improvements. The practical implication of this is that SRT2 has to deliver improved materials and decision support to farmers that build on rather than replace farmers' local knowledge. This hypothesis is tested by documenting adaptation of options by farmers so that the way in which they integrate components and knowledge within their systems can be compared with how the options were initially framed by scientists.

5.2.2 Methodology

This SRT will use classic systems analysis and modeling informed by agroecological approaches (Conway, 1985; McNeely and Scherr, 2003; Keating et al., 2010).

5.2.3 What's new?

The agroecosystems approach acknowledges that farmers and herders in these marginal environments are in reality dealing with multiple inputs, outputs, opportunities, and constraints. Understanding this complexity must involve the application of approaches for understanding dynamic evolving systems, including trade-offs among agroecosystem services (see, for example, the recent UK Foresight Project on Global Food and Farming Futures, www.bis.gov.uk/foresight) and the potentially different development trajectories that begin from a focus on the natural-resource base on which these communities intimately depend for their livelihoods. A mix of biophysical, social, economic, institutional, and policy issues need to be addressed in synergy if lasting change is to be achieved. Unique to SRT2 is the decoupling of efforts to raise productivity from those that aim at increasing temporal production reliability and stability and other resource-based livelihood options. It is also important to recognize that we are dealing with systems that are in transition. Our research aims to make that a positive transition for the people, their livelihoods, and the environment on which they depend, and will include targeting various strategies. In some cases, people will cease pastoral or farming activities, but many will still remain, and for them the opportunities for productive, stable, and equitable livelihoods will matter a great deal.

Results will include the following:

- Agroecosystem production approaches that spread the risk within and between production cycles
- Transition strategies for when long-term continuation of existing practices are likely to exacerbate degradation of the natural-resource base and affect the sustainability of livelihoods, calling for a move to new production systems or alternative livelihoods
- Participatory approaches that involve demand-driven needs assessment and land-use strategies
- Early warning systems, insurance schemes, and approaches to assess trade-offs that become an integral part of being a dryland farmer, pastoralist, tree grower, or fisher
- New focus on crops and activities of lower commercial potential that are nonetheless important for the sustainability of food security and food cultures
- Gender-differentiated strategies to avert risk and eliminate constraints to make use of opportunities to enhance livelihoods
- Assessment of the impact of these strategies contextualized in local realities and with a gender approach.

Indicators of successful delivery of these outputs and initial impacts include: improved and equitable livelihood benefits related to better management of environmental health and biodiversity; and increases in stability of production. In particular, resilience to risk and vulnerability will have markedly improved.

Ultimate impacts will include significant reduction in poverty and, more particularly, reduction of vulnerability of the resource-poor and the natural-resource base on which they depend.

In these most marginal systems, outcomes will depend on the one hand on the degree of vulnerability and on the other the potential for improved productivity. In the most vulnerable systems, beneficiaries will have more secure assets and habitat and will be able to benefit in equitable ways from their participation in environmental management. This requires improved risk management, early warning systems, and a diversity of social and institutional mechanisms (Output 2.2 and SRT1). In systems with higher resilience and production potential, beneficiaries will have more stability of production and the potential to engage in market enterprises either directly (as producers) or indirectly (as traders, processors, or other market agents). This requires outputs that enable equitable market participation and stabilize the production of crops and animals in an environmentally friendly way through combining biophysical water, soil, and agrobiodiversity management with appropriate crop and animal husbandry. Such strategies may eventually transition into the market-focused sustainable-development issues addressed in SRT3. In order for farmers to be able to take advantage of such approaches, new local institutional arrangements and enhanced access to knowledge and information will be required to facilitate scaling out; engagement at higher policy levels will be required to provide an enabling environment (Output 2.2 and using approaches developed in SRT1). Trade-offs in livelihood dimensions related to the management of natural resources and production enterprises, combined with a diversity of other drivers, will affect the potential of various strategies to impact positively and equitably on livelihoods of both women and men, and on the environment; thus, the approaches need to be well understood in this respect, and appropriately targeted (Output 2.3 and SRT4).

5.2.4 Outputs

Output 2.1: Combinations of institutional, biophysical, and management options for reducing vulnerability and mitigating risk

In dryland agriculture, risk and vulnerability are closely associated with water scarcity, ever-more-fragile land resources, loss of agrobiodiversity, and social dynamics such as disempowerment, lack of access to and control of productive resources, and lack of access to decision-making spaces.

Water is a significant source of variability. The amounts of water available are often too low for high or sustained production. Annual and intraseasonal variation in rainfall also increases instability and production risk. Despite general water scarcity, water runoff, soil erosion, and associated loss of soil fertility are widespread in low-input dryland agriculture. Predictions are that climate change will further increase rainfall variability; depending upon the region, circulation model, and scenario used, total rainfall may decline but intense rainfall events may increase, increasing both drought and the likelihood of runoff, flooding, and soil erosion. The selection of appropriate land use and associated management practices plays a major role in the management of ecosystem services and, where appropriate, stabilizing production (Davies et al., 2010). The local agrobiodiversity of plants and livestock, adapted to harsh conditions such as low-input agriculture, drought, and heat, may provide sources of variation to improve adaptation to and mitigation of the effects of climate variability and change. Indigenous knowledge and traditional risk-management methods will also be explored. This requires good baseline information about the composition and amount of agrobiodiversity maintained by rural households across the sites where CRP 1.1 will work, including associated local knowledge, specific uses, benefits, constraints, dynamics and threats. This will be used to generate information on where, how, when, and why the different species are used.

In rangeland environments, livestock, risk mitigation and availability of alternative livelihood sources are important to food security and protection of livelihoods. Strategies such as index-based livestock insurance (see Box 2) are being explored as a risk management option (Barrett et al., 2008) and there is considerable research related to the management of common properties and conflicts over their use (Turner et al., 2011) that is relevant to dryland management as well as to the intersection of livestock management with wildlife in some regions (see, for example, http://reto-o-reto.net/). The use of incentives to preserve the landscape and agrobiodiversity represent the application of an old approach to producing income from such beneficial services to society such as reduced emissions from deforestation and forest degradation (REDD) and increased carbon sequestration (De Pinto et al., 2010; CRPs 7 and 5) and wildlife preservation. A variety of such diversification options, including PES, may also have important roles to play in mitigating risk in marginal dryland environments, and demand significant research to address the complexities of institutional arrangements and knowledge flows as well as their biophysical underpinnings.

To reduce risk and improve agroecosystem productivity, available resources must be managed appropriately to minimize water and nutrient deficiencies. Risk and vulnerability can be reduced if producers use a combination of the right choice of crops (including vegetables, livestock, trees, and fish) and management options, and have access to appropriate information and incentives. Lessons can be learned from past successes. For example, where crop production is feasible, the impact of low and variable rainfall can be alleviated by the limited application of supplemental irrigation. Capturing rainfall runoff in water-harvesting systems and using this to alleviate soil-moisture stress during dry spells increases production and reduces production fluctuations and soil erosion. Where underground aquifers are used for irrigation, improved irrigation practices increase productivity while ensuring the sustainability of groundwater use (if appropriate policies are in place and enforced). Exploring the use of marginal-quality water resources such as urban wastewater and saline water, as has been done elsewhere, could play a crucial role in increasing crop production, agroforestry, and aquaculture under water-limited conditions. Millions of small-scale farmers around the world already irrigate with marginal-quality water, often because they have no alternative. Several organizations (including CGIAR Centers and partners) have jointly developed interventions for the safe and productive use of marginal-quality water resources, but further research is needed. CRP 1.1 will use research outputs from CRP 5 on water management as an input into systems research aimed at reducing vulnerability in drylands.

Degradation of water, land, and biodiversity are major threats. Biodiversity loss is particularly critical in dryland areas with annual rainfall ranging from 200 to 600 mm. More than 90% of crop diversity has disappeared from farmers' fields in these areas and half of the breeds of many domestic animals have been lost. Poor land, water, and agrobiodiversity management and use practices are the major causes of degradation (UNEP, 2007). The vulnerability of such systems relates to their exposure and sensitivity to perturbation and external stresses, and their capacity to adapt. To cope with risk, development and adoption of resilient systems for effective land/soil, water, and agrobiodiversity use is crucial.

Dryland systems face significant challenges that will necessitate sometimes drastic changes in production systems that may include changes in commodities, crop varieties, and livestock breeds, reintroduction of agrobiodiversity into the production system, and the abandonment of certain production systems for other income generating opportunities (both agricultural and non-agricultural). Dryland production systems depend on ecological processes, biodiversity, and the services provided by these ecosystems to maintain productivity and livelihoods. Over the last century inappropriate management of these agroecosystems has caused widespread changes in land cover, watercourses, aquifer use, and biodiversity, contributing to ecosystem degradation, declining productivity and undermining the processes that support agroecosystem services (Falkenmark et al., 2007).

Risk and vulnerability are also the product of disempowerment, unequal distribution of productive resources, lack of a voice in decision-making spaces, and lack of access to opportunities and information. SRT2 will analyze these components and develop best-bet strategies to empower the most marginal actors and sectors with consideration of social, biophysical, and institutional components.

SRT2 will investigate combinations of options for water, land, and agrobiodiversity management in conjunction with appropriate institutional arrangements that can contribute to production stability, leading, in appropriate circumstances, to greater environmental stewardship and diversification of income opportunities, with market engagement especially for dryland-specific products as one option. CRP 1.1 will engage closely with other CRPs whose outputs in many areas (crops, vegetables, livestock, NRM, climate change) are relevant to dryland agricultural systems.

Output 2.2: Options for reducing vulnerability and mitigating risk scaled up and out within regions

CRP 1.1 will use an integrated participatory planning and management framework to develop and validate options for farmers and livestock keepers that will reduce risk and vulnerability for communities as well as natural resources. The research will address issues related to stabilizing productivity, including options and incentives to better manage ecosystem services. In addition to resource-management options, other risk-management strategies such as index-based livestock insurance (see Box 2) will be developed and pilot tested, and their socioeconomic and environmental impacts evaluated. The biophysical research to address these challenges is described under Output 2.1. Technology-based approaches alone will not reduce vulnerability and mitigate risk in dryland areas. They must be contextualized in relation to local and wider-area stakeholders and the institutional and policy dynamics. Approaches described in SRT1 will be important for engaging a variety of stakeholders in acquiring, developing, and testing information, and creating an enabling policy environment.

The need for farmer participation and innovation is critical. Since most land, water, and biodiversity resource-management challenges tend to be site-, situation-, and farm-specific there will be a need for flexibility in the choices that are developed and implemented. There is clear need for diagnostic and prioritization tools to identify entry points and interventions that build on the available resources, particularly on agrobiodiversity, to improve farmers' livelihoods. Since approximately 70% of the world's poor are women, who shoulder a disproportionate role in securing food for households (WHO, 2000), it is important that interventions take into account any gender differences in needs, adoption, and use. Participatory approaches for sustainably managing natural resources can be extremely effective. Effective and equitable participation of the most marginal groups will be encouraged through targeted social analysis and gender-sensitive strategies that will support, whenever possible, collective action by women and men. There are numerous examples of collective action and community-based watershed management programs in South Asia that have been successful in addressing poverty and resource degradation (Wani et al., 2009b). Likewise, bottom-up community-based approaches in North Africa have resulted in strong adoption of new technologies such as alley planting of cacti to produce forage for livestock. A key element of SRT2 at target sites will be validating interventions that address local risk and vulnerability while also generating outputs with IPG potential.

Too often, dryland agroecosystems are managed as though they are disconnected from the wider landscape, with scant regard for maintaining the ecological components and functionality that underpin their sustainability (Falkenmark et al., 2007). There is clearly a need for more holistic planning and management, such as that demonstrated in watershed-based approaches that address biophysical and socioeconomic impediments and provide farmers and livestock keepers with decision-making tools to reduce risk and vulnerability in the production system while ensuring resilience to a range of change drivers.

Information access and exchange are vital for decision-making. Through working closely with stakeholders at various levels (using approaches described in more detail in SRT1), research will include strategies to develop and disseminate knowledge and information that will allow stakeholders to make informed decisions, allowing them to cope with and mitigate the effects of drought and other system degraders.

Output 2.3: Analyses, within target regions, of trade-offs among options for reducing vulnerability and mitigating risk, and knowledge-based systems for customizing options to sites and circumstances

A key issue for resource-poor communities in these regions is their ability to respond to a number of variables that operate at different temporal and spatial scales. At the local scale, variables range from slow ones, such as climate change, decline in or depletion of aquifers, growth of woody plants, trends in markets and investment, and changes in infrastructure, through to fast ones such as grass growth, animal numbers, and livestock prices. It is therefore crucial to better understand the interaction between these quick and slow hazards at various scales (Walker and Abel, 2002). CRP 1.1 will focus on local and regional levels, but needs to ensure that these more detailed assessments link well to the broader-brush evaluation of such dynamics as implemented in CRPs 5 and 7.

Managing various kinds of risk in complex dryland environments requires reliable and spatially explicit information systems, as well as knowledge-based systems to (i) transform raw data into useful information for decision-makers, and (ii) provide simulation modeling results on various aspects of risk management and vulnerability.

Early warning systems are an important component of drought-management strategies. Most early warning systems monitor rainfall or vegetation phenology, leaving it to the interpreter to assess the potential impacts on various production systems. SRT2 will support the design and development of innovative early warning applications that combine GIS and remote-sensing data with expert knowledge systems to forecast the likely impact on production-system output and provide advice on appropriate coping strategies given these forecasts. On the mitigation side, SRT2 will develop information systems that allow scenario-based assessment of the impacts of current and alternative land use on various dimensions of livelihoods in drylands, including vegetation, livestock, and crops, while integrating the quick and slow hazards mentioned above. Recent moves towards larger-scale agriculture in drylands (Cotula and Vermeulen, 2009) will also be investigated in this context.

Trade-offs in various dimensions such as vegetation, livestock, and crops are an important consideration, especially when addressing the fragile livelihood systems found in drylands. Trade-offs in relation to crop-residue access as animal feed or soil amendments will be investigated in SRT3. The theme will also consider impacts on ecosystem services of changes in, for example, water, vegetation, and rangeland management.

5.3 Strategic Research Theme 3: Sustainable intensification for more productive, profitable, and diversified dryland agriculture with well-established linkages to markets

This theme will target dryland systems with the greatest potential for impact on poverty in the short to medium term. Some of these agricultural systems are in transition from primarily subsistence to more market-oriented systems (e.g. parts of Central and South Asia, and North Africa). They offer possibilities for intensification of existing farming systems through more efficient use of scarce natural resources combined with production options and opportunities along the value chain. Sustainable intensification aims at increasing input use to increase output, based on principles of sustainability (Payne et al., 2001; Keating et al., 2010; Power, 2010). Sustainable intensification opens possibilities for adopting higher-value crops, improved livestock, and value-adding activities that increase profitability of the farming systems. Dry areas and oasis ecosystems with access to irrigation and/or potential for water harvesting can benefit more from intensification-related interventions than less-favored areas but may require careful attention to NRM and related incentives. Using partnerships and knowledge-sharing to empower small farmers with better agricultural technologies, inputs, market access, and new income opportunities can increase system productivity and sustainability, while at the same time reducing risk and vulnerability. Particular attention will be paid to empowering women farmers, who usually have poorer access to technologies, inputs, services, and information than do men, in order to ensure gender-equal access to new income-generating opportunities along the value chain. Women's access to and control of revenue is an essential element of household food security. Attention will also be given to youth farmers and youth enterprises, with a view to stemming the exodus from rural communities and addressing some of the causes and effects of urbanization.

Dryland farmers have many possible strategies for intensification and diversification that are used dynamically as opportunities and threats occur. Understanding how, why, and when these strategies are mobilized is important in developing sustainability. This SRT posits that: (i) there is more useful crop, vegetable, livestock, tree, and fish diversity available in the drylands than farmers are currently using; (ii) knowledge of, access to, and use of this additional diversity will improve production, farm income, and dietary diversity; and (iii) understanding the performance of their current crop, vegetable, livestock, tree, and fish diversity under various farming systems will allow farmers to cope better with the changing biophysical and institutional environments in which they live. This theme will design and develop sustainable intensification options (Output 3.1), out-scale these options (Output 3.2), and analyze and resolve system trade-offs for customizing solutions (Output 3.3).

Dryland agroecosystems are complex and may involve many components and products (crops, livestock, trees, fish, fruits, and vegetables) with multiple uses (e.g. food, feed, fiber, organic matter, medicines, and fuel) which can be used more effectively for enabling system intensification and generating new income opportunities. Sustainable NRM is a knowledge-intensive process, often requiring local assimilation and adaptation, which often is facilitated through participatory and collective/community action (Pound, 2008). Access to resources and information vary greatly among social groups, and more equitable involvement has to be achieved. Therefore, systems-based approaches with a strong commitment to broad participation and inclusive partnerships at various scales are required to understand, develop, and deliver productive and profitable technologies and diversified production systems to both women and men. An important component of an agroecosystems approach is to improve the capacity and knowledge of individuals and communities to innovate and adopt/adapt technological solutions and market-related opportunities. It also involves identifying local species with market potential and improving their marketability and value chains. Technologies and practices that lead to more-productive and sustainable agroecosystems will often be specific to a locale, country, or region, and they thus need to be developed and implemented within country agricultural R4D systems and policies. Other organizations and institutions, including those influencing and making policy, are, therefore, also need to be involved in the R4D progress to "enable" research and adoption, especially at local levels.

Sustainable intensification in mixed systems will focus strongly on crop–livestock–tree–fish integration, integrated soil-fertility management, and enhancing water productivity and profitability (Singh et al., 2009). A major issue for the crop–livestock and agropastoral systems of the drylands is competition for natural resources (e.g. water, land), especially crop and other biological residues. Research can assist farmers in better managing or negotiating these trade-offs in relation to livelihood options. Incentives and profit are the major drivers for technology adoption and intensification of farming systems—farmers are much more likely to invest in inputs and technologies for increased production where there is a profit incentive. A major objective of this SRT is to help farmers transition from subsistence to market-orientated agricultural production, by analyzing and resolving the constraints limiting market access. Agricultural intensification, whether through existing or new agricultural enterprises (with added value), is a pathway out of poverty.

5.3.1 Hypotheses

There are five hypotheses underlying SRT3.

1) H3.1: Combining gender-oriented innovations in crop–livestock integration, improved agricultural practices (including conservation agriculture), market access, value chains, and emerging markets for ecosystem services can provide site-specific options for sustainable intensification and pathways for poverty alleviation.

   The testing of this hypothesis will rely on: (i) comparative analysis of adoption of differential R4D strategies for enhancing intensification (including specific system components) by measuring output and input use; (ii) refining and testing site-specific hypotheses focusing on given sets of system components; this would also involve systems modeling and comparison of intensification strategies and interventions across sites and regions.

2) H3.2: Intensification interventions must be combined with better NRM practices in order to enhance system sustainability without necessarily affecting productivity.

   This hypothesis will be tested by monitoring short- and long-term feedback effects of NRM interventions on system productivity, and by analyzing and modeling system trade-offs between management of natural resources, including agrobiodiversity, and intensification.

3) H3.3: System trade-offs related to competing uses of biomass can be resolved through better integration of crop, fodder, tree, and livestock systems.

   This hypothesis will be tested using comparative systems analysis and monitoring of adoption of new integrated R4D packages in specific regions, specifically long-term adoption of conservation agriculture practices in mixed crop–livestock systems in West and East Africa. Testing of this hypothesis will build on the experience of the CGIAR Systemwide Livestock Program, and other ongoing research networks (e.g. CA2Africa).

4) H3.4: Dry areas with access to irrigation or potential for water harvesting can benefit from intensification-related interventions.

   This hypothesis will be tested through comparative analysis of system productivity with and without adoption of technologies, at various rainfed and irrigated sites across North Africa and West Asia. A similar approach could be adopted in the other target regions.

5) H3.5: Potential niches for scaling out intensified agricultural and pastoral systems can be identified within and across target regions.

   Testing this hypothesis will involve systems modeling and monitoring of adoption across sites and regions with similar characteristics (jointly with SRT4).

5.3.2 Methodology

An integrated R4D model will be adopted to promote sustainable intensification, using community-based approaches to identify entry points for a range of activities that integrate optimized production systems, NRM, and market opportunities. This will require concerted intervention of crop and livestock scientists, animal nutritionists, irrigation specialists, economists, social scientists, input suppliers, seed industry and local seed system functionaries, credit agencies, traders, male and female crop and livestock producers, feed manufacturers, end-product processors, retailers, and exporters. To understand, develop, and deliver options for sustainable intensification of production, CRP 1.1 will use systems-based approaches with a strong commitment to broad participation and inclusive partnerships (Sreedevi and Wani, 2009).

Site-specific research interventions will be developed with multidisciplinary approaches integrating NRM, genetics, agronomy, agroforestry and livestock systems, social sciences, and policy research. The genetic management options will aim at exploiting the variation in drought resistance available in ancient and modern crop germplasm (interaction with commodity CRP 3s) to promote crops with high productivity and efficient water use (Gowda et al., 2009; Serraj et al., 2011). This approach will be integrated with efficient management practices and dual-purpose crops optimized for crop–livestock integration. In areas with access to irrigation and/or potential for water harvesting, supplemental irrigation will be harnessed to intensify productivity with careful attention to NRM (Oweis et al., 2006). Increasing productivity through the optimization of input use based on agroecosystem principles of sustainability will enable the development of sustainable intensification options (Keating et al., 2010). Interactions between productivity and sustainability of smallholder farming systems will be investigated by multidisciplinary teams; these will analyze critical gaps in food/—feed, conduct related NRM research, and investigate suitable policy environments for crop–livestock system innovations (Singh et al., 2009; Herrero et al., 2010).

Site-specific conservation-agriculture options that integrate using crop residues for surface cover, minimal soil movement, and efficient crop rotations will be evaluated for their effects on intensification of cropping systems in dry areas by monitoring the long-term effects on yields, production cost, labor requirements, and soil properties. Special attention will be devoted to the assessment of the biophysical and socioeconomic conditions under which conservation agriculture would be adapted for smallholder farming (Giller et al., 2009). Sustainable NRM will also require local adaptation and decentralized approaches using participatory and collective/community action (Pound, 2008).

Yield-gap analysis and farming-systems modeling will be used to develop decision-support modules dealing with system productivity, NRM, and risk assessment. Remote sensing and GIS tools will be used to monitor rainfed and irrigated croplands, perennial tree crops, and rangelands in the target areas (Wu and De Pauw, 2011) and to identify opportunities and potential niches for scaling out intensified agricultural and agropastoral systems. Analysis of the constraints limiting market access will improve understanding of the pathways promoting farmers' transition from subsistence to market-orientated production. The intensification strategies adopted in the project target areas will be monitored on the basis of productivity, food security, environmental sustainability, gender equity, human health, and economic and social well-being, contributing to the development of global assessment networks (Sachs et al., 2010).

5.3.3 What's new?

Across all outputs in SRT2 and SRT3, an integrated development research model will be adopted. It uses community-based approaches to identify entry points for a range of activities related to natural resources and new production and market opportunities. Understanding the interactions between intensification, enterprise priorities, and markets will be a key output. The socioeconomic component affecting access to new opportunities for intensification will be also explored. Gender-sensitive strategies will be developed in order to ensure gender-equal access to and control of the means to participate in the new opportunities and benefit from them. This integrated research will use innovation systems approaches from SRT1; promising technologies for productivity and sustainable NRM from other CRPs such as crop, vegetable, livestock, tree, and fish husbandry from CRP 3; water and soil management from CRP 5; and policies to support farmers and input/output markets from CRP 2. There will also be strong links to CRP 7 on several aspects: reducing farmers' climate-related risks; mitigating the future impacts of intensification on climate change; and developing resource technologies that reduce risk but could also increase productivity under more favorable conditions.

5.3.4 Outputs

Output 3.1: Combinations of options for sustainable intensification and diversification of agricultural production systems

Extensive mixed crop–tree–livestock systems in dry areas are expected to be a major source of agricultural productivity growth in the coming decades. These areas do not have the same level of resource competition that more intensively farmed areas are currently experiencing. There are opportunities for improving components of the systems—soil and water management, crops, vegetables, rangelands, livestock, trees, fish, input use (e.g. nutrient management or feeds)—, improving integration of components (e.g. optimizing use of crop and other residues, grazing strategies), and introducing new components, especially new crops and value-added products and new uses and markets for local species. Especially if there is some supplemental irrigation water available, the inclusion of fruit and vegetables in these farming systems can add significant value. Urbanization and improved road and communication infrastructure in particular will offer some farmers greater opportunities to intensify. In livestock-based systems, improved pasture management and incorporation of crops and fodder have potential for intensification if carefully managed to ensure environmental sustainability and social equity (link with CRP 2).

Some CGIAR Centers have developed approaches for promoting *in situ* and on-farm conservation and sustainable use of agrobiodiversity, including the development of alternative sources of income by adding value to the products of dryland agrobiodiversity (e.g. native potatoes in the dry Andes). Farmers often gain only a fraction of the potential benefits from their local products because they sell them as unprocessed raw products; as a result, intermediaries collect most of the benefits. Moreover, women (and young women in particular) have limited access to markets because traditional limitations to their physical mobility restricts them to local markets only. They might be discouraged from dealing with unknown men (such as intermediaries or customers) and also often have limited access to information and communication technologies (ICTs) and information about marketing opportunities and prices. In general, post-harvest constraints have not received enough attention, and processing the crop, packaging it, and labeling it could increase the returns to local farmers, especially women who largely carry out these activities. These alternative options to add value, combined with improved access to markets, will help diversify livelihoods of rural poor living in the drylands.

Intensification of farming systems and increasing the sustainability of NRM depend on efficient integration of livestock and crop production. Livestock production needs to be more efficiently integrated with cropping systems to raise productivity, improve livestock health, increase feed resources, reduce feed costs, and reverse rangeland degradation. Small-scale small ruminant production has not received much technical and policy support to overcome deficits in feeding systems, reproductive improvement programs, animal health services and marketing, despite the almost universal ownership of small ruminants and poultry by smallholder farmers in dry areas. The quality and homogeneity of products from dryland agriculture must be improved to increase producer prices and market access. Policy research will also be key, especially at the local/country level, since some of the main constraints to agricultural productivity are not technical but institutional, including lack of infrastructure, services, and appropriate supporting policies.

Output 3.2: Options for sustainable intensification and diversification scaled out

Poor farmers in dry areas are heavily dependent on natural resources, including soil, water, and plant and animal agrobiodiversity. Their agricultural systems produce a multiplicity of products from agricultural and rangeland systems combining crops, vegetables, livestock, trees, and fish within spatially heterogeneous and temporally variable ecosystems. These diverse combinations allow farmers to cope with abiotic and biotic production stresses, as well as market risks (SRT2).

For scaling out sustainable intensification options, it is essential to draw lessons learned from when they were first implemented and from existing systems, such as the crop–livestock–tree system practiced in the Kano close-settled zone in northern Nigeria (Mortimore and Adams, 1999). Agricultural principles that promote conservation (e.g. minimum tillage, ground cover, rotation) and key interventions are well known and already widely practiced globally, even in some dryland pockets (e.g. Zimbabwe: see Mazvimavi et al., 2008), but their potential has still to be fully realized in the drylands and there are important trade-offs, especially for biomass use and residue management (Output 3.3.). Links with CRP 3 will be important in terms of accessing new crop, vegetable, livestock, tree, and fish technologies that can be validated and scaled up. However, given the complexity of the systems, and their often “local” nature, proven indigenous knowledge and practice may also be an important source of innovation and productivity improvement and can also provide information to feed back into both CRPs. Careful targeting, systems analysis, and impact assessment will be required to identify opportunities and take them to scale (SRT4).

Coalitions need to be formed with various actors, including crop, vegetable, and livestock scientists, animal nutritionists, input suppliers, economists, social and gender analysis experts, seed industry and local seed system functionaries, credit agencies, traders, farmers/animal keepers, feed manufacturers, end-product processors, retailers, and exporters. Some CGIAR Centers have already started such coalitions, for example the coalition promoting sorghum grain for poultry feed (Gurava Reddy et al., 2006) and one promoting development of Awassi dairy sheep.

Output 3.3: Analyses, within target regions, of trade-offs among sustainable intensification and diversification options, and knowledge-based systems for customizing options to sites and circumstances

Intensifying and diversifying dryland agriculture calls for combining various production and management technologies in ways that increase productivity without causing environmental (sustainability) and health problems (externalities) associated with crop–livestock–tree–fish systems in high potential areas. A key research question will, therefore, be how to achieve a balance (or understand the trade-off) between intensification and sustainability, especially across scales from farm to larger areas such as watersheds.

Conservation agriculture (CA) practices that combine crop residue cover, minimal soil movement, and crop rotations/diversification have shown promising results for cropping systems intensification in dry areas, for example in West Asia (www.icarda.org). Compared with tillage-intensive systems, CA can often maintain or increase yields, reduce production cost and labor requirements, improve soil physical, chemical, and biological properties, and reduce erosion. Wider adoption of CA could help overcome natural-resource shortages in drylands. However, these benefits might not apply to all agroecosystems; important variability and system trade-offs could limit the expansion and adoption of CA in smallholdings (Giller et al., 2009; Lahmar, 2010). The development and sustainability of CA systems tends to be highly site specific. There is thus a critical need for a comprehensive assessment of the ecological and socioeconomic conditions under which CA could be adapted for smallholder farming in dry areas. The shift from conventional agriculture to CA should involve all the relevant stakeholders to generate and to share knowledge necessary to adapt, adjust, and optimize the system's components. For example, competition between uses of crop residues (e.g. as livestock feed or as soil cover) could possibly be resolved through better integration of crop–fodder–tree–livestock systems. The dynamic functioning and evolution of these systems and their long-term impacts on agroecosystems also require sustained R4D attention in the future.

The CGIAR Systemwide Livestock Programme (SLP) has adopted an integrated approach that analyzes the trade-offs of mixed crop–livestock systems to build synergy among the various R4D interventions (www.vslp.org). Multidisciplinary teams investigate the complex interactions between productivity and sustainability of smallholder farming systems, including analyzing critical gaps in food–feed, conducting related natural-resources research, and investigating suitable policy environments that support crop–livestock system innovations (Herrero et al., 2010). SRT3 will build on the SLP's experience to undertake strategic and applied research linking research into crops, agroforestry, livestock, and natural resources and policy research.

Opening up pathways out of rural poverty and stimulating agricultural and rural transformation in low-income regions requires more-inclusive and competitive markets and market-related institutions that improve the rates of return on the limited assets the resource-poor own, and mechanisms that encourage uptake of more efficient production and post-harvest processing technologies for (Birthal et al., 2005). To make markets work for the rural poor and the most marginal groups among them, we need to address why the resource-poor, and women in particular, are today often systematically excluded from markets, or why market-driven development may have an uneven impact on them. Greater participation in more-remunerative marketing channels has spurred significant improvements in rural livelihoods and resulted in an inclusive agricultural transformation in many parts of the developing world, especially where there is good agricultural potential and access to complementary infrastructure. However, it is noticeably absent in highly marginalized regions of Africa, Asia, and Latin America, where less favorable agroecological conditions and weak institutional and physical infrastructure have hampered the development of markets and institutions that propel sustained improvement in livelihoods of the resource-poor. A value-chain approach, encompassing input suppliers to farmers to end-users of products, should be promoted. New innovative institutional arrangements will have to be promoted to link farmers to markets.

Key research questions that will have to be addressed include the following: What are the major feedbacks and trade-offs among resource-conservation technologies, intensification, and diversification options? How do local institutional arrangements such as community organizations or contract farming help or hinder access to high-value chains by poor women and men farmers? What policy and institutional interventions are needed to facilitate poor female and male farmers' access to critical services that affect market access (such as certification of organic and good agronomic practices)?

5.4 Strategic Research Theme 4: Measuring impact and cross-regional synthesis

SRT4 will map and characterize dryland agricultural systems, describing and quantifying the farm, non-farm, and value-addition opportunities, assessing *ex ante* the potential impacts of various agricultural innovations at household and intrahousehold level, and identifying priority areas in terms of the severity of poverty, severity of degradation and depletion of natural resources, potential impacts, and number of vulnerable people impacted, particularly women and children. SRT4 will also provide comparative analysis of the socioeconomic dynamics of dryland systems (including *ex post* assessments) across various dryland regions, and identify major external and internal drivers of system trends, including technologies, market access, capital and labor flows, and social capital at individual, household, community, subnational, and national levels. In addition, the effects of global changes on the vulnerability of and opportunities for dryland farmers will be a major focus. These studies will be grounded on solid databases on the state of production, use of natural resources, including agrobiodiversity, and welfare-outcome indicators against which progress will be measured. SRT4 will develop strategies to monitor and measure changes in selected environmental and livelihood indicators in the target dryland systems and provide explanations for changes and for the lack of change where change was expected. The rationale for public investment in agricultural research is based on the expected impacts of agricultural research on economic growth. The linkage between agricultural growth and poverty, for example in terms of reduced child malnutrition, has been a focus of much research (de Janvry et al., 2010; SPIA, 2010). This SRT will build on that rich literature and rigorously assess and monitor impacts of program research on development goals of poverty reduction and environmental sustainability.

Impact assessment has numerous challenges; these include establishing the counterfactual situation (or what would have happened if the research output were not adopted), which requires monitoring of adopters and non-adopters before and after the technology is introduced and ensuring that there is no spillover of information from adopters to non-adopters. Unlike economic impacts, measuring social and environmental impacts is hampered by the lack of markets that value the flows of goods and services resulting from the adoption of research outputs (Renkow, 2010). This SRT will make use of recent methodological developments in impact assessment (de Janvry et al., 2010; Renkow, 2010; SPIA, 2010) to address these challenges. Methods that will be deployed include: randomized control trials; village computable general equilibrium (CGE) models; regression methods using instrumental variables, household models, bio-economic modeling, and partial and general equilibrium models; participatory methods and qualitative analysis; and use of GIS-based spatial modeling. The target areas proposed in this CRP will also be used to monitor changes in relevant economic, environmental, and social indicators over time. The role of women in dryland agricultural systems is important and in some cases dynamic; for example, increasing migration of men in search of work is increasingly becoming an important alternative livelihood strategy in many dry areas. SRT4 will, therefore, will give special attention to gender disaggregation of analysis of both socioeconomic factors and technological and institutional options. Such analysis will also focus on other vulnerable groups such as landless/assetless or transhumant/nomadic households, and measure both negative and positive effects of proposed options on women, men, and vulnerable groups.

5.4.1 Hypotheses

SRT4 is underpinned by four hypotheses.

1) H4.1: Characterization of target dryland systems using integrated, comprehensive, systems-oriented methods will improve the targeting of key intervention points.

   Testing this hypothesis may require specific planning where some (similar) target sites are characterized by less integrated methods and then the results compared with those from a more systems-oriented approach. Target sites may also be analyzed using component vs. system-oriented approaches to determine similarities of key interventions identified.

2) H4.2: Lessons about successful interventions (what works, where, and why) that are synthesized from the target sites within and across target regions will be generalizable and scalable up/out across numerous dryland systems (i.e. as IPGs) rather than being site- or region-specific.

Lessons learned from target sites will be compared across sites and regions to determine similarities and differences to test this hypothesis. Lessons that are similar would have highest probability of being scalable and transferable across all regions. Future efforts could then determine the extent to which this is true. Lessons that vary across sites/regions could be studied further to determine the reasons for this variability.

3) H4.3: In most dryland systems, it will be possible to measure system impacts (e.g. increased productivity and sustainability and improved livelihoods) linked to specific interventions, not simply the impact of specific components.

   Preliminary studies would be required to determine the types of impacts measurable. These would be disaggregated into components to determine contributions. Working with other CRPs, especially those working on commodities, comparisons on measuring or attributing impacts to specific interventions could be analyzed.

4) H4.4: Interventions applied using an agroecosystems approach—as opposed to more traditional commodity-based approaches—will generate larger, more equitably distributed, and sustainable impacts.

   Comparisons of *ex ante* impact assessment studies could be compared to those following CRP interventions (these might be feasible in the second phase, depending on the intervention). Impact assessments could be compared between CRP 1s and CRP 3s.

5.4.2 Methodology

This SRT will use current developments in the areas of participatory outcome and impact evaluation and outcome mapping and assessment (Earl et al., 2001), livelihood analysis (Bebbington, 1999; Scoones, 2009), *ex ante* and *ex post* impact assessment that includes social (Becker, 2001) and economic (Lemieux and Wohlgenant, 1989; Evenson, 2001) aspects, using longitudinal data sets to monitor systems changes and resulting livelihood outcomes. It will also perform cross-regional comparisons of various approaches, e.g. systems diagnosis and problem identification approach vs. single component development approaches. Recent methodological developments in impact assessment will help address these challenges (de Janvry et al., 2010; Renkow, 2010; SPIA, 2010). These methods will help establish counterfactual situations (what would have happened if the research output were not adopted) by monitoring adopters and non-adopters (control group) before and after the technology is introduced, while ensuring that there is no spillover to the control. The lack of markets that put a value on goods and services resulting from the adoption of research outputs (Renkow, 2010) is another challenge, particularly for measuring the social and environmental impacts; this will addressed in this SRT by using methods for valuing environmental factors and natural resources (Harrison, 2006). With the aid of GIS tools and baseline characterization (biophysical, socioeconomic, and livelihoods) in each target area, cross-site analysis could provide insights on what is more likely to work in one place and what is not. A combination of methods will be deployed, including controlled trials, village CGE models, regression methods using instrumental variables, household models, bio-economic modeling, partial and general equilibrium models, and GIS-based spatial analysis. The target areas proposed in this CRP will also be used to monitor changes in key economic, environmental, and social indicators over time. The role of women in dryland agricultural systems is important and in some cases dynamic; for example, migration of men for work is an increasingly important livelihood strategy in many dry areas.

5.4.3 What's new?

The main innovation in this SRT is the comprehensive, integrated problem-solving approach adopted, starting with the identification and prioritization of dryland agricultural systems and identification and detailed description of livelihoods constraints by gender, through to monitoring the feasibility, adoption, and impacts of innovations, thus presenting lessons learned and a well-described impact pathway of

IAR4D interventions. This SRT integrates research results of agroecological, economic, and social studies within CRP 1.1 and from other CRPs based on research-specific and cross-regional analyses of future scenarios and priorities, livelihood characterization and adoption, and impact monitoring and assessment, thus contributing to the understanding of the whole impact pathway.

5.4.4 Outputs

Output 4.1: Analyses of future scenarios and priorities

A combination of external and internal factors affects the state of social, economic, and natural-resource conditions in the drylands. These driving factors must be identified, prioritized, and monitored and their impacts on the entire agroecosystem adequately understood, modeled, and projected if we are to ensure gender-neutral impact of interventions in the drylands. Internal drivers of change in dryland agroecosystems include population growth, land fragmentation, land-tenure change, migration and conflict, and an increased role of women in agriculture. External drivers include global- and domestic-market dynamics (including trade dynamics and an increasingly consolidated food retail sector) that affect input and output prices, changes in food-safety standards, new technological innovations (including new crop types and varieties), increasing opportunities in urban areas, changes in policy and institutional arrangements, climate change, and changing climate variability.

These changes in internal and external factors create both opportunities and constraints and a need to adapt R4D priorities and strategies to new realities. Such flexibility to adapt on the basis of regular updates of possible future scenarios will provide adequate and reliable guidance to maximize the impact of the R&D investments undertaken in this CRP. A high level of integration will need to be achieved between biophysical, environmental, social, and economic modeling, and this against a background of a changing climate, resources, markets, policies, and the wider economy. The specific outcomes of scenario studies may include the identification of new research priorities, policy changes that are needed, or possible development programs that would minimize risks and target the most vulnerable, as well as interventions to help smallholders or women to fully exploit emerging market trends. An example of such outcomes is the development and adaptation of innovative ways of communicating market information to farmers. The proposed scenario analysis will mainly serve as a way of informing all stakeholders in the whole of CRP 1.1 about possible future changes, their implications, and the opportunities and challenges they create, thereby helping in the whole process of priority setting and strategy development for dryland agriculture. The United Nations considers it critical that adaptation efforts systematically and effectively address gender-specific impacts of climate change, including effects of energy and water scarcity, food security, and potential conflicts. Gender inequalities in access to resources, including credit, extension services, information, and technology, will be taken into account in evaluating adaptation measures and in evaluating these scenarios.

The results from this research will help identify priorities for investment in R4D in dryland agricultural systems in general and in the target areas in particular; provide likely scenarios resulting from environmental and market changes at the global and agroecosystems levels, and inform the design of R4D strategies to help dryland communities adapt to these changes. This outcome will ultimately improve the well-being of poor rural dryland communities and reduce their vulnerability to risks created by these changes.

Output 4.2: Baseline characterization of livelihoods and ecosystems, and synthesis across regions of lessons learned about the options developed in SRTs 2 and 3

Dryland agricultural producers regularly deal with environmental and market risks. One strategy they use to handle these risks is diversification; they engage in multiple enterprises, including a mixture of crops, vegetables, livestock, off-farm employment, migration, and small-scale family enterprises. By so doing, they try to optimize the allocation of their natural, physical, financial, social, and human resources among these diverse livelihood options. One major challenge they face is that they often make production and consumption decisions with incomplete information about current and possible future states of markets and environmental factors. The adoption and adaptation capacities of resource-poor women and men and their potential to lift themselves out of poverty depends on the state of the various types of capital they have at their disposal (human, financial, social, etc), the policy environment, and their access to services, infrastructure, and markets. The sustainable-livelihoods framework provides a comprehensive model to assess the capabilities and constraints of rural livelihoods (Bebbington, 1999; Scoones, 2009). Understanding and characterizing the multidimensional livelihoods of rural communities allows the identification of what options may be best suited to what livelihood system, and helps to guide research and out-scaling strategies. A major entry point, given the importance of agrobiodiversity in these contexts, is to understand and monitor the individual and systemic roles that agrobiodiversity plays in farmers livelihoods and systems and how it relates to other type of capital and options available to farmers, and how these roles change over time and in specific contexts. This will require a monitoring and information system.

This research will be conducted at farm and community levels and will link to Output 4.1. The addition of a spatial dimension will help capture the spatial variation in livelihoods within the target areas, and comparative analyses will be conducted across agroecosystems and regions. Output 4.2 will develop baseline livelihood typologies that will be linked to the data generated by SRT2 and SRT3 and help assess the feasibility of options, taking into account the social, economic, and environmental implications of the proposed technologies and interventions. Panel household databases will be built to aid: (i) rigorous assessment of farmers' responses to changes; (ii) in-depth studies on the sustainability of diverse livelihood options for assorted farmers (male and female); and (iii) measurements of risks and the vulnerability of households and their members to various types of shock. The institutional arrangements (e.g. collective action, contract farming, or land tenure) and their effects on the adoption of proposed technologies and practices also will be analyzed. This output will be delivered through the use of available household models, village CGE models, dynamic farm-planning models (e.g. farming systems modeling), and other models that integrate farmers' production and consumption decisions in the context of the economic, resource, policy, and environmental constraints they face. This research output will generate a clear understanding of the characteristics of the livelihoods of rural households and will link to feasibility and trade-off analyses in SRT2 and SRT3. It will also provide baseline livelihood information that will permit the measurement of changes resulting from adoption of proposed options and their impacts.

Output 4.3: Assessments of program outcomes and impacts

The research in CRP 1.1 aims at delivering technical, institutional, and policy interventions that will reduce poverty and vulnerability in dryland agricultural production systems. Adequate *ex ante* and *ex post* assessment of the economic, social, and environmental impacts of these interventions form a crucial part of CRP 1.1. This research output will link with the overall monitoring and evaluation (M&E) of the program by providing measured outcomes and impacts of program outputs. In addition, this output, along with the other SRTs (particularly SRT1), will map out the pathways to the observed impacts, and will identify lessons learned across agroecologies and regions.

Ex ante impact assessment is conducted before the development and implementation of technologies and interventions. It has two purposes: to provide feedback to the design of proposed interventions, and to assess whether it is worthwhile to pursue the outcomes of the proposed research. *Ex ante* impact assessment therefore includes assessment of the potential economic, social, and environmental impact of proposed interventions and the choice of those that optimize anticipated impacts and the use of available resources. *Ex post* impact assessment is done after technologies and interventions have been developed and implemented; it assesses and evaluates whether the research succeeded in achieving the impacts it was designed for. *Ex post* impact assessment may also be used to assess the unintended side effects of technologies and interventions. M&E will further support the fine-tuning of the implementation of activities and the description of baseline conditions for later *ex post* assessment.

Output 4.3 aims to help the CRP 1.1 to design and implement technologies and interventions with high and sustainable impact. It strives to achieve this while helping the other SRTs in CRP 1.1 to optimize implementation and demonstrate impact of the research undertaken in CRP 1.1.

The types of assessments, methods, and approaches used will depend on the nature of the technologies or interventions being assessed. However, careful attention will be paid to methodology, specifying counterfactuals, being explicit about causal mechanisms, and using experimental and quasi-experimental approaches where possible. The SRT thus requires capacity in state-of-the-art methodology for impact assessment.

Impact ultimately depends on adoption of technology. Thus, monitoring of adoption disaggregated by gender and analyzing the constraints to technology diffusion will be major activities. Output 4.3 will benefit from knowledge generated by Output 4.2 on the feasibility of options, based on farmer and farm characteristics, market conditions, and risks, in addition to the policy and institutional environment influencing adoption.

The impact assessment will be done with staff implementing technologies in other SRTs together with partners from other CRPs. The results of the assessments will be used by CRP 1.1 partners to help design and refine R&D activities through an iterative IAR4D process. They will also contribute to the knowledge base on research impacts in drylands.

One of the novelties in this CRP is the size and scope of the dryland systems involved. Special effort will be made to include environmental impact assessment—especially in terms of impact on land, water, and biodiversity—along with the more traditional economic and social assessments (Rockefeller Foundation and Goldman Sachs Foundation, 2003; Becker, 2006) that are used to assess agricultural technologies and interventions, and to do so within complex agroecosystems. Most of the work under CRP 1.1 goes beyond technologies and single interventions, targeting programs and policies to enable change in agroecosystem production and associated livelihood systems. Some methodological development may be required to adapt impact-assessment methods to the highly stochastic nature of the social and biophysical environment in dryland systems. Special attention will be required to assess impacts targeted at vulnerability reduction (ProVention Consortium, 2007). Partner capacity will be crucial here.

5.5 Cross-cutting themes

In addition to the four SRTs, **four cross-cutting themes** will be mainstreamed throughout the Dryland Systems program. The first two, **gender** and **youth**, address social inequities. Most published definitions of sustainability include equity as an essential component. Without social equity, research impacts will be limited, and sustainability will not be achieved. The third cross-cutting theme, **biodiversity**, is essential to food security, risk mitigation, sustainability, and identification of new sources of income. The fourth theme, **nutrition**, is increasingly important because of profound negative effects that rapidly changing patterns of food consumption are having among different demographics. Each of these themes is briefly described below.

5.5.1 Gender

In most dryland regions, society does not adequately recognize the huge contribution that women make to agricultural systems, or their potential contribution to agricultural development. Women are the *de facto* household heads in many dryland systems, and they often have responsibility for high-value fruit and vegetable production. They almost always have key roles in food preparation and provision, nutrition, and maintenance of indigenous knowledge. Gender inequality directly affects likelihood of success in achieving development outcomes. Mainstreaming gender has rightfully been mandated at the Consortium Office level for all CRPs, with current thinking captured in the draft document entitled *Ensuring poor rural women benefit from the CGIAR's agricultural R&D with the integration of high quality and relevant research on gender*.

Research on gender-related issues will be a key component in all CRP 1.1 research. Opportunities for increased food security and improved livelihoods that are specifically suited for women will be sought through better understanding of gender roles and needs in farming and along the food value chain. This will include the suitability, adoptability, and impact of innovations, and ensuring that women participate fully in the innovation process.

Rural households in drylands employ complex and flexible livelihoods strategies that involve women and men in different and often complementary activities. These strategies include maintenance and production of the traditional knowledge related to these activities. Evidence worldwide shows that women have key roles in food provision, production, and in food cultures (Jiggins, 2011) related to both crop and livestock farming, and also as managers of natural resources (Flintan, 2008; Kristjanson et al., 2010; Quisumbing and Pandolfelli, 2010). Despite their multiple roles, rural women generally have limited access to and control of income and productive resources, limited decision-making power, and poor access to new opportunities and to information (e.g. new jobs, ICTs, and education). Men, on the other hand, are generally considered responsible for providing revenue for the family; in many regions they are forced to migrate in search of off-farm employment because small-scale agriculture is increasingly unable to support rural households. Male migration has been shown to be followed by a feminization of agricultural labor because women, children and older people usually stay on the farm and women mainly look after agriculture. The different activities, knowledge, and capabilities that women and men have in household livelihood strategies and the way these are shaped by household and wider social dynamics need to be factored into CRP 1.1 activities to ensure that both women and men benefit from development interventions and effectively contribute to enhancing their livelihoods and that of their households.

Gender-sensitive approaches will be adopted during the design, validation, implementation, and evaluation of this CRP. Social and gender analysis will be integrated in CRP 1.1 to both understand the specific needs of women and men in dryland farming systems and to strengthen the capacity of the most marginalized groups to articulate their views and participate effectively in the R&D process. This analysis will provide an important entry point for CRP 1.1 to design appropriate innovations and institutional arrangements that have positive poverty and equity impacts. The gender strategy will be twofold (Kauck et al., 2010): gender analysis will be integrated as a cross-cutting issue in all CRP 1.1 activities; and strategic gender research will be undertaken to support gender-balanced achievement of food security and nutrition, reduction of vulnerability, sustainable intensification of agriculture, and linkages to markets. Proactive approaches will be adopted when necessary to target interventions and ensure outcomes that favor improving the livelihoods of women.

Empowerment is key to overcoming gender-based inequalities, to enhancing the ability of farmers (and women in particular) to safeguard their interests, to allowing everyone in the target groups to be effectively involved in participatory development and enjoy its benefits, and to profiting from new opportunities (Kabeer, 2010; Galié, forthcoming). CRP 1.1 will provide empowerment opportunities that are relevant and context-specific for the most marginal farmers, and for women in particular. Policy recommendations will be developed to ensure that a supportive institutional environment (e.g. international, national and customary laws and policies) is provided for empowerment strategies to become effective. Collective action has been shown to be successful in providing support for change initiated by a group of individuals with similar interests (Meinzen-Dick and di Gregorio, 2004) and will therefore be supported in this CRP whenever appropriate.

The main objective of including gender in all aspects of CRP 1.1 R&D is to ensure that the knowledge generated by this research will have positive and equitable impact on both women and men and will not inadvertently disadvantage women or other vulnerable groups. Including gender in the research portfolio also increases the potential for overall impact. Leaving it out means a significant part of the population is excluded.

CRP 1.1 will apply best practices in gender research, development of standardized indicators, methodology development, and capacity strengthening. Methodologies will include participatory action research using social analysis tools and qualitative and quantitative analysis of disaggregated information. Monitoring and evaluation and impact assessment will be disaggregated by gender and wealth categories in order to understand the differential impacts of interventions on rural women, men, families, and other groups and ensure that project activities help support women and other vulnerable groups. Impact indicators will be formulated together with women and men based on their specific needs. Most importantly, where findings suggest that women may not benefit from ongoing or proposed interventions, we will study, develop, implement, and monitor complementary strategies to improve gender-equal outcomes.

Social and gender research must be part of a transformative[1] process to address inequities, empower marginalized groups, and help improve their lives. Gender transformation could be initiated through: (i) exploring and appreciating the different activities and knowledge of women and men in rural households; (ii) identifying and addressing differential development needs and intrahousehold equities; (iii) conducting *ex ante* monitoring and evaluation and *ex post* gender-disaggregated impact studies to measure the impact on women and men from marginalized groups and understand the factors that condition the size and distribution of impact; (iii) drawing policy recommendations that can address gender imbalances and women's development; and (iv) sharing (disseminating) lessons and experiences with other partners through various avenues, including electronic knowledge-management platforms where appropriate.

Addressing gender issues will require partner organizations with adequate skills. Capacity strengthening in gender analysis will be an important component of the CRP's work. Recruitment of social- and gender-analysis experts will guarantee the effective inclusion of gender approaches in CRP 1.1. To ensure equity in the capacity development of partners, the program will give equal opportunities to women professionals. Gender-balanced staffing in the Centers involved in this CRP will be pursued in line with equity principles and also because both female and male researchers, extension officers, and community facilitators will be needed to ensure the participation of women and men farmers in research activities in societies with a strong gender-differentiated organization. Encouragement of women in partner organizations to participate in IAR4D will be crucial. The women's units within government ministries (agriculture, social affairs, and women's affairs), designated CSOs, and extension agents will be key partners. They will be involved in research and also benefit from capacity-building activities.

Resources for social and gender analysis and gender-responsive activities will be allocated in the budgets to ensure that innovations are delivered to both women and men and that gender considerations are integrated into each region and SRT.

5.5.2 Youth

Megatrends in dry areas of the developing world that are related to youth include skewed population distribution, exodus from rural communities, urbanization, disproportionate youth unemployment, inadequate livelihood skills, and marginalization with regard to decision-making and access to natural resources and financial tools. These trends can lead to broader problems such as civil unrest, political stability, and conflict on local and regional scales. There are numerous recent incidents in the dry areas

[1] A transformative (participatory) research approach supports social actors as agents to build political capabilities, critical consciousness, and confidence to enable them to demand rights and enhance accountability. Ultimately, such an approach not only aims to understand power relations, but leads to shifts in thoughts, feeling, and actions towards social justice.

in which disenfranchised youth have expressed their frustration through civil unrest and violence. Despite the prevalence of these trends in developing countries and the unrest and instability that they portend, youth is seldom mentioned or stressed among the new CGIAR priorities. Addressing these megatrends will be a priority in CRP 1.1, and will be done through targeting research and capacity building to focus specifically on rural youth. The approach will be analogous to that taken in the U.S. land-grant-university system: a focus on training youth in farming skills that include technology use and in technical skills that lead to employment or creating businesses. The overall goals are to: (i) retain youth as part of vibrant rural communities to stem urbanization; and (ii) teach relevant skills that can be used for employment or business creation as a means to enhance value chains linked to rural communities.

5.5.3 Biodiversity

The livelihoods of smallholders in dryland systems depend upon complex, heterogeneous, and variable production environments that entail multiple risks. Most households rely on a diversity of plant and animal species (agrobiodiversity) for food and nutrition, income generation, production optimization, and risk management. Using this diversity more effectively is one of the pathways available for reducing vulnerability and enabling system intensification, which in turn contribute to poverty alleviation, increased system productivity, and improved nutrition while maintaining the natural-resource base. In fact, agrobiodiversity is an important component of the resource base. CRP 1.1 will actively focus on biodiversity research in both SRT2- and SRT3-type farming systems with a view towards achieving several objectives, including reversing land degradation, gene conservation, mitigating risk, targeting technologies to marginalized groups, improving nutrition and food security, and generating new products and services. The CRP 1.1 revised proposal has included extensive input from Bioversity International.

5.5.4 Nutrition

Accelerated urbanization and growing rural poverty in dryland systems, combined with trends in global trade in foodstuffs, have contributed to profound dietary changes. These trends have major implications for farmers and pastoralists in dry areas, not only in terms of what they can grow and sell but also in terms of what they consume. Especially in urban settings, there has been a shift from traditional staples to imported cereals (wheat and rice). More-affluent urban communities are consuming more meat, milk, and eggs, which are also increasingly imported, as well as more packaged and processed foods and more street or fast food. The deleterious health effects of such diets are well known and disproportionately affect poor women. Meanwhile, among the rural poor, diets have become increasingly less diverse and cereal-based as households struggle simply to meet caloric requirements in the face of one shock after another, including food price spikes and drought. Meat and milk consumption have actually decreased among rural poor; in Africa, fruit and vegetable consumption has decreased as well. Poorer rural diets have many attendant negative health effects, including weakened tolerance to HIV/AIDS and other diseases. Micronutrient deficiencies are especially pronounced in children and expectant mothers. Deficiencies in many micronutrients, such as iron, iodine, zinc, and vitamin A, are linked to child development disorders.

5.5.5 Inter-linkages

As a systems-research program, CRP 1.1 views these four cross-cutting themes as integrally linked. Gender, for example, is relevant to: (i) youth, because of roles that women have in raising children and young men have in civil unrest; (ii) nutrition, because small children and expectant mothers disproportionately suffer from malnutrition, and women are primarily responsible for preparing meals; and (iii) biodiversity, because of differential preferences among women and men for crop and animal genotypes, and indigenous knowledge of wild plant species that is entrusted to women in many cultures. Similar arguments could be made for the other cross-cutting themes.

To become truly cross-cutting in CRP 1.1, each theme will be mainstreamed into the conceptual framework and its four SRTs. This is ongoing, but will take time and further consultation. For gender, a number of consortium-level meetings are ongoing to develop a CRP-wide strategy that will be adopted and implemented within CRP 1.1. Additionally, the International Center for Agricultural Research in the Dry Areas (ICARDA) is recruiting a gender specialist to lead gender-related studies within CRP 1.1. A CRP-wide strategy for biodiversity is also being devised. Furthermore, the CRP 1.1 proposal has been reviewed and edited by the Deputy Director General, Research, and other researchers from Bioversity International. For nutrition, an international expert is being recruited to work with a systems modeler to develop a systems-oriented decision-support program to prioritize research efforts. Additional linkages will be developed with CRP 4. Youth receives surprisingly little emphasis in the current CRP portfolio. The CRP 1.1 strategy for this cross-cutting theme will be generally modeled after the U.S. land-grant-university system, and may include programs similar to the international 4-H program to target children in rural communities. Further consultation will be needed to elaborate this theme further, but it is likely that CRP 1.1 will lead this effort within the CGIAR system.

6. Where CRP 1.1 will work: Target Regions and Action Sites

The question of where CRP 1.1 would conduct its R4D activities was addressed consultatively, beginning with two meetings attended by a representative cross-section of partners and stakeholders—including CGIAR centers—who engage in agricultural R&D in the dry areas. From these deliberations, five target regions were identified at a continental scale that contain SRT2-type dryland agricultural systems, i.e. those facing serious challenges including food insecurity, endemic poverty, vulnerable populations, natural-resource degradation, and climate variability, and SRT3-type systems, i.e. those presenting the greatest opportunity for change with positive impacts on poverty in the short to medium term. The five target regions are:

1) The West African Sahel and dry savannas
2) East and southern Africa
3) North Africa and West Asia
4) Central Asia
5) South Asia

Within each target region, target areas were selected that represent a diverse and rich resource of knowledge on contrasting dryland agroecosystems, farming systems, and livelihood vulnerabilities. Some of the selection criteria used are listed in Table 4. Target areas are included as a standard or point of reference against which other areas may be compared or assessed. Primarily, target areas are designed to offer the opportunity to learn from and validate selection criteria for the action sites and to identify interventions that will form the basis of new research initiatives within CRP 1.1 and the possible establishment of new target areas. It is anticipated that synergies of research activities and areas among the partners in CRP 1.1 and other CRPs will grow and evolve during the initial three-year phase. Clearly, there are opportunities to embed or co-locate CRP 1.1 target areas within those of other CRPs, especially with CRP 5 and CRP 7, which may well result in highly desired synergies.

Table 4. A non-exhaustive listing of selection criteria for identifying CRP 1.1 target areas.

Biophysical	Socioeconomic
Accessibility • Closeness to partners' headquarters • Proximity to research facilities	Demography • Population • Poverty • Employment (e.g. women/men differential aspects) • Nutrition status
Climate • Rainfall patterns • Temperature profile • Drought and heat indices • Length of growing period • Elevation	Access to markets • Distance • Size • Competitiveness
Soils • Nutrient-supply capacity • Water-holding capacity • Morphology • Soil erodability • Degradation/desertification	Access to water and land • Communal/private ownership • Pricing • Access
Biotic stresses • Diseases • Pests • Weeds (e.g. *Striga* spp.)	Gender and disadvantaged groups' responsiveness • Differential aspects • Absolute aspects
Farming systems • Crops • Vegetables • Livestock • Trees • Mixed systems • Gap between actual economic and potential yields	Governance, institutions, and policy • Inclusiveness of stakeholders • Equity • Accountability • Transparency
Sensitivity to global change • Climate (variation and change parameters) • Globalization	
Land degradation • Physical • Chemical	

Source: After Palm et al. (1995), Wood et al. (1999), De Pauw (2003), Douthwaite et al. (2003b), Hyman et al. (2008).

CRP 1.1 will focus its activities at the highest level around target areas and selected action sites that operate in real-world farmer conditions, cover sizable areas that include whole farming communities, and are characterized as having representative livelihood systems that are dependent on the local natural-resource base. The action sites offer the opportunity to assess and develop interventions that address the complex interactions between biophysical and socioeconomic drivers associated with agroecosystems in an interdisciplinary manner. The action sites are representative of major portions of wider agroecosystems and hence their use will ensure that research is grounded in farming-system dynamics and realities, and that diversity is fully accounted for. Crucially, this approach ensures transferability (i.e. IPG potential) and applicability of technologies and other interventions, and facilitates scaling out within and among regions. It also helps ensure that research will be demand driven, and that the program will enhance local and national capacity to carry out IAR4D. Capacity development is critical because national researchers and development staff—not CGIAR Centers—must deal with location-specific constraints.

Action sites must be broad enough and diverse enough to capture a significant part of the diversity with each target area (including the livelihood dimensions), have potential for local to regional outcome delivery and impact, and be manageable for R4D purposes. Six criteria were used to rank potential action sites within each target areas within each target region. The list below describes some of the issues considered for each criterion.

1) *Accessibility, proximity to research facilities (partners, CGIAR Centers)*

   Is the proposed site readily accessible to key development and research institutions operating in the area? Which are these? What are their current portfolios and how do they relate to the priorities of CRP 1.1? Are there special issues that would make it specifically advantageous or difficult to work here?

2) *Potentially suited to testing research hypotheses*

   Are there clear development challenges related to SRT2 or SRT3? This has to be linked with the SRT hypotheses. What are the characteristics of the site that facilitate comparability (IPG nature)? Does it have appropriate conditions for comparability for testing hypotheses? Are data already available (preferable)?

3) *Representativeness*

   Is the site representative of the target area in terms of the key biophysical, socioeconomic, and institutional dimensions, including cross-border issues, where relevant?

4) *Potential for out-scaling: supportive institutional environment, other actors that can help achieve significant and relative impact, target population size*

   CRP 1.1 aims to achieve development outcomes. A diversity of actors will be key to ensuring that research outputs are available and delivered, engagement in markets is appropriate, communications are strengthened, etc. Are there significant development efforts in the site that would provide these kinds of synergies?

5) *Ability to attract resources*

   Are there other development or research efforts already ongoing in the site? Are there significant investors (especially bilateral and national) giving priority to the action site or its surrounding areas?

6) *Potential intersection and synergy with other CRPs*

   Which other CRPs plan to implement activities in the site? Would there be potential for intersections and synergies with CRP 1.1?

Table 5. Characteristics of potential action sites in SRT2 and SRT3-type target systems (maximum three per country, using scores as described above).

SRT2 or SRT3-type system	Potential Action Site 1	Potential Action Site 2	Potential Action Site "n"
Country			
Geographical location			
1. Accessibility			
2. Potential for hypothesis testing			
3. Representativeness			
4. Potential for out-scaling (impact)			
5. Potential to attract funds			
6. Potential to interact with CRPs			

Action sites are defined by political boundaries (e.g. region, county, state, district etc. depending on the country) but can span country borders.

The initial CRP 1.1 action sites were selected by CGIAR Centers and international, regional, and national partners in the Dryland Systems Regional Design Working Meeting held in Nairobi, Kenya, 20–-30 June 2011. Prior to this meeting, a number of detailed maps and data layers were produced to characterize the dryland regions and within them the target areas. Action sites were further refined and characterized as part of a transparent, participatory process during the inception phase (see Inception Phase Report), which included five RIWs and several preliminary subregional workshops.

As CRP 1.1 moves beyond its initial three-year phase and as new research activities are initiated within the SRTs, research efforts will be merged within key target areas. It is anticipated that up to 10 target areas (two per region) will be established, and that these may include existing and new target areas, contingent on the research portfolio and priorities agreed upon by CGIAR Centers and partners. The criteria for identifying target areas within the target regions will draw upon the wealth of information generated from previous CGIAR system-wide initiatives (e.g. Alternative to Slash and Burn, Ecoregional Program for the Humid Tropics of Africa [Douthwaite et al., 2003b]), the current suite of projects/sites mapped to the CRP, and other previous CGIAR research, particularly in drylands or drought-prone environments (La Rovere et al., 2006; Oweis et al., 2006; Hyman et al., 2008). These criteria are a researchable issue that will be undertaken over the first three years within SRT4. Possible criteria to ensure that future activities are founded and implemented in representative sites, and offer good potential for learning and for scaling out research outputs, are presented in Table 5. Such an approach will enable CRP 1.1 to incorporate evolving drivers of change (e.g. climate change, disease or pests, and trade regionalization and globalization) in refining the selection of action sites. Besides the fundamental condition of being representative of the target area, additional criteria could be used to select target areas and their corresponding action sites. For instance, accessibility to partner research facilities would be advantageous.

To ensure that this geographical division does not compromise sharing of experiences, the program's Research Management Committee (see Section 10) will ensure that the CRP 1.1 agenda includes comparisons within the SRT framework across a wide range of regional experiences and settings (i.e. testing common research hypotheses), and from a larger total research base. This systems view will also facilitate the generation and scaling out of IPGs, such as knowledge, tools, and approaches for dryland agriculture development, within and between regions. Indeed, such synthesis is at the heart of SRT4.

Satellite sites are critical to the success of CRP 1.1. They complement action sites by sampling the diversity within target areas and help evaluate the suitability and user acceptance of innovations developed at the action sites. They help take into account the broad range of biophysical and socioeconomic attributes in each target system. During the proposal development phase, representatives of NARS from emerging economies and one CGIAR Center expressed a willingness to be active partners in CRP 1.1 and contribute to the research effort of this CRP through satellite sites that are embedded in their own research systems. These organizations already have considerable experience, expertise, and resources in the analysis and potential interventions related to complex agroecosystems. Using separate funding they have contributed to the development and implementation of methodologies and tools applicable to the kind of work that CRP 1.1 will conduct in the action sites. It will be mutually beneficial if these experiences could be shared, validated, adapted, and adopted by CRP 1.1. Satellite sites are identified and characterized in the Inception Phase Report.

Knowledge-sharing centers (KSCs) will be the vehicle for transferring knowledge and underpinning methodologies developed at the action sites between NARS and CGIAR Centers. KSCs are conceived as an open community of practice organized as an evolving working group of institutions with experience in R4D projects in complex dryland systems. They also have analytical research, evaluation methods, tools, and databases that have been field tested, validated, and documented. The community of practice will be coordinated by CRP 1.1 management, and include member centers from developing and developed countries. The KSCs align with the overall concept embedded in target areas and satellite sites as discussed in the previous section. CRP 1.1 will benefit from lessons learned and knowledge generated by these NARS and CGIAR-Center initiatives that will further enhance our understanding of dryland agroecosystems under diverse socioeconomic and policy frameworks. Further details are provided in Annex 8.

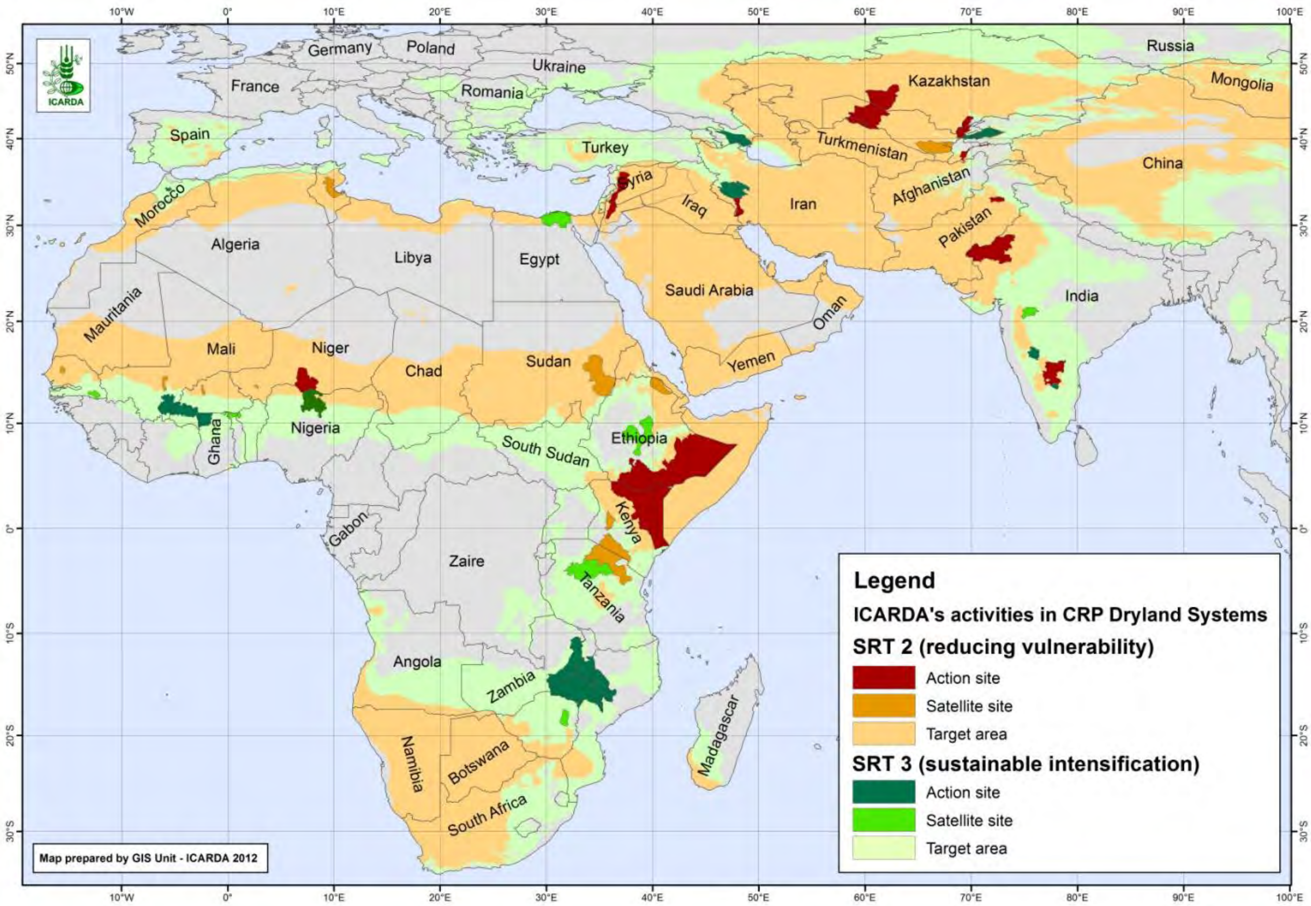
Discussions are underway with the Chinese Agricultural Academy of Sciences (CAAS) to establish a KSC as the basis of a center of excellence for dryland agriculture in China. A Memorandum of Agreement has been drawn up and agreed upon by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), ICARDA, and CAAS. Efforts to expand CRP 1.1 activities into Latin America and other target regions or target areas in the developing world will be pursued as CRP 1.1 begins its implementation phase, but these expansion efforts must be contingent on reaching a financial threshold and a critical mass of researchers and partners in those areas.

Target Areas, Action Sites and Satellite Sites

The target areas, action sites and satellite sites are shown below, globally, in Figure 8, and in detail for each of the five regions:

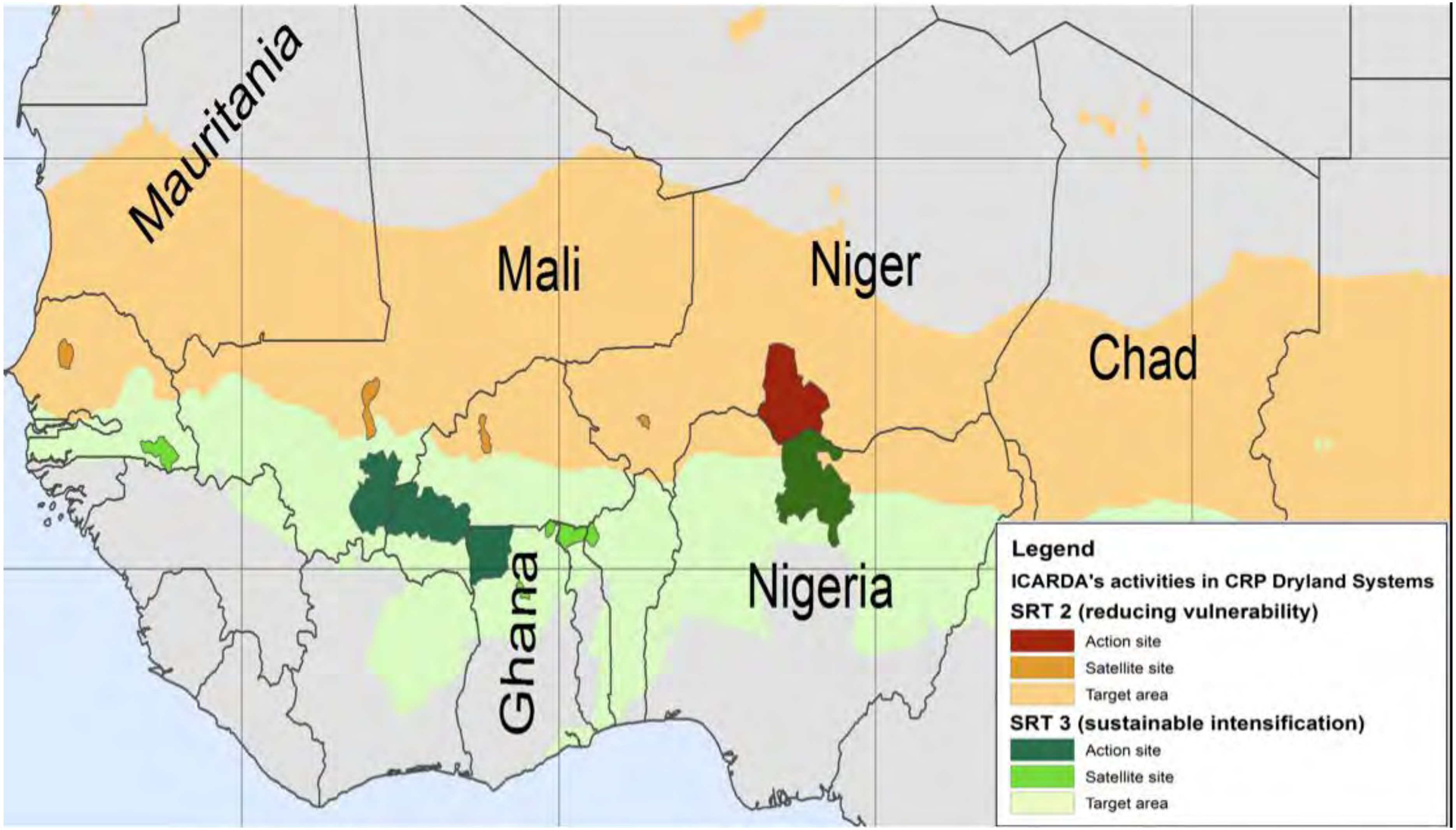
- The West African Sahel and dry savannas (Figure 9)
- East and southern Africa (Figure 10)
- North Africa and West Asia (Figure 11)
- Central Asia (Figure 12)
- South Asia (Figure 13).

Figure 8. CRP1.1 target areas, action sites and satellite sites



6.1 Target Region and Action Sites in West African Sahel and dry savannas

Figure 9. Action site transects and satellite sites in the West African Sahel and dry savannas.



Explanatory notes for Action Site Transects and Satellite Sites in the West African Sahel and dry savannas.

(A) Kano-Katsina-Maradi (KKM): North-south transect (Nigeria-Niger) driven by biophysical gradient, socioeconomically "fixed" (high population density and poverty levels everywhere; homogeneous social background). KKM is a historical hotspot of tightly coordinated research investments and site selection process, e.g. by SSA CP.

(B) Wa Bobo Sikasso (WBS): East-West transect (Ghana – Burkina Faso – Mali) driven by socioeconomic gradient (variable population pressures, poverty levels, fragmented social background) while biophysically "fixed." WBS has a history of loosely coordinated research investments. WBS hosts the Ghana CRP 7 site in Lawra-Jirapa district.

Satellite Sites:

(1) Segou (Cinzana-Markala-Niono districts of Mali) with large-scale irrigated systems integration with rainfed systems, also hosting Mali CRP 7 site,

(2) Mossi Plateau (Goursi-Yako-Ouahigouya districts of Burkina Faso), also hosting Burkina Faso CRP 7 site,

(3) Fakara district (Niger) that includes a HAPEX/AMMA historical site and hosts the Niger CRP 7 site,

(4) Bandafassi district (Senegal) representative of rapid LULCC dynamics with deforestation and potential for REDD+,

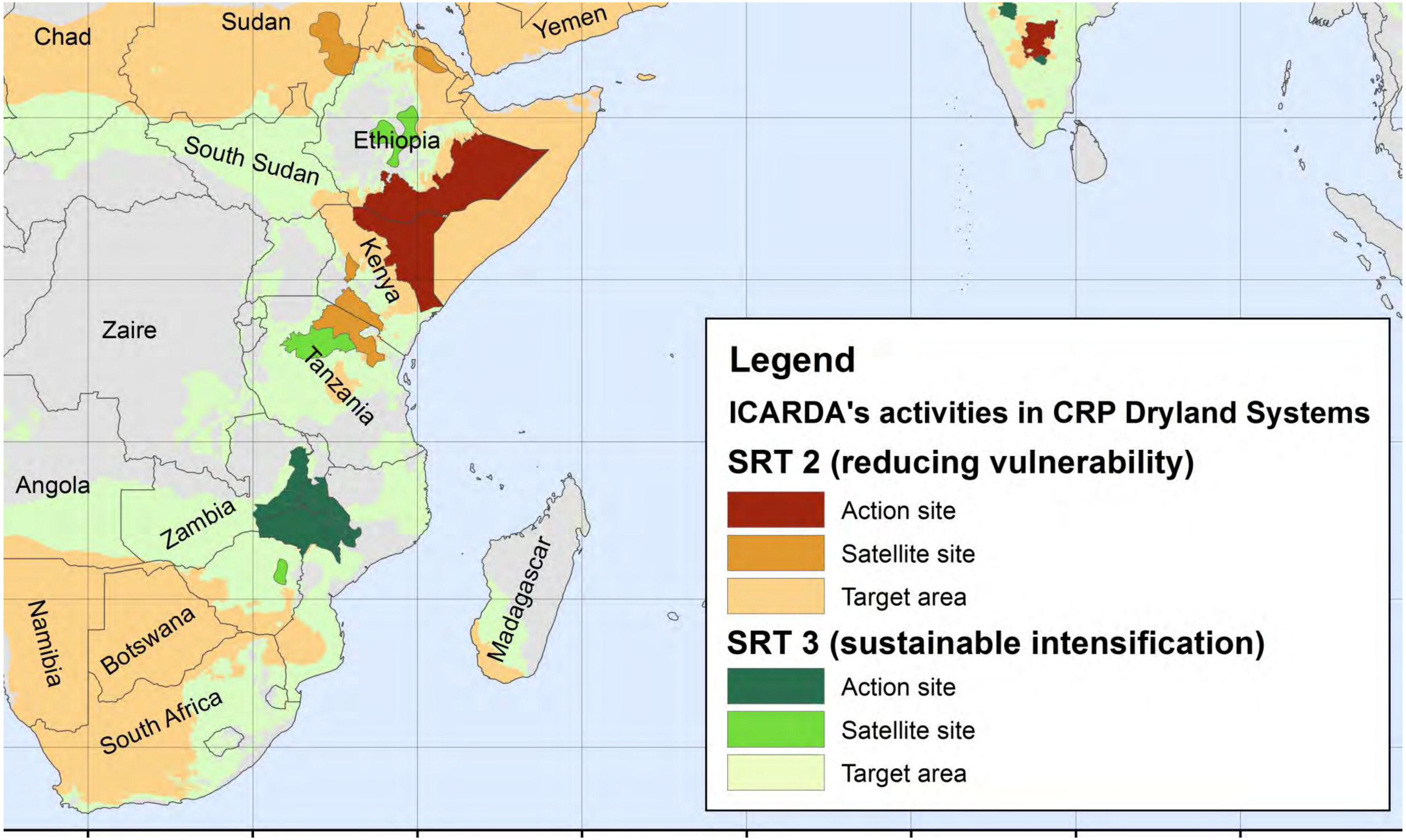
(5) Damango-Tolon-Kumbungu area (Ghana) combining rainfed and small-scale irrigation systems,

(6) Bawku-Tone-Materi transboundary corridor (Ghana – Togo – Benin) along a strong population density gradient,

(7) Dahra district in the Ferlo region of Senegal, representing more typical rangeland systems (CIRAD-PPZS sponsored).

6.2 Target Region and Action Sites in East and Southern Africa

Figure 10. Action sites, satellite sites, and target areas in East and Southern Africa.

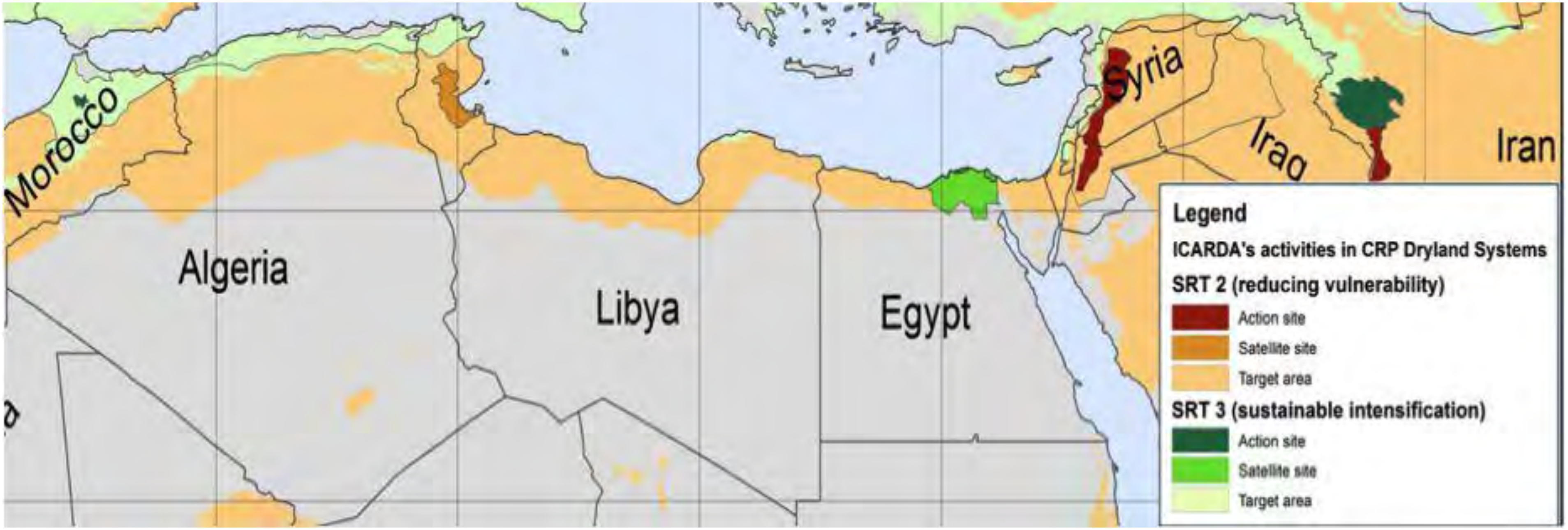


Explanatory notes for Action, Satellite and Knowledge Sharing (KSS) Sites in East and Southern Africa.

	Country(ies)	Location	Issues/Hypotheses
SRT2 sites			
Action site	Botswana, South Africa, Namibia	Ghanzi and Kweneng in Botswana; Vryburg and Kuruman in South Africa, Karas in Namibia	**Communal grazing** in extensive rangelands. Prevent land degradation by improving range and water management; adaptation to climate change; markets. For income and diversification: cross border comparisons of similar systems under different institutional contexts
Action site	NE Kenya / SE Ethiopia	Garissa in Kenya to Borana and Somali region of Ethiopia	Extreme climate variability and pressure on **mobile pastoralism**. Risk management, including via markets; sustainable productivity increases, diversification, including irrigation. Cross-country comparisons
Satellite site	N Kenya	Baringo	**Agropastoral** with some arable areas, livelihood transitions, wildlife. Improving livelihoods through land rehabilitation
Satellite and expansion site	Ethiopia	Geregera (East Tigray), Afar (Dalol) and Koneba	**Mixed crop-livestock-tree system** in dry highlands. Improving livelihoods through land rehabilitation. Potential expansion to pastoral (Afar) and SRT3 (Tigray)
Expansion site	Sudan	Gadrij	**Mixed crop-livestock**. Introduce systems approaches in sorghum-based systems, potential to be breadbasket
SRT3 sites			
Action site	Zambia, Malawi, Mozambique, Zimbabwe	Chinyanja Triangle	Improving **integration of crops and livestock**. Intensification and diversification through markets; innovation systems approaches
Action site	Central Ethiopia	Oromia Zones of E. Shoa, W. Shoa, Horagudru) and Amhara Zone of N.Shoa	**Integrated crop-livestock-tree systems**; improved land and water management, potential for high value crops, trees, livestock and market-led diversification
Action site	S Kenya / N Tanzania	Kajiado-Serengeti-Shinyanga	**Pastoral/agropastoral systems** under pressure; trade offs around land use, integration of crops and trees, water management, markets for traditional and new products and services
Knowledge sharing site	Kenya	Machakos	Critical assessments of past interventions in **mixed systems**
Potential expansion site	Sudan		**Mixed crop-livestock-tree systems**; soil management is a major issue

6.3 Target Region and Action Sites in North Africa and West Asia

Figure 11. Action sites and satellite sites in North Africa and West Asia.

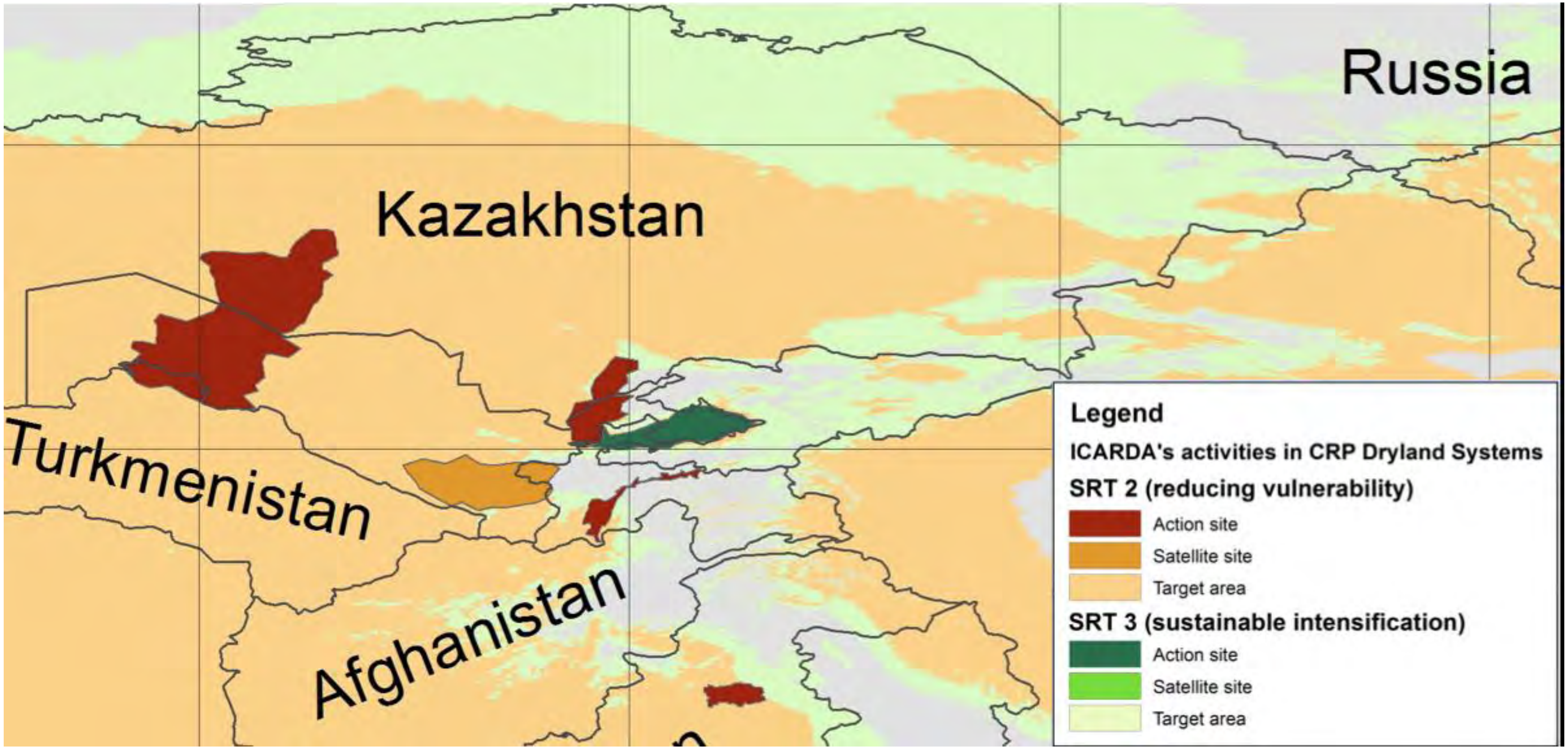


Explanatory notes for Action Sites and Satellite Sites in North Africa and West Asia.

Vulnerable systems (SRT-2 type)	Action Site 1	Action Site 2	Satellite Site
	Jordan/Syria Rangeland-livestock based system Extends from the Middle Badia of Jordan to Al Salamiah in central Syria. Covers several districts, with landscape and socioeconomic variability, that enable testing of the main hypotheses of CRP 1.1 under SRT2	**Syria/Turkey** Rainfed mixed crop-livestock based system (low potential) Extends from Hama in central Syria to north west Syria and southern Turkey. Covers several districts across borders, with major focus on SRT2 with small pockets of SRT3-type of target livelihood systems including a transition between SRT2 and SRT3	**Tunisia** Complements the Action Sites and addresses the mountainous agro-systems, rangelands and medium potential ecosystems especially those with indigenous water harvest techniques Could be a knowledge platform for North Africa Transect from central to southern Tunisia (semi arid to arid regions). Covers several districts
Sustainable intensification (SRT-3 type)	**Action Site 1**	**Action Site 2**	**Satellite Site**
	Morocco Meknes region	**Iran** Karkheh River basin. Research will use a transect approach covering highland (SRT2) and lowland (SRT3) areas	**Egypt** Nubarieh in the new lands and Behaira in the old lands

6.4 Target Region and Action Sites in Central Asia and the Caucasus

Figure 12. Action sites and satellite sites in Central Asia.

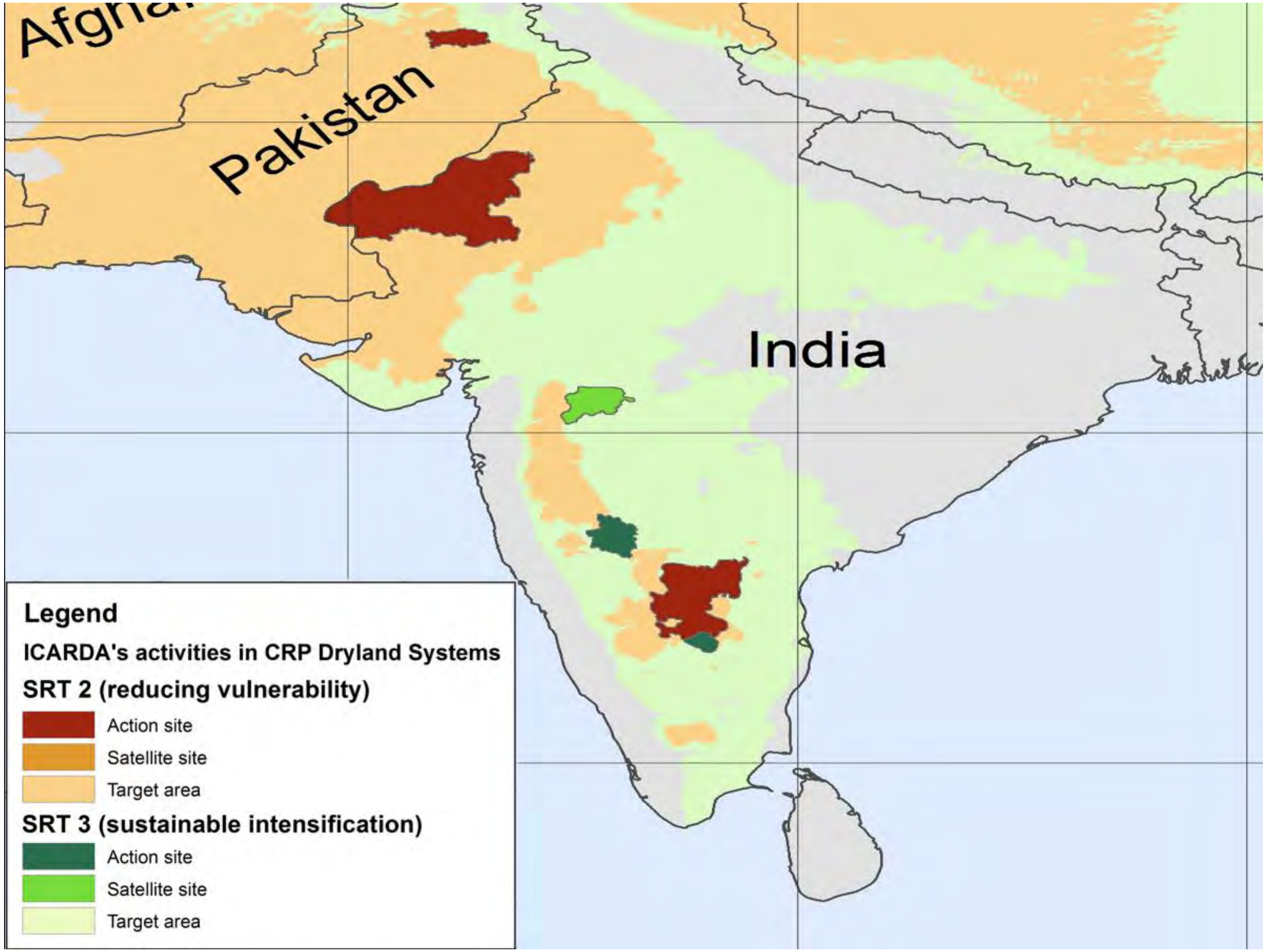


Explanatory notes for Action Sites and Satellite Sites in Central Asia and the Caucasus.

SRT2-type system	**Action Site 1**	**Action Site 2**
Country	Kazakhstan, Turkmenistan and Uzbekistan	Tajikistan, Kyrgyzstan
Geographical location	The Aral-Turkestan lowland [5 million inhabitants]	Rasht Valley [300 000 inhabitants]
SRT3-type system	**Action Site**	**Satellite Site**
Country	Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan	Uzbekistan
Geographical location	Ferghana Valley and southern Kazakhstan [3 million inhabitants]	Kashkadarya Region [2.6 million inhabitants]
		Satellite Site 2
Country		Azerbaijan
Geographical location		Kura-Araks Lowland [3.8 million inhabitants]

6.5 Target Region and Action Sites in South Asia

Figure 13. Action sites in South Asia.



Explanatory notes for Action Sites in South Asia.

SRT-type	Location (State, Country)	Area (km^2)	Population (million)	Poverty (%)
SRT3	Chakwal (Pakistan)	6524	1.3	35
SRT3	Udaipur (Rajasthan, India)	13419	2.4	21
SRT3	Indore (Madhya Pradesh, India)	3898	2.5	22
SRT3	Adilabad (Andhra Pradesh, India)	16105	2.5	26
SRT3	Chikballakur (Karnataka, India)	8223	1.4	13
SRT2	Anantapur (Andhra Pradesh, India)	19130	3.6	20

7. Research and performance management system

The basis for a performance management system was developed during the Inception Phase of CRP1.1.

Each target region has developed detailed logframes based on their problem analysis and associated research hypotheses that were identified with stakeholders during the consultative process. These logframes specify research outputs, activities and milestones, the location (action site), and research partners. These are too detailed to be included in the proposal, but are provided in the supporting Inception Phase reports. These are now being further developed as "**standardized logframes**" that will be linked to program level outputs and outcomes, and include indicators that measure the uptake of outputs (e.g., numbers of farmers adopting outputs, adoption of policy recommendations, etc) and their direct results (e.g., changes in productivity, changes in policy measures, etc). These standardized logframes will be incorporated into a research and performance management system that will track progress towards achieving CRP outcomes and the four SLOs.

The system, which is currently under development with the Statistical Services Centre at Reading University, will be linked to data acquisition, flow, and utilization, and will be used as a tool to prioritize and seek cost-effectiveness in budgeting by (i) tracking activity costs and outputs, and (ii) assessing performance through tracking and analyzing uploaded data. As objectively verifiable indicators are tied to each of the activities proposed, the performance management system will track progress toward achieving the program level outputs and outcomes.

Draft standardized logframes are available for each of the five target regions, but it must be stated that each of the outcomes, hypotheses, outputs, and activities need to be revisited to improve clarity and consistency; this is the first priority within the CRP upon its approval.

8. Timeframe and approach

The timeframe involves two six-year periods to move from classification of targets areas to sizable adoption of more-productive, resilient, mixed agroecosystems in the target areas. The timetable for technology adoption is six years: three years for development and fine-tuning, and three for dissemination and out-scaling. The originally envisaged sequence of actions was as follows:

1) In each target system, CGIAR Centers, NARS, ARIs, and other partners meet in inception workshops to develop an R4D portfolio based on the most promising crop, vegetable, land-use, livestock, tree, and fish combinations, as well as the specific natural resources and market and institutional challenges to be addressed. Opportunities for spillovers from different domains will also be important.
2) Research areas and sites (action sites) are identified. CRP 1.1 partners already work in areas of extreme poverty and vulnerability, and research sites and partnerships already exist for many systems.
3) Agroecosystems listed in Table 1 are characterized using geographic information systems (GIS), remote sensing, and other tools.
4) Research partners in all or most systems in Table 1 are identified and work together to identify priority constraints.
5) Partners develop a common understanding of opportunities, challenges, chance of success, and development strategies.

6) Knowledge (and lessons learned) from existing research, indigenous knowledge, and research networks is compiled and disseminated or made accessible in appropriate formats for women and socially disadvantaged groups, among others.
7) Key actors along the impact pathway are identified and brought into the process.
8) Technical solutions (either pre-existing or generated by CRP 1.1) are tested, validated jointly by researchers and farmers, and widely shared.
9) Capacity is built to conduct, deliver, and communicate R4D in complex systems.
10) Capacity building, learning systems, and feedback loops are put in place to ensure active participation of all partners.
11) Gender-sensitive and gender-responsive participatory, community-led processes for technology development are tested to ensure their effectiveness, governance, and ownership by farmers and other stakeholders.
12) Strategies are developed to scale up technologies and impacts in different agroecosystems and domains.

Items 1 and 2 in the sequence have been completed during the Inception Phase. Item 3 is nearing completion, as described in the Inception Phase report. Items 4 through 7 are ongoing, while the remaining items are being planned for the implementation phase. Actions that are ongoing or being planned are still subject to iterative review and adjustment. Additionally, cross-cutting themes will be worked into the action plan as consultation continues and strategy documents emerge.

9. Research Partnerships

9.1 CGIAR Centers involved in CRP 1.1 and their inputs

Several CGIAR Centers and a CGIAR Challenge Program are involved in CRP 1.1:

- Bioversity International
- International Center for Tropical Agriculture (CIAT)
- International Potato Center (CIP)
- International Center for Agricultural Research in the Dry Areas (ICARDA, the Lead Center)
- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
- International Livestock Research Institute (ILRI)
- International Water Management Institute (IWMI)
- World Agroforestry Centre (ICRAF)
- WorldFish Center
- Sub-Saharan Africa Challenge Program (SSA CP)

Each Center and the SSA CP will bring their own knowledge and experience of the agroecosystems or programmatic areas in which they already work to bear on the common problems associated with dry-area agroecosystems. The roles of each Center or CP in the various systems and interventions are indicated in Table 6. Inputs will be determined based on joint program activities that build on strengths, complementarities, and comparative advantages. This will promote synergies and collective action by ensuring that planning and implementation are done jointly by all partners.

Table 6. System types, types of intervention, and CGIAR Centers and Challenge Programs involved.

System	Biophysical constraints	Region/examples	Interventions				CGIAR Centers and Challenge Programs (alphabetical order)
			Technological	Social	Investment/ infrastructure	Policy	
Mixed irrigated arid/semi-arid	Severe land degradation in parts; groundwater depletion; water-quality deterioration; land; salinization; heat stress	Asia: Rice-based crop–livestock systems Eastern Indo-Gangetic Plain (IGP) of India (*high poverty, high potential*) Northern China	Intensification, including better management of water and livestock, reduced competition for residue/fodder, use of tree fodder & fuel supply, trees to improve water & nutrient cycling			Land-use systems & institutional constraints; incentives for better water management	CIMMYT, ICRAF, ICRISAT, ILRI, IWMI, IRRI
		West Asia and North Africa: Oasis systems (*highly vulnerable*)	Date-palm ecosystem with all its components, including fruit trees, field crops, forages, and local livestock breeds				ICARDA
		Africa: River basins in Sahel; small-scale irrigation (drip, *fadamas, dambos*) *high poverty, high potential*	Capacity building in irrigation and water management; suitable crop/vegetable cultivars and management practices; trees for fodder and water/nutrient cycling	Community empowerment, especially of women; capacity building; participatory irrigation management on larger schemes	Small-scale irrigation provision	Land tenure & rights/access on common land	AfricaRice, CIAT, ICRAF, ICRISAT, IWMI, SSA CP
Rainfed mixed (intensive crop–livestock systems)	Land degradation, widespread macro- and micro-nutrient deficiencies; climate variability; water scarcity; seasonal gaps in feed supply; increase zoonotic and other diseases; crop monocultures	South Asia and East Asia: Dryland systems in southern China, NE Thailand, Myanmar, fringe IGP (*high potential, pockets of poverty*)	Integrated watershed development, including natural resource management; trees to improve water & nutrient cycling	Community empowerment; self-help groups; income diversification; negotiation over land-use access & rights; linkages to providers & markets	Small check dams; rainwater harvesting and soil-erosion control structures; domestic water supply	Policy to support investment & capacity building; integrated development through “missions” to unite different Ministries	CIP, ICARDA, ICRAF, ICRISAT, ILRI

System	Biophysical constraints	Region/examples	Interventions				CGIAR Centers and Challenge Programs (alphabetical order)
			Technological	Social	Investment/ infrastructure	Policy	
		Africa: Intensive crop–tree–livestock systems in sub-Saharan Africa (SSA) (*high potential, pockets of poverty)*	Greater specialization and product development; diversification; tree fodder & fuel supply; trees to improve water & nutrient cycling				CIAT, CIP, ICRAF, ICRISAT, IITA, ILRI, SSA CP
		West Asia, and Central Asia and the Caucasus: Crop–rangeland–livestock systems	Drought-tolerant cultivars of traditional feed crops and alternative feed; small ruminant management; reduced competition for residue/grazing	Community development; conflict resolution; rangeland management		Overcome weak institutions and lack of policy options	ICARDA
Dry rainfed (extensive crop–livestock systems)	Land degradation; climate variability; seasonal gaps in feed supply	Asia: Deccan Plateau, India	Integrated watershed development centered on groundwater recharge, water harvesting, and integrated nutrient management; improved market access and enterprise diversification	Target women and other marginal groups to facilitate their access to new opportunities and to the derived benefits	Infrastructure, roads; post-harvest storage systems; water sources; product processing plants	Incentives and enabling environment; credit; land tenure; support institutions	ICRISAT, ILRI
		Latin America and the Caribbean: High plateau between Peru and Bolivia and northeast Brazil as knowledge-sharing centers	Areas with high potential for vulnerability reduction and productivity improvements	Community development; rangeland management; production & income diversification.	Greenhouse vegetable production; fish-farming	Land tenure	CIP
		Africa: Zimbabwe, Botswana, Namibia, Tanzania	Reduce goat mortality; develop sources dry season fodder (including tree sources); coordinate market information	Target women; capacity building in animal health	Livestock market infrastructure; abattoirs; vet services	Support to local government; develop markets in neighboring countries	ICRAF, ICRISAT, ILRI, SSA CP

System	Biophysical constraints	Region/examples	Interventions				CGIAR Centers and Challenge Programs (alphabetical order)
			Technological	Social	Investment/ infrastructure	Policy	
Agropastoral	Desertification; land degradation; soil erosion; climate variability; feed	West and Central Africa: Mali, Niger, Chad, Nigeria (*highly vulnerable)* East and Southern Africa Ethiopia, Kenya, Tanzania	Match livestock breeds to specific environments; change livestock species; better/more adapted crop species; early warning systems; price information; telecommunications; conservation of biodiversity; water harvesting	Community action to increase tree regeneration and manage trees & shrubs	Roads; livestock markets; health & education; development of water sources; food storage systems; telecommunications	Frameworks for diversifying income source; payment for environmental services (PES); insurance-based schemes; safety nets	Bioversity, CIAT, ICRAF, ICRISAT, ILRI, SSA CP
		West Asia, North Africa, and Central Asia and the Caucasus: Rangeland ecosystems (*highly vulnerable)*	Empowerment of livestock keepers; use of native biodiversity to rehabilitate degraded rangelands; water harvesting; better management of grazing; livestock health management	Community action to limit livestock damage to environment; grazing management; management of rangeland trees & shrubs		Strengthen or create policies for rangelands	Bioversity, ICARDA
		East and southern Africa	Improve access to water for livestock; increase livestock productivity (health, feed); improve livestock product quality; assess feasibility of carbon sequestration in rangelands	More appropriate relief and social protection to support livelihoods, e.g. smart destocking and restocking; conflict management; community organization & empowerment	Roads; market access for livestock products, including links between pastoral and peri-urban areas; strengthen information & communication technologies and rural financial sector (savings, insurance to manage risk)	Increased awareness related to pastoral development; institutional teamwork to support PES; participatory land-use planning	ICARDA, ICRAF, ICRISAT, ILRI, SSA CP

9.2 Integration with other CRPs

CRP 1.1 will build on an R4D focus. Comparative advantages are focused around integrated, multi-component, complex, dynamic, evolving agroecosystems, where change is predicted and anticipated. Opportunities for IPG potential will be prioritized.

CRP 1.1 will have links and collaborative work with a number of other CGIAR CRPs (Table 7). The following mechanisms will be used to capture and facilitate linkages with other CRPs:

1) Establish a CRP 1.1 portfolio of potential links to other CRPs in three domains as follows:
   a) What CRP 1.1 gives to other CRPs
   b) What CRP 1.1 brings in from other CRPs
   c) What CRP 1.1 jointly develops with other CRPs.
2) Examine the other CRP proposals, and identify specific outputs or activities that could potentially contribute to or link to CRP 1.1.
3) Map "interest-overlap" areas with other CRPs, as a way of indicating domains for joint efforts and linkages with other CRPs.
4) Engage other CRP Directors in discussions on specific forms of engagement in defined activities, and agree upon collaborations and relations.

Once these agreements have been reached with the identified CRPs, they will be built into CRP 1.1. CRP 1.1 should manage linkages with other CRPs on a routine basis, in addition to any CRP portfolio management performed by the CGIAR Consortium.

The proponents of CRP 1.1 envisage that this CRP will interact closely with CRP 1.2 and CRP 1.3 to develop new approaches and tools to address complex, dynamic agroecosystems. Research will be tightly structured around major system constraints and requirements for resilience, together with opportunities (such as new markets and other potential links to CRP 2). For example, following interactions with WorldFish, the Lead Center of CRP 1.3, CRP 1.1 proponents agree that some of the most important aquatic agricultural systems in Africa are located in arid regions, notably the Sudano-Sahelian zone. The Niger River system is one of these, and Mali has been identified as a potential focal country for developing CRP 1.3. The consultations required to develop the work of CRP 1.3 in Mali will be conducted to develop collaboration between the two CRPs, with a view to integrating past experiences as well as drawing on lessons from earlier work in sub-Saharan Africa and other regions. Wherever possible, specific collaboration on field research will be developed, e.g. on policy research in support of agricultural development. CRP 1.1 will also utilize outputs from Thematic Area/CRP 3, including livestock commodity value chains and genetically enhanced crop germplasm, and will provide feedback to the various CRP components of Thematic Area 3 on the performance of their products in these complex agroecosystems.

Because diversification of food systems is a priority in CRP 1.1, it aims to work closely with CRP 4 to further enhance food quality and dietary diversity. Interaction with CRP 6 is also important, as many agroecosystems include agroforestry. The agroecosystem research in CRP 1.1 will also link closely with, and utilize the results from, research on land and water management and ecosystem services in CRP 5. Furthermore, CRP 5 and CRP 1.1 will give priority to the same target areas, e.g. the Nile, West African Sahel, Central and West Asia, and North Africa. CRP 5 will be researching landscape and basin issues, as well as ecosystem services, and developing methods for irrigation and soil and water management. This suggests potential synergy through field world with CRP 1.1. Annex 1 provides more details of envisaged interactions between CRP 1.1 and CRP 5, which can be a model for working with other CRPs on boundary areas. The modeling and decision-support tools developed within CRP 5 for land and water management and in CRP 7 for adaptation/mitigation to climate change will be validated and used to support interventions in dryland areas. Likewise, CRP 7 and CRP 1.1 may work together in the same target areas, e.g. drylands in East and West Africa. For instance, CRP 1 will provide opportunities for developing climate-proofed technologies and practices, while modeling and decision-support tools developed within CRP 7 will be tested and validated within CRP 1.1. Annex 2 illustrates some of the interactions and working relationships between CRP 7 and CRP 1.1. Annex 3 describes additional examples of synergies between CRPs.

Collaboration between CRP 1.1 and commodity-led CRP 3s will be crucial for the success of each CRP (Table 7). CRP 1.1 can provide GIS and other information to CRP 3s and provide feedback on CRP 3 outputs that can be used in CRP 3's target regions. There is potential for joint research for identifying priority systems and traits required in new cultivars or livestock breeds, and for joint research on sustainable intensification of dryland systems using the outputs from commodity-led CRP 3s. CRP 1.1 envisages the participation of CRP 3s' researchers in jointly designing and implementing system research in areas of mutual interest. The inclusion of nutrition as a cross-cutting theme within CRP 1.1 underscores the importance of interacting closely with CRP 4.

Table 7. Collaboration and linkages of CRP 1.1 with other CGIAR Research Programs (CRPs) and mechanisms for achieving effective integration.

CRP	Scope for collaboration	Form of linkages			Mechanisms for achieving integration
		Contribution to CRP 1.1	Contribution from CRP 1.1	Joint research	
Theme 1 CRPs	CRP 1.2: moist savanna in West Africa, Nile Basin CRP 1.3: Mali	Sharing learning from integrated approaches in dryland systems	Sharing learning from approaches taken to: focus program on selected hubs; achieve integration; pursue impacts at scale; manage partnerships; livelihood and farmer-first approaches	CRP 1.2: Knowledge and best-bet technology for drylands of West African moist savanna and Nile Basin CRP 1.3: Role of aquatic agricultural systems in dry areas, using Mali and the Niger river as learning systems	Participation of CRP 1.2 and CRP 1.3 Directors and key partners in annual program meetings of CRP 1.1 and reciprocal participation of CRP 1.1 in similar events convened by both CRPs; joint programming for activities to help ensure that CGIAR conveys coherent approach to integrated agricultural systems
CRP 2: Policies, institutions and markets	Sharing research methods, models, and data, joint research	Models for projections and scenarios; policy analysis	Agroecosystem and livelihoods options that can be linked to national and global (impact) models	Analysis of policies and institutions affecting adoption, policy process, and value chain analysis	Joint research projects and joint appointments between CRPs
CRP 3 crops	WCA, ESA, WANA, Central Asia, South Asia CRP 1.1 areas where dryland cereals and legumes are being developed, especially for multipurpose crops. Especially where common foci exist, such as in West Africa, ESA, and South Asia	CRP 1.1 will use outputs from CRP 3 crops, particularly improved germplasm Dryland cultivars with multiple traits including food and feed	CRP 1.1 will provide feedback to CRP 3 on crop performance Shared learning on requirements for crop varieties and management to respond to multiple opportunities	Joint research to identify priority systems and traits required in improved cultivars Integration of cultivars, management, and testing in relation to grain, biomass, livestock production, soil fertility, and water management	Participation of CRP 3 Directors and key partners in annual program meetings of CRP 1.1 and reciprocal participation of CRP 1.1 in similar events convened by CRP 3; joint programming for activities Sharing parameters for crop breeding that include multiple traits; participation in local stakeholder fora
CRP 3.7: Livestock and fish	Intersection with priority value chains in CRP 3.7 and priority target areas in CRP 1.1: Small ruminants in Mali and Ethiopia Dairy in South Asia	Requirements for feed inputs into livestock value chains that may influence crop varieties and husbandry	Strategies for biomass management (production, processing, and trading) that contribute to livestock production. Options for sustainable intensification of feed production in relation to mitigation of environmental impacts of livestock production.	Joint research on intensification of crop–livestock systems in Mali, Ethiopia, and India, particularly addressing environmental dimensions of increasing feed production	Participation of key researchers in jointly designing research that considers animal demand in response to increasing value-chain participation in relation to feed and water supply

CRP	Scope for collaboration	Form of linkages			Mechanisms for achieving integration
		Contribution to CRP 1.1	Contribution from CRP 1.1	Joint research	
			Intersection of intensifying livestock value chains with pastoral systems that may be the source of animals (especially for small ruminants) and the implications for market engagement, environmental management, and incentives		
CRP 4: Agriculture for nutrition and health	Marginal and intensifying systems in SSA and South Asia	Options and strategies for improving nutrition and health in systems context	Better understanding of technical and institutional opportunities and constraints in dryland systems	Zoonotic disease and food safety; water-related diseases; reducing risk and vulnerability; nutrition indicators	Participation of key centers in both CRPs
CRP 5: Water, land, and ecosystems	CPWF benchmark basins in the Volta and Limpopo, Ghana, Burkina Faso, India, Pakistan, Central Asia, Ethiopia, Kenya, Mali, WANA	Options for rainwater management in crop–livestock systems; water productivity and ecosystem services in irrigated areas; nutrient efficiencies (N and P), carbon sequestration, and salinity management; water access and pastoral livelihoods at different scales; reuse of wastewater; impacts of land- and water-management interventions at landscape and basin scale; ecosystem services in rangelands (trade-offs, balancing environmental and production concerns); watershed management	Integration of rainwater management options into wider landscapes, and relationship to policy environment; higher scale and policy-level engagement on environmental-service management options; access to farming systems and communities; knowledge on the efficacy and impact of land and water interventions	Knowledge sharing, including at various levels of scale; positioning CRP 5 sentinel sites in CRP 1.1 target areas; collaborative research in rainfed and irrigated systems	Participation of key researchers in both CRPs; participation of CRP 1.1 and CRP 5 Directors along with key partners in annual work planning events undertaken by both CRPs; co-location of sentinel and target areas/action or satellite sites; programming of activities within the same target regions and target areas
CRP 6: Forests, trees, and agroforestry	Large opportunities for co-location of research in West Africa and ESA Complementary research focus in dry forest areas (facing high levels of threat)	Knowledge and tools for selecting and delivering tree germplasm and management options for integration into dryland production systems	Diagnostics on desirable characteristics for tree species and agroforestry practices Farmer-field-scale research results from target areas	Large opportunities for co-location of research in West Africa and ESA. While CRP 6 sentinel landscapes are still to be decided, a complementary	Knowledge and tools for selecting and delivering tree germplasm and management options for integration into dryland production systems tailored to specific socioeconomic and ecological circumstances

CRP	Scope for collaboration	Form of linkages			Mechanisms for achieving integration
		Contribution to CRP 1.1	Contribution from CRP 1.1	Joint research	
	is highly likely. Both CRPs will have research in Mali	Management of forests and agricultural lands to address conflict (competing land-use demands) or optimize synergy (multiple-use management) Knowledge on benefits from trees and forests: input into landscape-scale governance, zoning, and planning Knowledge of forest and tree component of climate-change mitigation and adaptation in integrated agricultural systems	Analysis of land-use change, land degradation, and rehabilitation Integration of trees with other dryland-system components Research and coordination on integration of outputs by other CRPs working in dry lands in terms of: (i) complementarity; (ii) synergies (build understanding of the full agroecosystem puzzle); (iii) constructive feedback (to help refine/refocus outputs); and (iv) collective/combined impact pathways for more effective, efficient, productive, profitable, and sustainable integrated agroecosystems	research focus in dry forest areas (facing high levels of threat) is highly likely and both CRPs will have research in Mali	Management of forests and agricultural lands to address conflict (competing land-use demands) or optimize synergy (multiple-use management) Knowledge on benefits from trees, forests, and goods and services they provide, for landscape-scale governance, zoning and planning Knowledge on forest and tree component of climate-change mitigation and adaptation in integrated agricultural systems
CRP 7: Climate change, agriculture, and food security	Vulnerability assessment and risk management of dryland production systems under climate-change scenarios for East and West Africa regions Prospects for CRP 1.1 target areas as new target regions for CRP 7	For East and West Africa regions, CRP 7 will provide downscaled assessments of the agricultural and livelihood impacts of climate change CRP 7 will provide modeling and decision-support tools to define possible agricultural development scenarios under climate change	Opportunities for developing climate-proofed technologies and practices (e.g. water-efficient management systems, conservation farming), options for reducing risk and improving resilience Testing and validating models and decision-support tools developed within CRP 7 We have agreed to co-fund climate-smart villages in India and Bangladesh. Funding has been supplied for 2012.	CRP 7 and CRP 1.1 will jointly test technologies and practices from CRP 1.1 in the context of integrated adaptation and mitigation strategies, through co-financing, which will provide opportunities for out-scaling and achieving outcomes related to climate change	Participation of CRP 7 Directors and key partners in annual program meetings of CRP 1.1 and reciprocal participation of CRP 1.1 in similar events convened by CRP 7; Planning of joint activities and participation of key researchers in both CRPs

CPWF: Challenge Program on Water and Food; ESA: East and Southern Africa; SSA: sub-Saharan Africa; WANA: West Asia and North Africa; WCA: West and Central Africa.

9.3 International, regional and national partners

CRP 1.1 aims to co-generate science-based knowledge on dryland agriculture development to benefit both the poor and the environment of target dryland systems. This requires careful, structured consultation with many partners to draw up a research agenda for the next 6 to 12 years (see Annex 5 for stakeholders´ inputs into the proposal development process).

CRP 1.1 takes careful note of the CGIAR Consortium Board´s general guidance on partnerships (issued in its feedback on the concept notes) which stated that “a clear strategic plan be envisaged in the proposal, [which] should include a proper balance of core partners, and a definition of partners´ roles.” This message clearly suggests that CRP 1.1 should not simply establish partnerships for partnership's sake, but rather establish partnerships selectively and strategically, based on a clear purpose and value-added benefit. CRP 1.1 will follow the principle that “science drives partnerships.” Partners come together on the basis of their capacity to effectively and cost-efficiently contribute added value to answering the research questions and hypotheses addressed through the SRTs. CRP 1.1 will use flexible, inclusive arrangements that enable changes to be made in partnerships as needs change and as this CRP evolves.

Table 8 outlines the types and purposes of partnerships CRP 1.1 foresees as important, and the value they will add to this CRP. These contributions will be discussed in joint planning sessions and assigned to each partner with a view towards a meaningful division of labor between partners and a critical mass in relevant areas. This approach will improve the relevance of CRP 1.1 activities and strategies, and complete the chain from research needs through knowledge-based technology design, development, validation, implementation, testing, and adoption. It will also lead to effective links to achieve scaling-up through systems and organizations that can help leverage impacts. It will be critical for CRP 1.1 to actively engage national policy-makers and other decision-makers as well as local institutions.

Since the science of CRP 1.1 requires a roll-out process, so too will the identification of matching partner arrangements and commitments. The strategic partners best placed to deliver the various SRT outputs can only be identified when CRP 1.1’s interdisciplinary regional teams are staffed with stakeholder representatives and become fully operational. Likewise, specific partners in regions are being identified through the process that identified target areas and action and satellite sites for implementing CRP 1.1.

It is clear that certain partners such as national programs (including universities) and regional fora and subregional organizations will play a key role in helping to identify IAR4D and development partners in the regions, just as international networks and relationships will assist in the identification of suitable partners from the industrialized world. Partners will also help CRP 1.1 better understand regional priorities and identify potential research areas, sites, and mechanisms. CRP 1.1 will also align with regional priorities as formulated by those partners.

Table 8. Type of partners, purpose, value added, and examples.

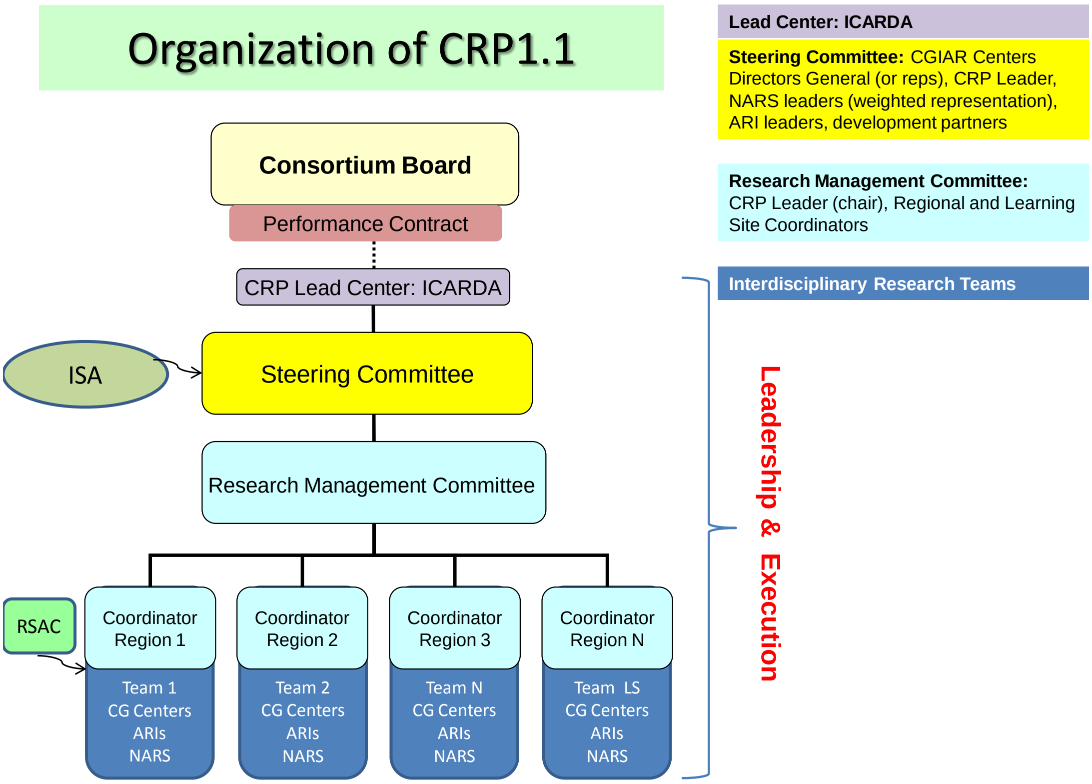
Partner type	Purpose	Value added	Examples
Global conventions	Political framework for action	Influence government and donor policies towards sustainable dryland management	UNCCD, CBD, UNFCCC
Advanced research institutions	Innovative science to help CRP 1.1 meet dryland agriculture challenges	New science methods enable new advances on dryland development	Partial list in Annex 4
Regional umbrella networks (networks of organizations)	Understand regional priorities and institutional landscape; recommend CRP 1.1 to development investors and decision-makers	Align with priorities and suggest most appropriate, effective partners and partnership mechanisms in regions; enhance resource mobilization to support CRP 1.1 work in the region	Partial list in Annex 4
Specialized regional research institutions	Provide strong research base with good regional knowledge	Enable execution of advanced science under developing-country conditions	Partial list in Annex 4
Innovative research scientists	Conceive and execute outstanding science	Create valuable new knowledge, tools, protocols	In NARs, ARIs, universities, and other research organizations
National policy-makers	Inform public policy with CRP 1.1 research findings	CRP 1.1 R4D influences national land-use policies	Ministers, Permanent Secretaries, members of Congress
National research institutions	Provide links between research and national governments	Research results translate quickly into national commitments	Partial list in Annex 4
Development agencies (public or NGO)	Leverage science for impact on the ground; communication channel with land users	Out-scaling of results; magnify the impacts of CRP 1.1	Partial list in Annex 4
Civil society organizations	Communicate land-user needs and extend CRP 1.1 outputs to communities and land users	Strong connections to local governance; mobilize land users	Partial list in Annex 4
Private sector	Commercial sustainability	Out-scaling; adoption; improve access to inputs; improve market access	Traders, processors, seed companies, local entrepreneurs, processors
Partners with gender expertise and/or mandate	Ensure equitable outcome for women and other disadvantaged groups,	Enhance sustainability and impact by involving and reaching all relevant target groups	Ministry of Women's Affairs, gender-specialized NGOs, women's organizations
Development investors and other donors	Provide means for the execution of CRP 1.1; enable impact by supporting the out-scaling of results from CRP 1.1 through development projects; influence policies and the enabling environment for adoption of CRP 1.1 outputs	Means enable CRP 1.1 goals and objectives to be achieved	CGIAR Fund members, regional development banks, philanthropic organizations
CRP 1.1 proposers	Leading providers of input on research, advice, and advocacy for CRP 1.1	Strengthen and broaden CRP 1.1 relationships; communicate the importance of CRP 1.1	All noted throughout this proposal
All partners	Catalyze CRP 1.1; lead its formulation; develop support; foster its growth; convene its processes; provide its legal identity	Create, foster, and sustain CRP 1.1's core functions and processes	Partial list in Annex 4

CBD: Convention on Biological Diversity; UNCCD: United Nations Convention to Combat Desertification; UNFCCC: United Nations Framework Convention on Climate Change.

10. Management arrangements and implementation

Based on the management principles defined in the CGIAR's SRF and the CGIAR Consortium Constitution, CRP 1.1 has a simple and cost-effective management mechanism that will rely almost entirely on the capabilities of participating Centers and other partners. This will ensure no increases in bureaucracy. ICARDA is the CRP 1.1 Lead Center, accountable to the Consortium Board. Governance, fiduciary oversight, and financial management of the main performance contract for CRP 1.1 will be the responsibility of the Lead Center. The detailed organization of CRP 1.1, modified based on the recent Consortium Board guidelines, the Consortium Constitution, the Stakeholders' Consultative Conference, and a series of communications between CGIAR Centers, ARIs, national and regional agricultural R&D organizations, and donor groups, is outlined in Figure 14.

Figure 14. Proposed CRP 1.1 management arrangements.*



* Four part-time independent scientific advisors (ISA) will be identified, reporting to the Steering Committee. Each target region will have a Regional Stakeholder Advisory Committee (RSAC). Due to space limitations, only one RSAC is shown in the Figure.

CRP 1.1 will have a **Steering Committee** that will provide strategic oversight and that will be responsible for the overall direction, monitoring, and resource allocation across the program. The Steering Committee will chaired by the Director General of the Lead Center. Other members will include:

- representatives of three CGIAR partner centers: ICRISAT, ILRI, and World Agroforestry Center;
- representatives of two advanced research institutions (rotating): Agropolis (France) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Australia);
- four national-system representatives (rotating): the Global Forum on Agricultural Research (GFAR)/Forum for Agricultural Research in Africa (FARA), the Ethiopian Institute of Agricultural

Research (EIAR), the Indian Council of Agricultural Research (ICAR) (South Asia), and the Institut national de recherche agronomique, Morocco (INRA-Morocco);

- Representatives of three development agencies (rotating): FAO, IFAD, and the Howard G. Buffett Foundation; and
- the Dryland Systems CRP Director.

The **Research Management Committee (RMC)** will be responsible for overall coordination and management of the research agenda. It will be chaired by the CRP Director, and consist of coordinators of the interdisciplinary research teams for each target region. Management of human resources, finances, and administration will be undertaken by the RMC in communication with partner organizations in each interdisciplinary research team. The RMC members will stay in close contact through electronic means and periodic meetings. The RMC will develop and propose medium-term and annual work plans and other planning tools as requested by the Steering Committee; these will be reviewed and approved by the Steering Committee. The RMC will also engage with the Regional Stakeholder Advisory Committees on a continuing basis to ensure a productive exchange of ideas with potential end users of CRP 1.1 outputs.

Each SRT will have a standing panel of four part-time (30–45 days per year) **Independent Scientific Advisors (ISAs).** The ISAs will be world-class scientific experts on the main subjects of each SRT. The ISAs will be appointed to fixed terms by the Lead Center in consultation with the Steering Committee. They will provide advice on quality of science. They will report directly to the Steering Committee and provide advice on any areas regarding the relevance and quality of proposed and ongoing research in annual work plans and annual reports. They may suggest amendments to the research agenda to the Director or to the Steering Committee. They can also recommend the formation of CRP 1.1 interdisciplinary teams to conduct comparative analysis of SRTs across regions and to assess the integration of SRTs within a region. ISAs may also give advice on trends and emerging issues relevant to CRP 1.1, and potential strategies for addressing them.

The **CRP Director** will be appointed by the Lead Center in consultation with the Steering Committee. The Director will provide a crucial leadership role in the R4D agenda, in consultation with the Steering Committee and the RMC. The CRP Director will be appointed as a full-time position in accordance with the policies of the Lead Center. In addition to daily management duties, the Director will lead resource mobilization efforts, partner and donor relations, and relations with the RMC and RSACs, and ensure timely and high-quality reporting to the Steering Committee and the Consortium Board through the Director General of the Lead Center. The Director will serve as the public representative of CRP 1.1, working closely with the Steering Committee to ensure that the program maintains a high and positive profile with investors and the public. The Director will ensure agreed outputs are achieved; organize program meetings and reviews; and assign high-level leadership and management tasks. Having a world-leading scientist in this position will give CRP 1.1 credibility and influence. To this end, the CRP Director will continue to be scientifically productive; 10% of his/her time will be allocated to CRP 1.1 research, including proportionate research budget, staff, and facilities. The Director will oversee a small management office, assisted by professional and support staff with positions approved by the Steering Committee.

Regional Coordinators (RCs) of the interdisciplinary teams will be part-time appointments of scientists/managers proposed by the Center coordinating each specific target region, and will continue to be affiliated with their home institutions. The Steering Committee will approve the appointments and, together with the CRP Director, evaluate their annual performance. The RCs will ensure that the activities in each SRT are effectively implemented, coordinated, cross-informed, delivered, and monitored/assessed. The RCs will also maintain strong and positive relationships with the CRP Director and partner institutions, donors, and stakeholders in each region.

The **Regional Stakeholder Advisory Committees** (RSACs) will provide a channel for input and dialog with the Steering Committee and the RMC. The RSAC will comment on the relevance and effectiveness of partnership arrangements, and advise and facilitate CRP 1.1 in reaching policy-makers and other decision-makers in target regions. Since the RSACs' role is advisory, RSAC members will be appointed by the Steering Committee to address priority needs and knowledge gaps in each target region. RSAC members will be representative of the intended users of CRP 1.1 outputs in each target region. The membership will thus include a mixture of representatives from a mix of constituencies covering policy, public research, development, NGOs, CSOs, and community-based organizations, and land users. Because of the high cost of physically gathering such a group, regular meetings will be supplemented with teleconferences, email, electronic surveys, and other electronic modes of communication. The Chair of each RSAC will organize these consultations, with assistance from the CRP's Office if needed. RSAC representatives in regions will also stay in frequent contact with their respective RCs, who will ensure that stakeholders' views are continuously shared with the entire RMC. The CRP Director in turn will consolidate and share such feedback electronically with the Steering Committee. The Steering Committee, at its discretion, may invite any of the RSAC Chairs to its meetings as resource persons.

The Lead Center will enter into Program Participant Agreements (PPA) consistent with the CRP 1.1 business plan and delivering results. This will ensure that, wherever possible, funds, responsibilities, and accountabilities are devolved to the Center/unit/partner undertaking specific tasks.

Communications, monitoring and evaluation, and reporting on the program as a whole will be delivered collectively under the auspices of the CRP Director using inputs from RCs and other partners according to the roles and inputs defined in their performance contracts. Resource mobilization (or fundraising) will be coordinated at the CRP 1.1 level by interactions among RMC members under the guidance of the Steering Committee.

Dispute resolution

Any disputes among CRP 1.1 partners or with external parties will be resolved according to policies established by the RMC if within the domain of R4D (including partnerships), or by the Steering Committee (if in the domain of institutional and legal responsibilities) following the principles of the CGIAR Constitution. In cases in which the RMC cannot resolve a dispute, the matter will be referred to the Steering Committee for guidance and action.

11. Innovation: what's new?

The CRPs were founded to foster, implement, and demonstrate innovation; to facilitate new areas of CGIAR work with interactions among Centers; and create wider partnerships (including outside the CGIAR Centers) in targeted regions. This IAR4D approach is not new, but recent advances in technologies and development strategies provide a new starting point for CRP 1.1. These include, for example, community institutions, community-based NRM, community-based livestock breeding, village-based seed and seedling enterprises, participatory market development, participatory research, micro-finance, production insurance, financial and social safety nets, alternative energy sources, mobile connectivity, and the increasing recognition by national governments of the need to empower local communities. These and other innovations can be tested at various scales, from farm to landscape level, in a globally coordinated manner. The success of this complex research by CRP 1.1 will lead to a revaluation of how drylands contribute to national development policies and economic growth. CRP 1.1 encompasses innovations in five areas:

- **Integrating local knowledge**. Building on local and indigenous knowledge of both women and men to address the management of local agrobiodiversity, the integration of different agroecosystems, the fostering of traditional institutions, the use of participatory approaches, and the introduction of concepts of community development. One example of this approach would be the development of a methodological framework for community-based improvement programs for smallholder livestock production. These will address, *inter alia*, institutions and infrastructural requirements and development of small-scale activities to add value to livestock and their products, including livestock fattening systems, dairy systems, and fiber processing. Another example is the analysis and understanding of traditional risk-management strategies based on crop diversification. This will contribute to the value added by CRP 1.1 in terms of translating location-specific outputs from natural-resource-management research into IPGs that will find wider adoption through integration of livestock and crop systems and better linkage to development.

- **Integrating new developments in science**. The complex, integrated nature of smallholder production systems, which combine private and common resources, requires social, institutional, and organizational research, and promotion of community-based, collaborative approaches to developing dryland agricultural systems. This integrated, multidisciplinary research responds to global interests (e.g. poverty eradication, reducing food insecurity, and managing climate variability), and will take advantage of innovations in science to improve agroecosystems, building on existing stakeholder knowledge. Understanding farmers' decision-making rationales and processes is key to targeting interventions. New decision-support and *ex ante*-analysis tools will be developed to analyze gender-differentiated resource allocation and decision-making (e.g. land, labor, water), and their specific impacts on livelihood and sustainability. Interactions and resource flows at intrahousehold level and at farm and landscape scales will be examined. The diversification/resilience balance will be studied, as will the trade-offs between intensification and natural-resource conservation and market linkages in these mixed systems. Enhanced participation of women along value chains will be promoted in various ways, including targeted capacity building, support for women to effectively participate in research design and in shaping new opportunities to benefit from them, and policy recommendations that facilitate the access of women to income-generating opportunities. The needs or requirements of other socially disadvantaged groups will also be assessed, together with their potential interest and capacity to contribute and benefit from interventions.

  Examples of new areas of research include the conjunctive use of rainwater and irrigation water in traditionally rainfed crops. Many scientists have worked on interventions such as zero tillage, supplemental irrigation, and crop improvement to increase yields in rainfed areas. However, no integrated studies have been conducted to understand the mechanisms and processes by which synergies among agroecosystem component (crops, vegetables, livestock, rangeland, trees, and fish) could improve and stabilize yield and water productivity, especially not at the numerous scales envisaged in CRP 1.1. The use of remote sensing and GIS tools for better targeting and out-scaling will enhance understanding of adaptive traits and help match breeds with environment. Interactions between crops, livestock, soil, and water will be studied simultaneously in mixed production systems. It is expected that a large number of new insights, tools, and outputs will be developed, but it is also conceivable that entirely new disciplines will emerge from applying systems approaches at a higher level of integration.

- **Tackling transformation and system change**. These mixed agroecosystems are undergoing rapid change as a result of a variety of external drivers including demographic change, migration, urbanization, globalization, and climate change. If these factors are not taken into account, innovations may become irrelevant before they are properly validated, promoted, and adopted. In other cases, a complex system change may be the only option to increase productivity and reduce poverty. Smallholder mixed systems, for example, are undergoing very rapid intensification processes and there is an urgent need to manage that change in such a way that the poor do not become poorer and resources are not further (irreversibly) depleted (e.g. irrigation development displacing grazing animals; depletion of soil carbon as a result of increasing encroachment of crops into rangelands; managing landscapes for overall increased production) while stabilizing markets.

This requires greater use of tools such as participatory scenario planning, the study of mixed dynamic systems, and qualitative analysis to shed light on unexplored dynamics that might affect the success of interventions. Innovations in promoting interaction between research and development efforts at various scales and in building diverse partnerships will enhance the transformation of dryland agriculture by delivering better targeted R4D investments. At the socioeconomic level this also requires research on innovative approaches to develop and implement targeted safety nets. This is important, as the lack of safety nets forces farmers, especially in highly stressed areas, to focus on reducing risk and production variability rather than on increasing productivity. Such an approach may retard growth and may prevent many dryland farmers from escaping the poverty trap. Studies on safety nets of various kinds are crucial to achieve food security at the larger scale.

- **Integration at the system level.** The agroecosystems approach will develop new integration across farm and landscape levels. CRP 1.1 will search for enhanced synergies among various crops, vegetables, livestock, rangeland, and fishery components, without neglecting local/minor crops of high nutritional value and resilience (linking closely with CRPs 4 and 7). It will strengthen integration with all actors, including across the CRP portfolio, and ensure that best practices, methods, tools, and expertise for gender mainstreaming within the agroecosystems approach are shared with the larger community through e-platforms or other appropriate mechanisms. It will also integrate across disciplines, linking agricultural improvements to market interventions and to innovations in risk management and vulnerability reduction. Technologies and techniques for better use of water resources and nutrients will also be integrated. Last but not least, the aim is to also intensify vertical integration between farming communities and science communities, so they develop a common vocabulary. Technology development will be accompanied by and integrated with policy measures and institutional set-ups to ensure significant impacts through wider dissemination of the technologies and their promotion by policy-makers.
- **Effective partnerships.** CRP 1.1 will link extensively with the private sector and ARIs with key complementary competencies that add value. For example, it will establish partnerships to improve stewardship of technologies emerging from private enterprise in order to accelerate impact. Interactions with private enterprise are also needed in the area of processing, i.e. adding value to primary products. Such public–private linkages may include both small local shops and large supermarkets. Greater efforts will be made to link science with the needs of farmers, particularly the poorest, leveraging the livelihood potentials of local agrobiodiversity and innovation of value-chain actors. Complex technical information will be packaged in ways that farmers can easily understand and apply. The program will support access to and use of new and appropriate ICTs for women and men to facilitate communication and partnerships.

12. Risks

There are several types of risks that this CRP may face:

- Integrated systems research, looking at interfaces between different system components, is more complex and demanding and therefore inherently more difficult and risky than component research. In some situations the right answers will be unknown; even the right questions and hypotheses may yet to be properly formulated. This is a sign of an impending paradigm shift that CRP 1.1 hopes to catalyze in dryland system research. Tools will be developed and tested. The program will build on successful experiences in fostering integration to minimize these risks.
- This type of research implies new relationships between partners. The risk is that the process of learning how best to work together may take longer than expected, delaying program

implementation in the field. The program will minimize this risk by developing joint research to enhance partnerships and benefit from the new CGIAR structure.

- Some dryland systems are located in areas with high social and political volatility, which may hinder the adoption of interventions. The program will minimize this risk by emphasizing local partnerships in such areas.
- To be successful, this CRP will have to involve a wide range of partners, particularly policy-makers, who may not be able to respond as quickly as desired or to provide the additional investments needed for scaling up and scaling out research results and lessons learned. To reduce this risk, the program will diversify partnerships to ensure greater involvement by NGOs and other community organizations.
- We also need to find ways to partner more effectively than in the past, especially in terms of promoting greater accountability and ownership by partners. This involves some risks, as many activities needed to achieve impact are beyond the control of the research program. Involving development agencies and extension services in research planning and implementation will help reduce this risk.
- Social and gender analysis and support for gender-responsive strategies—including management accountability mechanisms and adequate budget and staffing—must be effectively integrated in all stages of the SRTs (from design to implementation, monitoring and evaluation, and assessment). If this is not achieved, there may be a risk of non-adoption of new technologies, of increased social and gender gaps, and ultimately of reduced impact of CRP 1.1.

Agricultural systems in dry areas have always been characterized by risk. These risks are changing and in some cases increasing. In many pastoral dryland areas, degradation, tenure insecurity, reduced mobility and access, loss of indigenous knowledge, and disintegration of traditional collective systems contribute to the risks producers face. These factors are exacerbated by inappropriate government policies; for example, subsidies on livestock feed indirectly increases pressure on rangelands by encouraging livestock owners maintaining herd and flock numbers even during extended drought. Conflict over resources is a feature of many dry areas. At the same time, there has been a reduction in the capacity of people in these systems to manage risk as a result of declining resources, lack of information, land degradation, and land tenure insecurity. Sustainable and productive use of collective resources such as water and rangelands presents particular challenges, especially in the absence of an enabling policy environment and buy-in from local communities.

13. Capacity strengthening

Capacity strengthening is a core principle of CRP 1.1 and indeed among CRPs. Stronger NARS capacity is crucial if countries are to respond to the rapid changes occurring in the biophysical, sociocultural, technological, and policy environments, and to ensure sustainable impact in the fragile and complex agroecosystems of dry areas. CRP 1.1 will use new approaches in human and institutional capacity development that enable the NARS to build a cadre of well-trained researchers and extension agents capable of leading change and innovation. Capacity strengthening is emphasized along the entire IAR4D impact pathway, in every target region and every SRT. While details will need to be developed with the NARS, and more generally with the innovation platforms, the emphasis will be on: cooperating in teams, emphasizing science quality, relevance, and applicability of what is being learned; result- and impact-oriented approaches; and, equally important, making the learning process enjoyable. This process will be coordinated with the CGIAR's Capacity Strengthening, Learning, and Knowledge Sharing Unit as described in the SRF (CGIAR, 2011).

Using innovation approaches, as in SRT1, CRP 1.1 will facilitate joint identification of capacity-strengthening requirements and capacity-strengthening providers within the context of mutually identified outputs and outcomes. NARS and other platform partners will help plan relevant training programs tailored to their needs, in line with the thematic and geographic priorities of CRP 1.1. Specific NARS will be targeted with specific programs in a way that improves that NARS' research outputs, outcomes, and impacts. The train-the-trainer approach will be used for most activities to allow for wider and more rapid impact. CRP 1.1 will also co-develop similar efforts with universities and local, regional, and international organizations.

Disadvantaged groups, especially women and youth, will be targeted by capacity development activities to ensure that they are adequately represented in training programs, field experiments, extension activities, impact assessment, and other CRP 1.1 activities. This will help boost their knowledge, skills, and participation in decision-making. Achieving this will require engagement with organizations and professionals who already have experience with such groups.

Capacity-development activities will include short- and medium-term individual and group training of one week to several weeks and long-term individual training of several months, during which the trainees will gain hands-on experience with new system approaches and technologies. In addition, NARS staff studying for MSc or PhD degrees will be offered joint supervision of their thesis research by CRP 1.1 scientists and universities. This will provide excellent opportunities for CGIAR-brokered capacity strengthening at both individual and institutional levels of all types of partners. The methodologies used will include face-to-face workshops/training, field experimentation, farmer field schools, on-the-job training, distance learning, and other approaches, as needed and appropriate. These methodologies will build on the wealth of knowledge already available in the target regions elsewhere. For example, Brazil and India have considerable expertise that is relevant to Africa. Organizations from both countries have volunteered to work with CRP 1.1 in providing access to methodologies and knowledge-sharing sites. CRP 1.1 aims to exploit South–South and North–South collaboration. It will also engage with the private sector on specific areas.

Capacity development activities will include, but are not limited to: targeting crops and vegetables for research activities, and how those crops and vegetables are used; conservation and utilization of genetic resources that are not covered in CRP 3; seed production and delivery systems; integrated pest management; natural-resources management, particularly on-farm water-use efficiency and productivity; agronomy (particularly conservation agriculture); soil fertility; crop–livestock integration; small ruminant management and husbandry; rangeland management; forage production; agroforestry; fish population management; protected agriculture; and value addition. Each subject will be considered not in isolation but as part of a complex agricultural system. This is in addition to developing capacity in supportive skills such as: building research–extension linkages; integration of women and youth in the R4D process, including experimental design and statistical analysis; project management; risk management; writing project proposals; technical reporting; monitoring and evaluation; and enterprise management. Appraisals will be conducted to determine whether the knowledge and skills acquired through CRP 1.1 capacity-development activities contribute to the program objectives.

14. Communication and knowledge-sharing strategy

The success of CRP 1.1 depends on effective communications, knowledge sharing between stakeholders and researchers and among researchers from different disciplines and centers, and commitment and buy-in from all stakeholders involved. Bringing together partners at various levels presents communication and knowledge-sharing challenges that require innovative approaches.

The detailed development of the communication strategy and plan for CRP 1.1 began with the RIWs. This will be a consultative process that is part of the research-planning process and linked to the monitoring and evaluation framework. The strategy and plan will be designed to ensure that research outputs and outcomes and the new ideas generated are put into use as a part of the CRP 1.1 project cycle—defining specific activities, outputs, and outcomes planned during the program. The approach will be based on action plans for strategic communication—engaging specific groups of people to achieve a specific, defined, result—and knowledge sharing—sharing experience and learning together as a part of the project, both among the project team and with partners, and capturing and sharing this learning as the program progresses.

What is strategic communication?

The first step in the program's strategic communication calls for identifying the key groups of people that the program needs to engage with or influence to achieve its outcomes and objectives, and what we want them to do as a result of our communication effort. Once this is done we can define how we can engage with or influence them and the messages we wish to convey, and then develop specifically designed communications activities, products, and services to do so. We then measure the results and adjust the plan as needed. The purpose of strategic communication is to add value to the research of CRP 1.1 by increasing its visibility and influence and making the research results as useful as possible to various users worldwide.

What is knowledge sharing?

Knowledge sharing is about embedding approaches to capturing and sharing of experience in the program's existing work processes and creating an environment that encourages learning and sharing of useful information both within the program and with partners. The purpose of knowledge sharing is to improve the effectiveness of the program and its investment in research, and increase the speed with which we learn and transmit practical experience to our partners.

14.1 The approach: "outcome thinking"

The approach used in the design and measurement of the impact of the communications plan is inspired by outcome mapping. The plan will not use the full outcome-mapping framework but will employ key elements of the concept—aiming for specific action and behavior change among specific groups of people. The starting point is three key questions:

- **Who can we influence directly?** Identify specific groups of people that we can influence directly.
- **What do we want to happen?** Describe the specific actions that we want to see in the target groups that illustrates that the change has happened.
- **What communication activities, products and services will we create to reach this goal?**

To design the strategy, a special communication workshop is proposed where senior members of the CRP team will work together for one or two days to define the target groups, design an "influence pathway" and specific outputs for each key group, and draw up a series of outcomes that the program will aim to achieve through engagement with these groups. The workshop will result in a shared vision among research leaders on the communication goals and priorities of the program, and an action plan, developed together, with a clear indication of what is to be done and who is responsible for implementing each activity.

In particular, the communication strategy can build on the innovation systems being studied in SRT1, which will identify key points on the impact pathway where communication activities will be most needed.

Some of the communication challenges arise from the following:

- Multiple objectives with research-for-development aspects, such as reducing vulnerability and encouraging sustainable intensification and encompassing a range of planned regional and SRT outputs
- Complex impact pathways of CRP 1.1
- Multiple partners, many of them new
- Geographical structure requiring cultural and linguistic adaptations intersecting with research deliverables of the SRTs.

14.2 Basic principles and key considerations

> *"Take a gene out of an organism and it has no more meaning than a particular set of cards has outside … a game of poker or bridge. Both information value and function are context dependent." — P. Weiss*

CRP 1.1 needs to leverage, exchange, and combine old and new information in new contexts to create new meaning and value. It has to create a repository of knowledge on drylands and tailor it to different audiences. It has to create a new vision, values, and language. So it needs a new communication and knowledge-sharing philosophy to underpin its communication strategy and campaigns.

Jack Welch, former chief executive officer of General Electric, has been quoted as saying, "Making your numbers but not demonstrating our values is grounds for dismissal." CRP 1.1 grounded in strong values that represent the essence of the CGIAR reform process, has to communicate those values and to mainstream them in everything it does. This is an essential part of the philosophy. Right from the conceptual stage, CRP 1.1 adopted a clear philosophy for its communication and relationship management that drove the entire consultation and communication process. This will continue in the same mode.

The basic tenets of this approach are described here.

14.2.1 Emphasis on face-to-face communications

The greatest bandwidth is still in face-to-face communications.

CRP 1.1 is an ambitious program involving complex agroecosystems, multiple impact pathways, and a large number of partners. It is outside the traditional communication systems of CGIAR Centers. Its success will require substantial investment in high-quality communications and relationship building. While the latest and most powerful communication technologies and tools will be made use of, the focus on face-to-face communication will remain paramount. Communication is, in the final analysis, more about human attitudes, skills, and behaviors than technology, tools, or processes. Value is added by:

- developing a compelling vision together and owning it collectively;
- developing solutions and innovations through sharing knowledge with all stakeholders (both women and men) involved in rural development;
- conducting deeper and more meaningful conversations that are critical for sharing knowledge, building commitment, early resolution of conflicts, and trust building; the partners can respond immediately, clear any misunderstanding very early, and reach a consensus quickly;
- building trust and commitment, which are essential for creative and inspired effort from partners; and
- building credibility through full sharing of information and willingness to integrate various viewpoints.

The downside is higher transaction costs, and cost/benefit ratios need to be carefully optimized.

The effectiveness of CRP 1.1 meetings will be ensured by their having clear purposes and objectives, with a results and product orientation, and their being attended by all the relevant players on the impact pathway, from the onset to having impact on livelihoods.

The institutionalization of both explicit and implicit knowledge is a critical success factor for achieving the long-term goals of CRP 1.1. Communication tools and processes will be built to provide effective and timely access to the large amount of information that is currently held by various partners. CRP 1.1 will strive to create a culture of trust, information sharing, and continuous learning to bring the technical innovations to life. Communication training is an essential part of the strategy.

14.2.2 Communication model

The communication model and its operationalization are described below and shown in Figure 15. The process has four stages:

1) Goal setting
2) Design of the campaign (to be determined)
3) Roll-out of the campaign (to be determined)
4) M&E and feedback

Setting the goals and objectives for the communication and knowledge-sharing strategy involves a detailed analysis of communication requirements and establishment of broad goals for the communication campaign. Given the various outputs and outcomes for each SRT, varying impact pathways, and different time sequences, a separate campaign will be developed for each SRT and target region. The broad goals will be underpinned by clear, measurable, and time-bound objectives and performance indicators. This will be a significant part of the work at the Inception Workshops. Indicative areas for setting objectives are:

- Justification for the program
- Coherence and coordination among partners
- Benefits in terms of CGIAR goals as defined in the SRF
- Importance and impact on gender
- Capacity building
- Division of responsibilities among partners
- Interfacing with other CRPs

There are two kinds of M&E activities implicit in this model: effectiveness of the various initiatives within the campaign and effectiveness of the communication campaign itself. Formal feedback will also be collected from the target groups to ensure that their information needs are being effectively met.

Figure 15. Example of a communication model.

15. Monitoring and evaluation

The new CGIAR envisages that some aspects of evaluation will be centrally coordinated across all CRPs. CRP 1.1 will complement this evaluation with its own process of performance management, monitoring, evaluation, impact assessment, and internal learning. It will implement a framework for M&E at various levels using established methods, and possibly also some new ones. Table 9 describes the M&E plan, including the objectives, implementers, users of results, and the level and frequency of implementation.

Priority assessment in CRP 1.1 will be done at the regional level with partners. This process began at the global planning workshop (Nairobi, Kenya, 27–30 June 2011), continued at the five RIWs, and will be revisited regularly but not less than every three years.

Performance monitoring to ensure that CRP 1.1 is on track and that the scientific outputs are of sufficient quality will be managed by the RMC with support from the RSAC. This will be done on the basis of specific, measurable, achievable, relevant, and timely (SMART) milestones. Particularly successful results will be highlighted and corrective actions will be taken where milestones are not achieved and where current milestones are no longer appropriate. These "course corrections" could be based on, for example, new science, new information about the context, or changes in the target agroecosystems, target areas, or action sites.

This system will be as simple as possible so as to not overburden CRP 1.1 implementers. The indicator data and reports will be compiled by the RMC for consideration and endorsement by the CRP 1.1 Steering Committee (with the assistance of the ISAs), which will be responsible for monitoring the entire CRP in an advisory capacity.

Given the importance of participatory and action research in this CRP, M&E of institutional and technological interventions with stakeholders will be a regular part of the research activities. This M&E will also provide feedback to scientists (CRP and partners) and other participants and contribute to collective learning and co-production of knowledge by scientists and users. M&E will be managed by social scientists working in the SRTs, and will be designed to ensure that perspectives of various types of stakeholder, such as women or other disadvantaged groups, are included.

Following current practice in *ex post* impact evaluation, CRP 1.1 will look at the effects of research outputs on the behavior and welfare of users under "controlled" conditions, such as development projects (treatment effects), and will also undertake *ex post* impact assessment when system innovations resulting from research have been sufficiently widely adopted and have been used for long enough for impacts to have occurred. Assessing the impacts of innovations under controlled conditions is different from assessing *ex post* impact, since in the former case the innovation is specifically being promoted to certain users in a given area. However, if properly analyzed—using experimental or quasi-experimental approaches—such an analysis can provide important information on who is likely to benefit from the innovation and how large the benefits might be.

While *ex post* impact assessment can only be assessed quite long after innovations have been developed and disseminated, we can obtain intermediate indicators of impact in the form of outcome assessments. Outcomes, defined as use of research outputs by intended users, provide some confirmation that the program is progressing along its impact pathway. To increase the probability that outcomes materialize, CRP 1.1 will develop strategies that engage partners from the research sector (e.g. other CRPs or national partners), from the policy sector, or the non-governmental sector (NGOs, private companies) in their R4D work.

Finally, CRP 1.1 will make strategic use of external reviews to provide feedback on and input to science (e.g. SRT or output level), implementation (regional level), and management and administration.

Table 9. Elements of the CRP 1.1 monitoring and evaluation plan.

M&E element	Purpose	At what level, by whom?	Who will use the results?	How will results be used?	How often will it occur?
Priority assessment	Assessment of expected impact and key assumptions involved	Target area, supported by SRT4	• RMC • Scientists • Partners • Consortium • Donors	Strategic direction Resource allocation Scientist conceptualization	Every three years from inception workshop
Performance monitoring	Pace/quality of scientific progress and partnerships	RMC	• Steering Committee • Scientists • Partners • Consortium • Donors	Operational planning To determine achievement of milestones	Annual
Research process and intervention evaluation	Results of action research and user feedback on interventions	SRT level, by social scientists with input from other scientists	• Scientists • Partners (including other CRPs) • Users, beneficiaries, or their representatives	R&D planning within SRTs and regions	Annual
Outcome assessment	Use of research product and progress towards outcome	SRT level, by scientists and regional coordinators	• RMC and Steering Committee • Scientists • Consortium • Donors	Scientist learning Strategic direction Validation of impact pathway	Iterative

M&E element	Purpose	At what level, by whom?	Who will use the results?	How will results be used?	How often will it occur?
Ex post impact assessment	Benefits of research for users under controlled conditions and at scale	SRT or region, led by SRT4 with inputs from other scientists and partners	• RMC and Steering Committee • Scientists • Partners • Consortium • Donors • Users/beneficiaries	Strategic direction Scientist learning Justification of donor investment Validation of impact pathway	Iterative
External reviews	Feedback for specific management decisions	SRT, region, by external review panel	• RMC and Steering Committee • Regional coordinators • Scientists • CGIAR partners • Administrators • Donors	Strategic direction Scientist and partner learning Management of administrative processes	Periodic, as needed

16. Budget

The annual budget for CRP 1.1 is US$ 37.428 million in the first year (2013), increasing to US$ 44.5 million by 2015 Table 10. These are the minimum amounts needed for implementing CRP 1.1 under the CRP1 Theme. CRP 1.1 will also seek to mainstream the program into the agendas of national governments/ministries, development investors, and donors to leverage additional funding.

The budget uses the full-time equivalent (FTE) concept as unit of cost. FTE is a way to measure an internationally recruited staff's involvement in this CRP and includes all line items indicated in Table 11. In 2009 the average CGIAR FTE (which includes all objects of expenditure) cost about US$ 487,000. The share of each object of expenditure against total expenditure may vary between CGIAR Centers, reflecting the wide variation in the type of operations across the CGIAR System (CGIAR, 2010). Table 11 compares percentage budget allocations by object of expenditure of CRP 1.1 with those of the CGIAR System as a whole. For CRP1.1, each budget line item includes 17% indirect costs.

Percentage expenditure on personnel costs, travel, and operating expenses are lower for CRP 1.1 than for the last five-year average of the CGIAR System, whereas the percentage of the budget allocated to partners and collaborators by the CRP is higher than in the CGIAR 2005–2009 average. It is important to note that the CRP budget places high priority on partnership: funding for partnerships represents close to 20% of the total implementation phase budget because partnership funds include not only partners' contracts (15%) but also workshops and training (5%), visiting scientists at CGIAR Centers, and joint research with or at CGIAR sites (fields and labs) that are included among other operating costs for each CGIAR Center. Expectations are that most of the new funding that CRP 1.1 will generate will include at least 20% for partners and probably more in many cases.

CRP 1.1 will put aside resources for mainstreaming the four cross-cutting themes (gender, youth, nutrition, and biodiversity). Also, additional short-term external funding will be sought for specific or newly identified research topics and gender-proactive initiatives.

Table 10. CRP 1.1 2013–2015 budget (US$) by strategic research theme (SRT) and CGIAR Center (includes resource allocation to non-CGIAR partners).

Year 2013	ICARDA	ICRISAT	ILRI	CIP	IWMI	ICRAF	Bioversity	CIAT	WorldFish	Total
SRT1	3,769,517	1,536,955	1,425,272	332,855	0	184,350	184,250	132,940	0	7,566,138
SRT2	4,724,584	3,586,227	1,114,526	832,138	1,453,000	307,250	586,232	256,709	0	12,860,666
SRT3	3,843,205	4,610,864	1,965,986	1,386,895	0	430,150	202,675	66,905	0	12,506,680
SRT4	1,827,734	1,536,955	431,517	221,903	0	307,250	92,125	77,471	0	4,494,954
Total	**14,165,040**	**11,271,000**	**4,937,300**	**2,773,791**	**1,453,000**	**1,229,000**	**1,065,282**	**534,025**	**0**	**37,428,438**
Year 2014	**ICARDA**	**ICRISAT**	**ILRI**	**CIP**	**IWMI**	**ICRAF**	**Bioversity**	**CIAT**	**WorldFish**	**Total**
SRT1	4,146,468	1,690,650	1,490,530	355,558	0	202,785	194,528	146,234	0	8,226,753
SRT2	5,197,043	3,944,850	1,165,556	888,895	1,626,000	337,975	618,935	282,379	0	14,061,632
SRT3	4,227,526	5,071,950	2,056,001	1,481,491	0	473,165	213,981	73,596	0	13,597,710
SRT4	2,010,507	1,690,650	451,275	237,039	0	337,975	97,264	85,218	0	4,909,928
Total	**15,581,544**	**12,398,100**	**5,163,362**	**2,962,982**	**1,626,000**	**1,351,900**	**1,124,707**	**587,428**	**0**	**40,796,023**
Year 2015	**ICARDA**	**ICRISAT**	**ILRI**	**CIP**	**IWMI**	**ICRAF**	**Bioversity**	**CIAT**	**WorldFish**	**Total**
SRT1	4,561,115	1,859,715	1,565,057	379,699	0	223,064	202,610	160,858	0	8,952,117
SRT2	5,716,747	4,339,335	1,223,834	949,249	1,833,000	371,773	644,650	310,617	0	15,389,204
SRT3	4,650,278	5,579,145	2,158,801	1,582,079	0	520,482	222,871	80,955	0	14,794,612
SRT4	2,211,558	1,859,715	473,838	253,133	0	371,773	101,303	93,740	0	5,365,059
Total	**17,139,698**	**13,637,910**	**5,421,530**	**3,164,160**	**1,833,000**	**1,487,090**	**1,171,434**	**646,170**	**0**	**44,500,992**
Total 3-years (2013 to 2015)	**46,886,282**	**37,307,010**	**15,522,192**	**8,900,933**	**4,912,000**	**4,067,990**	**3,361,423**	**1,767,623**	**0**	**122,725,453**

* Consultations on collaborative research with CRP 1.3 (e.g. in Mali) will be held in 2011/2012, building on early experiences by the two CRP 1 programs. There may be extra resources for CRP 1.1, depending on the *modus operandi* for joint work with CRP 1.3. This is why WorldFish is not included in the budget tables; the amounts will be decided only in 2011/2012.

Table 11. Percentage budget allocations of CRP 1.1 compared with those for the CGIAR System.

Object of expenditure	CRP 1.1, 2013–15 (%)		Object of expenditure	CGIAR 2005–09 (%)
Personnel costs	42.50		Personnel	44.8
Travel	6.55		Travel	7.8
Operating expenses	24.81		Supplies and services	28.0
Training/workshops	4.66			
Partners/collaborators/consultancies	14.82		Collaborators and partners*	15.8
Capital and other equipment	4.83		Depreciation†	4.2
Contingency	1.83			

* Includes training and workshops.
† capital items.

The percentage budget allocations for each region and each SRT are shown in Table 12. More than 50% of total resources are devoted to Africa (North Africa is calculated as half of the WANA budget). This reflects CRP 1.1's focus on African drylands. South Asia will account for about one-quarter of the budget, the Middle East for one-eighth and Central Asia 9%.

The initial three-year budget allocates about 20% to SRT1, 35% to SRT2, 33% to SRT3 and 12% to SRT4 (Table 10). This first allocation also reflects some ongoing restricted funding commitments by some donors to special projects of individual CGIAR Centers. The in-kind or own funding of non-CGIAR partners has not been included in the budget, though some partners have already indicated their willingness to commit resources. Stakeholders' messages of support or partnering intent are provided in Annex 5.

Each participating CGIAR Center has submitted budget proposals with separate allocations for funding from the CGIAR Fund and current restricted donor grants. Until it is clear how much the CGIAR Fund will provide, there may be a need for Centers to utilize their own unrestricted funding. The amounts shown for restricted funding in 2014 and 2015 are higher than 2013, because restricted funding will compensate for the US$ 10 million of CGIAR Fund that were used during the Inception Phase. It is expected that bilateral funding will remain a key component, and partners will continue to vigorously pursue funding opportunities within the overall objectives of CRP 1.1.

Table 10 presents the indicative budgets as they have been submitted by individual Centers. At a later stage the budgetary structure will need to reflect the overall management and programmatic structure. A detailed budget allocation will be made in accordance with the proposed CRP 1.1 management structure, as set out in Tables 13 to 16.

Table 12. Budget allocation (%) by region and strategic research theme (SRT).

	Year 2013						Year 2014						Year 2015					3-year
Region	SRT1	SRT2	SRT3	SRT4	Sub-total		SRT1	SRT2	SRT3	SRT4	Sub-total		SRT1	SRT2	SRT3	SRT4	Sub-total	Regional
WCA	14	17	16	23	17		15	17	16	20	17		16	17	16	19	16	17
ESA	24	24	25	21	24		27	23	25	23	25		26	23	25	24	25	25
WANA	30	22	19	25	23		31	22	19	25	23		31	23	19	25	23	23
SA	21	22	28	22	24		17	23	28	23	23		17	23	28	23	23	23
CA	9	12	8	8	9		9	12	8	8	9		9	12	8	8	10	9
LA	2	3	4	1	3		1	3	4	1	3		1	2	4	1	3	3
	100	100	100	100	100		100	100	100	100	100		100	100	100	100	100	100

WCA: West and Central Africa, ESA: East and Southern Africa, WANA: West Asia and North Africa, SA: South Asia, CA: Central Asia, LA: Latin America (mainly dry Andes)

Table 13. Project Costs and Funding Source Summary – Inception Phase (2012)

Cost Group	Budget Line Item	ICARDA	ICRISAT	ILRI	CIP	IWMI	ICRAF	Bioversity	CIAT	Total Project Costs
	INCEPTION PHASE ACTIVITIES									
1	Ground work	869	460	329	146	132	281	152	131	**2,500**
2	Regional Inception Workshops	750	250	250	0	0	250	0	0	**1,500**
3	Planning for full Implementation	678	372	202	160	141	140	167	140	**2,000**
4	General Contingency	115	54	39	15	14	34	16	14	**300**
5	Funding for On-going CRP 1.1 Activities of Centers	1,127	642	240	141	98	0	159	94	**2,500**
	Sub-Total Inception Phase Activities	**3,539**	**1,778**	**1,060**	**462**	**384**	**705**	**494**	**378**	**8,800**
	OTHER START-UP ACTIVITIES									
6	Appointment of Director & Setting up of Management Unit	900								**900**
7	Resource Professionals	300								**300**
	Sub-Total Other Start-up Activities	**1,200**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1,200**
	GRAND TOTAL - INCEPTION PHASE	**4,739**	**1,778**	**1,060**	**462**	**384**	**705**	**494**	**378**	**10,000**

Table 14. Project Costs and Funding Source - Year 1 of Implementation (2013)

Cost Group	Budget Line Item	ICARDA	ICRISAT	ILRI	CIP	IWMI	ICRAF	Bioversity	CIAT	Total Project Costs
1	Personnel Cost	5,150	4,723	1,553	757	619	431	534	252	14,019
2	Travel	833	695	135	181	107	73	4	30	2,058
3	Operating expenses (see definition)	2,239	1,411	2,114	770	155	233	17	143	7,083
4	Training / Workshop	1,002	170	0	12	0	42	217	3	1,446
5	Partners / Collaborator / Consultancy	1,666	1,498	312	583	238	215	5	21	4,537
6	Capital and other equipment	914	390	0	102	48	21	16	6	1,496
7	Contingency	0	443	0	0	24	0	95	0	562
	Sub-Total	**11,804**	**9,330**	**4,114**	**2,405**	**1,191**	**1,016**	**888**	**455**	**31,202**
8	Institutional Overhead	2,361	1,941	823	369	262	213	178	79	6,226
	Total Project Costs	**14,165**	**11,271**	**4,937**	**2,774**	**1,453**	**1,229**	**1,065**	**534**	**37,428**

	Funding Sources	ICARDA	ICRISAT	ILRI	CIP	IWMI	ICRAF	Bioversity	CIAT	Total Contribution
	CGIAR Fund (Windows 1 and 2)	8,478	5,970	1,936	621	1,143	470	959	534	20,111
	Window 3 & Bilateral Restricted Grants	5,688	5,301	3,001	2,152	310	759	107	0	17,317
	Others	0	0	0	0	0	0	0	0	0
	Total Funds	**14,166**	**11,271**	**4,937**	**2,774**	**1,453**	**1,229**	**1,065**	**534**	**37,428**

Table 15. Project Costs Summary – Implementation Phase (2013 to 2015)

Cost Group	Budget Line Item	Year 1 (2013)	Year 2 (2014)	Year 3 (2015)	Total Project Costs
1	Personnel Cost	14,019	14,061	15,331	43,411
2	Travel	2,058	2,213	2,424	6,695
3	Operating expenses (see definition)	7,083	8,796	9,458	25,337
4	Training / Workshop	1,446	1,579	1,720	4,745
5	Partners / Collaborator / Consultancy	4,537	5,030	5,574	15,142
6	Capital and other equipment	1,496	1,640	1,799	4,936
7	Contingency	562	621	691	1,874
	Sub-Total	**31,202**	**33,939**	**36,999**	**102,140**
8	Institutional Overhead	6,226	6,857	7,503	20,585
	Total Project Costs	**37,428**	**40,796**	**44,501**	**122,725**

Table 16. Funding Source Summary – Inception Phase (2012) and Implementation Phase (2013 to 2015)

	Funding Sources	Inception Phase (2012)*	Year 1 (2013)	Year 2 (2014)	Year 3 (2015)	Total
	CGIAR Fund (Windows 1 and 2)	10,000	20,111	20,111	20,111	70,333
	Window 3 and Bilateral Restricted Grants	0	17,317	20,685	24,390	62,392
	Others	0	0	0	0	0
	Total Funds	**10,000**	**37,428**	**40,796**	**44,501**	**132,725**

* Note: As US$ 10 million of Windows 1 and 2 funds were earmarked for Inception Phase, the component of Windows 3 and Bilateral Restricted Grant funding will be increased by an equivalent US$ 10 million over the three years of the Implementation Phase 2013 to 2015.

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Annexes

Annex 1. Points of intersection and difference between CRP 5 and CRP 1.1[2]

CRP 5 has most in common with CRP 1.1 (Integrated agricultural production systems for dry areas) and CRP 7 (Climate change). Simply put, CRP 1.1 is about agricultural productions systems, CRP 5 is about sustaining the environment and natural-resource base used across a range of dry, subhumid, and humid zones. CRP 1.1 and CRP 5 have worked together to develop the following summary of complementarity—and the differences—between the two programs.

- CRP 1.1 is focused at field and farm level/scale, with entry points predominantly through improving agricultural production systems. CRP 5 is focused at landscape, watershed, and basin scales, with entry points predominantly through sustainable management of the natural-resource base.
- Both CRPs are concerned with improving livelihoods, reducing poverty, sustaining the environment, and increasing food production. To achieve these common goals, CRP 1.1 focuses mainly on managing risks and sustainably increasing production and profitability of crops, livestock, trees, and fish as components of an integrated agroecosystem. CRP 5 aims to protect the environment to ensure that water and soil resources and their quality are sustainably managed to underpin agriculture and ecosystem services and thus livelihoods.
- CRP 1.1 is concerned with crop/soil/water relations. CRP 5 is concerned with how agricultural land use and land-use change may impact run-off and drainage and thus availability and quality of downstream water resources.
- CRP 5 will take climate-change predictions from CRP 7 to determine changes in rainfall, run-off, and overall hydrological responses at basin and watershed level and use this information to provide CRP 1.1 with input data on water availability and quality for various cropping systems. CRP 1.1 will focus on adaptation of natural resources and cropping systems to expected changes, and on mitigation measures (e.g. conservation agriculture) when and where possible.
- CRP 5 will focus on aspects of supplementary and full irrigation as related to supply, conveyance, and allocation of water resources (surface and groundwater) from the point of view of governance, management, and sustainable use. CRP 1.1 will focus on field and farm irrigation techniques from a viewpoint of improving crop productivity.
- CRP 1.1 will address issues of water harvesting at the micro-catchment level, whereas CRP 5 will address macro-catchment issues, especially those of upstream–downstream relations.
- CRP 1.1 will look at crop nutrition at field and farm levels. CRP 5 will focus more on broader issues of soil fertility and soil management, including fertilizer sources, such as reuse of wastes and improving soil physical and chemical fertility and land cover to minimize erosion and subsequent sedimentation.
- CRP 1.1 will look at carbon in terms of on-farm fertility. CRP 5 will bridge to CRP 7 with respect to the issue of carbon storage at landscape level and its impacts on climate-change mitigation.
- CRP 1.1 will focus on impact pathways that lead to the adoption of a better mix of new technologies, varieties, and field/farm-management practices. CRP 5 will focus on impact pathways that lead to policy and governance changes required for better management of natural resources.
- CRP 1.1 will look at issues of biodiversity as they relate to cropping systems. CRP 5 will look at how agricultural landscapes can be better managed to deliver critical environmental services, including clean water supplies.

[2] This summary was developed jointly by IWMI and ICARDA.

- CRP 1.1 will look at ecosystem services in terms of food, feed, organic matter, fuel, and other production services. CRP 5 will focus on natural-resources resilience and regulations; CRP 2 will address cultural issues. CRP 5 further targets the spatial connectivity of ecosystems in accounting for the benefits of ecosystem services at different scales from farm to landscape to river basins. In particular, the regulating ecosystem services targeted here are concerned with loss of water quality and pollination efficiency and increased vulnerability to disease and arthropod pests and natural hazards (floods, droughts). The supporting ecosystem services targeted are hydrological cycling, soil nutrient cycling, and soil formation.

There are, of course, some grey areas in terms of which CRP provides the best fit. Management of both CRP 1 and CRP 5 undertake to ensure that these are discussed further as the work programs progress to ensure that there is no unnecessary duplication and that, where the work is equally relevant to both CRPs, results, outcomes, and, where possible, activities will be shared.

Annex 2. Interactions between CRP 7 and CRP 1.1[3]

Thematic areas/mega programs/services (with which CRP 7 will interact)	Work to be undertaken in CRP 1.1 that is relevant to CRP 7	Work to be undertaken in CRP 7 that is relevant to CRP 1.1
Integrated agricultural systems for the poor and vulnerable. Initially work will be conducted with CRP 1.1 in eastern and West African drylands. Future work with CRP 1.1 will be expanded to other regions	CRP 1.1 will provide opportunities for developing climate-proofed technologies and practices. Modeling and decision-support tools developed within CRP 7 will be tested and validated within CRP 1.1. Box 6 suggests how CRP 1.1 and CRP 7 can interact in terms of field testing.	For specific regions, CRP 7 will provide down-scaled assessments of the agricultural and livelihood impacts of climate change. CRP 7 will provide modeling and decision-support tools. CRP 7 will work with CRP 1.1 partners to define possible agricultural-development scenarios under climate change. CRP 7 will provide research methods to ensure that cross-regional comparisons with respect to climate change are possible (e.g. technologies currently being tested in one region may be useful for future climates in other regions). CRP 7 will provide opportunities for achieving outcomes and impacts related to climate change

Box 6. Working relationships between CRP 7 and CRP 1.1

Step 1. *Get agreement with CGIAR Centers and partners on goals that serve both CRP 1.1 and CRP 7*. This includes conducting scenario analyses of visions for the future.

Step 2: *Data collection* in CRP 1.1 on dryland agroecosystem characteristics, including land use (e.g. cropping, rangeland), geographical specifics (e.g. land slopes), poverty dimension, cropping patterns, crops grown, livestock specifics, rotation practices, soil specifics (e.g. organic matter, fertility), water availability (e.g. precipitation, wells, access to rivers), market connectivity, value-chain specifics, existing analysis on how future production systems may change under climate change.

Step 3: *Sharing data with modeling community*. Carrying out of modeling in CRP 7 using various climate-change and development scenarios to identify possible mitigation and adaptation interventions.

Step 4: *Joint analysis*, between CRP 1.1 and CRP 7 and partners. Selecting subset of scenarios that seem congruent in their predictions. Identifying possible sets of mitigation and adaptation interventions in terms of food security, poverty alleviation, and environmental sustainability (these options may come from any points in the overall food system).

Step 5: *Developing and testing options*. CRP 7 will translate the proposed scenarios into real production possibilities: e.g. cereal–pulse rotations, livestock mixtures (e.g. large and small ruminants, non-ruminants), and management (e.g. feed menus: organic crop waste, forage needs, rangeland contribution), cropping specifics (e.g. conservation agriculture options, tilling, resting, role of fallows), fishery specifics, and agroforestry components. CRP 1.1 will test possible options, with co-financing from CRP 7. CRP 7 will provide the expertise for climate-specific components where needed (e.g. climate-risk-insurance methods, improved climate information for smallholders, mechanisms to enhance access to carbon markets).

Step 6: *Multilocation and multi-year trials will be conducted in target areas*, both existing (with historical data already available) and new sites based on site-similarity and analogue mapping of the future production conditions for the target sites (from modeling). This will allow real-term experimentation on future predictions.

Step 7: *Joint analysis* between CRP 1.1 and CRP 7 and partners.

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[3] After Bruce Campbell (Director of CCAFS – lead proposer of CRP 7) with inputs from co-authors of the CRP 1.1 proposal.

Annex 3. Current ICARDA research priorities and their complementarities with CRP 1.1 initiatives

Currently ICARDA leads CRP 1.1. Very significant complementarities exist between CRP 1.1 and ICARDA's existing research program.

ICARDA's thematic areas in the Biodiversity and Integrated Gene Management Program universally align with CRP 1.1 priorities for using biodiversity as a cross-cutting theme in reducing vulnerability and promoting sustainable intensification, for incorporating improved crop varieties into dryland agricultural systems, and for enhancing access to inputs:

Theme 1.1 – Biodiversity and its utilization

Theme 1.2 – Integrated gene management: Crop improvement, including participatory plant breeding and integrated pest management and dissemination of improved germplasm within a production systems context

Subtheme 1.2.1 – Development of improved varieties of barley, wheat, and legumes adapted to various agroecologies and to climate change

Subtheme 1.2.2 – Development of integrated pest management

Theme 1.3 – Research on strengthening seed systems through private-sector participation and alternative delivery systems, including institutional and policy options; and improving the availability of improved varieties of barley, wheat, and food and feed legumes, and access to them by NARS and national seed programs

Theme 2.1 – The sustainable, equitable, efficient, and economic use of scarce water resources in agricultural production, with due concern for watershed management and wider environmental and social implications.

Subtheme 2.1.1 – Assessment of available water resources

Subtheme 2.1.2 – Options and strategies for sustainable use and improved water productivity of rain, irrigation, shallow aquifers, and marginal-quality aquifers in both rainfed and irrigated systems

Subtheme 2.1.3 – Methods, options, and strategies for drought characterization, preparedness, and mitigation

Subtheme 2.1.4 – Policy and institutional options

Similarly, ICARDA's Integrated Water and Land Management Program contains themes highly relevant to CRP 1.1:

Theme 2.2 – Combating land degradation and contributing to mitigation of, and adaptation to, climate change through sustainable management and utilization of natural resources, including soil, in cropland and rangelands.

Subtheme 2.2.1 – Development of a holistic approach to improved land management to combat desertification

Subtheme 2.2.2 – Development of multi-scale tools and methods to assess land degradation

Subtheme 2.2.3 – Best-bet technologies and practices developed for sustainable management of land, biodiversity, and rangeland resources, including community-based land-management practices

Subtheme 2.2.4 – Improved policy and institutional options

The same may be said for ICARDA's Diversification and Sustainable Intensification of Production Systems Program, for which the similarities and relevance are self-evident:

Theme 3.1 – Sustainable intensification of dry-area crop and livestock production systems with market orientation to increase agricultural productivity and to impact livelihoods through exploitation of yield potential, improved management, and sustainable use of genetic and natural resources

Subtheme 3.1.1 – Methods and options supporting crop intensification for enhanced productivity

Subtheme 3.1.2 – Agronomic practices to improve water-use efficiency and economic returns per unit of available water

Subtheme 3.1.3 – Sustainable and cost-efficient options within a range of production systems to intensify livestock production systems and capture diverse market opportunities.

Subtheme 3.1.4 – Framework for community-based livestock breeding to allow access to improved breeds, matching available animal genetic resources, market opportunities, and breed potentials

Subtheme 3.1.5 – Analysis of causes of yield gaps through modeling and identification of intervention to overcome such gaps in major staple crops

Theme 3.2 – Market-oriented income diversification and livelihood improvement from alternative crops and livestock systems and adding value to primary products

Subtheme 3.2.1 – Market-driven options for crop diversification considering crop and forage rotation strategies, involving alternative winter crops and summer crops/forages with supplemental irrigation and high-value options

Subtheme 3.2.2 – Market-driven options for livestock diversification through range/crop/forage integration; utilization of native livestock breeds; and capturing opportunities offered by safe peri-urban production

Subtheme 3.2.3 – Options for further income generation through value addition of primary livestock products; options for producing high-quality, hygienic, and safe products; improved market information, access, and transactions; and appropriate institutional organizations, including private sector and supporting policies

Finally, ICARDA's Social, Economic and Policy Research Program has themes that are highly relevant to CRP 1.1:

Theme 4.1 – Economics and policy research

Subtheme 4.1.1 – Analysis of policy and institutional options and development of priorities for public investment to improve rural livelihoods

Subtheme 4.1.2 – Development of policy options for sustainable use of water and land resources and their economic and social implications

Subtheme 4.1.3 – Adoption and impact assessment for technology uptake including analysis of adoption constraints

Subtheme 4.1.4 – Identification of tradeoffs associated with alternative technical and policy options

Subtheme 4.1.5 – Valuation of natural resources and environmental services to facilitate the conservation of the natural resource base

Subtheme 4.1.6 – Options for linking farmers to markets along the value chain

Theme 4.2 – Livelihoods

Subtheme 4.2.1 – Quantification of causes of rural poverty and determinants of rural livelihood strategies in dry areas, including interactions of agri-systems with other livelihood and socioeconomic priorities

Subtheme 4.2.2 – Characterization of women's roles in rural livelihoods; assess impact of gender constraints on livelihoods

Subtheme 4.2.3 – Analysis of impacts of intensification and diversification of production system options on livelihood, nutrition, and health

In conclusion, the above themes and subthemes illustrate clearly that the ICARDA research agenda is closely aligned with CGIAR reforms and CRP 1.1 priorities. The thematic research areas of ICARDA's Strategic Plan fit closely with CRP 1.1's mandate and area of focus.

Annex 4. Potential non-CGIAR partners[4] (contributions shown in parentheses) according to strategic research theme (SRT) outputs and across target regions and knowledge-sharing centers[5]

West Africa: Sahel and dry savannas	Eastern Africa	Southern Africa	Central/West Asia and North Africa	South Asia	South America[6]	Northern China
SRT1						
FARA (learning from SSA CP) **CORAF/ WECARD** (coordinate and support NARS) **ARCN** **INRAN** **AVRDC** (innovation platform and participatory R4D working with private-sector models, PPP to help create private seed companies and community seed-supply systems)	**FARA** (forum) **ASARECA** **AVRDC** (innovation platform and participatory R4D working with private-sector models, PPP to help create private seed companies and community seed-supply systems **KARI-Kenya** **MOA-Kenya** **SARI-Tanzania**	**FARA** (learning from SSA CP) **CCARDESA** **AVRDC** (innovation platform and participatory R4D working with private-sector models, PPP to help create private seed companies and community seed-supply systems **DAES-Malawi** **DARS-Malawi** **IIAM**	**AARINENA** **CACAARI** **NASRO** **IER-Mali**	**APAARI**	**FORAGRO** **EMBRAPA** (learn together) **CONDESAN**	**CAAS** (research staff)
SRT1.1						
CSIR-Ghana (together with local universities: favorable policy, research testing sites, PPP) **USDA/ARS** (strengthen CGIAR partnerships, info and knowledge exchanges, facilitate other US and USDA partnerships)	**USDA/ARS** (strengthen CGIAR partnerships, info. and knowledge exchanges, facilitate other US and USDA partnerships) **ARC-Sudan** (Kenana site) **KARI-Kenya** **MOA-Kenya** **SARI-Tanzania**	**CSIR-South Africa** **DAES-Malawi** **DARS-Malawi**	**AVRDC** (partnership methods) **GDAR-Turkey** (research staff) **GSCAR-Syria** (info. sharing on partnerships, training) **NCARE-Jordan** **IER-Mali** **IRA-Medénine** (whole continuum, technology pole) **ITGC/INRA-Algeria** (experience with new strategy) **INRA-Morocco** (Green Plan Morocco: Aggregator)		**PROCISUR** (successful partnership cases)	**CAAS** (CEDA as an example)

[4] These partnerships are examples that are not exclusive. They are based on the suggestions of partners attending the planning and consultative conferences or through email. Other partnerships will be assessed during the implementation process (as indicated in the activities of Output 1.2).
[5] See Annex 9 for acronyms and initialisms used in this table.
[6] Dry Andes: particularly high plateaus in Bolivia and Peru, drylands of northeast Brazil, Chaco, northern Argentina, and arid zones of Chile.

West Africa: Sahel and dry savannas	Eastern Africa	Southern Africa	Central/West Asia and North Africa	South Asia	South America[6]	Northern China
SRT1.2						
	ARC-Sudan (Kenana site including PPP) Egypt (Nile Delta sites) **KARI-Kenya** **MOA-Kenya** **SARI-Tanzania**	**DAES-Malawi** **DARS-Malawi**	**ICBA** (innovative PPP lesson sharing) **NCARE-Jordan** **IRA-Medénine** (incubator's ideas) **IER-Mali**			**CAAS** (capacity building)
SRT1.3						
FAO (linkages to non-NARS policy-makers plus farmers, to ministers (global), international agreements and instruments, e.g. ITPGRFA, IPPC)	**EIAR-Ethiopia** (facilitate partnerships and approaches to influence policy-makers) **Egypt** (northern coast, Mersa Matroh) **KARI-Kenya** **MOA-Kenya** **KIPPRA-Kenya** **SARI-Tanzania**	**DAES-Malawi** **DARS-Malawi**	**IER-Mali** **MOA-Mali** **MOA-Nigeria** **IAR-Nigeria**		**PROCISUR** (public policies for drylands)	**CAAS** (policy-driven study as an example)
SRT2						
FARA (SSA CP learning sites) **CORAF/ WECARD** (coordinate and support NARS) **CILSS** (regulation seeds, influencing policy) **AVRDC** (vegetables for markets, nutrition, and diversification) **CIRAD-INRA** (knowledge exchange)	**ASARECA**	**FARA** (SSA CP learning sites and projects) **CCARDESA** **DAES-Malawi** **DARS-Malawi** **IIAM**	**CACAARI** **CIRAD-INRA** (knowledge exchange) **ICBA** (information sharing) **NASRO** **AREEO-Iran** (knowledge, resource sharing) **GDAR-Turkey** (research staff, sites, and information) **INRA-Morocco** (water mgmt, land suitability, system approaches, socioeconomics, local coordination, and facilities) **IRA-Medénine** (land mgmt, system approaches)	**AVRDC** (vegetables for markets, nutrition and diversification)	**EMBRAPA** (knowledge development and exchange)	

West Africa: Sahel and dry savannas	Eastern Africa	Southern Africa	Central/West Asia and North Africa	South Asia	South America[6]	Northern China
SRT2.1						
FAO (linkage to farmers through network of field schools) **FAO** (Niger River countries: reduce river pollution through improved agric. practices) **AVRDC** (research sites) **ARCN** (sites, knowledge and tech for Sudan and Northern Guinea savannas) **CSIR-Ghana** (crop–livestock) **INRAN** (experience sharing, biodiversity conservation, water harvesting techniques **PPILDA** (community-based conservation through use)	**AVRDC** (research sites) **Millennium Villages** (sites at Karamanga, Uganda) **Nile Delta** (irrigated water benchmark site) **ARC-Sudan** (northern Kordofan, Darfur, and Butana sites) **EIAR-Ethiopia** (research staff, infrastructure, rainfed water benchmark at Amhara region) **KARI-Kenya** **SARI-Tanzania**	**USDA/ARS** (resource sharing, germplasm, irrigation resources) **CSIR-South Africa** (water research and governance, PES assessment) **DAES-Malawi** **DARS-Malawi**	**AVRDC** (research sites) **ICBA** (biological remediation of saline-affected lands, research on saline soils, brackish water for salt-tolerant forages, introducing and scaling up/out forage–livestock production systems in saline environments, comparisons of saline land plus water-use types, testing salt-tolerant plants under various agroclimactic zones, exp. sites) **GCSAR-Syria** (info and knowledge sharing, exp. sites) **NCARE-Jordan** (rangeland rehabilitation by water harvesting, Badia site) **IRA-Medénine** (agrobiodiversity)	**AVRDC** (research sites) **ICAR-India** (knowledge sharing, expertise, funding, research staff, infrastructure, germplasm exchange, capacity development)	**PROCISUR** (water and land mgmt and use, rangeland mgmt, PES)	**CAAS** (sharing data and skills)
SRT2.2						
CIRAD-INRA (knowledge exchange on participatory tools) **USDA** (research methods and technology sharing) **ARCN** (soil/ water conservation and land use for Sudan and Northern Guinea savanna) **INRAN/PPILDA** (participatory approach to planning, implementation, co-validation, validation, and evaluation)	**ARC-Sudan** (Gezira site) **EIAR-Ethiopia** (research staff, infrastructure) **KARI-Kenya** **SARI-Tanzania**		**CIRAD-INRA** (water mgmt, Maghreb sites for research on vulnerability) **ICBA** (cropping systems, capacity development, exp. sites) **AREEO-Iran** (knowledge and capacity sharing) **GDAR-Turkey** (exp. sites) **GCSAR-Syria** (knowledge sharing, exp. sites) **INRA-Morocco** (expertise) **IRESA-Tunisia**	**ICAR/CRIDA-India** (knowledge sharing on rehabilitation of degraded land, participatory action research on water productivity, watershed mgmt, climate-resilient agriculture, water productivity and risk mgmt)	**EMBRAPA** (participatory land use)	

West Africa: Sahel and dry savannas	Eastern Africa	Southern Africa	Central/West Asia and North Africa	South Asia	South America[6]	Northern China
SRT2.3						
CILSS (early warning systems) **INRAN** (experiences on community rural methods for dissemination, e.g. seed fairs or open days)	**EIAR-Ethiopia** (research staff, infrastructure) **Egypt** (decision support system for climate change, Water Management Training Center) **DRSRS-Kenya** **KARI-Kenya** **KWS-Kenya** **NEMA-Kenya** **SARI-Tanzania** **UNEP/GRID**	**CSIR-South Africa** (decision support system) **DAES-Malawi** **DARS-Malawi** **DNRS-Malawi**	**ICBA** (knowledge sharing, methods, capacity development) **ARC-Sudan** (northern Kordefan and northern Darfur sites) **GDAR-Turkey** (exp. sites) **NCARE-Jordan** (info. and knowledge sharing, capacity building) **IRA-Medénine** (GIS tool expertise) **INRA-Morocco**	**ICAR/CRIDA-India** (development and validation of decision support system for risk mgmt)		
SRT3						
FARA (SSA CP learning sites and projects) **CORAF/ WECARD** (coordinate and support NARS) **CILSS** **INRAN** **AVRDC** (improved germplasm of market-demanded exotic veg., promote indigenous nutrition-driven leafy and fruit veg., PPP-based available and affordable seed systems) **CIRAD-INRA** (knowledge exchange) **ICBA** (applied research and technology sharing)	**AVRDC** (improved germplasm of market-demanded exotic veg., promote indigenous nutrition-driven leafy and fruit veg., PPP-based available and affordable seed systems) **ASARECA**	**FARA** (learning from SSA CP) **CCARDESA**	**AVRDC** (improved germplasm of market-demanded exotic veg., promote indigenous nutrition-driven leafy and fruit veg., PPP-based available and affordable seed systems) **CAACARI** **GCSAR-Syria** (expertise, info. sharing, exp. sites) **IRA-Medénine** (diversification and trees, medicinal and aromatic plants)	**AVRDC** (improved germplasm of market-demanded exotic veg., promote indigenous nutrition-driven leafy and fruit veg., PPP-based available and affordable seed systems)	**EMBRAPA** (knowledge development and exchange)	**CAAS** (lessons from integrated dryland mgmt in benchmark sites)
SRT3.1						
FAO (global wheat rust monitoring system) **CIRAD-INRA** (res. sites for farming system approaches, sustainable intensification, MOOVE) **ARCN** (irrigated vegetables for Sudan	**EIAR-Ethiopia** (crop, soil, and water tech., highland area sites, research staff and resources) **Egypt** (high-yielding crops, irrigated agriculture)	**USDA/ARS** (info. sharing, resources)	**ICBA** (research on marginal water and saline environments) **ARC-Sudan** (tolerant crops) **AREEO-Iran** (resources and knowledge sharing) **GDAR-Turkey** (knowledge sharing,		**PROCISUR** (irrigation for crops and forages, small ruminant production, sustainability assessment tool, knowledge and tech. for mixed crop–livestock, fishery and organic cotton,	**CAAS** (dryland practices)

West Africa: Sahel and dry savannas	Eastern Africa	Southern Africa	Central/West Asia and North Africa	South Asia	South America[6]	Northern China
savanna, Fatama sites) **CSIR-Ghana** (crop–livestock projects in place, 13 research institutes, agric.-based policy and Information)			exp. sites) **NCARE-Jordan** (water-use efficiency) **INRA-Morocco** (expertise and facilities) **IRESA-Tunisia** (expertise)		criolia adding value: wool, milk, meat, strategies to market for small families)	
SRT3.2						
ARCN (crop–livestock integration in Sudan and Northern Guinea savannas)	**ARC-Sudan** (Butana and Gozina sites)	**CSIR-South Africa** (diversification options with natural-resources focus)	**CIRAD-INRA** (field sites, MOU'VE, ILSREU) **ICBA** (research on marginal water, saline environments) **GDAR-Turkey** (knowledge sharing) **NCARE-Jordan** (genetic resources mgmt, herbal and medicinal plants) **INRA-Morocco** (expertise and facilities) **IRA-Medénine** (platform)	**ICAR/CRIDA-India** (sharing of outputs of ongoing action research, capacity building)	**PROCISUR** (see above)	**CAAS** (see above)
SRT3.3						
CSIR-Ghana (and in partnership with local universities: value chains for mango and guinea fowl, clusters development)	**EIAR-Ethiopia** (research staff, infrastructure and resources) **Egypt** (horticulture, medicinal and herbal plants)		**GDAR-Turkey** (knowledge sharing, exp. sites) **NCARE-Jordan** (marketing-chain and post-harvest research) **IRA-Medénine** (medicinal and aromatic plants value chain)		**PROCISUR** (see above)	**CAAS** (see above)
SRT4						
FARA (SSA CP knowledge sharing) **CORAF/ WECARD** (coordinate and support NARS)	**ASARECA** **ARC-Sudan** (Gezira)	**FARA** (learning from SSA CP) **CCARDESA**	**AREEO-Iran** (resources) **INRA-Morocco** (water mgmt and land suitability, expertise in system approaches and socioeconomics, local coordination and facilities)		**EMBRAPA** (learn together)	**CAAS** (benchmark site in northern China)

West Africa: Sahel and dry savannas	Eastern Africa	Southern Africa	Central/West Asia and North Africa	South Asia	South America[6]	Northern China
SRT4.1						
USDA (knowledge sharing)	**ARC-Sudan** (socioeconomic constraints of WHs)		**AREEO-Iran** (resources, knowledge, sharing, capacity development) **GDAR-Turkey** (knowledge sharing, research staff) **IRA-Medénine** **INRA-Morocco** (Centre Aridoculture)		**PROCISUR** (methods, secondary data)	**CAAS** (scenarios and benchmarks)
SRT4.2						
CIRAD-INRA (knowledge sharing)	**EIAR-Ethiopia** (research staff)		**CIRAD-INRA** (knowledge exchange) **GDAR-Turkey** (research staff) **GCSAR-Syria** (knowledge sharing) **INRA-Morocco** (expertise)		**EMBRAPA** (methods)	**CAAS** (ecosystem assessment, jointly develop tools) **India** (innovation policies, inter-sector convergence of resources, modeling safety nets in participatory development)
SRT4.3						
FAO (info. sharing through State of the World Report, early warning systems, vulnerability data) **ICBA** (knowledge sharing on methods and impact pathways) **CIRAD-INRA** (knowledge exchange)	**ARC-Sudan** **EIAR-Ethiopia** (resources, knowledge sharing) **Egypt** (water basin hydro. salinity and production model, decision support system, crop–water climate-change interaction model)		**CIRAD-INRA** (knowledge exchange)	**CRIDA** (climate change project approach and details)	**CONDESAN**	**CAAS** (jointly develop tools for dryland productivity and ecosystem health assessments)

Annex 5. Water scarcity in CRP 1.1 target regions by country

Target region Country	Population 2010	TARWA* volume in 2005 ($km^3 year^{-1}$)	TARWA per capita in 2010 ($m^3 year^{-1}$)	Water scarcity level
West African Sahel & Dry Savannas				
Niger	15,203,822	34	2,236	Economic scarcity
Mali	14,517,176	100	6,888	Economic scarcity
Ghana	24,233,431	50	2,063	Economic scarcity
Burkina Faso	15,730,977	13	826	Water poverty
East and Southern Africa				
Kenya	38,610,097	30	777	Water poverty
Ethiopia	79,455,634	122	1,535	Appr. water poverty
Zimbabwe	12,571,000	20	1,591	Appr. water poverty
Mozambique	22,416,881	217	9,680	Economic scarcity
Malawi	14,901,000	17	1,141	Appr. water poverty
South Africa	49,991,300	50	1,000	Water poverty
North Africa and West Asia				
Egypt	80,197,000	58	723	Water poverty
Sudan	43,552,000	65	1,492	Appr. water poverty
Iraq	31,672,000	75	2,368	None
Iran	75,275,000	138	1,833	Appr. water poverty
Syria	21,043,000	26	1,236	Appr. water poverty
Morocco	32,139,000	29	902	Water Poverty
Tunisia	10,549,100	4.6	436	Absolute scarcity
Algeria	36,300,000	14	386	Absolute scarcity
Turkey	73,722,988	214	2,903	None
Jordan	6,187,000	1	162	Absolute scarcity
Libya	6,355,000	1	157	Absolute scarcity
Saudi Arabia	27,136,977	2.4	88	Absolute scarcity
Lebanon	4,228,000	4	946	Water poverty
South Asia				
India	1,210,193,422	1897	1,568	Appr. water poverty
Pakistan	175,974,000	223	1,267	Appr. water poverty
Central Asia				
Uzbekistan	27,445,000	50	1,822	Appr. water poverty
Kyrgyzstan	5,418,300	21	3,876	None
Tajikistan	6,879,000	16	2,326	None
Afghanistan	31,412,000	65	2,069	Economic scarcity
Turkmenistan	5,042,000	25	4,958	None
Kazakhstan	16,473,000	110	6,678	None

* TARWA: total available renewable water resources

Annex 6. Sub-Saharan Africa Challenge Program and CRP 1.1[7]

The Sub-Saharan African Challenge Program (SSA CP) has been implementing research-for-development activities following the innovation systems perspective across sub-Sahara Africa for about seven years. It has introduced and tested the paradigm of integrated agricultural research for development (IAR4D). This paradigm may be summarized as follows:

- IAR4D is about change or innovation as an outcome, not just about information, knowledge, or technology as a product.
- IAR4D places "research" as one of the components contributing to the development process, rather than its pivotal point.
- IAR4D focuses on processes and performance rather than just products (e.g. technologies, policies); to put it another way, improved processes are the product.

The central assignment of the SSA CP is to prove the IARD4D concept. The proof has hinged on showing whether IAR4D works in providing benefits. Does it work better than traditional approaches? Is it replicable beyond test areas?

The SSA CP used the innovation platform (IP) as the institutional innovation through which the activities were undertaken. Fundamental to the IP is the objective of increasing farmer income through off-farm activities or through selling a surplus of food crop produce or a cash crop grown specifically for sale. The productivity interventions organized by the IPs involve a range of on-farm activities. Productivity of existing crops was improved through crop intensification using improved technologies such as fertilizer, improved varieties, and quality seed, and agronomic practices such as optimal plant density, weeding, intercropping, crop rotation, and use of organic matter. New crops such as vegetables and tree crops were also introduced with the help of non-research partners, including government extension services and the private sector.

The IPs have taken a systems approach, i.e. they have looked at the entire agricultural production system, the relevant value chains, their environment, and the interactions between them. For commodities (livestock, food crops, or cash crops), the IPs have taken a value-chain approach; that is, all aspects from the availability of rural credit and the purchasing of seed and other inputs to land preparation, agronomic management, quality control to meet market standards, post-harvest technology, packing and transport, food processing, and interactions with output markets. The value chain is placed in an infrastructural, institutional, socioeconomic, and policy environment. The key role of the IP is to help farmers access research, extension services, credit, improved seeds, fertilizers and agrochemicals, post-harvest technology, transport, and output markets, as well as training in agricultural technologies. Although the policy environment and the presence of government institutions are very important—especially for the provision of infrastructural support—the role of the (emerging) rural private sector is pivotal. This is particularly true for seeds, fertilizers and agrochemicals, rural agricultural financing, and access to output markets. The IPs have provided a win–win situation: farmers are better off than before; input suppliers sell seeds, agricultural chemicals, and fertilizers to more farmers; output markets receive a more regular supply of better-quality products; farmers actively seek advice and technologies from the village- and district-level staff of the Ministry of Agriculture and the progress made reflects positively on the Ministry of Agriculture; and the international agricultural research centers benefit from better development and delivery mechanism for their technologies, whether variety based (as carrier technologies) or NRM based (as support technologies).

The SSA CP started with a protracted inception phase during which a robust R&D infrastructure was put in place. The inception phase was followed by a three-year research phase; this has been considered to be too short for the planned impact assessment and the proof of the IAR4D concept.

[7] Based on draft provided by SSA-CP Director Adewale Adekunle (FARA, Accra, Ghana).

Following an external review in December 2010, a two-year extension was given to the program, which will now operate up to 2013. During this extension period, the SSA CP will undertake activities to conclude the proof of the concept of IAR4D and enable better understanding of how the process delivers its benefits.

The SSA CP's principles and approaches are similar to those planned for CRP 1.1. Specifically, two pilot learning sites of the SSA CP are within the SRT3 mapping of sub-Saharan Africa. In this context, SSA CP activities will be subsumed under CRP 1.1 in both the Kano–Katsina–Maradi (KKM) axis of West Africa and the Zimbabwe–Mozambique–Malawi (ZMM) transect of Southern Africa. KKM has been identified within the CRP 1.1 action transect for West Africa as providing a perfect environment for integration of the activities in West Africa. In southern Africa, the Chinyanja Triangle, which covers the ZMM transect and eastern Zambia, has been identified as an action site for CRP 1.1. This also provides a good location for integration of SSA CP work into CRP 1.1 activities in southern Africa, with an added opportunity for readily scaling out successes into Zambia.

In the first two years KKM and ZMM will serve more as learning sites within CRP 1.1, enabling the SSA CP to complete the proof of the concept of IAR4D. Within that period, there will be a progressive transition leading to a complete integration of its activities into those of the CRP 1.1 by 2013.

Annex 7. Knowledge-sharing centers

Rationale

CRP 1.1 will use an agroecosystems approach for conducting R4D at action sites within target areas, focusing on the integration and diversification of complex agricultural systems and their environmental, social, and economic context. Several partner institutions in CRP 1.1 already have considerable experience with R&D interventions in complex agroecosystems. Using separate funding they have contributed to the development and implementation of methodologies and tools applicable to the kind of work that CRP 1.1 will conduct. It will be advantageous that these experiences be shared, critically reviewed, validated, adapted, and adopted by CRP 1.1. Knowledge-sharing centers (KSCs) will be established to provide a vehicle for transferring this knowledge and underpinning methodologies to be adapted to the research and evaluation activities to be conducted at each action site.

KSCs are conceptualized as an open community of practice—an evolving group of institutions that have considerable experience in implementing R4D projects in complex dryland systems and also have a wealth of research and evaluation methodologies and tools that have been field tested, validated, and documented. The KSC community of practice will be coordinated by CRP 1.1 management.

Objectives

1) KSCs will serve CRP 1.1 as a source of integrated information, proven methodologies, and implemented tools applicable to R4D in complex dryland agroecosystems.
2) KSCs will contribute to the testing of hypotheses related to system states, system dynamics, system interactions, and scaling-out within the CRP 1.1 framework.
3) KSCs will be an important node of collaboration among CRPs as they will collate the knowledge, methods, technologies, and tools produced by other CRPs for potential application to CRP 1.1 work.

Location of KSCs

The initial KSCs may be located in geographical regions that are not within the CRP 1.1 target regions (such as Latin America) but that have been suggested by the reviewers as being relevant to CRP 1.1. Thus, the experiences on agroecosystems research will be shared by KSCs with all CRP 1.1 partners. These open communities of practice will evolve with the addition of more institutions from various regions, including target regions and developed countries. KSCs will inventory their research to identify research outputs that complement CRP 1.1 work. The basis for identification could be either the system characteristics or the methodological approach used.

Knowledge-provider institutions

The Agricultural Research Education and Extension Organization (AREEO), Iran, CIP, the Centre de coopération internationale en recherche agronomique pour le développement (CIRAD), France, the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brazil, the General Directorate of Agricultural Research (GDAR), Turkey, and the Institute of Environment and Sustainable Development in Agriculture of the Chinese Academy of Agricultural Sciences (IEDA-CAAS) will initiate the network of KSCs. Each of these institutions will propose outputs of agroecosystems research that are ready for scaling out.

Examples include the following:

- AREEO will share the experience gained during the first phase of CPWF in the Karkheh River Basin on highland agricultural systems.

- CIP will share experiences from the Andean Agriculture in the Altiplano (ALTAGRO) project in the dry Peruvian-Bolivian Highlands and from the Papa Andina project, which linked smallholders with markets and innovation systems.
- CIRAD will contribute the analysis of vulnerability and methodologies involving multi-agent simulation.
- EMBRAPA will share experiences in small ruminant production systems in dry areas and the Brazilian experience in government policies to improve market access for smallholder farmers.
- GDAR will provide research results on water management, soil conservation, rangeland management, and drought-tolerance breeding from SRT2-type areas.
- IEDA-CAAS will share experiences on supplemental water management for high productivity and integrated crop–livestock dryland systems.

This list of reference contributions will increase as the KSC network grows.

Activities

Suggested activities to be conducted by the KSC, some of them in collaboration with other CRPs, include the following:

- Compilation of analyses of gathered data, description and comparison of the process, methodologies, and tools used to develop integrated production and livelihood systems in the areas where KSC projects were implemented.
- Verification, comparison, and repackaging of previous KSC projects using criteria, methods, and modeling in CRP 1.1, including data collection, processing, validating, and mapping to evaluate the possibility of knowledge transfer to CRP action sites.
- A critical review of the methods used for impact evaluation.
- Design and development of a process of capacity building in the target regions based on lessons learned from the previous work. This would include visits to project areas, "virtual" interactions, and specially designed workshops or training sessions on some methods.
- A critical evaluation of the added value of partnerships in project implementation.
- Development, parameterization, and validation of various models such as:
    - Computer-assisted dynamic model of an integrated complex production system, able to simulate the performance of a system and its components under variable climatic conditions.
    - 3D geo-referenced virtual tool to simulate the impact of a complex production system on its natural-resource base.
    - Computer-assisted simulation model to analyze the effect of an integrated production system on the soil-carbon stocks and dynamics.
    - 3D virtual models of the systems being characterized derived from a selection of outputs and made available on line.

Specific activities and responsibilities will be reviewed and agreed during the inception workshops to be conducted following the approval of the CRP 1.1 proposal.

Annex 8. Abbreviations and acronyms

AARINENA	Association of Agricultural Research Institutions in the Near East and North Africa
APAARI	Asia-Pacific Association of Agricultural Research Institutions
ARC	Agricultural Research Corporation (Egypt)
ARC	Agricultural Research Corporation (Nigeria)
ARC	Agricultural Research Corporation (Sudan)
ARCN	Agricultural Research Council of Nigeria
AREEO	Agricultural Research Education and Extension Organization (Iran)
ARI	advanced research institute
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AVRDC	World Vegetable Center
BMGF	Bill & Melinda Gates Foundation
CACAARI	Central Asia and the Caucasus Association of Agricultural Research Institutions
CAAS	Chinese Academy of Agricultural Sciences
CCARDESA	Centre for Coordination of Agricultural Research and Development in Southern Africa
CEDA	Centre of Excellence for Dryland Agriculture (China)
CIAT	International Center for Tropical Agriculture (Centro Internacional de Agricultura Tropical)
CILSS	Comité permanent inter-états pour la lutte contre la sécheresse au Sahel
CIMMYT	International Maize and Wheat Improvement Center (Centro Internacional de Mejoramiento de Maíz y Trigo)
CIP	International Potato Center (Centro Internacional de la Papa)
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
CONDESAN	Consorcio para el Desarrollo Sostenible de la Ecoregión Andina
CORAF/WECARD	Conseil Ouest et Centre africain pour la recherche et le développement agricoles
CP	Challenge Program
CPWF	Challenge Program on Water and Food
CRIDA	Central Research Institute for Dryland Agriculture (India)
CRP	CGIAR Research Program
CRP 1	CRP Theme 1: Integrated agriculture systems for the poor and vulnerable
CRP 1.1	CRP on Integrated agricultural production systems for the poor and vulnerable in dry areas
CRP 1.2	CRP on Integrated systems for the humid tropics
CRP 1.3	CRP on Harnessing the development potential of aquatic agricultural systems for the poor and vulnerable
CRP 2	CRP on Policies, institutions, and markets to strengthen assets and agricultural incomes for the poor
CRP 3	CRP on Sustainable production systems for ensuring food security (includes one CRP each on dryland cereals, grain legumes, livestock and fish, maize, rice, roots, tubers and banana, vegetables, and wheat)
CRP 4	CRP on Agriculture for improved nutrition and health
CRP 5	CRP on Durable solutions for water scarcity and land degradation
CRP 6	CRP on Forests and trees: livelihoods, landscapes and governance
CRP 7	CRP on Climate change, agriculture and food security
CSIR-Ghana	Council for Scientific and Industrial Research (Ghana)
CSIR-South Africa	Council for Scientific and Industrial Research (South Africa)
CSO	civil society organization
CWANA	Central and West Asia, and North Africa
DAES	Department of Agricultural Extension Services (Malawi)
DARS	Department of Agricultural Research Services (Malawi)
DRSRS	Department of Resource Surveys and Remote Sensing (Kenya)
EIAR	Ethiopian Institute of Agricultural Research
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária
ESA	East and southern Africa
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
FORAGRO	Foro de las Américas para la Investigación y Desarrollo Tecnológico Agropecuario
GCSAR	General Commission for Scientific Agricultural Research (Syria)
GDAR	General Directorate of Agricultural Research (Turkey)
GIS	geographic information systems
IAR-Nigeria	Institute of Agricultural Research (Nigeria)
IAR4D	integrated agricultural research-for-development

IBLI	index-based livestock insurance
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICBA	International Center for Biosaline Agriculture
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-arid Tropics
IER-Mali	Institut d'economie rurale (Mali)
IFAD	International Fund for Agricultural Development
IGP	Indo-Gangetic Plain
IIAM	Instituto de investigação agrária de Moçambique
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INERA	Institut de l'environnement et de recherches agricoles (Ouagadougou)
INRA-Algeria	Institut national de recherche agronomique (Algeria)
INRA-Morocco	Institut national de recherche agronomique (Morocco)
INRAN	Institut national de la recherche agronomique du Niger
INSAH	Institut du Sahel
IP	innovation platform
IPG	international public good
IRA-Médenine	Institut des regions arides - Médenine (Tunisia)
IRESA	Institution de la recherche et de l'enseignement superieur agricoles (Tunisia)
IRRI	International Rice Research Institute
ISA	independent scientific advisor
ITGC	Institut technique des grandes cultures (Algeria)
IWMI	International Water Management Institute
KARI	Kenyan Agricultural Research Institute
KKM	Kano–Katsina–Maradi pilot learning site of the SSA CP
KSC	knowledge-sharing center
KWS	Kenya Wildlife Service
M&E	monitoring and evaluation
MOA	Ministry of Agriculture
MP	CGIAR Mega Program (= today's CRP)
MSSRF	M.S. Swaminathan Research Foundation
NARS	national agricultural research system
NAS	National Academy of Sciences (Turkmenistan)
NASRO	North African Sub-Regional Research Organization
NCARE	National Center for Agricultural Research and Extension (Jordan)
NE	northeast
NEMA	National Environment Management Authority (Kenya)
NGO	non-governmental organization
NRAA	National Rainfed Area Authority (India)
PDII	potential drought impact index
PES	payment for environmental services
PPILDA	Projet de promotion de l'initiative locale pour le développement à Aguié (Niger)
PROCISUR	Programa Cooperativo para el Desarrollo Tecnológico Agroalimentario y Agroindustrial del
R4D	research for development
RC	Regional Coordinator
RMC	Research Management Committee
RSAC	Regional Stakeholder Advisory Committee
SARI	Selian Agricultural Research Institute (Tanzania)
SRF	CGIAR Strategy and Results Framework
SRT	strategic research theme (formerly known as SRO, strategic research objective)
SSA	sub-Saharan Africa
SSA CP	Sub-Saharan Africa Challenge Program
SWAC/OECD	Secretariat of the OECD Sahel and West Africa Club
TARWA	total available renewable water resources
UK DfID	United Kingdom Department for International Development
UNEP/GRID	United Nations Environment Programme/Global Resource Information Database
UNU-INWEH	United Nations University Institute for Water, Environment and Health
USAID	United States Agency for International Development

USDA/ARS	United States Department of Agriculture/Agricultural Research Services
WANA	West Asia and North Africa
WCA	West and Central Africa
WRC	Water Research Commission (South Africa)
ZMM	Zimbabwe–Mozambique–Malawi pilot learning site of the SSA CP

Box 7. A systems approach for sustainable, profitable dryland agroecosystems

Research that focuses on individual components of an ecosystem, in isolation, leads to limited impacts on the ground (*bottom*). Dryland agroecosystems involve complex and dynamic relationships between multiple components: soil, water, crops, vegetables, livestock, trees, fish … and people. If this reality is not well understood, research outputs are not always adopted by the intended users. When researchers join farmers, livestock keepers, foresters, and fishers, focusing on integrated systems rather than individual components (*top*), understanding increases, research becomes demand-driven, and outputs are aligned to users' needs. This approach leads to more effective use of natural resources and better food security and livelihoods for resource-poor households.

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