GRAIN LEGUME VALUE ALLIANCE
Leveraging legumes to combat poverty, hunger, malnutrition and environmental degradation

A CGIAR Research Program submitted by ICRISAT, CIAT, ICARDA and IITA to the CGIAR Consortium Board

3 May 2011

In collaboration with
Generation Challenge Program (GCP);
The World Vegetable Center (AVRDC);
Indian Council of Agricultural Research (ICAR);
National agricultural research and extension systems in Africa, Asia and Latin America and the Caribbean; and National and international public and private sector research and development partners
Foreword

We are pleased to present our proposal for CGIAR Consortium Research Program (CRP) 3.5 entitled ‘Grain Legume Value Alliance’. The first two words, Grain Legume, are self-explanatory; they identify the topical domain. The second two words – Value Alliance – require a bit of explanation.

A theme that emerged again and again in our formative discussions was value. Grain legumes add value in ways that directly serve the CGIAR System Level Outcomes and are highly complementary to sister CRP targets. Grain legumes earn cash for farmers, increase and complement the nutritional value of cereals for consumers, and add value to farming systems through nitrogen fixation and through sustainable intensification by fitting into underutilized seasonal and cropping system niches.

Because value concepts were so prominent we decided to harness them as an analytical framework. We saw that a value chain perspective could help us understand impact pathways, since value motivates change leading to impact. Since value is quantifiable, it is useful for priority-setting, monitoring, evaluation and impact assessment. And it broadened our horizons beyond just the production system to the larger food/fodder/land health system, prompting us to ask new questions – questions about where and how much value is to be found in grain legume cropping, how it can be increased, and how poor smallholders can benefit from and capture more of it. New questions lead to new innovations.

But value does not materialize in a vacuum. It is created by people and institutions through the knowledge that they generate and share with others. We realized that we needed an Alliance of partners to make value chains work for the poor.

We also realized that an Alliance creates value of its own. Bringing seven world-leading grain legume programs together enables us to learn much more effectively from each other than in the past, increasing our impact. We will share expertise, facilities and services that improve all partners’ efficiency and effectiveness. We will communicate more clearly and effectively with our stakeholders and with those whom we need to influence in order to achieve change on the ground.

Our title therefore embodies our promise: the Grain Legume Value Alliance (GLVA). This proposal describes how we will deliver on that promise.

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Ruben G Echeverria, Director General, CIAT
Mahmoud Solh, Director General, ICARDA
Hartmann, Director General, IITA
Acknowledgments

The seven core partner institutions of GLVA wish to offer their sincere thanks to more than one hundred scientists and external partners who have put large amounts of time and energy into this proposal. They crossed institutional boundaries to work as a united team. They gathered information and brainstormed ideas in two global meetings and in many focused sub-meetings and workshops over the course of 2010/11 in order to draft, revise and refine this proposal. The effort has been well worth it, clarifying our ideas and sparking new ones that will improve our focus and direction in the coming years.

Apart from the scientists, many other staff in all the institutes (administration, finance, human resources and others) worked overtime to provide additional information and data, and to meet deadlines. We would like to express our thanks to all of them. Helpful suggestions have come from the members of ICRISAT’s Governing Board and the CGIAR Consortium Board as well as external experts. We thank you all for making this a better proposal.
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# Acronyms & Abbreviations

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<th>Description</th>
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<tbody>
<tr>
<td>AGLN</td>
<td>Asian Grain Legumes Network</td>
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<tr>
<td>AICRP</td>
<td>All India Coordinated Research Programs</td>
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<tr>
<td>AID</td>
<td>Analysis tracking ID</td>
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<tr>
<td>AIP</td>
<td>Agri-business Innovation Platform</td>
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<tr>
<td>AMDAAD</td>
<td>Authority of Merowi Dam Area for Agricultural Development</td>
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<tr>
<td>ARI</td>
<td>Advanced Research Institute</td>
</tr>
<tr>
<td>ASARECA</td>
<td>Association for Strengthening Agricultural Research in Eastern and Central Africa</td>
</tr>
<tr>
<td>ASR</td>
<td>Asian soybean rust</td>
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<tr>
<td>AVNET</td>
<td>Asian Vegetable Network</td>
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<tr>
<td>AVRDC</td>
<td>AVRDC - The World Vegetable Center</td>
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<tr>
<td>BMGF</td>
<td>Bill &amp; Melinda Gates Foundation</td>
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<tr>
<td>BNF</td>
<td>Biological Nitrogen Fixation</td>
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<tr>
<td>CAADP</td>
<td>The Comprehensive Africa Agriculture Development Programme</td>
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<tr>
<td>CBO</td>
<td>Community-based Organizations</td>
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<tr>
<td>CCRN</td>
<td>Cooperative Cereals Research Network</td>
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<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
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<tr>
<td>CIAT</td>
<td>Centro Internacional de Agricultura Tropical</td>
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<tr>
<td>CLAN</td>
<td>Cereals and Legumes Asia Network</td>
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<tr>
<td>CMS</td>
<td>Cytoplasmic-Nuclear Male Sterility System</td>
</tr>
<tr>
<td>CORAF</td>
<td>Conseil Ouest et Centre Africain Pour la Recherche et le Developpement Agricoles</td>
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<tr>
<td>CRPs</td>
<td>CGIAR Research Programs</td>
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<tr>
<td>CSO</td>
<td>Civil Society Organizations</td>
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<tr>
<td>CWANA</td>
<td>Central and West Asia and North Africa</td>
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<tr>
<td>DARE</td>
<td>Department of Agricultural Research and Education (India)</td>
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<tr>
<td>ECABREN</td>
<td>Eastern and Central Africa Bean Research Network</td>
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<tr>
<td>ELS</td>
<td>Early leaf spots</td>
</tr>
<tr>
<td>ESA</td>
<td>Eastern and Southern Africa</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<tr>
<td>FPVS</td>
<td>Farmer-participatory varietal selection</td>
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<td>GCP</td>
<td>Generation Challenge Program</td>
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<tr>
<td>GLVA</td>
<td>Grain Legume Value Alliance</td>
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<td>GWS</td>
<td>Genome wide selection</td>
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<tr>
<td>HPREC</td>
<td>Hybrid Parents Research Consortium</td>
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<tr>
<td>ICAR</td>
<td>Indian Council of Agricultural Research</td>
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<tr>
<td>ICARDA</td>
<td>International Center for Agricultural Research in Dry Areas</td>
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<tr>
<td>ICIPE</td>
<td>International Centre for Insect Physiology and Ecology</td>
</tr>
<tr>
<td>ICM</td>
<td>Integrated Crop Management</td>
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<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
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<tr>
<td>IDM</td>
<td>Integrated Disease Management</td>
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<tr>
<td>IITA</td>
<td>International Institute of Tropical Agriculture</td>
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<tr>
<td>IP</td>
<td>Intellectual property</td>
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<tr>
<td>IPDN</td>
<td>International Plant Diagnostic Network</td>
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<tr>
<td>IPG</td>
<td>International Public Goods</td>
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<tr>
<td>IPM</td>
<td>Integrated Pest Management</td>
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<tr>
<td>IPPPT</td>
<td>Improved Pulse Production and Protection Technologies</td>
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<td>IT</td>
<td>Information Technology</td>
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*CRP3.5 Grain Legume Value Alliance—May 3, 2011*
ITC  Indian Tobacco Company
ITPGRFA  International Treaty on Plant Genetic Resources for Food and Agriculture
KM  Knowledge Management
KS  Knowledge Sharing
LAC  Latin America and the Caribbean
LIFDC  Low Income Food Deficit Countries
LLS  Late leaf spot disease
LPB  Legume pod borer
M&E  Monitoring and Evaluation
MAP  Modified atmosphere packaging
MARKETS  Maximizing Agricultural Revenue and Key Enterprises in Targeted Sites
MARS  Marker assisted recurrent selection
MAS  Marker assisted selection
MaviMNPV  Maruca vitrata nucleopolyhedrovirus
NARES  National Agricultural Research and Extension Systems
NARS  National Agricultural Research Systems
NCBI  National Centre for Biotechnology Information
NCDs  Non-communicable Diseases
NEPAD  New Partnership for Africa’s Development
NFSM  National Food Security Mission (India)
NGICA  Network for the Genetic Improvement of Cowpea for Africa
NGO  Non-government Organizations
ODAP  β-N-oxalyl-L-α, β-diaminopropionic acid
OILFED  Oilseed Federation (India)
PABRA  Pan-African Bean Research Alliance
PAC  Program Advisory Committee
PCCMCA  Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales
PEDUNE  Protection ecologiquement durable du niebe
PROFRIJOL  The Regional Collaborative Bean Program for Central America, Mexico, and the Caribbean
PRONAF  Projet Niebe pour l’Afrique
PRONAF-GIL  Participatory Development, Diffusion and Adoption of Cowpea Technologies for Poverty Reduction and Sustainable livelihoods in West Africa
PTTC  Platform for Translational Research on Transgenic Crops
R&D  Research and Development
R4D  Research for Development
REMALA  Recherche et Developpement des Legumineuse Alimentaires
RENACO  Reseau de Recherche sur le Niebe pour l’Afrique de l’Ouest et du Centre
RFOs  Raffinose family oligosaccharides
RIL  Recombinant inbred lines
RMT  Research Management Team
RFL  Rainfed Rice Fallow Land
SABRN  Southern Africa Bean Research Network
SADC-FANR  South African Development Community – Food, Agriculture and Natural Resources
SAVERNET  South Asia Vegetable Research Network
SC  Steering Committee
SIMLESA  Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA)
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>SLOs</td>
<td>System Level Outcomes</td>
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<tr>
<td>SRF</td>
<td>Strategy and Results Framework</td>
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<tr>
<td>SROs</td>
<td>Sub-regional organizations</td>
</tr>
<tr>
<td>SSEA</td>
<td>South and Southeast Asia</td>
</tr>
<tr>
<td>TILLING</td>
<td>Targeting Induced Local Lesion in Genomes</td>
</tr>
<tr>
<td>TL I</td>
<td>Tropical Legumes I (funded by Bill &amp; Gates Foundation)</td>
</tr>
<tr>
<td>TL II</td>
<td>Tropical Legumes II (funded by Bill &amp; Gates Foundation)</td>
</tr>
<tr>
<td>USA</td>
<td>United States of America</td>
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<tr>
<td>USDA</td>
<td>United States Department of Agriculture</td>
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<tr>
<td>VBSE</td>
<td>Village-Based Seed Enterprises</td>
</tr>
<tr>
<td>WCA</td>
<td>West and Central Africa</td>
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<tr>
<td>WECABREN</td>
<td>West and Central Africa Bean Network</td>
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1. Executive Summary

The GLVA partnership
The Grain Legume Value Alliance (GLVA), also known as CGIAR Research Program 3.5, brings together four CGIAR partner centers (ICRISAT, CIAT, ICARDA, IITA) with three core collaborating partners (AVRDC, Generation Challenge Program, and ICAR) that contribute deep and complementary experience on grain legume research-for-development (R4D) to benefit the poor of the developing world. The development challenge addressed by GLVA will be to enable the poor to capture a far larger quantity of the value-chain benefits that grain legumes offer, increasing their incomes, securing their food supplies, improving their nutrition and health, and increasing the sustainability of their farming systems.

These partners will link with regional grain legume networks and value chain partners to translate R4D innovations into locally-attuned impacts that benefit poor smallholders and consumers. By working together these partners will increase their collective effectiveness by:

- Presenting an integrated, streamlined interface to partners in each focus region rather than the current multiple interfaces;
- Improving knowledge acquisition and sharing through comparison/contrast learning across ten mandate crops and systems in their distinctive regional settings;
- Sharing R4D facilities and expertise to increase operational efficiency and effectiveness.

Justification
Grain legumes contribute in major ways towards all four of the CGIAR’s System Level Outcomes (SLOs): reducing poverty, improving food security, improving nutrition and health, and sustaining the natural resource base. They significantly increase income in farming systems by sustainably intensifying them as intercrops and rotation crops and through value-added postharvest activities. Poor farmers grow them for both food and for cash, optimizing the balance between the two as needs and conditions warrant, providing crucial livelihood resilience. Grain legumes restore soil fertility through biological nitrogen fixation, by breaking pest, disease and weed cycles and by extending protective land cover. They make vital contributions to the human diet due to amino acid profiles that complement those of cereals, and through their provision of micronutrients and healthy oils. Grain legumes are in high demand by poor consumers; the farm-gate monetary value of the GLVA grain legume crops is on a par with that of maize in low-income food-deficit countries.

However grain legumes face major challenges. Policies favoring cereals have inadvertently pulled investments away from grain legume R4D, institutions, capacities and services. This has marginalized grain legume cultivation to stress-prone, short-season niches fitted between main-season crops, constraining yield growth and productivity increases that otherwise could have made them more affordable for the poor, and could have expanded their environmental benefits.

Seed systems are particular bottleneck. The seed industry has been reluctant to invest heavily in grain legumes due to larger profit opportunities with fewer large-volume cereal crops. Encouraging crop diversity is highly strategic for the CGIAR in order to achieve the SLOs.

Running against these headwinds, GLVA core partners have nonetheless achieved remarkable impacts in all regions. They have helped countries to increase grain legume yields substantially; brought destructive diseases under control; made headway against the complex problem of drought; and connected grain legumes to export markets. GLVA partners foresee even greater impacts ahead as they unite to improve their effectiveness.
Objectives
Since all four SLOs are strongly relevant to grain legumes in smallholder systems, GLVA has chosen four Objectives that align directly with them:

- **GLVA Objective 1. High value grain legumes to reduce rural poverty**
- **GLVA Objective 2. Productive grain legumes to secure food supplies**
- **GLVA Objective 3. Nutritious, safe grain legumes**
- **GLVA Objective 4. Grain legumes for sustainable intensification**

Impact pathways and monitoring and assessment, including gender issues
To pursue the four GLVA Objectives through a unified, monitorable, impact-oriented framework, GLVA will approach its work through **grain legume value chains**. Value associated with different core processes in these chains is measurable while also being a major motivator of decisions that result in development and impact. Value in GLVA will not be measured solely in direct monetary terms, but also in terms of human health benefits, food security benefits and agro-ecosystem benefits.

Women are especially prominent in grain legume value chains, particularly in Africa, and will receive particular attention both in research design and in impact assessment. Benefits to children, who are particularly dependent on women and especially vulnerable to malnutrition issues that grain legumes can help address, will also be carefully monitored and assessed.

GLVA scientists project that its R4D innovations combined with development partner-led interventions will close approximately one-quarter of the current gap that exists between actual yields at the farm level and realizable farm yields (those that are obtainable by the best farmers using all recommended practices). This portion of the gap will be closed over approximately 20% of the grain legume area in low-income food-deficit countries by 2020. The cumulative value of this gain over the 2013-2020 period is estimated at 17 billion US dollars, roughly seventeen times the cost of the R4D investment over the proposed ten-year time frame of GLVA. Gains beyond the production system are not included in this estimate but will be additionally very large through improvements in input supplies, processing and product value addition, novel and expanded markets, diversified products including fresh vegetables and more diverse processed products, and other innovations that increase total value and value capture by the poor. Gains from expansion of the area (hectares) sown to grain legumes are also additional to this estimate; their penetration into existing cropping systems is only about 15% at present.

Regional foci
GLVA will think globally but act regionally in ways that support partners to achieve high impact locally. Regional priority-setting, monitoring and evaluation will continuously update the global agenda to ensure that issues of widest importance take priority. GLVA will work in five regions: Western and Central Africa, Eastern and Southern Africa, South and Southeast Asia, Central and Western Asia and North Africa, and Latin America and the Caribbean. The first three will receive prime focus due to the larger numbers of extremely poor and hungry people that inhabit them. Partners with established presences in these regions will collaborate closely and assist each other to make best use of their locational assets and partnerships. Regional teams will partner with value-chain actors from diverse sectors (public, NGO, private, CSO and farmer & women’s organizations) to effectively customize and deliver GLVA’s international public goods to meet those partner’s needs.
Main activities and outputs
Following the CGIAR Strategy and Results Framework GLVA will pursue Objectives (introduced above), Outputs and Activities monitored by Milestones. Specifically, within the four GLVA Objectives the following Outputs will be pursued:

GLVA Objective 1. High value grain legumes to reduce rural poverty
Value chain models will be developed to frame GLVA’s priority-setting, work planning, monitoring, evaluation and impact assessment. Opportunities to increase income will be exploited for four product/service categories: dry grains, fresh vegetables, livestock feed/fodder, and soil fertility enhancement. Efficiency gains will be sought through small-scale mechanization, and policy analysis will examine ways to enhance grain legume value chains.

GLVA Objective 2. Productive grain legumes to secure food supplies
More effective use of genetic resources to enhance productivity will be pursued using modern biotechnology tools to accelerate conventional breeding for difficult but high-payoff traits, especially disease and pest resistance and adaptation to drought, heat and low soil fertility. Seed systems will be improved to enhance impact, and gender equity will be a crosscutting objective.

GLVA Objective 3. Nutritious, safe grain legumes
Nutritional qualities particularly micronutrients, protein, oil and vitamin A will be enhanced both through genetic and processing means. Mycotoxins, neurotoxins and antinutritional factors will be reduced through integrated health management approaches (including breeding). Communication efforts to raise awareness of nutritional issues and of evidence-based solutions will be important.

GLVA Objective 4. Grain legumes for sustainable intensification
The fitting of grain legumes to a wider range of cropping system niches will foster the sustainable intensification of food production. Integrated soil fertility management capitalizing on grain legume’s capacity for biological nitrogen fixation will be improved through combined genetic and soil fertility management interventions. Integrated pest and disease management protocols will be made increasingly practical and affordable for smallholders.

Genetic diversity is crucial for resilient farming systems, and a key asset that GLVA will leverage for the poor. Crops are also a central organizing principle for commodity value chains. GLVA partners hold a treasure chest of genetic diversity and knowledge in the form of germplasm and expertise of the ten leading grain legume crops of the poor: common bean, chickpea, cowpea, faba bean, grasspea, groundnut, lentil, mung bean, pigeonpea, and soybean. In addition these partners are gaining valuable learning from, and will explore the potential utility of bambara nut, tepary bean, lima bean and pea. This rich diversity provides solutions for a very wide range of agro-ecosystems, climatic conditions and market demand situations.

Innovation
By bringing together major partners across crops, regions and institutions, GLVA will spark cross-learning that foments new and innovative ways of approaching the challenges outlined above. GLVA’s unified interface with partners is itself a major and strategic innovation that will increase mutual learning and improve communications.

The value chain perspective provides an innovation framework for integrating social and economic analysis with traditional strengths in crop improvement and production systems. It brings additional attention to constraints that have hobbled impact in the past, such as insufficiencies in input supplies (e.g. seed and soil fertility inputs). It will also innovate gains in value capture by the poor through enlarged, higher-value and novel markets, creating particular opportunities for women who bring special strengths to postharvest and marketing issues.
Research across ten focus grain legume crops plus four exploratory crops will generate innovative and important insights. These crops provide an unparalleled learning opportunity at the genetic and phenotypic levels. Cross-crop learning will improve the understanding of genetic and physiological mechanisms and control points for disease and pest resistance, drought and other stress adaptation, nutritional quality, biological nitrogen fixation, and other key traits. The sharing of facilities and testing environments will enable the partners to learn more about each crop and expand the range and impact of all these crops.

**Time frame**
GLVA is proposed as a ten-year program in three phases: three years (2011-13), three years (2014-16) and four years (2017-20). Milestones are specified for the first phase.

**Management**
ICRISAT will be the Lead Center for GLVA. Oversight will be provided by ICRISAT’s Governing Board and its Director General in consultation with a GLVA Steering Committee. A GLVA Director will lead a Management Team including Regional Coordinators. Each region will form a Regional Coordination Committee to advise the Regional Coordinators. The Steering Committee and the Management Team will be assisted on a needs basis by an external R4D Advisory Pool.

**Budget**
Current commitments of the GLVA partners plus essential GLVA startup and consolidation costs amount to US$42.2 million in 2011. To capitalize on additional value chain opportunities as justified above, GLVA will require US$ 56.2 million in 2012 and 62.4 million in 2013. Total GVLA budget for 2011-13 is US$ 160.8 million.
2. Statement of Objectives

The over-arching development challenge to be addressed by GLVA is to enable the poor to capture a far larger quantity of the value-chain benefits that grain legumes offer, increasing their incomes, securing their food supplies, improving their nutrition and increasing the sustainability of their farming systems. In short: leveraging legumes to benefit the poor.

By joining forces the partners in the Grain Legume Value Alliance (GLVA) will i) streamline and harmonize their interface with regional partners, ii) improve their knowledge-sharing and iii) increase their operational efficiency and effectiveness by sharing facilities, expertise, locational presences and services. The convening partners are four CGIAR centers (ICRISAT-lead, CIAT, ICARDA, IITA) together with three core collaborating partners (AVRDC, Generation Challenge Program, and ICAR) that are all leaders in complementary topics and regions on these crops.

Chapter 3 explains why GLVA directly aligns its four top-level Objectives with the four System-Level Outcomes (SLOs) articulated in the CGIAR Consortium Strategy and Results Framework (SRF), which are:

- System Level Objective 1. Reducing rural poverty
- System Level Objective 2. Improving food security
- System Level Objective 3. Improving human nutrition and health, and
- System Level Objective 4. Managing natural resources in a sustainable manner

GLVA thus defines its four Objectives as:

- **GLVA Objective 1. High value grain legumes to reduce rural poverty**
- **GLVA Objective 2. Productive grain legumes to secure food supplies**
- **GLVA Objective 3. Nutritious, safe grain legumes**
- **GLVA Objective 4. Grain legumes for sustainable intensification**

Details on how these GLVA Objectives will be achieved are provided in Chapters 4, 5, and 13, including the R4D logical framework that connects them to Outputs and Activities as well as the Milestones that will be used to monitor and evaluate progress. Chapter 5 further elaborates prime research questions addressed by each Objective, exciting opportunities, partnerships, gender benefits and other key dimensions.

**Target regions**

GLVA will target five major regions where legumes grown and consumed extensively. These are: South and Southeast Asia (SSEA), Eastern and Southern Africa (ESA), West and Central Africa (WCA), Central and West Asia and North Africa (CWANA), and Latin America and Caribbean (LAC). These regions are home to large numbers of poor and stunted children (Table 2.1)
Table 2.1. Characteristics of GLVA target regions

<table>
<thead>
<tr>
<th>Major legumes</th>
<th>SSEA</th>
<th>ESA</th>
<th>WCA</th>
<th>CWANA</th>
<th>LAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea, common bean, cowpea, groundnut, lentil, grasspea, fababean, mungbean, pea, pigeonpea, soybean</td>
<td>Chickpea, common bean, cowpea, groundnut, lentil, pea, grasspea, pigeonpea, soybean</td>
<td>Bambara bean, common bean, cowpea, groundnut, lentil, pea, grasspea, pigeonpea, soybean</td>
<td>Chickpea, common bean, cowpea, groundnut, lentil, peas, grasspea, pigeonpea, soybean</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Rural population (millions) | 1477 | 273 | 243 | 217 | 122 |
| Urban population (millions) | 832 | 112 | 192 | 290 | 467 |
| Number of poor (<US$ 1 per day) (millions) | 443 | 85 | 121 | 8 | 45 |
| Number of stunted children (millions) | 62 | 11 | 13 | 3 | 5 |

Major opportunities in brief

Below we briefly highlight some of the most exciting R4D opportunities that we foresee contributing to the GLVA Objectives.

GLVA believes that a value chain perspective as described under Objective 1 will extend the partner’s horizon into a potent new range of potential income gains for the poor. Two major categories of opportunity are envisioned: increasing the total value of these chains, and increasing the proportion of that value that is captured by the poor. Often these two value dimensions expand at the same time as a result of high-leverage interventions.

GLVA partners are currently involved a number of striking examples of rapid increases in grain legume production associated with high-value demand. South Asian populations (and their global diaspora) generate a large market demand for chickpea and pigeonpea exports from Africa, and all ethnic groups worldwide consume beans, confectionery groundnut and lentils as well as oils from soybean and groundnut. Value chains are rapidly increasing in sales volume and sophistication in Ethiopia, Kenya, Malawi, Tanzania and other Eastern Africa nations to capitalize on this demand.

However smallholder producers are currently capturing only a small fraction of the value in those chains. R4D will develop and foster improved models of collective action that drive down input costs and increase their availability, along with the knowledge flows required to strengthen smallholder capacities for using inputs effectively. Major income gains will also be realized through GLVA R4D that helps these poor participate in initial processing steps (e.g. cleaning, sorting, mycotoxin-free quality assurance, reducing pest damage in storage) so that wastage will be reduced while substantially higher grain prices will be captured. Collective action in marketing grain legume products will further enhance net income. A fourth collective action opportunity is to expand markets for novel or unfamiliar products such as fresh legume pods, peas, sprouts, leaves, and
Drought, heat and other types of environmental stress are major constraints within the grain legume systems of the poor, which are mostly rainfed with few soil-ameliorating inputs. Drought tolerance is best understood as the manifestation of optimized adaptation to particular environments rather than an isolated trait. End-of-season residual moisture niches are particularly important for grain legumes and increased rooting depth can be particularly effective in exploiting receding water tables (a common adaptive niche for grain legumes). Early maturity also avoids drought.

Root research is costly and difficult, though. GLVA sees major opportunity in cross-learning and sharing costly screening facilities, genetic maps and biotechnology expertise across crops. For example, cowpea and chickpea are highly drought-tolerant and learning from the body of research and screening tools already developed for those crops can contribute to improve the drought tolerance of more drought-sensitive crops such as common bean and soybean. Heat tolerance at flowering is seen as a major opportunity for progress, and one especially important for climate change-proofing the grain legumes.

Poor small-scale grain legume producers currently operate well below the yield potential of existing varieties. But increasing yield potential can itself help create market ‘pull’, by increasing value chain profit potential. That potential in turn can motivate greater use of inputs and management practices that raise yields towards that potential. Major yield gains have already been achieved by breeding short-duration, determinate-flowering types to complement the traditional long-season indeterminate options. Further gains are envisioned by genetically increasing the sink strength of reproductive organs as they develop. A tradeoff versus vegetative matter yield (‘haulm’ or stalk

preparing foods (e.g. soy flour, milk, tofu/cheese and others). Since women are centrally involved in grain legume production and marketing, all the above offer exciting opportunities for increasing the benefits received by women.

Within the production segment of the value chain a wide range of potential gains also await. Yield gap analysis by GLVA experts concludes that on average across grain legumes, current yields are one-third to one-half of the realizable on-farm potential (Chapter 3). They project that smallholder-adoptable innovations by GLVA and partners will close about one-quarter of that gap for adopting farmers within the next ten years.

Disease control will make a major contribution. Diseases are a major point of vulnerability for grain legumes, and major value gains, in the range of hundreds of millions of dollars annually have already been achieved through disease resistance breeding (e.g. against Fusarium wilt, Ascochyta blight, a range of foliar diseases, and several viruses). Yet much remains to be achieved. The new tools of biotechnology are particularly useful for combating diseases, particularly those controllable through the actions of relatively small numbers of genes. Many of the tools and lessons are applicable across crops, adding efficiency and effectiveness through a cross-crop GLVA approach.

Insects are major constraints for grain legumes, but progress will be more difficult. The largest impact will likely be in the area of controlling pests of stored grains, because storage is an easier operational stage for combining management and genetic interventions. Considerable potential exists for both (elaborated in Chapter 5). In the production stage, R4D focus will be tightly around pod-borer insects such as Helicoverpa that have proven difficult to contain through plant breeding. Wider use of genetic resources, accelerated and made more effective through the use of new molecular breeding methods could generate breakthroughs not foreseen at the present time. Genetic engineering to deploy Bt insect resistance genes holds enormous potential but faces formidable policy obstacles. Integrated pest management advances hold considerable promise, as described further below.
yield) cannot be assumed, since legumes can increase photosynthesis rate in response to increased sink demand (Kaschuk et al. 2009). Small amounts of nutrient amendments, water harvesting and other small-scale appropriate management interventions that overcome binding constraints to BNF can trigger large productivity responses in a highly cost-efficient manner. The development of hybrid breeding pools also holds enormous potential (~30-40% yield gains), building on the recent breakthrough in pigeonpea to also explore hybrid potential in faba bean and soybean.

Seed systems have long been a bottleneck for grain legumes for a number of reasons. Policy bias in favor of cereal crops creates an economic headwind against grain legume systems by rendering them less remunerative than other crops. Although crop diversity is an asset of grain legumes from many perspectives that are relevant to the CGIAR (stabilizing agro-ecosystems and livelihoods, diversifying diets), smaller sales volumes from multiple grain legume crops increases costs relative to revenues for seed companies compared to fewer high-volume crops. Groundnut and chickpea feature unusually low seed-to-seed multiplication rates that further raise costs. However GLVA believes that these constraints can be largely overcome through a number of strategies (elaborated in Chapter 3) including stronger value chain integration to increase the value added by quality seed, specific seed technology improvements, and innovative institutional models for seed multiplication and delivery. Effort in these areas is especially strategic because once seed flows, the impacts of a whole range of genetic advances expand widely.

The nutrition and health Objective encompasses major opportunities for enhancing the mineral content of grains. In particular the knowledge and methodology advances in increasing iron and zinc content in bean, enabled by the HarvestPlus Challenge Programme, will be leveraged to other grain legumes, achieving much wider impact over time. Vitamin A enhancement also forms an interesting longer-term opportunity for grain legumes through genetic engineering approaches.

Increasing protein and oil contents would likely involve yield tradeoffs (though some room for net gains is probably available, and targeting to certain uses may justify such tradeoffs). However, improving protein and oil quality would probably not invoke such tradeoffs (e.g. raising methionine content, a limiting amino acid in many grain legume species, and shifting the oleic/linoleic fatty acid balances in oils in favor of the former). More nutritious grains can inadvertently result in increased storage insect pest attacks, but those are foreseen as manageable through integrated genetic/management approaches. Reductions in anti-nutritional factors are also achievable though possible tradeoffs against pest/disease resistance will need to be monitored. Progress in this direction has been notable to date in grasspea (breeding low-ODAP varieties – Kumar et al. 2011).

Strategies for reducing mycotoxin contamination are well known but impact pathway innovations appear to hold much promise to increase their effective deployment. For example institutional innovation has enabled the control of aflatoxin contamination of groundnuts by well-organized smallholders in Malawi, opening the door to exports to the UK.

Sustainable intensification, the fourth GLVA Objective, holds great opportunity through the collaboration with and complementation of the N2Africa project, increasing biological nitrogen fixation (BNF) in grain legumes across Africa. R4D contributions by GLVA such as increased stress resistance (drought, low soil P, and others) and adaptation to a wider range of rhizobia will generate large impacts by powering-up the N fixation machine that is enabled by N2Africa. These gains will trigger yet additional impacts in terms of yield increases of following non-legume crops. Increased productivity of grain legumes will spur their wider inclusion as intercrops, relay crops and rotation crops in non-leguminous cropping systems, increasing cropping intensity on existing farmland in a sustainable manner.
Integrated pest management advances will enable progress against difficult pod borer and storage grain insects that have proven difficult to defeat through plant breeding to date. Bottlenecks to IDM/IPM adoption will be eased by GLVA and partner efforts to strengthen value chains that motivate and reward investments in that technology.

**Vision of success**

Our vision is to double smallholder farm family income from grain legumes in targeted intervention areas in low-income food-deficit countries (LIFDCs as defined by FAO; see Chapter 5) by 2020 through innovations along the value chain (as outlined above) relevant to particular settings. We expect to achieve R4D gains that are adoptable by smallholders that close an average of one-quarter of the yield gap between current farm yields and realizable farm yields. We will set in motion the impact pathways that achieve these gains on-farm over 20% of the total grain legume area in LIFDCs by 2020 and continue to expand thereafter. This gap closure will be constituted from both yield stability and yield level gains through improved disease and pest control, drought adaptation and integrated soil fertility enhancement including more effective biological nitrogen fixation. We estimate the cumulative value of this R4D gain from 2013 to 2020, including grain value plus soil nitrogen substitution value, across low income food deficit countries, to be US $16.9 billion (Table 2.2).

**Table 2.2: Benefits from GLVA in different regions**

<table>
<thead>
<tr>
<th></th>
<th>SSEA</th>
<th>ESA</th>
<th>WCA</th>
<th>CWANA</th>
<th>LAC</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legume area (million ha)*</td>
<td>66.1</td>
<td>9.7</td>
<td>21.6</td>
<td>3.7</td>
<td>49.3</td>
<td>150.3</td>
</tr>
<tr>
<td>Number of beneficiaries at Farm level (million)**</td>
<td>343.1</td>
<td>34.3</td>
<td>52.0</td>
<td>5.5</td>
<td>3.3</td>
<td>438.2</td>
</tr>
<tr>
<td>Total current annual benefit from BNF (billion US$)**</td>
<td>1.4</td>
<td>0.1</td>
<td>0.6</td>
<td>0.1</td>
<td>1.2</td>
<td>1.4</td>
</tr>
<tr>
<td>Additional cumulative discounted benefits from 25% yield increase in 20% area by 2020 (billion US$)**</td>
<td>6.0</td>
<td>0.5</td>
<td>1.6</td>
<td>0.2</td>
<td>8.5</td>
<td>16.9</td>
</tr>
</tbody>
</table>

* 2008 crop area from FAOStat (http://faostat.fao.org/); ** Average landholding estimated from FAO (2010) and average household size from Bongaarts (2001); *** BNF benefits calculated based on Herridge et al. (2008). Urea price US$0.425/kg for Africa and 0.375/kg for India; **** Calculated based on 2008 data for area, production, yield, and price from FAOStat (http://faostat.fao.org/). Assumptions: Yield increase by 25% in 20% area by 2020; price taken are weighted global average price of 2008 from FAOStat.
3. Justification

Why Grain Legumes Matter to the CGIAR SLOs

Reducing rural poverty: Grain legume crops deliver poverty-fighting income by yielding premium-valued grains and oil that are in high demand locally, in urban centers and in export markets. At the same time these crops yield protein-rich haulms and press-cake (residual matter following oil extraction) that are highly valued for livestock fodder and feed. Grain legumes are also harvested ‘green’ to provide a range of very high-value vegetables – pods, peas, and leaves - that can multiply farmer’s income per hectare several fold. Grain legumes create major income-earning opportunities for poor women who predominantly cultivate them and prepare and market a wide range of staple prepared foods from them. Grain legumes also deliver fertilizer value through their unique capacity for biological nitrogen fixation (BNF), substituting for manufactured chemical fertilizers that are usually insufficiently available to meet the needs of the rural poor. In addition to cost substitution, this leverages added value for nitrogen-demanding sister CRP crops (cereals, roots/tubers).

Securing food supplies: Grain legumes increase the total production of food per hectare by sustainably-intensifying cereal based cropping systems through intercropping, relay cropping and rotation cropping. They sharply increase total farm output when inserted into underutilized seasonal niches. By raising food production through BNF of the following cereal crop, they also increase food security. They cushion against production risks such as drought and other hazards; if a drought or a disease happens to devastate the main cereal crop, the later-sown legume often escapes it and rescues the farm family’s food supply.

Nutritious, safe grain legumes: Grain legumes are rich in protein, oil and micronutrients such as iron and zinc. Their amino acid profile complements that of cereals such that ‘the total is worth more (nutritionally) than the sum of its parts’. High iron and zinc content is especially beneficial for women and children at risk of anaemia and has proven to be genetically malleable. Grain legumes also contain bioactive compounds that show some evidence of helping to combat cancer, diabetes and heart disease. They also enrich nitrogen-limited livestock diets triggering large improvements in animal weight gain and health, an enormous value to the poor who depend on animals for draft power, milk, meat and money.

Sustainable intensification: Grain legumes improve soil fertility, break weed and disease cycles of companion crops (yet another complementary contribution to sister CRPs), and extend the cover of land by biomass. They increase the effective capture, productive use and recycling of water and nutrients, such as end-of-season residual moisture and rice-fallow moisture and nutrient resources. By fixing nitrogen in biological forms that are more slowly released over time than chemical fertilizers they can improve nitrogen use efficiency in farming systems (Crews and Peoples 2005; Nyiraneza and Snapp 2007) fostering healthier soils richer in biological activity and higher in organic matter content.

Strong and growing demand

While grain legume benefits are congruent with the SLOs, are they large enough to matter?

Despite policy incentives strongly favoring other crops, grain legumes remain very important in the Low Income Food Deficit Countries (LIFDC, as defined by FAO1) where most of the poor live.

1 FAO’s criteria for classifying Low Income Food Deficit Countries are given at http://www.fao.org/countryprofiles/lifdc.asp The list currently includes 39 countries in sub-
Collectively the grain legumes are worth US$26 billion annually at the farm gate across the LIFDCs, on a par with maize (Table 3.1).

### Table 3.1: Production and value of grain legumes in LIFDC and world 2008

<table>
<thead>
<tr>
<th>Crops</th>
<th>Production (million t)</th>
<th>Average producer price (US$/t)</th>
<th>Value of production (US$ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIFDC</td>
<td>World</td>
<td>LIFDC</td>
</tr>
<tr>
<td>Groundnuts (with shell)</td>
<td>18.33</td>
<td>38.22</td>
<td>537</td>
</tr>
<tr>
<td>Soybean</td>
<td>12.29</td>
<td>230.58</td>
<td>358</td>
</tr>
<tr>
<td>Beans (including mungbeans)</td>
<td>7.77</td>
<td>20.40</td>
<td>498</td>
</tr>
<tr>
<td>Chickpea</td>
<td>6.72</td>
<td>8.50</td>
<td>346</td>
</tr>
<tr>
<td>Cowpea</td>
<td>5.52</td>
<td>5.74</td>
<td>651</td>
</tr>
<tr>
<td>Pigeonpea</td>
<td>3.48</td>
<td>4.11</td>
<td>339</td>
</tr>
<tr>
<td>Lentil</td>
<td>1.20</td>
<td>2.83</td>
<td>423</td>
</tr>
<tr>
<td>Grain legumes total</td>
<td>55.31</td>
<td>310.38</td>
<td>25.7</td>
</tr>
<tr>
<td>Maize</td>
<td>99.35</td>
<td>826.22</td>
<td>270</td>
</tr>
<tr>
<td>Wheat</td>
<td>131.88</td>
<td>683.41</td>
<td>251</td>
</tr>
<tr>
<td>Rice</td>
<td>328.93</td>
<td>685.87</td>
<td>314</td>
</tr>
</tbody>
</table>

Source: FAOSTAT (2008)

Price is one indicator of demand. People will pay higher prices for things they want more of. Consumers pay 2-3 times more per unit weight of grain legume than for cereals (Fig. 3.1).

The demand for grain legume foods is strong and is expected to continue to strengthen over the current decade (Parthasarathy Rao et al. 2010; Birthal et al. 2010; Kumar et al. 2009). Income elasticity for grain legumes in the largest legume consuming and producing nation, India among the poor are solidly positive in contrast to moderately negative elasticity for cereals, indicating that the poor would purchase relatively more grain legumes than cereals if extra income were available to them (Kumar et al. 2009). Projections of per capita consumption by the rural population for the period 2011 to 2022 are for a 9% increase in grain legume consumption, compared to no increase for cereal consumption (same reference). The trend difference is even stronger for the urban population: a 14% increase for grain legumes compared to a 6% decrease for cereals. Supplies in India fall well short of demand, however necessitating large volumes of costly imported grain – expenditures that could have gone into the pockets of the nation’s poor if their own commodity systems had been sufficiently competitive.
Figure. 3.1. Global average prices received by farmers for staple legume and cereal crops (FAOSTAT).

Producers prices US$/ton 2000-2008

Because demand outstrips supply in developing countries, driving up prices, grain legumes are one of the most profitable staple crop options available to smallholder farmers. In a survey of more than 300 farmers in Kenya, Shiferaw et al. (2008) found that chickpea and mung bean had the highest returns to land and management and were twice as profitable as both first- and second-season maize. Due to a demand-supply gap in South Asia, lentil prices have always been strong but have risen even further in the recent past, making it one of the most remunerative temperate-zone export crops for countries in Central and West Asia/North Africa (Aw-Hassan et al. 2009). India experienced a major shortfall in mung bean production in recent years which has created a lucrative export opportunity for producers in Myanmar and beyond. International prices have risen to USD1200/ton, making mung bean for export one of the most profitable tropical grain legumes.

These trends confirm that grain legumes are in high demand as dietary staples of the poor, and significantly lift farm incomes.

Despite this demand, however grain legumes were left behind when policy supports were deployed to support the Green Revolution in rice and wheat. For example in the Indian states of Andhra Pradesh and Karnataka daily allowances of rice and wheat are sold at approximately 70% below their unsubsidized prices, i.e. at an average of US$0.08 per kilogram. Thus, subsidies cut cereal prices to just about one-tenth of the prices of grain legumes from a poor consumer’s perspective, inevitably influencing purchasing decisions.

This inadvertent but influential policy bias against grain legumes affects all aspects of their value chains including public and private R&D investments, input supplies, land allocation, output markets and others. For example with the spread of heavily subsidized irrigation and fertilizer and improved varieties, subsidized wheat, rice and cash crops have displaced grain legumes from their traditional zone of cultivation in the lush Indo-Gangetic Plain (Joshi 1998). Grain legumes are being shifted to hotter, more drought-prone areas with poorer soils and secondary niches in cropping systems such as post-cereal residual moisture situations – where they perform admirably well given the conditions, but nevertheless yields are curtailed. Although major technical advances for yield and yield stability have been achieved (described later), impact has been confined to limited areas in large part due to the lack of broad policy support. Production constraints in a situation of high demand cause higher prices, limiting the ability of the poor to buy grain legumes in the quantities that they wish to consume. GLVA will confront these issues by contributing technical innovations as
The poor across the developing world relish grain legumes, consuming them in a diverse array of delicious forms:

- **Dhal**, a split-grain porridge from chickpea, pigeonpea, mung bean, lentil and other grain legumes, widely consumed by the poor in South Asia and worldwide; and **sambar**, a curry to accompany rice dishes in the region;

- Beans, known as **Maharagi** in Swahili and **Ibishyimbo** in Kinyarwanda, are integrated into East African diets, e.g. **githeri** (boiled beans with maize) is a staple dish often served in boarding schools in Kenya - students have been known to revolt if beans drop in proportion to maize;

- Beans with rice or maize in Latin America and the Caribbean, with many variations such as **gallo Pinto** in Central America, **moros y cristianos** in Cuba, **bandeja paisa** in Colombia and **feijoada**, a bean/pork stew in Brazil;

- Nutritious pastes such as **hommus** in the Middle East and peanut (groundnut) butter consumed worldwide, notably including the lifesaving famine-relief preparation based on peanut butter known as “plumpy’nut”;

- Groundnut sauces in many variants are hallmarks of francophone West African and Thai cooking;

- High quality cooking oil from groundnut and soybean used globally;

- Fritters such as **moin-moin** and **akara** from cowpea in Nigeria and **falafel** from chickpeas and faba beans in the Middle East;

- Roasted nuts from groundnut, chickpea, faba bean, bambara nut and soybean eaten as snacks worldwide;

- Thread noodles from mung bean in Asia;

- A range of soy products such as soy milk, yoghurt, tofu/cheese, and flour originating from Asia but spreading fast in African countries such as Nigeria (where the CGIAR played an important role);

- Fresh mung bean sprouts eaten in salads or stir-frys across Asia and worldwide;

- Fresh or cooked pods in Africa and Asia with growing export markets;

- Cowpea leaves consumed in stews in Eastern and Southern Africa.

**Why a Consortium Research Program on Grain Legumes?**

GLVA partners have been working independently on grain legumes for decades. Why join forces now?

1. **Improve our interface with partners**

At present all seven GLVA institutions interface independently with partners on different crops at global, regional and sub-regional scales. Partners find this confusing and burdensome. Many have a single, often under-resourced office or program handling all legume crops. They feel overwhelmed.
by the multiple interfaces that they are expected to maintain and meetings they are expected to attend with numerous external institutions. Streamlining and harmonizing this interface will significantly improve the effectiveness and efficiency of communication, collaboration and advocacy. To give just one of many important examples, evidence to inform decision-makers as they seek greater regional harmonization of seed policies will be far more compelling and effective if presented across crops by solid regional R4D partnerships speaking with a unified voice.

2. Cross-learn in priority R4D domains

Important learnings can be acquired through the sharing of lessons learned and expertise across crops, regions and partnerships. Grain legume crops are genetically related and therefore exhibit synteny at the genetic and genomic levels and consequently functional similarities at physiological and phenotypic levels. Studies of these comparisons/contrasts offer a potential gold mine of useful learning. Can the high drought tolerance of cowpea and chickpea teach us how to enhance these traits in common bean and soybean? Can the high BNF capability of soybean, groundnut, chickpea, lentil and faba bean indicate ways to improve that trait in other grain legumes? Sink strength appears to be genetically controlled, and how can high-yielding features in soybean teach us ways to improve yield in low harvest-index (highly vegetative) legumes? Beyond the crop production stage, many other cross-lessons could be learned about partnership innovations, successes/lessons in collective action in value chains, opportunities for novel products and markets, and others.

3. Share expertise and facilities

Centers have established specialized, costly facilities and expertise for different activities and in different regions. By joining forces they can share these assets to leverage higher value from them. To name just a few complementary strengths (see Appendix 1 for a fuller exposition), AVRDC holds knowledge on fresh-vegetable legume breeding, testing and advocacy; CIAT for geospatial mapping, seed systems, nutrition and disease diagnostics; GCP for molecular and functional genetics; ICAR for locational testing in the center of South Asia; ICARDA for geospatial targeting, seed health and rhizobium R4D; ICRISAT for root screening for drought tolerance, rapid-throughput molecular mapping, and public-private partnerships; and IITA for host-rhizobium interactions, postharvest processing, value chain analysis and advocacy. GLVA will provide the framework to generate valuable synergies from these strengths.

Our track record

Global grain legume yield data provide a superficial impression of yield stagnation, but as explained earlier, this is largely attributable to working against a strong headwind: the marginalization of these crops to low-yielding drought-prone environments due to policy bias favoring cereals in recent decades. In reality, GLVA partner institutions have achieved impressive impacts, such as the twelve samples from across the developing world described below.

Climbing beans in Rwanda and Eastern and Southern Africa

Largely as a consequence of 25 years of research by CIAT and national partners, Rwanda has gone from hunger-inducing shortages of beans to producing surpluses for export. Consumers in the Great Lakes Region of Eastern and Central Africa eat beans at one of the highest rates in the world, around 60 kg per capita per year. Climbing bean varieties had been adapted only at high elevations in the country. CIAT introduced germplasm capable of tripling yields in mid-altitude environments. Within a few years, adoption rates reached 90% in the target areas. Today the Rwandan research program has matured and is producing its own improved varieties for home consumption and for high end markets. Farmers are harvesting 2-4 tons per hectare, well above averages for other parts of Africa.
Returns on cowpea and soybean research in Africa
The net present value of benefits from investments in cowpea research and extension convened by IITA over a 20-year period is estimated at upwards of US$ 1.09 billion with an internal rate of return ranging between 50–103 percent. Similarly, the value of benefits associated with soybean improvement over the period 2011–2030 is estimated at US$880 million in Nigeria, Malawi, Mozambique, Kenya and Tanzania. Poverty reduction due to soybean improvement in these countries is significant.

Pigeonpea in Northern Tanzania
Fusarium wilt-resistant, seasonally-adapted varieties of pigeonpea adopted on 25,000 hectares in northern Tanzania have tripled yields and created a thriving export market, producing an additional 1.3 tons per hectare or 33,000 total extra tons - delivering approximately US$33 million in extra value to impoverished farmers. Usually intercropped with maize, pigeonpea also increases the resilience and productivity of that vital cereal crop through biological nitrogen fixation and natural weed control.

Chickpea earning export income for Ethiopia
Improved varieties from the CGIAR combined with effective extension by the national program EIAR in East Shewa Zone of Oromia region, Ethiopia are increasing chickpea yields by 90% (2003-05 average compared with 2008) and a 40% increase nationwide. Total production doubled from 312,000 tons from 2003-05 to 2008, multiplying chickpea export earnings 26-fold, from $1 million in 2004 to $26 million in 2008.

World’s first hybrid grain legume: pigeonpea in India
ICRISAT and Indian partner’s creation of the world’s first hybrid variety of a food legume, pigeonpea is on the cusp of major impact. These CMS (cytoplasmic male sterile) hybrids increase yield by an average of 33% in on-farm trials, adding about US$400 to net income per hectare. They are expected to revolutionize the production of this high-protein ‘poor people’s meat’ crop across India, Myanmar and China in the coming years.

Drought & heat-tolerant chickpea in southern India
Earlier-maturing, heat tolerant high-value chickpea varieties from ICRISAT, particularly JG11 have more than doubled yields, from 600 to 1400 kg/ha in Andhra Pradesh state, India, stimulating a fourfold increase in sown area from 160,000 to 630,000 hectares. The added value of grain is $69 million annually reaped by 6 million people in rural farm households.

New groundnut (peanut) variety spreading in the world’s largest groundnut cultivation area
Anantapur, India where over 50% of farm income comes from groundnut. The new variety ICGV 91114 from ICRISAT increases yield by 23% and is more drought tolerant with higher-value large seeds, more uniform harvest maturity, disease tolerance and greater palatability of haulms (straw) for livestock. An estimated additional 42,000 t of groundnut is being produced annually, worth US$3.7 million to 30,000 farm households (150,000 people). Net income from this crop increases by 35% on the average 1.5 ha groundnut field area per farmer, worth $110 extra US dollars. Cows fed with these haulms also produce 11% more milk. Impact is projected to increase to 35% of the 0.75 million hectares of groundnut in Anantapur by 2020.

Winter Chickpea in Central and West Asia and North Africa (CWANA)
Research on winter chickpeas by the Syrian national research program and ICARDA has created the conditions needed for significant increases in production of this regionally important crop. Until recently, farmers in CWANA avoided winter sowing to reduce the risk of severe winter weather and Ascochyta blight disease. Improved winter varieties have now been widely adopted, particularly by
poorer farmers. Yield increases compared with spring-sown chickpea ranged from 33 to 61 percent and net farm income rose by US$220.

**Lentil Production in South Asia and Ethiopia**
Over the last 30 years South Asian lentil production has doubled, reaching 1.27 million tons. The increase is due equally to productivity growth and area expansion. The driving factor is farmer adoption of short-duration, disease resistant varieties developed by ICARDA in partnership with India, Nepal, and Bangladesh. Annual economic gains are estimated at US$ 30 million in Bangladesh and US$ 42 million in Nepal. Impact is also reported in Ethiopia with a 150% increase in production and 73% increase in area under cultivation.

**Vegetable soybean**
Chinese farmers have grown vegetable soybean for over 1,000 years, but the crop has now expanded well beyond East Asia. At locations as diverse as Mauritius, Bangladesh, Sudan and Vietnam, AVRDC advocacy has resulted in rapid acceptance of this alternative to the more familiar dry-grain soybean. To date, more than 30 improved varieties have been developed and released to farmers in Africa, the Americas and in Asia. They yield up to 10 t/ha (fresh weight) of marketable pods plus 30 t/ha of nutritious fodder in just 75 days. They provide dietary pro-vitamin A, vitamin C, and isoflavones that help prevent hormone-dependent diseases such as osteoporosis, cardiovascular diseases, cancer, and postmenopausal syndrome.

**Mung bean variety impacts in Asia**
Although AVRDC’s mung bean research achieved spectacular success in Southeast Asia and China, the main region in need of improved varieties was South Asia, where the mung bean yellow mosaic virus severely constrained crop production. Shuttle breeding resulted in improved virus-resistant varieties released in Bhutan, Bangladesh, India, Nepal, Pakistan, and Sri Lanka yielding at least 2 tons per hectare and maturing in 55 to 65 days. By 2005 improved mung bean was being cultivated on 1.5 million hectares of land. Today improved varieties occupy almost 90 per cent of the mung bean area in Pakistan and Thailand, 85 per cent in China, and 50 per cent in Bangladesh and Myanmar, accounting for almost 3 million hectares of land.

**Drought tolerant beans for Nicaragua and Rwanda**
In 2000, CIAT plant breeders in Colombia made drought tolerance the centerpiece of their efforts to improve small-seeded Meso-American bean types farmers grow in difficult environments. Many of these lines have now been released in Nicaragua and Rwanda (three are pending release in Malawi). These materials represent the first drought-resistant bean varieties developed and released for the warm tropics. Farmers recognize the difference; in Nicaragua they pointed out how the new variety uniformly fills its seeds under drought. In Malawi farmers described most important traits from rooting depth to biomass production, and subsequently grain filling. This highlights the potential for farmer participation in selection as more attention is focused on abiotic stress in the face of climate change.
4. Quantified Impact Pathway

Value chains to quantify impacts of GLVA

The previous section explains the strong relevance of grain legumes to the CGIAR SLOs. However the question remains: how will R4D innovations in grain legumes translate into impacts that contribute materially to those SLOs? In this section we introduce a pathway that makes this development connection while providing quantifiable metrics: grain legume value chains.

Grain legumes add a strong value dimension to smallholder farming. Income-earning opportunity is consistently a prime reason that poor smallholder farmers give for cultivating these crops (documented in results of ICRISAT Village Level Surveys and Tropical Legumes II project baseline surveys). Despite this farmer priority, value per se has often been only a secondary or implicit consideration in CGIAR priority-setting.

Historically, increases in gravitational mass (weight) of harvested product (i.e. ‘yield’) have been the dominant metric used to monitor progress. In common usage, the term ‘productivity’ has become nearly synonymous with yield per unit land area. But yield is only one attribute that the poor care about. They also care about how valuable that yield is terms of food security, health, cash, labor productivity, livelihood capital enhancement (human, social, physical, natural, financial) and other value metrics.

Yield (weight) is a particularly incomplete metric for grain legumes. Legume grains are worth 2-3 times more per unit weight than cereals. Per unit weight they are much higher in nutritious, high-value protein and oil than cereals, roots and tubers. Grain legumes also reduce input costs substantially through biological nitrogen fixation (BNF) - not only for legume crops themselves but also for following crops through residual N left in the soil. Due to rapidly increasing demand for livestock products, haulm and press-cake value are also increasing rapidly.

Monetary value of production cannot capture all these value dimensions but does reflect more of the total value than does the weight of grain. For the ten mandate grain legume crops currently addressed by four CGIAR Centers and AVRDC, the value of harvested grain in low-income food deficit countries is on a par with maize (Table 3.1). This does not include the value of nitrogen-rich vegetative matter used as livestock fodder (stems and leaves, often called ‘haulms’), nor the value of fresh pods, peas and leaves, nor the fertilizer substitution value of nitrogen left in the soil following legume cultivation. Nor does it include the secondary value added through difficult-to-quantify health benefits of enhanced micronutrient, protein and oil content on maternal health and childhood development, the livelihood benefits of stimulating cash crop-based market-oriented development, reducing system risk through diversification, and other powerful benefits. Economists have developed a number of methods for estimating the value of environmental services (Requier-Desjardins et al. 2011).

A broader value chain perspective is required in order to accurately reflect grain legume contributions to the SLOs, as well as for R4D relevance. A value chain perspective creates a clear path and vision for increasing SLO-relevant impact: to increase the quantity and share of the value in the chain that is captured by the poor, both as producers and consumers.

For impact pathways to be useful as tools for achieving change, they must not simply be statements of different system states, such as Outputs and Outcomes. Statements of states do not indicate what causes the change from one state to the next to occur. What actually motivates a development partner to take up a CGIAR innovation and disseminate it, and what actually motivates an intended beneficiary to acquire and utilize that innovation to change his/her state towards a less-
poor, better-fed, better-nourished, more-sustainable state? And how can R4D foster that motivation?

For simple, specific products such as food grain commodities, a value chain perspective offers a powerful motivator of change: the increased value received for adopting and utilizing an R4D innovation. By tracking such value gains, a value chain perspective can identify bottlenecks (where value is insufficient or obstructed for some reason), knowledge gaps (where understanding is insufficient about value and how it can be captured by the poor), and priority challenges (where problem/opportunity insight combined with knowledge of how value ramifies along the chain indicate large likely returns from R4D investments).

While they are a powerful motivator, value gains in the conventional sense (monetary rewards or their equivalent) are not enough to fully explain all behavior. Cultural and social norms, risks, capacities, preferences and other motivators also condition behavior. However value chain analysis can also be used as a framework for understanding how these more complex motivators affect change and therefore affect impact. Advanced scientific methods such as agent-based models can simulate the motivational consequences of different value-chain scenarios (Rich et al. 2011). The external enabling environment including policies, markets and institutions can also be mapped to the pressure points that they exert on value chains, and those dynamics can be modeled to identify ways to alter those pressures.

**How will value chain analysis help GLVA?**

In support of this aim, a grain legume value chain framework for GLVA will:

- Provide a more relevant basis for priority-setting, i.e. one based on the whole range of livelihood and well-being benefits that poor smallholders care about;
- Provide an analytical framework that reveals key knowledge gaps and prompts impact-oriented R4D questions (e.g. Where are the bottlenecks and opportunities in the value chain? How much and what kind(s) of value would innovations in the chain deliver? Value to whom? How would such innovations affect, and be affected by other processes in the chain?)
- Provide a development pathway logic for increasing impact, since value gains at different steps in the chain are powerful motivators of change;
- Provide clear and concrete metrics for monitoring and evaluating progress towards the SLOs (i.e. elements of value generated, delivered, and realized);
- Provide a systems integration framework for cross-crop, cross-region and cross-Center analysis, planning and execution (by their nature value chains require inter-disciplinary, multisectoral analysis);
- Reorient partnership-building towards improving value delivery by forming innovation systems (partnerships of innovators) to overcome longstanding bottlenecks in value chains (e.g. seed, fertilizer inputs and many others);
- Provide a framework for identifying gaps in capacities and in enabling environments (e.g. policies, institutions, markets) needed to improve the functioning of value chains that benefit the poor, particularly women.

A value chain framework will position GLVA to complement and interface logically with sister CRPs in quantifiable ways. For example GLVA will devise biological nitrogen fixation (BNF) and soil fertility value innovations that CRP 1 will integrate into broader agro-ecosystems. Similarly GLVA will contribute grain legume-related value insights that will help CRP 2 to inform policy deliberations;
grain legume nutrition and health value enhancements that contribute to CRP 4; and climate change-relevant innovations that contribute in quantified-value ways to CRP 7 (e.g. the monetary value of grain gained from yield stabilization due to higher temperature tolerance).

Mapping the grain legume value chain

Value chain analysis is frequently used in large-scale commercial product-oriented industries but there are very few reports of its application to staple food crops cultivated by smallholders, and processed and marketed under developing-country conditions. A value chain framework for grain legumes will be a GLVA innovation, so the elaboration of this framework will itself require research within Objective 1 (Chapter 5).

To begin, however our initial elaboration follows the protocol recommended by DFID’s “Making Value Chains Work Better for the Poor” (M4P 2008). The first step is to map the core processes involved. Across the CGIAR grain legume crops, regions and systems, we consider the following core processes to be of high relevance to the SLOs (Fig. 4.1)

**Grain Legume Value Chain - Core Processes**

![Diagram of the grain legume value chain]

**Figure 4.1. Core processes of the grain legume value chain**
Some important messages in the map are:

- Four major products/services are important for grain legumes: dry grain-based products, fresh vegetable products, fodder/feed products, and soil enhancement services;
- The value chain perspective enlarges the vision of GLVA well beyond the historical domain of production systems, enlarging potential impacts as well;
- Value chain analysis aids in the identification of bottlenecks and opportunities that, when overcome, will unleash benefits from other parts of the chain;
- Value gains can be quantified at different steps along the chain, enabling rigorous monitoring, evaluation and impact assessment;
- Value chains provide a development logic for mobilizing novel and diverse partnerships to address essential issues that have long hindered impact such as input logistics, credit, postharvest engineering, marketing and many others;
- Since the core processes must feed each other for the chain to succeed, collective action and related social organization issues loom large;
- A value chain perspective thus demands a more inter-disciplinary approach, particularly uniting socio-economic with biophysical R4D.

Specifically, GLVA believes that major gains are possible through value chain interventions such as:

- Collective action to reduce the cost of inputs such as certified seed and starter fertilizers tailored for grain legume growing conditions on particular soils and in particular cropping systems;
- Greater value capture by poor farmers by improving and extending their engagement into initial processing operations (grain threshing, cleaning, storage), raising grain value;
- Collective marketing and enhanced information flows to poor farmers that increase the sales price obtained for grain legumes;
- Social mechanisms to purchase grain legumes in bulk at better prices, combined with action to build and store own reserves of these grains to moderate wild swings in prices and supplies of essential foodstuffs;
- Increased incomes of women through value-added products sold in retail markets;
- Improved family nutrition and health through increased quantity and quality of home-consumed grain legumes;
- Improved soil condition through enhanced biological nitrogen fixation over larger areas and more frequent/pervasive inclusion of grain legumes in smallholder cropping systems.

Figure 4.2 estimates potential value gains along the impact pathway that can be attained through GLVA and partner innovations.
Figure 4.2. Quantification of gains in the grain legume value chains

- **Dry grain products**: Urban & export quality +25%
- **Fresh products**: Urban & export quality +100%
- **Feed fodder**: Custom enriched feeds +30%
- **Increased yield of next crop**: Higher yield +20%

- **Processing & distribution**: Reduced losses, breakage +30%
  - **Processing & distribution**: Fresher, less losses +40%
  - **Processing & distribution**: More palatable, nutritious +30%

- **Collection, consolidation**: Clean, plump grains +20%
  - **Collection, consolidation**: Reduced losses +20%
  - **Collection, consolidation**: More nutritious feeds +15%
  - **Residual N, land cover, disease control**: Together +20%

- **Production operations**: Disease resistance +30%
  - **Integrated pest & disease mgmt**: +15%
  - **Yield potential**: +20%
  - **Drought tolerance**: +10%

- **Inputs**: Starter fertilizer +70%
  - **Healthy seed**: +20%
  - **Information**: +20%

- **Own farm feed, fodder, soil services**: Milk +10%
  - **Meat**: +15%
  - **Fertilizer save**: 20%
Mapping these core processes is just the beginning of value chain analysis. Fig. 4.1 provides a framework upon which numerous additional dimensions will be layered (following M4P 2008):

- The actors involved, and what they do
- Where and how the poor participate and benefit
- The flows of products in the chain, their volumes, values, and value addition at each step
- Relationships, linkages, feedback loops and other dynamics among chain processes
- Services outside the chain that are required for the chain’s effective functioning (i.e. the enabling environment)
- The policies, markets, and institutions that regulate the chain
- Information and knowledge flows along the chain
- Constraints and R4D opportunities along the chain

In the final two sections of this chapter we highlight concrete examples for two crucial components of grain legume value chains: seed systems and social cooperation models. They illustrate the challenges and opportunities inherent in improving value chains.

Inadequate seed systems are an especially serious constraint in achieving impact from improved grain legume varieties. There are several reasons for this:

1. Self-pollinated reproductive system: enables farmers to re-use their own or their neighbor’s seed instead of buying fresh seed each year, reducing incentives for the private seed sector
2. Policy bias: legumes must compete against heavy incentives provided to farmers to grow other crops, reducing legumes’ attractiveness to seed companies
3. Insufficient scale leverage: Diversity is a virtue for livelihood security, nutritional balance and ecosystem resilience, but economies of scale in seed production favor fewer ‘mega-crops’
4. Low seed-to-seed multiplication ratio and rapid loss of viability in a few legume crops, particularly groundnut and chickpea

Nevertheless, imaginative approaches are overcoming or circumventing obstacles.
Successful seed systems

In sub-Saharan Africa...

Novel seed distribution mechanisms offer promise against this bottleneck. CIAT initiated studies of local seed systems more than 20 years ago in Rwanda. They found that farmers were willing to purchase small seed packets of 100-200 grams each to experiment in small plots on their own farms. Under the Tropical Legumes II project this small pack model was further explored and systematized, involving national programs and the private sector.

The national seed program of KARI-Kenya connected with Leldet Seed Company and CIAT/PABRA to test the marketing of small seed packs. A company pickup truck traveled to villages on market days and announced the sale of samples of new varieties from the back of the truck with a loudspeaker. Often the truck was mobbed by enthusiastic farmers seeking access to the new varieties; many were women. Leldet became convinced that this was a significant market opportunity. The cost charged per gram of seed for these small packs is in fact higher than for conventional large bags, yet the absolute cost of the seed pack is well within reach of poor women (less than US$ 0.13/ 100 gm) and provides enough seed for a home garden. The immediate sales are profitable for the seed company, and as varieties become known through this mechanism the company hopes that this can generate further demand. Four more PABRA countries are now experimenting with the small-pack approach.

A second approach pursued with KARI (Kenya) is the revolving seed loan program. Local agencies receive initial seed through purchases or grants and together with the farming community identify good farmers to be loaned that seed. After harvest farmers return one to three times the amount of seeds to the service providers/organizations. Upon receiving the returned amount the service providers, again with farming communities identify additional beneficiaries on a similar loan arrangement. The revolving loan continues for three to four seasons until the variety becomes widespread.

A related model is to revolve cash earned from sales of the seed, rather than revolving the seed itself. Donors put up the initial cash to establish the seed multiplication capacity, and that cash revolves back following seed sales. ICRISAT is catalyzing this nonprofit model for groundnut and pigeonpea in Malawi in close partnership with NASFAM.

From 2007 to 2010, a community based seed system was established in the Dosso region in Niger, enabled by the Tropical Legumes II project. Farmers and small-scale seed producers were trained in seed production and small-scale business management and marketing. The national research program INRAN was tasked to supply breeder seed to these community-based organizations (CBOs). This was very successful. After 4 years, CBOs produce about 65% of the total certified seed produced in Niger (Republic of Niger, Ministry of Agriculture and livestock, Directory on the Availability of Improved Seed. 2010/11). Seed from small-scale farmers is now in demand by many NGOs. FAO also purchases seed stocks for emergency reserve.
In Southern/Southeastern Asia...

The Punabarao Deshmukh Krishi Vidyapeeth (PDKV) model originating from Punjabrao Deshmukh Agriculture University at Akola, Maharashtra in India overcomes seed industry ‘market failures’ by helping farmers to grow their own. Farmers are provided with free planting seed and production information on new varieties. Starting with 2 kg of groundnut, a farmer can multiply enough to cover one hectare in three years. For example in Namakkal district in Tamil Nadu where most farmers save their own groundnut seed for the next cropping season this model is vigorously being followed to achieve the rapid spread of newly-identified groundnut variety ICGV 87846. This has also been the most successful means of increasing the availability of mung bean seed. Initiated for this crop by Punjab Agricultural University in 2003, enough seed is distributed to sow 0.4 ha for 270 farmers in 30 villages.

Seed growers’ cooperative societies have also been formed to carry out seed production, processing and marketing at the village level. These societies are linked with the formal seed sector. Because pigeonpea can easily cross-pollinate and is thus vulnerable to outcrossing contamination, a ‘One Variety-One Village’ concept is followed in order to maintain the required minimum isolation distance of 300-500 m between varieties.

In Central/West Asia and North Africa

Fostered by ICARDA, village-based seed enterprises (VBSEs) are owned and managed by farmers in Afghanistan, Algeria, Morocco, Tunisia, Iraq, and Pakistan. Village farmers are provided with essential facilities (mobile cleaners, storage facilities and others) and trained in seed production and business management. They are linked to formal sector institutions (e.g. R4D and seed companies). They are monitored and evaluated for their profitability and sustainability. VBSEs form a network at provincial levels for facilitating flow of information for seed marketing and experience sharing. In Afghanistan over 2003-2006 VBSEs earned a net profit of US$3.1 million from cereal and grain legume seed provided to about 154,000 farmers.

The bottom line: where conventional private sector seed systems have proven difficult, other approaches can work.
Collective action is required so that poor smallholders can gain the scale and clout to influence value chains and to capture a larger share of benefits that flows from them. Here we highlight some learning achieved and successes in grain legumes.

Both cooperatives and small farmer groups dealing with legumes such as beans exist in many African countries. Small-scale farmer groups predominate in some countries while in other such as Ethiopia formal cooperatives are the main model of input distribution and marketing. Small-scale farmer groups are in most cases informally generated between neighboring households while cooperatives usually have larger membership and more formal, state-supported protocols.

Women have been deliberately engaged in microfinance cooperatives in some countries (e.g. Ethiopia, Uganda); however the majority of producer/marketing cooperatives are owned and managed by men. A current trend is that small-scale women’s groups are connecting to form higher-level platforms as an umbrella to access profitable markets. Cooperatives are attempting to integrate vertically to encompass the processing and marketing stages of the value chain. It is rare for these cooperative arrangements to specialize in one crop; they handle a range of crops. Inadequate funding is a commonplace feature of cooperative arrangements.

A bean processing industry is emerging in Rwanda and Kenya especially targeting large communities such as schools, prisons and supermarkets with pre-cooked beans. PABRA is currently linking this emerging industry to preferred varieties and input supply chains.

Vegetable soybean is Taiwan’s largest frozen vegetable export. Japan imports around 70,000 tons annually. Farmer cooperatives are a key feature of the organization of this value chain. Farmers and processors meet annually with Japanese buyers to share new products and discuss market expectations. These producer groups have also stimulated local consumption in Taiwan.

Madhya Pradesh Cooperative Oilseed Growers’ Federation Limited (OILFED), India was established in October 1979 to integrate the production, procurement, processing and marketing of oilseeds (mainly soybeans) on cooperative lines. OILFED is credited with pioneering the production and processing of soybeans in the State of Madhya Pradesh. It has also developed and is engaged in the marketing of various soya value-added consumer products.

The bottom line: Although operational issues often arise, farmers in developing countries readily come together in order to increase their gains from value chains.
5. Main Activities to Generate Outputs and Outcomes

Regional targeting

GLVA will place its main emphasis on sub-Saharan Africa and South Asia, where the largest populations of poor grain legume producers and consumers are located. Pockets of poverty and hunger in Central America and the Caribbean, Central/West Asia/North Africa, and East Asia will also be addressed. Our focus will be further sub-delineated towards the poorest sectors within those target areas. In-depth descriptions of major trends and issues for grain legumes in each of these regions are provided in Appendix 2.

GLVA considers FAO’s classification of Low-Income Food Deficit Countries (LIFDCs) to be a reasonably accurate screen for delineating the countries most in need of international agricultural R4D assistance, and grain legumes are important staple foods in most of these countries. The list currently includes 39 countries in sub-Saharan Africa, 12 in South and East Asia, six in Central Asia and the Caucasus, five in Oceania, four in West Asia/North Africa, three in Central America and the Caribbean, and one in Europe. LIFDC excludes the large-scale commercial and economically-emergent soybean producing countries (USA, Brazil, Argentina, and China). FAO’s criteria for classifying Low Income Food Deficit Countries and the list of current countries are given at http://www.fao.org/countryprofiles/lifdc.asp

Though GLVA’s prime focus will be on LIFDC countries, it will partner closely with R4D institutions in many non-LIFDCs that hold strong expertise in grain legumes in order to mobilize their expertise to contribute to the global GLVA effort. GLVA will enable spillovers of its advances to all parts of the world by placing its knowledge and technologies in the public domain.

Crop diversity

Crop diversity is a key asset for GLVA. Diversity provides options. It gives farmers the chance to adjust their strategies according to market demand and agro-ecological conditions, particularly as the world prepares for climate change. It gives researchers the opportunity to better target solutions to needs, and to complement each other’s knowledge and expertise.

As discussed in Chapters 3 and 4, GLVA partners will capitalize on the opportunity for cross-crop learning to further accelerate value chain impact. Much can be learned through comparison/contrast analyses in all the scientific domains relevant to value chains, e.g. in socio-economic, institutional, biophysical and other realms.

GLVA brings together deep expertise on ten crops: two oilseed grain legumes, four warm-climate grain legumes, and four cool-climate grain legumes.
Oilseed grain legumes (also consumed as food, feed, fodder)
  - Groundnut, *Arachis hypogaea* L.
  - Soybean, *Glycine max* (L.) Merr.

Warm-climate grain legumes
  - Common bean, *Phaseolus vulgaris* L.
  - Mung bean, *Vigna radiata var. radiata* (L.) R. Wilczek
  - Pigeonpea, *Cajanus cajan* (L.) Millsp.

Cool-climate grain legumes
  - Chickpea, *Cicer arietinum* L. (recently expanding into warm climates also)
  - Faba bean, *Vicia faba* L.
  - Grasspea, *Lathyrus sativus* L.

Four additional crops will receive exploratory attention, but will not be foci of breeding effort for impact at this time. They will add importantly to R4D learning as comparison/contrast points in trait studies, as well as being important on-farm in particular locations.

Exploratory grain legumes

*Warm-climate*
  - Bambara nut, *Vigna subterranea* (L.) Verdc.
  - Tepary bean, *Phaseolus acutifolius* (A. Gray)

*Cool-climate*
  - Lima bean, *Phaseolus lunatus* L.
  - Pea, *Pisum sativum* L.

More background on all these crops is given in Appendix 3.

**Standard profiles of Objectives**

The following pages provide detailed descriptions of each of the four GLVA Objectives, including the structured hierarchy of Outputs and Activities under each. Milestones are provided in Chapter 13.

At a bird’s eye level, it is necessary to indicate relative priorities among all the Outputs across the five focus Regions. These are listed in Table 5.1 below.
Table 5.1 Regional priorities for outputs in GLVA

<table>
<thead>
<tr>
<th>Objectives/Outputs</th>
<th>Regions</th>
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<tbody>
<tr>
<td><strong>Objective 1: High value grain legumes to reduce rural poverty</strong></td>
<td>SSEA</td>
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<tr>
<td>1.1. Value chains for value addition</td>
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<td>1.2. Perishable fresh products</td>
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<td>1.3. Dry seed products</td>
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<td>1.4. Animal feeds and haulms</td>
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<td>1.5. Small-scale mechanization</td>
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<td>1.6. Policy suggestions for value addition</td>
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<td><strong>Objective 2: Productive grain legumes to secure food supplies</strong></td>
<td>SSEA</td>
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<td>2.1. Utilization of genetic resources</td>
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<td>2.2. Novel breeding methods</td>
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<td>2.3. Climate resilience</td>
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<td>2.4. Legume cultivars for production systems</td>
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<td>2.5. Sustainable seed systems</td>
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<td>2.6. Capacity strengthening of partners</td>
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<tr>
<td><strong>Objective 3: Nutritious, safe grain legumes</strong></td>
<td>SSEA</td>
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<td>3.1. Gene pools for enhanced nutritional value</td>
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<td>3.2. Pre- and postharvest management</td>
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<td>3.3. Communication networks</td>
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<td><strong>Objective 4: Grain legumes for sustainable intensification</strong></td>
<td>SSEA</td>
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<td>4.1. Enhanced N2 fixation efficiency</td>
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<td>4.2. Integrated soil and crop management</td>
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<td>4.3. Policy and capacity strengthening</td>
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GLVA Objective 1: High value grain legumes to reduce rural poverty

Overview
As outlined in Chapter 3 a value chain perspective is highly useful for designing, monitoring and evaluating GLVA’s R4D agenda. Too often the processes outside the production stage have been overlooked even though the potential for value addition postharvest is very high. The value chain perspective guides GLVA to attend to these major missed opportunities. But to capture these opportunities requires a much better understanding of legume value chains, their key constraints and how R4D innovations might overcome them. As farmers gain confidence in collective action and appreciate the rewards that it brings they become motivated to seek further gains in value. Major gains await from helping the poor expand their activity domains into additional core processes of the value chain, e.g. grain cleaning and quality control, collective marketing, and the processing and sale of more nutritious fodder products. To achieve this, value chain models are needed that help researchers understand farmer motivations and decision-making about their participation in various core processes in the value chain.

In areas of high poverty there are many constraints that GLVA partners will help overcome through a better understanding of value chains and innovations that unleash their potential. For example, smallholders usually sell their produce in a relatively poor condition with high content of shriveled, discolored and (in the case of groundnut) even mycotoxin-affected grains, with a high content of stones and dirt. They also sell during glut harvest periods when prices are lowest. Milling losses are regularly on the order of 15% and often higher than that. Farmers sell without knowledge of current market prices to middlemen whose interests are to pay farmers the lowest possible price. All these factors conspire to leave far less income than is possible in the hands of farmers.

Fig. 4.2 (Chapter 4) illustrates the wide range of potential value gain points that grain legumes offer. Oil from soybean and groundnut are globally marketable high-value commodities. Thriving urban, industrial and export markets exist for a wide array of specialty foods such as peanut butter, bean thread noodles, fresh and cooked beans for breakfast and for salads, and a range of fermented and fresh soy products. Livestock markets also pay premium prices of up to three times more per unit weight for grain legume haulms (stems and leaves) than for cereal haulms due to the higher nutritive value. For indeterminate low harvest-index crops like cowpea and lentil the haulm crop is often as valuable as the grain crop (Erskine et al. 1990).

Addressing the very high quality standards of sophisticated urban and export markets provides one such opportunity. Examples of important legume export markets include the export of pigeonpea and chickpea from Africa to India (Jones et al, 2002; Simtowe et al, n.d.), haricot bean export from Ethiopia (Ferris and Kaganzi, 2008), and regional West African cowpea trade (Langyintuo, 2003). Considerable effort is being made to improve the domestic cowpea value chain in Nigeria, for instance, including the development of new commercial food enterprises (Lowenberg-DeBoer and Ibro, 2008).

Large local markets already exist for the green (immature) peas of faba bean, chickpea and vegetable soybean, but it is very labor-intensive to shell them. Simple mechanical shellers could help expand the market for such products and increase marketable volumes to the levels needed for exporters to achieve a critical mass of reliable supply to retail outlets. Value can also be added to livestock products e.g. by baling haulms and by enriching feeds with legume haulms, press-cake, and other highly nutritious components.
Vision of Success

GLVA believes that sufficient potential exists with grain legumes under Objective 1 to realistically help to double smallholder farmers’ incomes from grain legumes in areas that adopt these value chain enhancement innovations. This confidence is based on the wide range of value addition points illustrated in Fig. 4.2. GLVA’s focus will be on R4D to generate internationally-applicable knowledge and technology such as grain legume-relevant value chain analysis and learning models, farmer collective action models and protocols, knowledge-sharing mechanisms, technology prototypes (e.g. for improving the cleaning and quality of harvested products), and others. Particular emphasis will be placed on strengthening and extending the participation of women in those value-added core processes in ways that increase their incomes while moderating the time-consuming low-income drudgery that they face today (e.g. in manual shelling and cleaning and in arduous low-income street marketing).

Table 5.2: Common areas for value chain enhancement across major legume crops

<table>
<thead>
<tr>
<th>Crops1/Opportunities2</th>
<th>CB</th>
<th>CP</th>
<th>CW</th>
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<td>New varieties for high value</td>
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<td>High growth market opportunities</td>
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<td>Niche high value</td>
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<tr>
<td>High value product type</td>
<td>Fresh food</td>
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<td>Processed grain</td>
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<td>Animal feed</td>
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<td>Processing location</td>
<td>Home</td>
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<td>Extension or marketing needs</td>
<td>Farmer</td>
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</table>

2 No star = not important, * = low importance,** = medium importance,*** = high importance

R4D questions

- How do poor smallholder grain legume value chains function and where are efficiency and value gains needed and achievable?
- Can generalized (cross-crop, cross-region) grain legume value chain models be developed that help to orient R4D towards effective entry points that lead to wide IPG impact potential?
- What value-adding traits reside unrecognized within grain legume germplasm collections, and how can they be exploited to benefit the poor?
- How should smallholder farmers organize themselves collectively to best capture different opportunities within value chains?
• How can the role and share of value captured by women be sustained and increased as value chains develop, rather than being overtaken by men?
• How can traditionally informal livestock feed/fodder value chains be enhanced to capture the sizeable revenue opportunity?
• How can GLVA as an international organization find an appropriate niche to foster the use of labor-saving, quality-enhancing postharvest processing machinery for grain legumes?
• How can the health benefits of grain legumes be quantified and compared vs. monetary benefits as required for true full impact assessment?
• How can smallholder collective action mechanisms tame the headwind of country and global macro-economic dynamics that often seem in conflict with grain legume cultivation?

**Exciting Opportunities**
• Social organization models that open a wide range of substantial income opportunities for the poor
• Novel high-value processed grain legume products for urban and high income markets
• Expanded markets for fresh legume products through cross-regional initiatives facilitated by GLVA, particularly green seed of chickpea, pigeonpea, faba bean and vegetable soybean, and sprouts from mung bean and chickpea
• Value-adding income-earning opportunities for women
• Mechanization of small-scale farm operations

**Key Measurable Indicators**
• Value chain models published and effectively used for GLVA planning, research design, monitoring, evaluation and impact assessment
• Trends in proportions of smallholder crops home-consumed vs. commercially sold, with growth in the latter (relative to counterfactuals) accompanied by net income growth indicating successful addition of value
• Data collected on major value added grain legume products to identify the range of product options available for smallholder farmers
• Partnership built with International Pulses Trade and Industry Confederation representing over 500 pulse commodity traders to identify global priority opportunities for expansion of high value pulse products in ways focused on helping the poor of the developing world
• Global case studies of recent high value legume product market expansion completed and utilized in R4D planning
• Ten potential new markets and locations identified for testing the development of new high value fresh products, processed grain products or animal feed
• Identification of the key players in the priority value chain case studies and the main opportunities to benefit women through technical or social interventions and the key partners needed
• Successful development of priority case studies for new fresh, dry grain and animal feed high value legume products, and lessons learned documented
• Principles and prototypes of machinery designed to increase value quantity and capture by the poor
• Policies implemented to assist in the scaling up of successful case studies of high value markets that have been identified
• Common bean varieties released for the canning industry in at least 2 African countries
• Large-seeded kabuli chickpea varieties with better quality released in 2 target countries
• At least one variety suitable for mechanical harvesting developed in chickpea and lentil for each target country
• At least 100 germplasm accessions / year screened for value adding traits in each focus crop
Innovations to increase the profitability of crops that were formerly of little economic value or for activities like marketing, managing end-product enterprises and decision making. The participation of women in the value chain could increase their involvement in higher level economic activities that can directly benefit them if carefully introduced. It is expected that the increased and focused participation of women in the value chain could increase their involvement in higher level economic activities like marketing, managing end-product enterprises and decision making.

Impact Pathways
The main driver of impact under Objective 1 is value addition. People involved in value chains weigh the tradeoffs between the benefits of increased incomes versus the costs of obtaining those benefits (e.g. risks of failure, requirement to go into debt in order to obtain the gains, loss of land for food crops to cash crops, violation of cultural traditions etc.) As long as the net gain is real and substantial and tradeoffs are not too severe, adoption and impact is likely.

The creation of those gain opportunities requires close collaboration between actors in relevant positions along the value chain. GLVA will work closely with such partners to understand how those chains function, where the obstacles lie and to test the feasibility and tradeoffs of potential interventions. Where promising innovations survive these tests, value chain partners will be asked to pilot-test them within their domains (they are likely to be willing to do so because of the potential benefits that they could receive if the innovation is truly successful).

Research and development partners
The work on value chain analysis and development will be carried out in conjunction with partners such as CRP 2, government food technology and food policy agencies, legume trader associations, major legume product manufacturers, supermarket chains, health-oriented NGOs, women’s self-help groups and cooperatives, and others as relevant to the chain under study. The processing methods for perishable fresh products will be developed in partnership with NARS, NGOs and local processing industries. Innovations in dry seed processing appropriate to the poor will involve partnerships with grain processors and exporters, the international grain legumes trading association, farmer cooperatives and NARS. High value animal feeds will be developed in partnership with CRP3.7 – especially in relation to the fish and dairy sectors, the fodder trade, NGOs, CRP 1.1 and CRP 1.2, and CRP 2. Small-scale mechanization of crop production will be done in partnership with input suppliers including engineering companies and organizations, NGOs, CBOs, and NARS. We will work with local governments to inform policy deliberations that foster value addition (see details in Chapter 6 on Partnerships).

Empowering Women
Changing the value chains for legume crops can have significant gender effects, and this needs to be carefully considered in the design of any interventions to add value. Who will benefit most from new products and processing? Regional and ethnic domains also differ significantly for gender roles. While men tend to dominate cereal production in many societies, women are more likely to take a major role in the growing of legumes, especially in Africa. Women carry out weeding and harvesting, so interventions to make these activities less arduous can particularly benefit them. While men tend to dominate the marketing of dry grains, women are more likely to dominate the marketing of perishable and value-added products. Women are also more involved with small scale processing, food preparation for home use or local sale, so the introduction of simple processing technologies can directly benefit them if carefully introduced. It is expected that the increased and focused participation of women in the value chain could increase their involvement in higher level economic activities like marketing, managing end-product enterprises and decision making.

Innovations to increase the profitability of crops that were formerly of little economic value or for home use can improve the incomes of women, but this can also pose new challenges. Past experiences have shown that men often take over such enterprises after they become profitable. Social organization helps to protect women’s interests. Care needs to be exercised that interventions happen in ways that do not create community conflicts (see also Chapter 7 on Gender Research Strategy).
Outputs and Activities (Milestones are listed in Chapter 13)

Output 1.1: Value chains analyzed for value addition opportunities
Value chain analysis generates information and knowledge about the value-adding process, while value chain development helps to better link farmers to high value markets. Both are important to improving incomes. This work will require advanced modeling expertise be done in conjunction with partners such as CRP2, legume trader associations, major legume manufacturers, supermarket chains and health NGOs.

Activities
1.1.1 Develop value chain models that quantify key dynamics including the impacts of potential innovations, tradeoffs and scenarios
1.1.2 Monitor changing patterns of domestic (rural and urban) and export demands for grain legume products.
1.1.3 Identify opportunities for value addition that especially benefit women
1.1.4 Knowledge-sharing and capacity building in value added products, quality control and business development

Output 1.2: Value addition to perishable fresh products developed and promoted
Fresh leaves, pod or green seeds of many legumes can also be used as vegetable, in addition to the mature seeds. The processing and marketing of perishable food products involves different actors than that for mature seeds. Women usually dominate the fresh food processing and marketing of fresh foods such as legume leaves. Because of the perishable nature of these products, transportation, hygiene and handling issues can also be different from those for dry seed products. This work will be done in conjunction with universities, NARS, NGOs, and local processing industries

Activities
1.2.1 Identify/develop smallholder-appropriate mechanization of green seed extraction (shelling)
1.2.2 Identify/develop smallholder-appropriate practices to increase shelf life of perishable grain legume products
1.2.3 Assess available varieties and breeding options to produce high value market preferred fresh grain legume products
1.2.4 Disseminate promising technologies and knowledge

Output 1.3: Dry seed products: high value technologies developed and promoted
Legumes are primarily grown for their dry seed, and as a relatively durable product it is more easily traded over long distances than fresh legume products. Larger trading and processing industries can be involved in handling legumes as bulk commodities for international trading, but there are also opportunities for small scale value adding for local sale. This work will be done in conjunction with grain processors and exporters, NARS with postharvest and gender expertise, and NGOs interested in smallscale machinery innovation.

Activities
1.3.1 Assess smallholder and women-appropriate processing methods for novel products (eg. oil extraction, legume starch extraction, soya-milk or cheese production)
1.3.2 Devise smallholder-appropriate solutions to losses from storage pests
1.3.3 Identify/develop varieties that are easier to split with higher milling recovery, reduced cooking time, and suitable for specialty high-value urban & export markets

1.3.4 Disseminate promising technologies and knowledge

**Output 1.4: Animal feed and fodder: high value technologies developed and promoted**

Legume haulms can provide high quality animal feed and legume seed can be an important source of protein and other nutrients for feed rations. Oilcake from groundnut and soybean are major sources of animal feed and used extensively in feed mixes. This work will be done in conjunction with CRP3.7 – especially in relation to fish and dairy sectors, the fodder trade, NGOs, CRP 1.1 and CRP 1.2, and CRP 2.

*Activities*

1.4.1 Breed more nutritious and higher yield of haulms for animal fodder
1.4.2 Improve fodder processing to raise nutritional quality
1.4.3 Assess tradeoffs (if any) in total crop productivity and value chain benefits associated with genetically higher haulm yield/quality
1.4.4 Assess livestock and human health risks (if any) and management strategies associated with use of presscake and haulm as animal feeds
1.4.5 Disseminate promising technologies and knowledge

**Output 1.5: Mechanization of small-scale crop production developed**

Small scale mechanization aims to increase the profitability of growing a crop by reducing production costs, but also to allow the development of new legume products and markets. This work will be done in conjunction with input suppliers including the chemical industry, NGOs, CBOs, universities and national agricultural research services.

*Activities*

1.5.1 Assess employment and profitability implications of intensifying management.
1.5.2 Assess alternative mechanical, chemical or biological options for weed control and their implications for women.
1.5.3 Develop women-friendly options for small scale mechanical harvesting and threshing.
1.5.4 Identify/develop varieties for improved weed control and mechanical harvesting.

**Output 1.6: Market, policy and institutional innovations that increase value chain benefits for poor smallholders (in close coordination with CRP 2)**

Legume production competes poorly with subsidized cereal production in a number of key markets (such as India) and this has been a key factor constraining production. Government policies that set minimum prices or procurement targets can affect the profitability of legumes to farmers, while policies on rural investments, infrastructure and trade can also impact the viability of establishing value adding operations or developing new markets.

*Activities*

1.6.1 Assess the effects that policies favoring competing crops exert on legume value chains, and provide evidence to policymakers
1.6.2 Devise social and collective action options that increase the quantity and proportion of value captured by poor smallholders
1.6.3 Assess the current and potential impact of public and private investments on value addition in grain legumes at a scale and in locations that will benefit smallholder farmers, including women

1.6.4 Assess the impact of trade and food industry policies on developing new markets for processed high value legume products

Phasing of Objective Components
In the first phase of this Objective (2011-13), GLVA will collect social and technical information on current opportunities for grain legume value addition and develop functional models as analytical tools. Successful case studies of the development of high value legume products for national, export or niche markets will be studied for lessons learned. These value chain studies for fresh, processed dry grain or animal feed products will identify opportunities for benefiting the poorest participants in these chains and women in particular. They will be examined for regional or global lessons that can be learned for scaling them up for wider national benefit or for duplicating them in different locations or with different crops, and the implications for technical, social or policy innovations. Research will also be done on opportunities to reduce the costs of legume production, particularly in weeding and harvesting, and the implications for women. This will be through both a literature review and targeted studies in areas of high poverty incidence.

The second three-year phase (2014-16) of the project research and development will focus on the key case studies identified in the first phase, and will support partners to scale up promising innovations. This will involve building stronger links with industry and national research partners, NGOs and farmer organizations. It will involve market research, processing research with a particular focus on small-scale processing technologies, studies on policies to strengthen market growth and maintain quality control, breeding of improved varieties and partnerships to promote new products to consumers.

In the third phase (2017-20), the monitoring and evaluation that has been an ongoing part of previous phases will be drawn upon to reassess what interventions have been most successful and why, and where needs still exist. Markets are in constant flux and the lessons learned in earlier phases will be used to identify changing trends and new processing opportunities and research needs. A key aim of this phase will be to build even stronger linkages with industry, national research partners, policy makers, NGOs and farmer organizations in order to ensure the sustainability of successful interventions, and that the legume value-adding industry continues to be competitive and is structured to ensure that legume production is of particular benefit for smallholder producers and women.
Overview
The average farm yield of legumes, in comparison to staple cereals (rice, wheat, and maize), is very low, and there is a wide yield gap exist between current farm yield and the yield obtained at research stations and well-managed farmers’ fields (Bhatia et al. 2006, Singh et al. 2001, 2009). The global average yield of chickpea, common bean, cowpea, lentil, mung bean, pigeonpea, and grasspea is less than 1.0 t ha\(^{-1}\) (FAOSTAT 2009), which is not even half of their potential yields. There are opportunities for narrowing these yield gaps and increasing the production of grain legumes. Thus primary aim of this objective is to increase productivity and stabilize yield of target legumes in dryland and rainfed farming systems, leading to improved food and feed security, and income and nutrition of the poor. Cultivars with adaptation to different agro-ecologies will be developed, and farmer-participatory varietal selection (FPVS) process will be used to identify cultivars for adoption through promotion of innovative legume seed production and delivery systems. The Tropical Legumes II project, funded by the Bill & Melinda Gates Foundation (BMGF), has taken lead in exploring novel models of seed production and dissemination, looking at more than 15 different models in different countries in Africa and India (http://www.icrisat.org/tropicallegumesII/lessons.html).

Yield gap analysis and plausible closure of yield gap through R4D

Using yield gap analysis, the loss in yield in different legumes due to insect pests, diseases, drought/water management, biological nitrogen fixation, labor and mechanization, and crop improvement was estimated as a proportion of the total yield gap between realizable yield (average yield that farmers can plausibly obtain in their fields using optimum but achievable crop management) minus actual yield (average yield actually harvested by the farmers across regions (FAOSTat 2009). Proportional loss in yield due to different stresses was based on the contribution of a trait/factor to the total yield gap. Plausible closure of yield gap was based on the yields which could be realized by overcoming various yield reducing constraints over the next 10 years through R4D (Expected production - (% yield gap – % plausible closure of yield gap)/100 x expected production).

The average realizable yield gap in grain legumes has been estimated to be 61% (35% in soybean to 70 % in chickpea), of which insects accounted for 8.8 %, diseases 10.4%, drought and water management 10.1%, weeds 4.8%, and poor soil fertility 11.6%.

Plausible closure of yield gap through R4D (over the next 10 year period) can increase production from 217.38 million tons to 323.78 million tons. The value of increase in production will be US$46.68 billion. Of the total loss in yield, disease accounted for $6.68 billion, insect pests for $6.38 billion and weeds for $3.02 billions. Yield gap closure would increase crop value by $5.90 billion annually, while realizable management of soil fertility could add $7.66 billion.
Table 5.3. Yield gap (actual on-farm vs. realizable on-farm) in grain legumes and value of its predicted partial closure through GLVA and partner R4D

<table>
<thead>
<tr>
<th>Crop</th>
<th>Area (m ha)</th>
<th>Actual production (m t)</th>
<th>Actual yield (t ha⁻¹)</th>
<th>Realizable yield (t ha⁻¹)</th>
<th>Yield gap (%)</th>
<th>PCYG through R4D (%)</th>
<th>Expected production (m t)</th>
<th>Plausible production through R4D (m t)</th>
<th>Additional production (m t)</th>
<th>Average market value of grains (US$ metric ton)</th>
<th>Value of additional produce (US$ billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans (including mungbean)</td>
<td>25.5</td>
<td>18.6</td>
<td>0.7</td>
<td>2.0</td>
<td>63.6</td>
<td>34.5</td>
<td>51.0</td>
<td>36.1</td>
<td>17.6</td>
<td>498.0</td>
<td>8.8</td>
</tr>
<tr>
<td>Chickpea</td>
<td>10.6</td>
<td>7.9</td>
<td>0.7</td>
<td>2.5</td>
<td>70.1</td>
<td>38.5</td>
<td>26.4</td>
<td>18.0</td>
<td>10.2</td>
<td>346.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Cowpea</td>
<td>11.9</td>
<td>5.7</td>
<td>0.5</td>
<td>1.5</td>
<td>68.0</td>
<td>36.0</td>
<td>17.8</td>
<td>12.1</td>
<td>6.4</td>
<td>651.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Groundnut</td>
<td>23.2</td>
<td>35.8</td>
<td>1.5</td>
<td>3.5</td>
<td>55.8</td>
<td>30.0</td>
<td>81.0</td>
<td>60.2</td>
<td>24.3</td>
<td>537.0</td>
<td>13.1</td>
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<tr>
<td>Lentil</td>
<td>2.4</td>
<td>1.6</td>
<td>0.7</td>
<td>2.0</td>
<td>66.6</td>
<td>32.5</td>
<td>4.7</td>
<td>3.1</td>
<td>1.5</td>
<td>423.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Pigeonpea</td>
<td>4.9</td>
<td>4.1</td>
<td>0.8</td>
<td>2.5</td>
<td>66.2</td>
<td>36.7</td>
<td>12.2</td>
<td>8.6</td>
<td>4.5</td>
<td>339.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Soybean</td>
<td>63.0</td>
<td>143.7</td>
<td>2.3</td>
<td>3.5</td>
<td>34.9</td>
<td>19.0</td>
<td>220.7</td>
<td>185.6</td>
<td>41.9</td>
<td>358.0</td>
<td>15.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>141.4</strong></td>
<td><strong>217.4</strong></td>
<td><strong>1.0</strong></td>
<td><strong>2.5</strong></td>
<td><strong>60.7</strong></td>
<td><strong>32.5</strong></td>
<td><strong>413.8</strong></td>
<td><strong>323.8</strong></td>
<td><strong>106.4</strong></td>
<td><strong>450.3</strong></td>
<td><strong>46.7</strong></td>
</tr>
</tbody>
</table>

The groundnut yields are with shell, as most of the commodity is traded along with the shell in the market. (Shell is about 30% of total weight)
Actual yield is the average yield harvested by the farmers across regions (FAO stat 2008)
Realizable yield is the average yield that can be obtained in most of the areas with optimum crop management
Yield gap = (Realizable yield – actual yield)/realizable yield x 100
PCYG = Plausible closure of yield gap through R4D over the next 10 years = Gain in yield that can be realized by overcoming biotic and abiotic stresses and optimizing crop management over the next 10 years through R4D
Plausible production = Expected production - (Yield gap - PCYG)/100 x Expected production
**Vision of Success**

Because of limited availability of land for planting grain legumes, the demand must be met by raising productivity from the present level of 800 kg/ha to at least 1500 kg/ha and, in the short term, by replacing existing local varieties with improved varieties and effective crop husbandry and management technologies. The partners envision many important advances resulting from a coordinated research for development initiative under GLVA, especially for common but complex constraints. Improving and stabilizing legume yield *per se* through integrated approaches will enhance legume production and directly contribute to food security, while making legumes more affordable for the poor rural and urban consumer, with positive effects on nutrition and health. Greater seed availability of improved varieties by 25% within 5 years (subject to 5-10% seed replacement for new varieties) will greatly contribute to increased production of grain legumes. Better management of biotic and abiotic stresses and improved biological nitrogen fixation (BNF) will vastly improve soil fertility, systems sustainability and the income-generating potential of legume-based cropping systems. We envision attaining maximum potential of legumes production in collaboration with CRP1.1 and CRP1.2 through technological innovations, and their introduction in new niches and short season windows of existing cropping systems for long-term sustainability of agricultural production systems.

**Challenges, Opportunities and Synergies**

Grain legume consumption is expected to grow by 10% in the next decade, and by 23% from the current level by the year 2030, leading to a wide gap in the global demand-supply equation for legume crops (World Pulse Outlook, 2009). Consumption is expected to grow more rapidly in Asia and Africa where the world’s most undernourished people are concentrated. Recent FAO reports suggest that as many as 840 million people in South Asia and Sub-Saharan Africa are still malnourished. African demand for pulses could rise 27% within the next decade and another 50% by 2030, while in South Asia it is expected to grow 11.6% by 2020 and 23.6% by 2030 (World Pulse Outlook, 2009). In South Asia alone, demand for pulses is expected to top 27.8 million tons by 2020 (Paroda and Kumar, 2000).

With cereal yields expected to double over the next 30 years (Specht et al., 1999), an expectation is that cereals will continue to occupy and expand in more favorable environments available to producers and drive legume crops to still more marginal areas where intensity and occurrence of adverse events such as drought and temperature extremes would be more frequent and intense. These marginal areas are also characterized by poor soils, fragile ecosystems and comparatively short growing periods. While pests, diseases and extreme climatic events are seasonal and represent risks and large yield fluctuations and instability, edaphic constraints maintain yields at low levels year after year. Grain legumes are remarkably diverse in their range of adaptation (Hall, 2004), and GLVA will explore how best to exploit the diversity of legumes, including underutilized species, to confront the challenges of climate, soil and biotic constraints. Thus a major challenge for researchers will be to help farmers to produce more legumes to meet this demand through a strategic combination of productivity and resilience increases and bridging the yield gaps besides their introduction in new niches and short-season windows of the existing cropping systems.

The CG and non-CG partners involved in this alliance are best suited to address the challenges to grain legumes to impact on the livelihoods of the smallholder farmers in developing countries. Building on the previous efforts of IARCs and NARES, the alliance is determined to tackle production constraints (Table 5.4) of these legumes through joint efforts which include sharing research facilities, knowledge and human resources. Some examples of efficiency gains that come from working together include: testing of improved germplasm and underutilized species in new niches; screening for abiotic and biotic stresses in target environments and controlled conditions; exploiting
genomic resources across species and using tools like GIS/Remote sensing for targeting constraints, technology testing and dissemination.

**Table 5.4. Priorities across legumes for improving yield levels and reducing production constraints**

<table>
<thead>
<tr>
<th>Crops¹/Priority Traits²</th>
<th>CB</th>
<th>CP</th>
<th>CW</th>
<th>FB</th>
<th>GN</th>
<th>GP</th>
<th>LN</th>
<th>MB</th>
<th>PP</th>
<th>SB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield potential and stability</td>
<td>***</td>
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<td>***</td>
<td>***</td>
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<tr>
<td>Hybrid Technology</td>
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<tr>
<td>Disease resistance/tolerance</td>
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<tr>
<td>Foliar</td>
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² No star = not important, * = low importance, ** = medium importance, *** = high importance

**R4D questions**

- How can characterization of grain legume genetic resources be most effectively and efficiently designed to identify novel, potentially useful genes/alleles to increase yield potential and to improve biotic and abiotic stress resistance/tolerance?
- How can stable CMS (cytoplasmic-nuclear male sterility systems) for hybrid production in legumes (pigeonpea, soybean, faba bean) be identified or developed?
- What are the genetic and environmental mechanisms that drive the switch from vegetative to reproductive mode and from vegetative plant habit to determinate plant habit in grain legumes, and how do they influence grain yield and agro-ecosystem adaptation?
- How can high throughput genotyping and phenotyping be most efficiently and effectively used to better understand the genetic and physiological basis of biotic and abiotic stresses?
- How can a better understanding of population life cycles, dynamics, diversity and distribution of current and potential new diseases/pests be utilized to improve integrated disease/pest management?
- What are likely risks and impacts of introgressing novel traits into elite legumes lines via transgenic and non-transgenic approaches?
The major findings from process and impact evaluation studies will be compiled and shared widely among farm groups, gender, wealth group, ethnicity, and other spillover and indirect economy-wide effects. Changes in production and variability therein; changes in agronomic practices and level of inputs; changes in production costs and profitability. These changes will influence household economies in terms of income, asset accumulation, human capital, food consumption, nutrition, and health. These effects will be scaled up at macro level to assess changes in producer and consumer welfare, changes in asset position, food and nutritional security, and changes in poverty, education, and health (across farm groups, gender, wealth group, ethnicity) and other spillover and indirect economy-wide effects. The major findings from process and impact evaluation studies will be compiled and shared widely.
among project partners, development organizations, local governments and policy makers through various platforms like workshops, seminars, policy briefs, etc. to inform and influence future courses of action to enhance production of legumes.

**Research and development partners**

This program objective will work closely with CRP 1.1 and CRP 1.2 to develop suitable legume varieties for different production systems, with CRP 7 (Climate Change) to target the development of resilient legume varieties for changing climatic conditions and with other CRP 3’s (WHEAT, MAIZE, GRiSP, and DRYLAND CEREALS) for effective and integrated cereal-legume cropping systems. Research will be carried out in close collaboration with national research programs, advanced research institutes, universities, and the private sector. The advanced research institutes will be mainly involved in upstream research and capacity building, while adaptive research involving location-specific technologies and approaches will be developed and tested in partnership with national research programs. This objective will engage numerous types of partners to disseminate information and technologies to the intended users.

The GLVA partner institutions will carry out research on genetic resources in partnership with national and regional partners as well as international and advanced partners such as Bioversity International, national genetic resources centres of Australia and the USA. The up-stream research, including genomics will have partnership of Advanced Research Institutes in Australia, India, Europe and USA; and other NARS in SSEA, ESA, WCA, CWANA and LAC. Research partners in development of improved cultivars and technologies will include NARS in several countries and Advanced Research Institutes in USA, Canada, Australia, France, Germany, Italy and Spain. In addition, regional Research organizations will be involved in technology up scaling and help to bring NARS together to tackle regional priorities on grain legume research for development. The development partners for seed system and transfer of technologies will include NARS in target countries, Public seed sectors; Private Seed Sectors; Agriculture Departments and Extension Agencies, NGOs and Networks. Details of partnership involvement are in Chapter 6 on Partnerships.

**Empowering Women**

Legumes are often described as women’s crops. Women comprise major labor force for weeding and harvesting in developing countries of Asia and sub-Saharan Africa (FAO, 2011). Closing the gender gap in agriculture would generate significant gains for the society. If women had the same access to productive resources as men, they could increase yields on their farms by 20-30%. Traits/preferences of women, e.g., micronutrient-rich legumes, mechanically harvestable legumes, herbicide tolerant varieties to minimize drudgery for women, will be given prominence. Special attention will be given to gender studies in the research design, dissemination activities, and ex-ante impact studies. Decision-makers will formulate institutional and policy measures that will encourage adoption of new technologies, ensure the equitable distribution of benefits, and improve the targeting of gender sensitive research and development programs. A participatory monitoring and evaluation system will integrate local- and gender-specific indicators for monitoring GLVA outcomes. Data from GLVA activities, monitoring and evaluation processes will be disaggregated by gender and this will be analyzed to provide feedback lessons for better main-streaming of gender into GLVA programming and implementation process. Views, perceptions and knowledge of rural women will be fully captured and incorporated into the research process. The program will aim for a balanced staff structure where women researchers and students will be encouraged. (See also Chapter 7 on Gender Research Strategy).
Outputs and Activities (Key Milestones are given in Chapter 13 on M&E)

Output 2.1: Enhanced utilization of genetic resources in developing high yielding, broad based cultivars

Legume germplasm with novel traits such as resistance/tolerance to biotic and abiotic stresses, and nutritional quality will be identified through intensive testing of core- and mini-core collections, reference sets, and focused identification of germplasm strategy (FIGS) subsets for use in breeding programs. This will require the development of high throughput and precise phenotyping platforms. Emphasis will be placed on identifying new and useful allele combinations of favorable genes for developing genetic stocks with traits of interest for use in crop improvement. Wild relatives of grain legumes will be explored for identification of specific sources of rare genes of interest for biotic/abiotic stresses and nutritional quality. Genetic base of legume cultivars will be broadened through the use of intra-specific and inter-specific crosses, and shared with the partners.

Activities

2.1.1 Identify germplasm from international legume collections using core- and mini-core and focused identification of germplasm strategy (FIGS) subsets for traits of interest.
2.1.2 Optimizing/Standardizing assessment protocols across legumes, especially for complex traits (abiotic stresses) to allow cross-species comparison of adaptive mechanisms
2.1.3 Evaluate core/mini core, reference, and FIGS subsets for target traits through various approaches, including TILLING and Eco-TILLING, to identify new and useful allele combinations of favorable genes.
2.1.4 Develop and evaluate genetic stocks with traits of interest for genetic studies and characterization. Explore the wild relatives of grain legumes for the identification of specific sources of rare genes of interest.
2.1.5 Explore the wild relatives of grain legumes for the identification of specific sources of rare genes of interest.
2.1.6 Broaden the genetic base of legumes using inter-specific and inter-generic crosses, including related species adapted to climate change and low soil fertility, and share with partners.
2.1.7 Assemble, conserve, regenerate, monitor for health and viability, and distribute genetic resources (including DNA) along with updated information for utilization in crop improvement.
2.1.8 Capacity of NARS partners enhanced in managing genetic resources

Output 2.2: Novel and efficient breeding methods for cultivars development established and shared

Innovative genotyping and phenotyping platforms will be established to understand the genetic and physio-chemical basis of resistance to diseases, pests and environmental stresses for individual legumes, and across legumes (comparative genomics) using high-throughput phenotyping and genotyping approaches for targeted traits to identify trait-linked diagnostic markers for use in marker-assisted selection, and also for genome-wide selection to maximize genetic gains in target environments. Advanced tools such as molecular markers derived from the CGIAR’s Generation Challenge Program (GCP) and other efforts, and trait-specific germplasm will be used to design better legume varieties with farmer/and consumer-preferred traits. Genetic and phenotypic diversity of legumes’ genetic resources will be assessed to identify novel, potentially useful genes/alleles, to increase yield potential, and improve resistance/tolerance to biotic and abiotic

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stress. This would enable researchers to introgress novel alleles from landraces and crop wild relatives into elite germplasm using conventional, doubled haploid, transgenic, and non-transgenic approaches to broaden the genetic base (nuclear and in some cases also cytoplasmic) of legume crops for increased productivity.

**Activities**

2.2.1 Generate the entire genome sequences for selected legume species and test genotyping by sequencing approaches for genome-wide selection.

2.2.2 Identify molecular markers linked to genes that confer resistance or tolerance to key abiotic and biotic stresses.

2.2.3 Develop cost effective marker technology and accompanying breeding methods to increase efficiency and accelerate breeding cycles.

2.2.4 Exploit crop-specific phenotypic and genotypic and comparative information using biotechnological tools for the development of improved germplasm.

2.2.5 Develop transgenics for stresses for which high levels of resistance are not available in primary gene pools (eg. pod borer resistance).

2.2.6 Optimizing/Standardizing and exploiting doubled haploid technology in legumes to shorten breeding cycle.

**Output 2.3: Climate resilient cultivars with appropriate traits developed**

The major factors contributing to low and unstable yield of grain legumes include biotic and abiotic stresses, poor adoption of improved cultivars, production technologies and limited access to quality seed and other inputs. In addition, climate variability and change are bringing new challenges as it is estimated that some areas will be getting drier while others will become wetter (Lobell et al., 2008; Battisti and Naylor, 2009). This will result in shortening of the crop growing period and greater moisture stress during seedling and reproductive stages of the crops, resulting in reduced and variable yields. Rising temperatures and changes in moisture are predicted to alter the disease and pest spectrum and dynamics, particularly the distribution, virulence of the pathogens, and emergence of new biotypes of pests affecting these crops (Yadav et al, 2011). Therefore, there is a need to identify traits useful in climatic extremes such as high temperatures and drought, and gain an understanding of the population biology of major legume pests and diseases, and their response to climate change. High throughput phenotypic platforms need to be established to assess critical traits for climate resilience across crop species to develop climate-resilient varieties with tolerance/resistance to key abiotic and biotic stresses.

**Activities**

2.3.1 Test underutilized/neglected species (eg. *P. coccineus*, *P. dumosus* and/or *P. acutifolius*, *V. subterranea*, *L. sativus*) with potential under changing climate scenarios and identify traits useful in climatic extremes such as high temperatures and drought.

2.3.2 Generate new knowledge of the population biology of major legume pests and diseases and their response to climate change.

2.3.3 Study components and genetics of tolerance to drought and heat stresses

2.3.4 Develop high throughput phenotypic platforms to assess critical traits for climate resilience across crop species

2.3.5 Develop climate-resilient varieties with tolerance/resistance to key abiotic and biotic stresses.
Output 2.4: Improved legume cultivars (yielding at least 15% higher) with enhanced resistance/tolerance to biotic and abiotic stresses for different production systems developed

Information and knowledge on the possible changes in expression of resistance/susceptibility to current and potentially new diseases/pests and drought is very limited. We need to use conventional and modern approaches to develop cultivars with adaptation to these stresses in different legumes and agro-eco-systems. There is also a need to develop high yielding legume varieties with improved resistance to biotic stresses and tolerance to abiotic stresses for various agro-ecologies. High yielding varieties with multiple resistance/tolerance to biotic and abiotic stresses need to be developed for sustainable production of grain legumes. Efforts will also be made to develop early- and extra-early legume varieties for short-window cropping systems and drought escape.

Activities

2.4.1 Develop legumes varieties with improved resistance to abiotic and biotic stresses, including the use of inter-specific crosses for various agro-ecologies and crop simulation modeling for effective targeting

2.4.2 Develop high yielding varieties with multiple resistance to biotic and abiotic stresses

2.4.3 Use crop simulation modeling to predict the effect of traits in order to guide decision on key breeding targets

2.4.4 Develop early- and extra-early legume varieties for short-window cropping systems.

2.4.5 Explore (and/or expand/diversify) the use of stable sources of CMS (cytoplasmic nuclear male sterility system) for hybrid production in legumes (pigeonpea, soybean, faba bean)

Output 2.5: Sustainable and efficient seed systems refined and promoted to enhance adoption of farmer-and market-preferred varieties

Availability of quality seed at affordable prices is the first step for increasing and stabilizing production of grain legumes. Marketing seed in small seed packs of 200 to 500 grams has been especially successful, particularly in Africa, for reaching the poor women farmers, who frequent local markets. This strategy has also been attractive to the private sector. In India, where majority of the farmers use their ‘own-saved’ seed or buy seed from neighboring farmers or local markets, there is a need for seed sufficiency of farmer-preferred legume varieties. This is essential to drive adoption and impact of improved legume varieties in the targeted regions so that higher productivity and sustainability are realized. Efforts will be made to identify farmer-and market-preferred varieties in targeted production areas, and analyze efficiency of the legume seed sector storage and marketing capacity of public- and private-sector seed producers to ensure better access to quality seed of the improved varieties. Decentralized, farmer-based seed production, processing, storage and marketing units will need to be established, with the greater involvement of women’s self help groups and farmers’ cooperatives to cater to the local and regional seed demands. Seed policies should encourage for greater involvement of the private seed sector, which has been very limited. Efforts will also be made to enhance the capacity of public/private seed sector institutions to increase the availability of quality seed to the legume farmers at affordable price.

Activities

2.5.1 Identify farmer-and market-preferred varieties through participatory varietal selection (PVS) in targeted production areas.

2.5.2 Develop DNA fingerprinting profiles and purity test kits for seed quality assurance

2.5.3 Analyze efficiency of the legume seed sector storage and marketing capacity of public- and private-sector seed producers to ensure better access to seed of new varieties, including small seed pack approaches.
2.5.4 Establish decentralized, farmer-based seed production, processing, storage and marketing units with greater involvement of women’s groups to cater to the local and regional seed demands.

2.5.5 Enable seed policies to diversify and expand the legume seed sector through the participation of the private sector and farmer groups.

2.5.6 Enhance the capacity of public and private seed sector institutions in seed systems.

**Output 2.6: Gender-balanced research capacity of national programs enhanced**

Knowledge and skills for interdisciplinary, inter-institutional and multiple-stakeholder problem solving will be strengthened to increase the production and productivity of grain legumes. There is a need to train young scientists, especially women, of the developing national programs in integrated breeding and management of grain legumes. Women take a major role in the growing of legumes, and are involved in weeding, harvesting and marketing of legumes. Therefore, there is a need for interventions to increase their incomes and reduce drudgery. Efforts will also be made to train farmers and extension personnel, particularly women, to carry out participatory varietal selection, and establish NGOs and women self help groups that specialize in seed production, processing and marketing of grain legumes.

**Activities**

2.6.1 Strengthen the knowledge and skills needed for successful gender-sensitive, interdisciplinary, inter-institutional and multiple-stakeholder problem solving.

2.6.2 Training young scientists (especially women) of the national programs in integrated breeding and crop management approaches.

2.6.3 Training /sensitizing potential groups of farmers, especially women, towards increasing the use of grain legumes

2.6.4 Training farmers and extension personnel, particularly women, to carry out participatory varietal selection of legume crops.

2.6.5 Establish women and youth groups that specialize in seed production, processing and marketing of legumes.

**Phasing of Objective Components**

The Phase I (four years) will initiate (i) genome sequencing of selected legume crops and high-throughput marker genotyping platform, (ii) establishing global legume phenotyping network, (iii) development and evaluation of specialized germplasm sets and under-utilized crop species, (iv) identification and deployment of molecular markers for breeding for resistance/ tolerance to biotic/ abiotic stresses, (iv) fast-tracking of suitable legume varieties using farmer participatory variety selection (FPVS), (v) enhance the capacity of public and private seed sector systems, (vi) capacity building of young scientists in the area of integrated crop breeding and training farmers and extension personnel in participatory selection and increasing the use of legume crops. The Phase II (three years) will be devoted to: (i) analyze genome sequence for genetic dissection of traits conferring resistance/ tolerance to biotic and abiotic stresses, (ii) use of structural, functional and comparative genomics to understand gene expression and gene isolation, (iii) accelerate use of molecular breeding approaches (MAS, MARS) and FPVS for developing superior legume varieties, (iv) development and sharing of superior lines including climate resilient legume germplasm with NARS partners, (v) accelerated development and characterization of transgenic lines, (iv) production of adequate amounts of breeder and foundation seeds of farmer-preferred varieties, and (v) continuation of capacity building and training activities. The Phase III (four years) will include: (i) routine use of molecular breeding (MAS, MARS, GWS) and FPVS in breeding program (ii)accelerated
breeding of new farmer- and market-preferred as well as climate-resilient legume varieties, (iii) continued production of adequate amounts of breeder and foundation seeds of farmer-preferred varieties by NARS and IARCs, (iv) better access to seeds of superior varieties and hybrids through strengthened public and private seed system, and (v) continued capacity building and training activities to the stakeholders.

GLVA Objective 3: Nutritious, safe grain legumes

Overview
Carbohydrate rich foods that are more affordable for the poorest section of society (Burslem, 2004) lead to dietary imbalances. Therefore, protein malnutrition (or protein calorie malnutrition) continues to be a major public health concern in developing countries, particularly in infants, young children, pregnant and nursing mothers. One out of five persons in the developing world is chronically undernourished and nearly 200 million children suffer from protein malnutrition (Pellett, 1996). Micronutrient deficiencies such as Zn and Fe also create havoc in poor communities. Legumes are much richer sources of micronutrients compared to cereals (Welch 2002, Hemalatha et al. 2007). HarvestPlus has taken the lead with the biofortification of common beans, and high mineral varieties are now being released. Harvestplus sponsored a bioefficacy study with high iron beans in Mexico that showed a beneficial effect on iron status (Haas et al. 2010), which can be extended to other countries where HarvestPlus does not work. This objective will focus on development of legume varieties with higher protein and micronutrient contents and reduced levels of anti-nutritional factors, and containment of Aflatoxin contamination. Nutritionally speaking, the world’s poor now face a double threat (Burslem, 2004; Tanumihardjo et al., 2007). Alongside undernutrition, poverty drives them to consume cheap energy rich foods, which trigger a chain reaction of chronic or non-communicable diseases (NCDs) such as diabetes, cancer and cardiovascular disease. In Latin America, diabetes is estimated to drain $64 billion annually (Barceló et al., 2003), and NCDs are now appearing in urban Africa. The USDA now puts high priority on increasing consumption of legumes to combat NCDs (USDA, 2010). In developing countries where legume consumption is traditional, health workers, policy makers and consumers need to be made aware of the beneficial implications of a diet that includes legumes before this healthy custom is lost. While CRP 4 (Health and Nutrition) focuses its research on biofortified beans in Rwanda, GLVA seeks to work on nutritional quality traits of other legumes in target countries.

Vision of Success
In the regions where legume consumption is significant, and that are targeted by GLVA (Sub-Saharan Africa, South and Southeast Asia, Latin America and Caribbean, Central and West Asia and North Africa), an estimated 223 million preschool children and 127 million women are anemic (http://www.harvestplus.org). Most countries in Sub-Saharan Africa and Asia have high prevalence of anemia. Breeding of common bean and lentil for HarvestPlus focal countries will be extended to all countries, with a significant bean and lentil consumption. High mineral common beans have already been released in several countries, and this should be expanded in Phase 1 (within 3 years). The groundwork will be laid for breeding groundnut, chickpea and pigeonpea as important sources of protein, especially in the diets of the poor in the semi-arid tropics or drylands of Asia and Africa. Release of other high micronutrient legumes will initiate in Phase 2 (years 4-7). At least 20 million legume producers and consumers in target areas will be reached by year 10 with nutritionally improved legumes. Health and agriculture workers, policy makers, and the general public will be made aware of the benefits of legume consumption, and the best methods of legume processing and preparation, and thus, help to maintain levels of consumption among populations that traditionally consume legumes as part of their daily diets.
Challenges, Opportunities and Synergies

Opportunities to exploit legumes for nutrition can be observed in a growing appreciation for the potential for agriculture to contribute to public health. Biofortification is now recognized as a viable tool to be employed together with increasing the diversity of diets. In this broad based effort, legumes have a special role to play. Legumes are also known for their beneficial effects on reducing some of the chronic diseases. GLVA will link with the ARIs that are studying the effects of legume consumption on chronic and other types of diseases. The presence of the CGIAR throughout the developing world offers the opportunity to publicize results globally and within developing countries.

Advances in genomics can make a contribution by focusing on specific genes for protein and micronutrient accumulation, and this can be employed across legume species. HarvestPlus has demonstrated the feasibility of improving micronutrient concentration in some crops and this can be extended to other crops and regions. In addition to enhancing protein and micronutrient concentrations, there is a need of reducing anti-nutritional factors in some legumes, such as β-N-oxalyl-1-α,β-diaminopropionic acid (ODAP) in grasspea and flatulence inducing oligosaccharides in common bean and chickpea. The bioavailability of particular nutrient in grains can be changed substantially by processing. For instance, de-hulling, soaking in water, seed germination and boiling significantly reduce polyphenols. Sprouting is known to reduce phytate in mung bean (AVRDC, 1994) and flatulence inducing oligosaccharides in chickpea (Aman, 1974). Slight modifications to traditional recipes can also produce significant improvements in nutritional value. The development of improved homestead gardens has been shown to be a particularly valuable intervention to improve the nutrition of women and children. These have a long history of implementation in Bangladesh and are now being expanded to Southeast Asia and West Africa (HKI, 1991; Talukder et al., 2000).

### Table 5.5. Priorities on nutrition and anti-nutritional factors across legumes

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2 No star = not important, * = low importance, ** = medium importance, *** = high importance
Challenges that have been experienced in biofortification are those that are standard to all breeding programs: those of combining multiple traits under quantitative genetic control; and problems of genetic linkage drag or unadapted sources. Yet these challenges have been overcome with persistence and recurrent selection. Still greater challenges are either to encourage greater diversity in diets which can mean increasing the range of legumes and legume products consumed or to target the promotion of biofortified crops on specific vulnerable populations. These latter challenges are perhaps easier, with the help of NGOs and local organizations in direct contact with the target population.

R4D questions
- What is the potential upper limit for enhancing nutritional quality of grain legumes, and what if any tradeoffs are incurred as nutrient contents are raised?
- How can the retention and stability during cooking of micronutrients and vitamins in grain legumes be improved?
- What is the bioefficacy and bioavailability of micronutrients from legume-based diets in improving the nutrition and health of children and women and preventing/mitigating human diseases?
- How can better communication improve the dissemination of information and the adoption of nutritious legume cultivars to improve health and nutrition of smallholder families?

Exciting Opportunities
- Development of low cost, high protein and micronutrient dense varieties of legumes
- Groundnut varieties with a high oleic/linoleic fatty acid ratio
- Varieties with low levels of anti-nutritional factors for improved nutrient bioavailability
- Novel processing options and products for reducing anti-nutritional factors and enhancing availability of nutrients
- Protocols for legume-based products with no or reduced levels of mycotoxins

Key Measurable Indicators
- Most needy target populations identified in at least 12 countries, and potential contribution of legumes for specific nutrients estimated for those populations based on likely consumption and bioavailability
- Identify four best bet legumes/cultivars identified to increase daily iron intake by 1.5 mg.
- G x E effects estimated for 8 crop-nutrient combinations.
- At least 20 high protein and 20 high Fe and Zn lines of 5 legumes made available for evaluation in malnutrition dominated areas in South Asia and Sub-Saharan Africa
- At least 20 low ODAP lines of grasspea made available for evaluation in South Asia and Sub-Saharan Africa
- At least two groundnut genotypes with improved oleic/linoleic ratio of fatty acids available for evaluation
- Defined recommendations to reduce post-harvest mycotoxin contamination in 2 legumes
- Three legume-based complementary (weaning) food preparations developed to maximize nutritional value for young children, and tested as potential micro-enterprise options for women.
- Retention of pro-vitamin A carotenoids determined for 2 legumes under typical storage and preparation methods.
- Availability of at least 2-3 legumes for introducing improved legumes with low antinutritional traits in diet and/or through food modification methods
- Management and food processing options to increase nutrients content and reduce anti-nutritional factors developed in at least 2 legumes.
Impact Pathways
Enhanced public health benefits, enhanced purchasing power, increased market demand for new improved nutritious legume varieties and products, and improved health status of the poor rural and urban population, especially women and children shall be the key impact indicators of this objective. At the farm-level the activities shall impact the productivity, nutritional quality and profitability of grain legumes and the livelihoods of small-holder farmers, and, ultimately improve the nutrition and health of the consumers. We envision availability of affordable and nutritious legumes for both the rural and urban poor leading to enhanced consumption of legumes resulting in improved health and nutrition. The impact would be assessed primarily by monitoring the consumption pattern of legumes by the poor in rural and urban areas. This data shall be linked to the improved health conditions of the rural and urban poor, especially women and children. In addition, health conditions of target populations shall also be enhanced due to adoption of improved varieties along with improved household food preparation techniques. A targeted reduction in incidence of malnutrition among children and health status of women in these populations shall be a good indicator of the impact of this objective at macro level. Focus on providing aflatoxin and mycotoxin free legumes will have a positive impact on the health of the population. The impact on health due to consumption of toxin free grain legumes shall be perceived over a period of time. However, the immediate target shall be to increase trade due to availability of toxin-free legumes, especially aflatoxin free groundnut. Increase in trade of legumes shall result in higher export earnings. Monitoring the adoption of improved nutritious varieties of legumes by the food and feed industry shall be part of the impact assessment of this objective.

Research and Development Partners
The SRF notes that researchers in “nutrition, infection and chronic disease” and even within each of these categories, there are separate sub-communities for iron, for zinc, for vitamin A, for diabetes, etc. The SRF notes that these require “separate institutional arrangements with health research communities.” such as University of California, Davis (iron); Cornell University (zinc); University of Wisconsin and Iowa State University (vitamin A); Michigan State University and Colorado State University (cancer); Instituto Nacional de Salud Pública, Mexico (diabetes); Michigan State University (HIV/AIDS); University of Saskatchewan (polysaccharides); Instituto de Investigación y Formación Agraria y Pesquera de Andalucía, Spain (antinutritional factors); Ghent University, Belgium (low vicine Convicine, and ODAP). Researchers at several of these institutions have already expressed a desire to collaborate in joint research. This objective will have strong linkages with HarvestPlus and AgroSalud and the research institutions in the United States, Canada and Australia who work on legumes and health. Researchers at several of the institutions have already expressed a desire to collaborate in joint research. Communication network established in CRP 4 will be used to exchange the latest information regarding effects of legumes on chronic disease and legumes as sources of micro and macro-nutrients, including a web page with relevant refereed publications. Funding permitting, a conference of nutritionists and agriculturalists will be held every three years to update each other mutually.

Empowering Women
Women and children (the most vulnerable groups) will be the primary clients of this Objective. Since women play a critical role in the intervention in nutrition education component, they must be the focus of the communication strategy, both for their own health, and in light of their role as care givers, homemakers (including food preparation) and those in charge of homestead. Women play a central role concerning the impact of legume preparation on food value, and the role of legumes in improving the nutritional value of homestead gardens. The most likely role of legumes is in improving maternal health, especially during pregnancy, which in turn impacts on infant health. The IFPRI Conference on Leveraging Agriculture for Health and Nutrition (10-12 Feb 2011, New Delhi, India)
identified women as key enablers in the integration of the three viz. sectors: Agriculture, Health and Nutrition. Also increasing the consumption of legumes by women and children could help to break the cycle of “intergeneration disadvantage” among women being passed from one generation to another due to lower consumption of proteins and micronutrients during pregnancy and post-natal care. It is estimated that legume consumption could provide over three-fourth of the protein and one-fourth to one-fifth of recommended nutrient intake (RNI) of minerals like iron, zinc, calcium, etc. (see also Chapter 7 on Gender Research Strategy)

**Outputs and Activities (Key Milestones are given in Chapter 13 on M&E)**

**Output 3.1: Legume gene pools and varieties with enhanced nutritional value developed**

In addition to protein malnutrition, micronutrient malnutrition is a serious health problem affecting more than half of the world’s population. Partnering with CRP 4, we will determine the nutritional needs of specific populations, especially women and children, identify research gaps based on consumption, bioavailability, and retention. Genetic variability for key nutritional quality traits will be identified in the cultigen and the wild relatives for use in pre-breeding. Varieties with enhanced levels of iron and/or zinc, pro-vitamin A carotenoids, and protein; and reduced levels of anti-nutritional factors will be developed. The relationship between nutritional traits and/or anti-nutritional factors with productivity and resistance to diseases and/or insect pests will also be established. Nutritional traits will be combined with a range of agronomic traits to facilitate their adoption as varieties in the short run, but eventually high nutrient varieties with a broad suite of agronomic traits must be developed, to improve the probability of adoption and subsequent impact.

**Activities**

3.1.1 Determining nutritional needs of specific populations (especially women & children) in context of global food systems.

3.1.2 Determining research gaps and feasible target levels (based on consumption, bioavailability, preparation, retention).

3.1.3 Analyzing genetic variability of legumes for key nutritional traits.

3.1.4 Identification/isolation and characterization of useful genes, related to nutritional quality traits, from wild relatives and use them in pre-breeding.

3.1.5 Develop varieties with enhanced levels of iron and/or zinc, pro-vitamin A carotenoids, and protein.

3.1.6 Develop varieties with lower levels of anti-nutritional factors.

3.1.7 Develop groundnut varieties with a high oleic/linoleic fatty acid ratio.

3.1.8 Determine the relationship of nutritional traits and/or anti-nutritional factors with productivity and resistance to diseases and/or insect pests.

**Output 3.2: Pre- and post-harvest management options to optimize nutritional value developed**

Legumes are recognized as healthy components of a balanced diet, and as a traditional food that should not be lost as societies develop economically and urbanize. Non-genetic factors have significant effects on the nutritional value of foods. This may take the form of enhancing nutrient concentration of the raw product coming from the field through simple processing such as dehulling, splitting or sprouting, reducing losses during storage, and processing to enhance the bioavailability of the nutrients in the consumed product. Other practices serve to reduce anti-nutritional and health risk factors such as mycotoxin contamination (in groundnut); ODAP (in grasspea); RFOs (in chickpea); vicine and convicine (in faba bean). Some practices such as fertilization with zinc may
increase the concentration of zinc in the grain as a micronutrient or reduce levels of ODAP. Infants and young children consume relatively small amounts of legumes, but preparations of complementary foods may permit contributing to a solution of infant nutrition. The potential of homestead gardening approaches to enhance the nutritional impact of grain legumes will also be assessed for improving the nutrition of the rural poor.

Activities

3.2.1 Developing crop management and food processing techniques that enhance nutritional quality or reduce anti-nutritional or toxic factors.

3.2.2 Assessing the potential of homestead gardening approaches to enhance the nutritional impact of grain legumes.

3.2.3 Developing post-harvest techniques that enhance nutritional quality or reduce anti-nutritional or toxic factors.

Output 3.3: Communication networks that enhance research capacity and outcomes promoted

Both policy makers and the public in general need to be made aware of the benefits of using grain legumes in daily diets to improve nutrition and health, and to reduce the risk of chronic disease that both developing and developed countries are now experiencing. Efforts will be made to publicize current knowledge about legumes and health, including that generated by research groups in advanced institutions in partnership with ARIs, NARS, NGOs, women self help groups, and the food processing industry. Interaction with the various stakeholders will open up the opportunities for research on other legumes of the CRP. Legumes also have potential to be made even more healthier, especially as sources of micronutrients. The experience of HarvestPlus and AgroSalud in genetic improvement of common bean should be shared with others and used as model to facilitate genetic improvement of legumes for nutrition and health.

Activities

3.3.1 Establish and enhance linkages to the nutrition community working on legumes.

3.3.2 Advocacy and raising awareness for nutritional benefits of grain legumes.

3.3.3 Building capacity of researchers (including women) in developing nutritionally enhanced legume products, and in communicating with the nutrition community.

Phasing of Objective Components

Phase 1 (3 years) will initiate: (i) transferring of high iron common beans and lentil into the varietal testing stage and their release in an increasing number of countries in Latin America and Africa, (ii) determination of genetic diversity and the potential for genetic improvement for other legumes, (iii) development of low ODAP breeding lines and their distribution to NARS partners in south Asia and sub-Saharan Africa, (iv) fine tuning of biofortified crops to the sub-national level, and (v) scientific discussions about the healthy benefits of legume consumption by organizing one conference and dissemination of outcomes to policy makers, consumers, etc. Phase II (3 years) will be dedicated to: (i) monitoring adoption of micronutrient rich common beans, (ii) accelerated breeding of micronutrient rich common beans and lentils, (iii) transferring of high iron lines to the varietal testing scheme and reaching the pre-release phase, (iv) extension of studies with partners in ARIs on non-communicable diseases to other legumes besides common beans and soybeans, and (v) incorporation of knowledge on health benefits of legumes into consumer education messages in Latin America, Africa and South Asia. Phase II I (4 years) will have: (i) established full-fledged breeding programs for high micronutrient legumes in IARCs and some NARS, (ii) bioefficacy trials
with other legumes in other cultural settings by partners from ARIs and (iii) dissemination of micronutrient rich legumes in addition to beans initiates in at least 10 countries.

GLVA Objective 4: Grain legumes for sustainable intensification

Overview
Food security requires increasing the productivity of every hectare of land. Yet the land is degrading due to the intensification of cereal systems. For example, total factor productivity has declined significantly in the intensive rice-wheat cropping system in the Indo-Gangetic Plains of South Asia despite high and increasing fertilizer rates. For most resource-poor farmers in developing countries, fertilizer is not an option, so the soil is being mined of nutrients through food production is increasing. Estimates of soil nutrient losses in Sub-Saharan Africa, Asia and Latin America suggest a current net removal of between 20 and 70 kg ha\(^{-1}\) of N from agricultural land each year. Replacing soil nutrients in sub-Saharan Africa alone would cost at least US$4 billion annually.

Grain legumes possess an enormously valuable trait the ability to fix atmospheric nitrogen, through biological nitrogen fixation (BNF), into plant-available forms. They effectively make their own nitrogen (N) fertilizer and also leave significant amounts of N, in the soil that benefit subsequent crops (Bado et al. 2006; Kumar Rao et al. 1998; N2 Africa Project). The proportion of total N in legume plants sourced from atmospheric fixation varies widely (0-95%) depending on factors such as the crop species, the availability of soil soluble N, the availability of suitable rhizobia, the suitability of soil conditions for productive symbiosis, and other environmental factors. Understanding the genetic factors underlying these differences could make a major contribution to increasing the overall contribution of BNF to crop productivity.

Thus, BNF increases total system biomass production on agricultural lands, increasing land cover by leafy plants that protect soils from exposure to wind and water erosion. Growing legumes contributes to intensifying cropping systems, and diversifying them promotes sustainability. Policy analysis and advocacy is needed to sensitize policy makers to the importance of grain legumes to sustainable intensification of cropping systems and to encourage them to invest in input support systems for legume farmers as is the case for cereal farmers.

Because of their high nutritional value, legumes are as equally attractive to insects and diseases, as they are to humans and livestock. Breeding has overcome some of these problems, but pesticide applications are needed for many pest problems. Our vision at the production level is to expand pest and disease management options to include integrated pest management approaches, especially with biopesticides—particularly those that may have application across legumes. Crop rotation and intercropping practices using grain legumes will reduce the intensity of weeds, diseases and other pests that are growing in importance in cereal-dominated cropping systems. Resilient cereal-legume cropping systems will result in more stable crop production and reduce vulnerability in areas threatened by climate change.

Vision of Success
Our vision is to reduce environmental degradation by increased cultivation of legumes in cereal cropping systems through crop rotation and intercropping, and reducing over dependence on inorganic fertilizers in intensified production systems by providing legume varieties with enhanced nitrogen fixing capacity. At the global level, our vision is a better understanding of the genetic and situational constraints on biological nitrogen fixation (BNF), and to enhance it across legume species.
At the production system level our vision is to clarify the best cropping rotations, varieties and systems to increase the benefits of BNF in situations where it is most likely to reduce poverty and environmental degradation. Land degradation and nutrient depletion is particularly severe in sub Saharan Africa, particularly in arid areas such as the Sahel and over populated areas such as the great lakes region of East Africa.

Challenges, opportunities and synergies
The tendency by producers to allocate more fertile land to staple cereals have pushed the cultivation of food legumes into marginal and sub-marginal areas which are characterized by poor soils, frequent occurrence of biotic and abiotic stresses, fragile environments and short growing seasons. Agricultural soils in many parts of the world, particularly the tropics, are low in nitrogen content and are generally degraded. This is the result of continual depletion from the soil pool by processes such as volatilization, leaching and removal of nitrogen-containing harvest products and crop residues from the land. Legume cultivation has a paramount effect in reversing land and soil degradation through a series of complex interactions involving soil water, nutrient supply and interruption of pest cycles. For example, the net soil nitrogen accrual from the incorporation of grain legume residue in the soil can be as much as 140 kg N/ha (Giller, 2001). Thus, using legumes in the farming system will help reduce dependence on mineral N fertilizer for cereals, which reduces the cost of production for farmers and minimizes environmental pollution. Studies show that grain legumes contribute more than 20 million tons of fixed N to agricultural crops each year (Herridge et al., 2008). However, BNF is one of the most sensitive processes to abiotic stresses such as drought (Sinclair and Serraj, 1995; Serraj et al., 1999), which reduces legume yields and their potential benefit in the rotations. Therefore, a special effort is required to identify legumes and rhizobium strains that are better adapted to environmental stress. In addition, legumes that are efficient at acquiring phosphorus from high fixing soils are needed in order to increase the benefits from BNF. Use of legume varieties that are efficient at acquiring phosphorus from less available sources would also benefit subsequent cereal crops such as maize.

Past research on legume N fixation has largely been driven by a commodity based plot- or field-scale approach, despite the increasing realization that natural resource management has to be tackled at the system scale. Farmer-led evaluations of suites of promising N2-fixing legume-based technologies will lead to rapid understanding of local adaptation and potential from the variety of available legumes. A major aim must be to break down commodity-related barriers to allow a focus on the wide role of legume nitrogen fixation within the farming systems in stimulating productivity and contributing to sustainability.

The positive rotational effect of legumes on subsequent crops goes well beyond BNF benefit. The ‘push-pull’ technology developed by International Centre for Insect Physiology and Ecology (ICIPE), Rothamstead Research and national partners is one of the best examples of ecological engineering for integrated pest, weed and soil management in cereal-livestock farming systems. Stem borers are attracted to Napier grass (*Pennisetum purpureum*), a trap plant (pull), and are repelled from the main cereal crop using a repellent legume intercrop (push), desmodium (*Desmodium* spp.). Desmodium root exudates effectively control the parasitic *Striga* weed by causing abortive germination. Desmodium also improves soil fertility through nitrogen fixation, natural mulching, improved biomass and control of erosion. Both companion plants provide high value animal fodder, facilitating milk production and diversifying farmers’ income sources (Khan et al., 2011).
Table 5.6. Opportunities for addressing system resilience issues across crops

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² No star = not important, * = low importance, ** = medium importance, *** = high importance

R4D questions

- How can cross-legume studies of gene expression be designed to usefully elucidate controller genes that determine trait expression for BNF in grain legumes?
- Can the characterization of mechanisms of P mining and deep root growth allow more rapid targeting of syntenous genes in related species?
- Do indigenous *Rhizobium* strains exist that are more stable in adverse and variable environments than those currently available?
- Can productivity of legume-cereal cropping system be substantially improved by optimizing the interaction between the legume genotypes, *Rhizobium* strains, and agro-environmental conditions?
- How can modeling be used and customized to more effectively contribute to the productivity of farming systems and facilitate the introduction of specific legumes to marginal lands and new niches?
- Can legume root-microbial interactions improve crop tolerance to soil borne pathogens and enhance phosphorus and micronutrient uptake?
- What kinds of supporting evidence would be most effective for informing policy deliberations to increase the cultivation of legumes for more sustainable intensification?
Exciting Opportunities

• Cross-legume comparative studies on BNF and adaptation to poor soil and marginal environments.
• Capitalizing on BNF for reduction in use of N fertilizers
• Benefits to soil health and cropping system productivity
• Reduction in pesticide residues in legume products
• Expanding legume cultivation in rice-fallow
• Influence of legume root-microbial and endo-symbiont interactions on crop tolerance to pathogens and insect pests

Key Measurable Indicators

• Listing of technical and management interventions that are most likely to improve BNF and system productivity in areas with high incidences of poverty.
• Collation of innovative legume cropping systems used by smallholder farmers that are more productive or that have particular benefits for pest and disease control, and evaluation of their biological and economic benefits and potential for wider adoption.
• Number of sources of high BNF and P use efficiency identified for each grain legume
• Number of breeding lines with enhanced BNF identified/developed and shared with partners
• Number of integrated legume-based production technologies developed in target countries
• Number of private industries that produce and market inoculants identified and linked with farmers in target countries
• Strong research-extension-farmer linkages in target countries are made available
• Improved and cost-effective information dissemination pathways used in major legume
• Modeling studies on the contributions of legumes to the overall productivity of farming systems to assess their overall economic benefits – particularly the contribution of improved BNF, and opportunities for expanding legumes to new areas and cropping systems.
• Policy studies completed to assess the macro-economic benefits of enhanced legume use to reduce reliance on fertilizers and pesticides, and the benefits of supporting inputs and markets for legumes at the national and local levels.

Impact Pathways

Increasing commercialization of agriculture is causing degradation to natural resources (soil health, and water and air quality), which ultimately impair human and animal health and their productivities directly or indirectly. This objective will focus on (i) promotion of grain legumes to enhance availability of biologically fixed nitrogen to reduce use of chemical fertilizers in intensive cereal-based cropping systems; and to develop and disseminate environment-friendly pest management technologies for legumes to reduce pesticide use without causing any adverse effect on crop yields.

Baseline surveys will be established in the target domains to assess tangible and intangible benefits of wider adoption of these technologies. The main impact indicators at the farm-level will include: changes in fertilizers and pesticide use in different cropping systems, changes in crop yields, changes in cost of production, farm incomes, human and animal health. The changes will progressively lead to reduced vulnerability, higher production, improved food security, increased marketed surpluses, higher incomes, and improvements in sustainability of the agro-ecosystems. Farmers may encounter many problems in adoption of these technologies especially pest management which is knowledge-intensive. These will be documented to draw lessons for future research.

A database on economic and environmental indicators will be developed and used to scale up benefits of biological nitrogen fixation and pest management technologies. This will be done in close collaboration with social scientists. The major clients of this initiative will be legume breeders and agronomists, policy analysts, governments, NGOs and the private sector. The initiative will enhance
the client orientation and impact of legume R&D, helping development partners, governments and local actors to translate outcomes into concrete progress toward higher-level development goals.

Research and development partners
Research will be carried out by the GLVA partners in close collaboration with national research programs, advanced research institutes, universities, and the private sector. This objective will work closely with BMGF funded N2 Africa Project in target countries. The advanced research institutes will be mainly involved in upstream research, while all location-specific technologies will be developed and tested in partnership with national research programs. The work on rhizobia biodiversity and genomics will be carried out in partnership with NARS and ARIs. Efficient production and delivery systems for Rhizobium inoculum will be done with Rhizobium manufacturing government sectors and industries, N2 Africa Project and NGOs. The work on integrated soil and crop management, policy advocacy and capacity building will be done in partnership with NARS institutes and NGOs.(see more details in Chapter 6 on Partnerships)

Empowering Women
Technologies related to Rhizobium, biopesticides and overall system intensification are gender neutral. Gender mainstreaming will enable identification of potential opportunities to ensure successful introduction of interventions in ways that will enhance family income and livelihoods. In this way, farmers’ uptake and benefit from improved agricultural technologies will not be jeopardized because of underlying household interactions. In contrast, the opportunities to build upon the advantages of, for example, women’s participation because of their crucial role in household economies and welfare, will be also be enhanced. This will be facilitated through identification and involvement of female extension agents, their training, where needed in gender mainstreaming, and organizing focused group meetings and workshops to ensure gender mainstreaming is internalized by partners. Other participatory strategies at community level will also be used to promote appreciation and understanding of the importance of gender roles, and thus help communities develop strategies to enhance their livelihoods through increased participation of women. It is recognized that in some communities the religious and cultural context will demand that separate male and female groups work on such issues; in others, joint participation will be possible. Starting in this way at the community level will ensure that equity is promoted, while simultaneously encouraging individual, community, and group initiatives to take ownership and responsibility for the implementation of activities. (see also Chapter 7 on Gender Research Strategy).

Outputs and Activities (Key Milestones are given in Chapter 13 on M&E)

Output 4.1: Enhanced N2 fixation efficiency of legumes
Grain legumes possess an ability to fix atmospheric nitrogen into plant-available forms, and also leave significant amounts of N in the soil that benefits the subsequent crops (Bado et al. 2006; Kumar Rao et al. 1998). They provide an important alternative means of maintaining or increasing soil nitrogen levels as compared to nitrogen fertilizers, which are both energy intensive to produce and often beyond the financial reach of smallholder farmers. Grain legumes also leave considerable amounts of organic matter in the soil through leaf fall, and the root mass in the rhizosphere. Species and varieties vary in the amount of nitrogen they provide to following crops. Herridge et al. (2008) estimated that 50% of N fixed by a chickpea crop remains underground; 33% for soybean; and 30% for other grain legumes. Greater gains may be possible from crops or varieties of longer duration such as multi-purpose soybeans selected for vegetative growth, climbing beans, indeterminate
cowpea, faba bean and long-duration pigeonpea. This objective will focus particularly on the effect of drought on N fixation, develop and use protocols to breed for effective manipulation of BNF efficiency, and understand the biodiversity of Rhizobia and other beneficial microorganisms for increasing productivity of grain legumes. In addition, there is a need to develop production and delivery systems for quality products of Rhizobia and other beneficial micro-organisms.

**Activities**

4.1.1 Study the genetic basis of legume response under drought conditions to phosphorus and BNF.

4.1.2 Compare BNF across legume species to understand and harness key mechanisms contributing to high BNF potential across a range of constraints.

4.1.3 Develop and use new protocols in legume breeding for effective manipulation of BNF efficiency.

4.1.4 Understanding biodiversity of Rhizobia and other beneficial microorganisms for grain legumes.

4.1.5 Identification and development of legume germplasm that integrates BNF/P efficiency with stress adaptation in different cropping systems.

4.1.6 Develop efficient production and delivery system for Rhizobium and other beneficial microorganisms.

4.1.7 Technology for efficient products of Rhizobia and other beneficial microorganisms transferred to NARS for dissemination of BNF technologies for increased adoption.

**Output 4.2: Integrated soil and crop management for sustainable intensification**

The intensification of agricultural production systems through better crop management practices such as high yielding crop varieties, fertilizers and pesticides has led to serious problems of land and environmental degradation. Due to increasing pressure on land, traditional fallow systems have declined, resulting in significant losses of soil fertility and biodiversity. Soil productivity continues to decline, as the current farming systems are both unproductive and unsustainable. Rising concerns over possible negative environmental effects of chemical fertilizers and pesticides, necessitates the need to expand the use of alternative technologies that offer the greatest environmental and economic benefits for resource poor farmers. Growing legumes contributes to intensify cropping systems, and diversifying them will promote sustainability of the farming systems. Technologies and integrated approaches are needed that recognize the centrality of smallholder farmers and adequately address issues of the environment and the need for integrated crop, soil fertility and pest management options.

**Activities**

4.2.1 Compare legumes for specie-specific adaptation traits to understand, capitalize, and extrapolate to less endowed species.

4.2.2 Develop and test models on contribution of the legumes to improve productivity of farming systems across diverse agro-ecological systems.

4.2.3 Develop and disseminate integrated soil, water and crop management to optimize effects of legumes in the cropping systems.

4.2.4 Develop and promote eco-friendly biopesticides as a component of IPM/IDM for grain legume based cropping systems.

4.2.5 Intensification of cropping system with legumes (eg. legumes in rice fallows and other niches)
4.2.6 Evaluate different legumes species to identify new legume options for crop niches.

**Output 4.3: Policy suggestions and enhanced capacity for sustainable intensification of cropping systems with legumes**

Enabling policy environment is critical to sensitize policy makers and researchers to the importance of grain legumes and their ability to fix atmospheric N for sustainable cropping systems, and to encourage investments in input support systems for Rhizobium inoculum, beneficial microorganisms, bio-pesticides, and the grain legume growers in general. Opportunities for introduction and expansion of legume-based technologies will be based within a whole systems approach to ensure an optimal contribution to productive and sustainable agriculture. Proven legume based technologies should be widely adopted by the farmers through the creation of suitable environment for their cultivation and support price to reap the benefits, and improve the capacity to mitigate the risks related to the use of beneficial microorganisms for crop production and crop protection. The adoption of legume-based technologies will not only improve biophysical condition of the soil, but also help in enhancing the socio-economic resilience of smallholder farmers by improving the stability of cropping systems.

**Activities**

4.3.1 Identify inoculum supply constraints including those related to quality and regulatory systems for developing policy suggestions.

4.3.2 Determine feasibility and risks associated with application of beneficial microorganisms and biopesticides.

4.3.3 Develop efficient strategies and adequate institutional environment, to provide incentives to farmers for adopting N2-fixing legumes.

**Phasing of Objective Components**

The first three year phase will involve collating information and data on legumes in cropping systems and their contributions to overall productivity, and document to what extent BNF contributes to overall system productivity and the constraints. We will also compile data on innovative uses of legumes particularly in innovative intercropping or relay cropping systems, to better understand the biology, pest and disease management aspects of less mechanized but often highly productive smallholder farming systems. This phase will help to put the range of potential improvements in BNF into context. In the second phase detailed studies on cross-species studies of Rhizobium and BNF will be undertaken to understand the options to select for improved BNF. This will involve genetic studies of both host plant and Rhizobia strains and microbiological studies of cocktails of rhizobial strains, mycorrhiza, endophytes and trace elements with potential to enhance biological activity. A key aim of this phase will be a full understanding of the genetic and biological factors affecting BNF, opportunities to exploit it. The constraints in exploiting BNF and means to overcome will also be studied. This will involve crop management research as well as research on marketing strategies, supportive policies and institutional arrangements to ensure sustainable supplies of high quality and appropriate inoculum. The third phase will involve modeling, using data generated in first and second phases to help decide which specific legumes use/introduce in marginal land areas and new niches, besides guiding policy makers on the macro-economic benefits to overall cropping system productivity of improved BNF and how much fertilizer and costs are saved at the national level through use of legumes.
6. Partnerships

GLVA will generate IPGs (international public goods) that will be customized to meet local needs and conditions by partners. To connect global intent to local action GLVA will harness well-established regional networks. GLVA partners have found regional networks to be highly effective for accelerating impact and strengthening capacities. However the focus of those networks has in the past been largely limited to germplasm issues. GLVA will assist the regional networks to widen their scope and impact along the value chain.

We begin by outlining the impressive network resources that are available on grain legumes (fuller expositions on each are in Appendix 4):

**Africa**

- PABRA (Pan-Africa Bean Research Alliance) is a consortium of sub-regional bean networks: ECABREN (Eastern and Central Africa), SABRN (Southern Africa) and WECABREN (West and Central Africa). PABRA is quite large, with 350 direct and indirect partners from NARS, IARCs, donors, NGOs, sub-regional organizations (ASARECA, SADC-FANR, CORAF), community-based organizations, seed producers, traders and the commercial private sector.
- PRONAF (Projet Niebe pour l’Afrique) on cowpea in West Africa
- NGICA (Network for the Genetic Improvement of Cowpea for Africa) an informal but progressive international network applying modern ICT and biotechnology

**Latin America and the Caribbean**

- PROFRIJOL (bean network - funding expired but fruitful relationships continue)
- AgroSalud (regional biofortification project including bean)
- PCCMCA (Central America regional agronomy meetings including bean)

**Central and West Asia and North Africa**

- WANA Regional Seed Network
- Nile Valley Regional Food Legume Network includes three sub-networks: on wilt and root rot diseases (Ethiopia coordinating), integrated control of aphids and viruses (Egypt coordinating), and socio-economic studies (Egypt also coordinating).
- Mahgreb Food Legumes Network (currently dormant)

**South and Southeast Asia**

- AICRP (All India Coordinated Research Programs) guides and coordinates research on lentil, chickpea, pigeonpea, groundnut, and grasspea germplasm in India
- Cereals and Legumes Asia Network (CLAN) is sponsored by the regional organization APAARI and co-facilitated by AVRDC, ICARDA and ICRISAT
- SAVERNET (South Asia Vegetable Research Network – currently dormant) and ARNET (AsSEA-AVRDC Research Network)

These networks are all regionally-based, which (desirably) places them close to the socio-economic and biophysical context in which adoption and impact occurs. Additional value will be gained by extending that learning across regions/crops through GLVA for value chain challenges that they all
share. These networks will also act as the ‘eyes and ears’ of GLVA, feeding back regional knowledge on grain legume issues, trends and priorities.

Among the key functions that networks will perform under GLVA are:

- Sharing evidence, best practices, innovative ideas and problem-solving expertise across crops and regions;
- Sharing facilities and services among those best equipped to carry out different tasks;
- Coordinating and fostering inter-disciplinary and cross-crop project collaboration;
- Mentoring and training of young scientists and providing them a range of opportunities for professional development;
- Creating scientific consensus of opinion to inform policy-making.

Unfortunately a number of networks have become dormant in the past decade due to lack of resources. Several have made adjustments to continue to contribute to the extent possible, functioning at a very basic level without special support. Opportunistic physical meetings are enabled by single-event and often problem-focused support and/or as side meetings at other events, rather than through long-term core network support.

GLVA will attempt to support the historical trend, because that strategy has worked well in the past. GLVA will exploit the new opportunities that the trend provides, in the context of the value chain systems perspective.

**GLVA: A platform for value chain innovation**

GLVA sees these networks collectively as an international innovation platform (Hall and Yoganand 2004) for grain legumes. This platform will be the base from which targeted innovation partnerships are launched. Innovation partnerships will focus on specific value chain problems/opportunities. They will carry out the entire R4D cycle, from idea generation to fundraising, project execution, and monitoring and evaluation. GLVA will coordinate and advocate these innovation partnerships to investors and other stakeholders, and will provide other core services such as catalytic and advisory support, quality monitoring, the establishment and monitoring of reporting standards, and public awareness services, all aimed at maintaining high credibility and visibility for the Alliance. Table 6.1 depicts in brief some of the main types of partners that will be essential to innovations in different core processes of the value chain.
### Table 6.1. Roles of partners by Objective/Output in GLVA

<table>
<thead>
<tr>
<th>Output</th>
<th>NARS in ESA, WCA, SSEA, CWANA, LA&amp;C</th>
<th>ARIs</th>
<th>Private Sector</th>
<th>NGOs, Farmers Organizations</th>
<th>CGIAR Centers</th>
</tr>
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<tbody>
<tr>
<td><strong>Objective 1 - High value grain legumes to reduce rural poverty</strong></td>
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<tr>
<td><strong>Output 1.1: Value chains for value addition</strong></td>
<td>Identify and monitor local legume products, look for opportunities for empowering women</td>
<td>Assist with methodologies and gender perspectives</td>
<td>Assisting in identification of key legume products, opportunities and major markets</td>
<td>Promoting adoption of key legume products</td>
<td>Assist in identifying, and developing high value grain legume products and capacity building</td>
</tr>
<tr>
<td><strong>Output 1.2: Technology for high value perishable fresh products</strong></td>
<td>Assessment of available varieties to produce high value perishable fresh products</td>
<td>Methodological support for developing technologies for high value products</td>
<td>Promotion of high value specific perishable products</td>
<td>Scaling up of adoption of high value perishable legume products</td>
<td>Cross-learning of technologies, development and promotion of high value perishable fresh legume products</td>
</tr>
<tr>
<td><strong>Output 1.3: Technologies for high value dry seed products</strong></td>
<td>Identification and evaluation of high value dry seed products</td>
<td>Technical support for developing high value dry seed products</td>
<td>Promotion of high value specific dry seed products</td>
<td>Scaling up of adoption of high value dry seed legume products</td>
<td>Cross-learning of technologies, development and promotion of high value dry seed legume products</td>
</tr>
<tr>
<td><strong>Output 1.4: Technologies for high value animal feeds and haulms</strong></td>
<td>Identification of new varieties and under-utilized legume species for high value animal feed and fodder/haulms</td>
<td>Technological support in assessing risks associated with high value animal feed and fodder</td>
<td>Commercialization of selected feed and fodder varieties</td>
<td>Promotion of suitable feed and fodder products</td>
<td>Identification, integration and development of high value animal feed and hauls for enhancing livestock production</td>
</tr>
<tr>
<td><strong>Output 1.5: Mechanization for small-scale crop production</strong></td>
<td>Evaluate varieties and technologies suitable for small scale farm mechanization</td>
<td>Provide assistance on possible models, and any feedback and learnings</td>
<td>Commercialize appropriate varieties and technologies for small scale mechanization</td>
<td>Creating awareness, skill development in the utilization of improved farm machinery</td>
<td>Develop and evaluate improved women friendly small scale farm mechanization options</td>
</tr>
<tr>
<td><strong>Output 1.6: Policy suggestions for sustainable value addition</strong></td>
<td>Evaluate and adopt suitable policies for sustainable policies for value addition</td>
<td>Assist with policy formulation, based on experience in other countries/institutions.</td>
<td>Promotion of selected policies for suitable value addition, benefitting women farmers</td>
<td>Promotion of adoption of suitable policies for sustainable and profitable value addition</td>
<td>Develop best suited policies for sustainable and profitable value addition</td>
</tr>
<tr>
<td>Output</td>
<td>NARS in ESA, WCA, SSEA, CWANA, LA&amp;C</td>
<td>ARIs</td>
<td>Private Sector</td>
<td>NGOs, Farmers Organizations</td>
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<tr>
<td><strong>Strategic Objective 2 - Productive grain legumes to secure food supplies</strong></td>
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<tr>
<td><strong>Output 2.1: Enhanced utilization of genetic resources</strong></td>
<td>Evaluate and select germplasm sets (core, mini core, reference, TILLING population and FIGS subsets) for target traits</td>
<td>Support to develop new tools, methods and approaches and capacity building</td>
<td>Use selected germplasm in developing high yielding, broad based cultivars, including hybrids</td>
<td>Testing and adoption of selected germplasm and high yielding broad based cultivars</td>
<td>Develop, identify, evaluate and conserve suitable germplasm sets to broaden genetic base</td>
</tr>
<tr>
<td><strong>Output 2.2: Novel and efficient breeding methods</strong></td>
<td>Use modern breeding methods in their breeding programs to enhance efficiency and delivery of products</td>
<td>Technological support, graduate students training in development and use of genomics technologies</td>
<td>Cost-effective and high-throughput genomics technologies for the legume R4D community</td>
<td>Promoting and enhancing adoption of modern breeding methodologies in crop improvement</td>
<td>Develop and use of genome sequences, molecular markers, transgenics and modern breeding methodologies to broaden the genetic base and genetic improvement of legumes</td>
</tr>
<tr>
<td><strong>Output 2.3: Climate resilient cultivars</strong></td>
<td>Evaluation and adoption of developed climate resilient varieties under key biotic and abiotic stresses</td>
<td>Assistance in developing high-throughput phenotyping platforms</td>
<td>Commercialization of the proven technologies and superior resilient varieties</td>
<td>Promoting the proven technologies and adoption of climate resilient varieties</td>
<td>Development and use of high-throughput phenotypic platforms for the key biotic and abiotic stresses for developing climate resilient varieties</td>
</tr>
<tr>
<td><strong>Output 2.4: Improved legume cultivars with enhanced resistance/tolerance</strong></td>
<td>Evaluate and adopt improved legume varieties and hybrid pigeonpea under various production systems</td>
<td>Capacity building (including graduate students training) in use of modern breeding</td>
<td>Development and commercialization of superior varieties and hybrid pigeonpea</td>
<td>Up scaling the promotion of superior varieties and hybrid pigeonpea</td>
<td>Development of improved legume varieties with enhanced resistance to biotic and abiotic stresses for various agro-ecologies by using modern breeding methodologies</td>
</tr>
<tr>
<td><strong>Output 2.5: Sustainable and efficient seed systems</strong></td>
<td>Identify efficient formal and informal seed systems for preferred crops and varieties, suitable for the location/region</td>
<td>Seed coating technologies to deliver nutrients and inoculants</td>
<td>Develop infrastructure for efficient seed production, seed storage and distribution/marketing</td>
<td>Establishing linkages between formal and informal seed systems and niche markets for improved seed</td>
<td>Identify and develop suitable and efficient seed systems. Assist in capacity building of national systems.</td>
</tr>
<tr>
<td>Output</td>
<td>NARS in ESA, WCA, SSEA, CWANA, LA&amp;C</td>
<td>ARIs</td>
<td>Private Sector</td>
<td>NGOs, Farmers Organizations</td>
<td>CGIAR Centers</td>
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<tr>
<td>Output 2.6: Gender-balanced research capacity</td>
<td>Participation in integrated crop breeding and management including participatory research, seed production, processing and marketing of legumes</td>
<td>Assistance in capacity building of young scientists particularly women</td>
<td>Provide better opportunities for women scientists in research, extension and marketing</td>
<td>Establishing women and youth groups and improving their capacity in participatory research and seed production, processing and marketing</td>
<td>Training young scientists in integrated crop breeding and management, farmers, NGOs in participatory varietal selection and establish women and youth groups for seed production, processing and marketing of legumes</td>
</tr>
</tbody>
</table>

### Strategic Objective 3 – Nutritious, safe grain legumes

<p>| Output 3.1: Legume gene pools and varieties with enhanced nutritional value | Participate in assessing research gaps on nutritional importance of grain legumes, and identify legumes and genotypes for use in breeding | Upstream research on inter-specific and inter-generic cross-compatibilities | Provide tools and technologies to access genes and genotypes for enhancing gene pools | Creating awareness among the farming communities about nutritional value of legumes and disseminate the knowledge to target communities | Genetic improvement of legume varieties with specific nutritional traits. Provide learnings and new technologies |
| Output 3.2: Pre- and post-harvest management options | Identify and prioritize constraints in post-harvest crop management and participate in R4D, | Generate information on nutritional quality, anti-nutritional and toxic factors. Technologies to reduce toxins and antinutritional factors. | Commercialize farmer preferred varieties and women-friendly post-harvest technologies | Create awareness about the improved technologies and varieties and promote these among stakeholders | Develop, evaluate and share improved legume technologies to address various pre and post-harvest crop production constraints |
| Output 3.3: Communication networks | Document existing communication networks and establish linkages with other stakeholders for improving the efficiency of communication | Provide new information and communication technologies and tools to enhance existing communication systems | Evaluate and identify cost effective and affordable communication system to suit the interests of end users | Promote the use of communication tools and technologies and assist in their adoption | Identify potential new technologies and partners and linking them with various stakeholders |</p>
<table>
<thead>
<tr>
<th>Output</th>
<th>NARS in ESA, WCA, SSEA, CWANA, LA&amp;C</th>
<th>ARIs</th>
<th>Private Sector</th>
<th>NGOs, Farmers Organizations</th>
<th>CGIAR Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output 4.1:</strong> Enhanced N2 fixation efficiency of legumes</td>
<td>Develop database of knowledge on regional Rhizobia and other beneficial organisms, and participate in N-fixation research and Rhizobium inoculum production</td>
<td>Development of more efficient strains of Rhizobia and other beneficial microorganisms</td>
<td>Large scale multiplication of selected Rhizobial strains and their distribution/sale</td>
<td>Promote utilization of effective Rhizobium inoculum to increase grain legume production</td>
<td>Rhizobial collection, evaluation, and their promotion through different delivery systems</td>
</tr>
<tr>
<td><strong>Output 4.2:</strong> Integrated soil and crop management</td>
<td>Identify and prioritize various constraints for developing Integrated Crop management (ICM) practices for crop intensification and system resilience</td>
<td>New IPM/IDM technologies/modules, and train graduate students</td>
<td>Produce and market quality inoculum, beneficial microorganisms and Biopesticides for intensification of legume crop production</td>
<td>Implementing best bet technologies across the region for legume crop intensification</td>
<td>Develop high yielding varieties, efficient integrated crop management technologies with emphasis on eco-friendly approaches</td>
</tr>
<tr>
<td><strong>Output 4.3:</strong> Policy suggestions</td>
<td>Identify and document various gaps with respect to BNF, beneficial microorganisms and Biopesticides for policy formulations/briefs</td>
<td>Methodological and analytical support for BNF, beneficial microorganisms and Biopesticides production units</td>
<td>Promote ICM technologies, including Biopesticides for sustainable legume crop production</td>
<td>Disseminate ICM technologies and internalize policies for accelerated legume crop production</td>
<td>Assist in identification, and developing efficient strategies to improve the existing policy framework</td>
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</table>

**Strategic Objective 4 - Grain legumes for sustainable intensification**
The core partners in GLVA (ICRISAT, CIAT, ICARDA, AVRDC, GCP and ICAR) believe that a wide range of partners across the five regions are essential to implement the R4D activities envisaged. These include both the traditional partners, and many new partners as we plan to initiate research in areas that were not on our R4D agenda previously. These partners includes the Advanced Research Institutes (ARI) in both developed and developing countries; several national agricultural research systems (NARS) institutes, including universities, non-governmental organizations (NGOs), farmers organizations, private sector, and other CGIAR centers. Table 6.1 provides details of activities that the set of partners are expected to contribute to GLVA R4D efforts. Appendix 5 has a complete list of global partners.

**Stakeholder support**

Innovation partnership proposals will be marketed to coalitions of traditional and new development investors – those who hold stakes in grain legume value chains but have been largely overlooked in the past. For example, wholesalers and processors hold stakes in grain harvests that are more consistent in volume and quality; seed companies hold stakes in more profitable and efficient seed systems; and retailers hold stakes in the improved quality and diversity of final products. The poor, and especially women are stakeholders of prime interest to GLVA, and the road to success must be in finding win-win innovations for both the commercial stakeholders and the poor stakeholders. R4D avenues will be pursued that increase the value of all their stakes so that all are motivated to adopt them. GLVA will seek out win-win opportunities for both the poor and for these interest groups in enhancing the core processes of the value chain (see Fig. 4.1).

Realistically, new windows of support from stakeholders will be modest in the beginning. Support will be through both cash and in-kind support to projects (expertise, facilities, testing services etc.) Beyond support, the active involvement of value chain stakeholders will increase the relevance of R4D and accelerate its impact. Value chain stakeholder support will not replace the need for traditional development investor support, which is especially crucial for activities that benefit the poor, and women, in particular. But including those stakeholders represents a significant new way of doing business. Initial, even if modest support will demonstrate commitment to the GLVA partnership by stakeholders. Over time as returns-on-investment become tangible, we expect that the quantity of this new support will grow.

GLVA will proactively market innovation partnerships by dialoguing with stakeholders about the mutual benefits that all can obtain through R4D, taking their ideas and suggestions onboard to increase the relevance and effectiveness of project design. A number of recent institutional innovations in this direction bear testimony to the viability of this approach, e.g. the Hybrid Parents Research Consortium (involving IARCs and seed companies) and the Agri-Business Incubation platform fostering agri-entrepreneurship catalyzed by ICRISAT in India, and the AVRDC - APSA partnership linking AVRDC to over 400 seed company members of the Asia and Pacific Seed Association.

**ICT for efficient networking**

Addressing the decline in general network support for essential core functions such as coordination and communication, GLVA will capitalize on ever richer ICT capabilities such as virtual meeting technology, web-enabled community-of-practice and professional networking applications, tele- and video-conferencing, online sharing of rich interactive databases, geospatial applications, and genetic maps. Bandwidth and user sophistication are steadily increasing across the developing world, and such tools are continuously emerging and improving at ever-lower cost. They enable both broad sharing of information/expertise at regional and global levels as well as focused problem-solving teamwork (e.g. virtual team formation for proposal development and execution). Targeted event
funding will also be sought to ensure periodic physical meetings that are required to sustain mutual trust, understanding and team coherence.

The potential of ICT to increase value capture by the poor is illustrated by the case of e-Choupal in India (Choupal means ‘gathering place’ in Hindi). India Tobacco Company (ITC) initiated an e-Choupal effort that places computers with Internet access in rural farming villages. The e-Choupals serve as place for exchange of information and an e-commerce hub. The farmers use the computer to access daily closing prices on local markets and to find information about new farming techniques. The village internet kiosks are managed by farmer-intermediaries called “Sanchalaks” who facilitate access to the information on market prices and trends, weather, crop management, scientific farm management, risk management and disseminate the knowledge in their own language. Farmers also use the e-Choupal to order seed, fertilizer, and other products such as consumer goods from ITC or its partners at prices lower than those available from village traders. At harvest time ITC offers to buy the crop directly from any farmer at the previous day’s closing price; the farmer then transports his crop to an ITC processing center, where the crop is weighed electronically and assessed for quality. The farmer is then paid for the crop and a transport fee. “Bonus points” which are exchangeable for products that ITC sells are given for crops with quality above the norm. In this way, the e-Choupal system bypasses the government-mandated trading exchanges.
7. Gender Research Strategy

Men tend to dominate cereal production in many societies, but women are more likely to take a major role in the growing of legumes, particularly in Africa. Women provide more labor for activities such as weeding and harvesting, so R4D interventions that make these activities less demanding and reduce drudgery can have positive impacts on women. While men tend to dominate the marketing of dry grains, women are more likely to dominate in the marketing of perishable (green seeds and leaves as vegetables) and value-added products (sprouts, processed food, etc.). Women are also more involved with small scale processing, food preparation for home use or local sale, and often participate in community-based efforts (cooperatives, self-help groups, etc.), hence the introduction of simple processing technologies can directly benefit them if carefully introduced.

Alterations to value chains for grain legume crops can impact gender benefits, and this needs to be carefully considered in the design of R4D. Who will benefit most from particular innovations? Are these innovations equitable and efficient? These are some of the issues that will be carefully considered when developing strategies and interventions for enhancing the value chains and improving market access for women.

Innovations to increase the profitability of crops that were formerly of little economic value or for home use can improve the incomes of women, but this can also pose new challenges. Past experiences have shown that men often take over such enterprises after they become profitable. There are also examples of women being given poor lands to cultivate crops. Once the lands become fertile (say after growing legumes for a few years) the men tend to take them over for growing high value crops. Social organizations in formats such as women’s self-help groups can help protect women’s assets from redistribution. Care needs to be exercised that improving benefits to women does not create community conflict. Insights from the gender-based field surveys and discussions with women who already produce and market many of the legumes will be taken into account.

Gender disaggregated analysis increasingly show evidence that, in the context of diversity in the production patterns, incorporating gender-related concerns makes a difference in achieving higher levels of efficiency and socioeconomic welfare. Given the crucial role women play in legume production and provisioning, efforts to increase women’s productivity and share of benefits are vital. Results from different studies reveal that making women more productive and hence more effective income earners, enhances their status and security in the family as well as in the community.

In Asia, women are involved in all activities in legume production, except field preparation and marketing of the produce. Studies on the impact of groundnut innovations on women in India reveal that the binding constraints faced by women tend to differ from those of men. While men are more concerned about the economic viability and yield increases, women tend to be concerned about the workability of the technology, taste, color and ease of processing. These user preferences will be factored in the design and targeting of new legume technologies.

In sub-Saharan Africa, women are heavily involved in groundnut, cowpea and soybean production, processing, and marketing implying that they are also the direct beneficiaries of economic gains from these value chains. There is a growing recognition that cash incomes earned and food produced by women tends to be equitably distributed among members of the family, particularly benefiting children. In Senegal, Nigeria, and Niger, for example, the processing of cowpea is almost exclusively undertaken by women. They produce a range of products that are sold as street food. The products that they produce range from cowpea and rice to dan wake, moin-moin (ground
cowpea that is mixed with other ingredients and prepared by boiling or steaming to make a meat substitute), and akara, which is a deep-fat fried fritter from cowpea and the most popular of the cowpea-based food products.

Women are also increasingly involved in soybean processing and product development, including, akara (fried fritter), dan dawa, moin-moin (soybread), soy-cake, soy-milk, and soy-cheese. In Nigeria, IITA developed and disseminated household level processing technologies and small scale processing technologies using an extruder and an oil press. Currently, over 80 soybean-based agro-processing businesses exist in Nigeria.

Examples from Africa and Asia reveal that women handle much of the legume production - cowpea and soybean production in Africa; chickpea, groundnut and pigeonpea in Asia - integrating production, processing, and marketing activities to generate cash incomes in addition to ensuring household food and nutrition security through increased home consumption. For example, promotion of soybean recipes in Nigeria led to increased local trading of soybean food products, with attendant improvement in the nutritional status of many Nigerians, particularly infants and school children. Increased demand for soybean-derived products in turn led to increased production of soybeans (World Bank, 2009). Similarly, research efforts for low aflatoxin contamination in groundnut will have direct positive impacts on women and child health.

Gender will be integrated into each research component of GLVA to identify the differential needs, constraints, and opportunities of women and men with regard to legume cultivation and processing. It will identify the constraints to women’s full participation in legume production, post-harvest processing and marketing as well as document the impacts of innovations on women. Value-chain work will identify ways of ensuring that commercialization does not transfer control from women to men. By including gender concerns in the different objectives, it is aimed at addressing the specific constraints that women and men face in legume production, and thereby identify strategies to overcome these constraints and stimulate gender-equitable change processes.

GLVA (working with other CRPs, especially CRP 2) will capture a full understanding of household production including (1) who does what activities, (2) who has access to what resources, and control over what resources and (3) who makes what decisions regarding legume production, value chain and marketing. Ultimately, it is envisioned that the activities of GLVA will contribute, long-term, to the significant involvement of women and their empowerment both at the farm, household and community level.

GLVA will build on the pro-women opportunities of grain legumes by:

- R4D on women’s collective action mechanisms, training on good post-harvest handling and value addition; and linking them to markets for seed and grain that can increase their benefits. Formal and informal networks, and groups especially for women will be used (if already in place or created) to facilitate legume seed production and multiplication. Such networks like the women self-help groups in India will be used as channels for information flows related to crop management, market access, health and nutrition e.g. reducing aflatoxin contamination in groundnut, improving nutritional value of legumes through post-harvest processing, storage and cooking/preparation methods

- Women also can benefit nutritionally from legumes since their micro-nutrient requirement is greater than that of men. Legumes bio-fortified with iron and vitamin A will be especially relevant for the health of women and children, and especially pregnant women and nursing mothers.

- Helping understand and design mechanisms that enable women to access credit to start viable business in seed production and marketing. For example in the study by Ferris et al.
2008 average profit margins in Ethiopia for small-scale women retailers of common bean ranged from US$ 800-1000/year. Providing linkages with financial institutions, seed producers, consumers and traders will benefit women to get easy access to such resources

• Labor-saving technologies in legume production (eg. seed sowing, weeding, harvesting and post-harvest activities) to save women’s time and free them to participate in other income generating activities and family care.

• Providing mechanisms that enable women to gain from increasing grain prices after harvest time through access to ICT tools and knowledge centres (eg. e-choupal in India) and the accompanying credit to enable them postpone immediate sales of grains legumes after harvesting.

• Use of small sized packs for lower income groups (women and poor) to access seeds on wider scale.

• Legumes are predominantly women’s enterprises along the value chains (seed/grain production and trade). Hence, providing knowledge and access to storage facilities and marketing will have positive beneficial impacts.
8. Innovations

Value Alliance framework

GLVA innovations begin with the Value Alliance concept itself. In the past, CGIAR grain legume research was mainly focused on plant breeding for the production stage of farming. Now, the value chain perspective opens the door to value-adding innovations across the entire spectrum of core processes, from inputs to production systems to harvesting to storage, processing and marketing. Another innovation will be the application of value chain metrics and models for monitoring & evaluation, impact assessment and for scenario analysis.

This horizon-broadening requires that partnerships also become more diverse yet more targeted on particular value chain core processes, involving those that can make the most significant contributions to improving the functioning of those processes. Diversified partnerships run the risk of culture clashes. In the recent past, concerns about intellectual property right (IPR) issues caused the public sector to isolate itself from the private sector. GLVA will innovate new productive partnership modalities with the private sector based on clearly-articulated and mutually-beneficial IPR agreements. Network partners in each region will pioneer this innovation, negotiating clear relationships with the private sector as well as with government agencies and others involved in value chains.

Cross-learning in R4D

GLVA overcomes institutional barriers, enabling scientists to learn from each other. Cross-learning is relevant to almost all the topics on GLVA’s agenda (see Chapter 5). Progress against important and difficult topics should accelerate, including seed systems, diseases, insect pests, drought, and low soil fertility. Biotechnology has a particularly strategic role to play because, following the principle of gene synteny, it can reveal genetic control systems in one crop that can help researchers find the same trait in another. The integration of biotechnology knowledge management systems with field breeding systems will create a more efficient, powerful platform for progress.

Crop and agro-ecosystem modeling is another area ripe for cross-learning. ICARDA’s application of the Focused Identification of Germplasm Strategy (FIGS) system and ICRISAT’s mini-core collections system for example help to identify useful material in vast germplasm banks or even in the field. CIAT has a strong geospatial capability that will help all the GLVA partners to more effectively diagnose grain legume systems and trends.

Innovative R4D initiatives

In Chapter 5 GLVA proposes to tackle the innovative ideas below.

- Identify photoperiod insensitivity gene(s) to develop grain legume cultivars with wider adaptation
- Model plant attributes to help determine trait arrays most useful for adaptation to different environments
- Understand whether there are tradeoffs in selecting for fodder traits vs. grain traits in legumes and the extent to which grain legumes can/cannot increase photosynthetic rate in response to stronger sink demand (grain and haulm as sinks)
- Model seed systems to identify obstacles in advance
- Explore the potential consequences of distributing natural enemy insects (parasitoids and entomopathogens) across continents
• Genetically map genes for resistance to diseases that attack several grain legume species (e.g. rust) to identify alleles that might be able to be ‘awakened’ in susceptible crops
• Apply learning gained about cowpea and chickpea drought tolerance to increase drought tolerance in common bean and soybean
• Identify mechanisms of reproductive stage stress tolerance for drought, heat and salinity across crops
• Utilize bio-economic modelling to understand the climate resilience potential of heat and drought tolerance
• Understand and apply stay-green traits to enhance grain filling under drought stress in legumes
• Assess the potential of legumes to provide certain ultra-high value industrial or pharmaceutical products such as those currently sourced from soybean
• Isolate and utilize high-protein genes from wild species in tertiary gene pools
• Model plant type of other grain legumes after soybean to raise BNF and yield
• Induce mutations for herbicide tolerance to facilitate no-till and conservation farming
• Develop dryland-adapted soybean, possibly using cowpea as a model crop
• Induce haploids by manipulating a single centromere protein (the centromere-specific histone CENH3) to enable doubled haploid transgenic technology in grain legumes (reduces average breeding cycle time by 40%)
• Understand the functional roles of anti-nutritional factors of grain legumes in plant physiological terms, and means for reducing them
9. Interactions of GLVA with Sister CRPs

GLVA will always strive to complement other CRPs rather than to duplicate them. GLVA will be working with: CRP 1.1 – Integrated Agriculture Production Systems for the Dry Areas; CRP 1.2 – Integrated Systems for the Humid Tropics; CRP 2 – Policies, Institutions, and Markets to Strengthen Assets and Income for the poor; CRP 3.1 – WHEAT; CRP 3.2 – MAIZE; CRP 3.3 – GriSP: A Global Rice Science Partnership; CRP 3.6 – DRYLAND CEREALS; CRP 3.7 – Sustainable Staple Productivity Increases for Global Food Security: Livestock and Fish; CRP 4 – Agriculture for Improved Nutrition and Health; CRP 5 – Durable Solutions for Water Scarcity and Land Degradation; and CRP 7 – Climate Change, Agriculture and Food Security.

GLVA’s focus on uni-crop legume value chains provides a clean yet complementary separation from the target of CRP 1 which addresses cross-crop system issues. GLVA outputs will ‘plug into’ CRP 1 as crop inputs. Learning gained from CRP 1’s testing of those inputs will help GLVA revise and improve the relevance of its work.

For example, while CRP 4 concentrates on biofortified beans in Rwanda, CRP 3.5 will work on the biofortification of beans and other grain legumes in other countries. GLVA will contribute improved legume varieties and crop management practice (such as IPM/IDM) for different cropping systems and niches (CRP1.1 and CRP 1.2); research methods, models and data for value chain analysis and policy advocacy for identification of new market opportunities for grain legumes (CRP 2); enhance knowledge base through newer tools, techniques for genetic enhancement and phenotyping, and diversification of other cropping systems for improving productivity and sustainability (other CRP3s); generating and providing more nutritious varieties, methods and processes for enhancing specific nutrition and health benefits (CRP 4); durable legume-based solutions for addressing water scarcity and land degradation (CRP 5); and providing climate change-ready, resilient legume varieties and management practices to adapt/mitigate the impact of climate change (CRP 7). These partnerships will lead to synergistic interactions and shared accountabilities amongst CRPs and other non-CGIAR partners that will enable clarifications and further harmonization of the respective CRP’s approaches.

A stylized view of the linkages between the respective CRPs is shown in Figure 9.1. Table 9.1 provides details of specific interactions.
Table 9.1. Interactions of GLVA with other Consortium Research Programs

<table>
<thead>
<tr>
<th>CGIAR Research Program</th>
<th>Outputs from GLVA</th>
<th>Inputs to GLVA</th>
<th>Joint Actions with other CRPs</th>
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</thead>
</table>
| **CRP 1.1 - Integrated Agricultural Production Systems for the Dry Areas** | Improved grain legume germplasm, production and processing technologies, and information on seed systems | Prioritization and targeting of grain legume-based production systems. | (1) Characterizing and cataloging different farming systems jointly, and identifying constraints to production in target agro-ecologies to understand the varietal needs for food legumes  
(2) Modeling and evaluating cropping options for boosting productivity of legume based cropping systems  
(3) Utilizing early maturing legume varieties for short-window cropping systems and varieties with plant types suitable for intercropping in rainfed/irrigated production systems  
(4) Using nutrient-use efficient varieties with resistance/tolerance to abiotic and biotic stresses in different cropping systems  
(5) Evaluating jointly appropriate integrated crop management practices to enhance productivity of different cropping systems  
(6) Capacity building of NARS, NGOs, and farmers, with particular emphasis on women, by introducing improved cultivars and production technologies in different cropping systems |
| **CRP 2 - Policies, Institutions, and Markets to Strengthen Assets and Agricultural Incomes for the Poor** | Value-added grain legume cultivars, information on productivity, value chains, market access, and gender issues, related to grain legumes-based production and processing technologies. | Policy advocacy and promoting conducive markets for more profitable grain legume production systems. Methods for value chain and analysis, and tools for impact assessment. | (1) Jointly identifying deficiencies in existing value chain systems for grain legumes and devise efficient value chain systems  
(2) Developing policy briefs that promote farmer-friendly, particularly women, marketing infrastructure and protocols for enhancing value of grain legumes  
(3) Jointly identifying and standardizing quality control mechanisms for legumes, and train men and women farmers and buyers in quality control and monitoring for product quality  
(4) Promoting the interface between food processors and legume growers and train stakeholders along all key points of the value chain  
(5) Identifying policy interventions jointly for effective seed systems for ensuring availability of quality seed of legume varieties to farmers at affordable price  
(6) Promoting institutional arrangements for enhancing production and utilization of grain legumes through networking, including women self-help groups  
(7) Strengthening the skills of partners for gender-sensitive, interdisciplinary, inter-institutional and multiple-stakeholder problem solving |
<table>
<thead>
<tr>
<th>CGIAR Research Program</th>
<th>Outputs from GLVA</th>
<th>Inputs to GLVA</th>
<th>Joint Actions with other CRPs</th>
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<tbody>
<tr>
<td>CRP 3.1 – WHEAT</td>
<td>Legume varieties and production technologies suitable for cereal-legume intercropping, crop rotations, and crop-livestock production systems</td>
<td>Cereal varieties and production technologies suitable for cereal-legume and crop-livestock production systems</td>
<td>(1) With CRP 3 Rice, developing and testing legumes for sustainability of the rice-wheat cropping system, and rice-fallow legumes in South Asia and other eco-systems. (2) With CRP 3 Maize, evaluating legumes in the maize-based systems in southern and eastern Africa, S and SE Asia and in Central and South America (3) With CRP 3 Livestock and Fish, providing improved dual purpose legume varieties with better fodder quality traits and development of integrated crop management practices for ensuring high quality of legume fodder; promote safe storage practices at farm level for legume fodder, and enhance awareness and significance of safe legume fodder/feed among farmers and livestock producers.</td>
</tr>
<tr>
<td>CRP 3.2 – MAIZE</td>
<td>Nutritively enhanced and safe grain legumes cultivars and legume food products for improved health and nutrition</td>
<td>Promotion of nutritionally enhanced grain legumes and their products, and interaction of gender, nutrition, and health.</td>
<td>(1) Collating information on consumer demand and nutrition and health benefits of nutritious/biofortified legumes (2) Using improved legume varieties with better nutritional quality and consumer acceptance; and agronomic practices for improved product quality (3) Developing new products and processing methods in partnership with stakeholders for enhanced nutritional value of legumes, especially for women and children (4) Studying the effects of nutritive legume consumption on non-communicable diseases (NCDs) (6) Advocating the consumption of safe legumes and their value added products for nutrition and health</td>
</tr>
<tr>
<td>CRP 3.3 – GRISP: A Global Rice Science Partnership</td>
<td>Information on water, land, and ecosystems, and changes in grain legume based production systems</td>
<td>(1) Evaluating improved legume varieties with better water and nutrient use efficiency for water and nutrient conservation. (2) Exploiting productive legume varieties with better N-fixing abilities for reducing demand for chemical N (3) Enhancing soil and crop health through addition of organic matter and using beneficial microorganisms (4) Increasing system productivity through incorporation of legumes in various cropping systems</td>
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<td>CRP 3.7 – Livestock and Fish</td>
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<tr>
<td>CRP 4 - Agriculture for Improved Nutrition and Health</td>
<td>Improved cultivars and best-bet management practices for different grain legume production systems</td>
<td>Information on water, land, and ecosystems, and changes in grain legume based production systems</td>
<td></td>
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<tr>
<td>CRP 5 - Water, Land, and Ecosystems</td>
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<tr>
<td>CGIAR Research Program</td>
<td>Outputs from GLVA</td>
<td>Inputs to GLVA</td>
<td>Joint Actions with other CRPs</td>
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</table>
| **CRP 7 - Climate Change, Agriculture and Food Security** | Improved grain legume cultivars, and grain legume-based production technologies for resiliency to the impacts of climate change | Strategic foresight on the potential impact of climate change on the patterns of biotic and abiotic stresses and their management in grain legume production systems | (1) Evaluating improved legume varieties resilient to impacts of climate changes, especially with resistance to biotic stresses and tolerance to high temperature and drought  
(2) Testing early to extra-early maturity cultivars to fit into shortened cropping duration as result of climate change  
(3) Integrating activities of CRP3.5 Grain Legumes with CRP7 to help disseminate the most appropriate climate-ready varieties and management practices; and minimizing the effects of climate variability on grain legume productivity |
10. Management Arrangements for Implementation

The governance and management of Grain Legumes Value Alliance (GLVA) are based on the principles outlined in the CGIAR Strategy and Results Framework (SRF). Effective management of research for development will require a significant investment of time by all partners, especially by those appointed as the GLVA Director and Regional Program Coordinators. Therefore, we have chosen to maintain a minimal Research Management Team that will have the ability to interact often for effective management of research progress, especially during the initial few years of the CRP. We recognize that the proposed management structure (see Figure 10.1) may require alterations as the CRP develops, both in terms of membership and responsibilities, hence such possibilities will be monitored, evaluated and changes made as required.

Figure 10.1. GLVA Governance and Management Structure

Roles and Responsibilities

As with all CRPs, the Lead Center (in this case, ICRISAT) will sign a Performance Contract with the CGIAR’s Consortium Board for implementation of the CRP. The Lead Center, represented by its Governing Board and Director General, will be responsible for the overall performance
of the CRP by providing a clear vision, direction, priorities and focus through an inclusive, consultative and transparent partnership process.

The **Governing Board of ICRISAT** will have the fiduciary and legal responsibility and accountability for the implementation of GLVA. It will appropriately monitor the management and implementation of the CRP, including the performance of the GLVA Director, Steering Committee and Research Management Team. The governance and/or management entities of the other Principal Partners will be expected to provide similar oversight of their respective institute’s involvement in GLVA. This would include ensuring that their institution’s policies, vision and mission are in agreement with the CRP, that GLVA is appropriately included in their strategic plans, and that their institution assumes fiduciary and legal responsibilities and accountabilities for implementing the agreed research agenda of GLVA.

The **Director General of ICRISAT** and other CGIAR Partner Directors General will work together to assure the success of GLVA. Specifically, they will:

- Ensure full implementation of GLVA, including the effective integration of existing and new bilateral projects,
- Assign required staff to the GLVA management committees/teams,
- Appoint and empower Regional/Program Coordinators and provide required support, and
- Ensure the performance contracts are successfully managed, including management of risks.

Overall governance of GLVA will be by a **Steering Committee (SC)**, that will be chaired by the Director General (or designate) of the Lead Center, and whose members will include the Directors General (or designates) of all Principal Partners, and selected representation from other partners (e.g., regional/sub-regional organizations, IARCs, NARS, ARIs and private sector) participating in GLVA. The aim is for the SC to limit its total membership to no more than 12 individuals. The GLVA Director will serve as the secretary to the SC. The SC will be responsible for:

- Overall strategic direction of the CRP,
- Monitoring overall progress across the CRP,
- Advising on mechanisms to enhance the operations of the CRP,
- Enhancing strategic alliances with partners,
- Deciding upon suggested resource allocations across CRP research programs and partners, and
- Establishing guidelines for conflict resolution.

It is expected that the SC will meet in person at least once per year, with at least one additional meeting conducted electronically. It would be desirable if all decisions reflect a consensus among the SC members, but if necessary a simple majority vote will be followed.

For effective management of GLVA, a **Research Management Team (RMT)** will be chaired by the GLVA Director and will include the Regional/Program Coordinators (see below) and an appropriate research director from all Principal Partners who are not represented by a Regional Program Coordinator. The RMT will be primarily responsible for the overall monitoring of research outputs, human resources and finances of the CRP. In the spirit of streamlining management, we propose to maintain the RMT at an initial minimal level of membership, but allow the RMT to request other CRP staff to participate in its meetings as required. We believe the RMT will require at least bi-monthly meetings during this initial phase of the CRP. Many of these will be conducted electronically, but the RMT would plan to meet in person at least quarterly. The RMT will develop annual research plans and other
planning tools as requested by the SC, for the SC’s review and approval. The RMT will also request and receive advice from the members of a R4D Advisory Pool. All such interactions will be properly recorded and made available to the SC.

The GLVA Director will be contracted by the Lead Center in consensus with the SC. The Director will lead the CRP’s research-for-development agenda in consultation with the SC Chair and the RMT. This position will require a full-time commitment and be compensated accordingly; she/he will be covered by the policies of the Lead Center. The SC Chair will oversee the recruitment, approve the Terms of Reference for, and annually evaluate the performance of the GLVA Director, all in consensus with the SC. The Director will lead the CRP’s resource mobilization efforts, partner/donor relations, and ensure timely and high-quality reporting of program activities and progress to the SC and the Consortium Board, through the SC Chair. The Director will also serve as the public representative of GLVA, working closely with the SC Chair to ensure that the CRP maintains a high and positive profile with investors and the public. The Director will organize GLVA SC, RMT and other meetings and reviews, chairing such meetings where required. The Lead Center will provide an appropriate level of administrative staff to support the functions of the Director.

GLVA will be implemented on a regional basis, and be implemented by a Regional Program Coordinator for the five regions – South and Southeast Asia; Central and West Asia and North Africa; Eastern and Southern Africa; Western and Central Africa; and Latin America and Caribbean. The Regional Program Coordinator (RPC) will be at least a half-time appointment of a scientist/manager and will continue to be affiliated with their home institution, with the agreement of the institution. Efforts will be made to have inclusive Principal Partner representation across the Regional Program Coordinators. The Principal Partners will nominate the coordinators, with appointments being made by consensus of the SC. The coordinators will ensure that the activities for delivering the agreed outputs within each regional program are effectively implemented, coordinated, delivered and monitored/assessed. The coordinators will also maintain strong and positive relationships with the GLVA Director, participating in all RMT meetings, as well as with the other coordinators, relevant partners, donors and stakeholders involved in the CRP. RCC will include the RPC, representatives of partner CGIAR centers, NARS, and NGOs in the region. RCC will be responsible for planning, monitoring, and reporting of R4D activities in the respective regions.

A R4D Advisory Pool will provide a channel for input and advice on GLVA strategic and implementation issues. The panel will interact primarily with the RMT, but will also have opportunities to provide input/feedback directly to the SC. Given the complex and evolving nature of GLVA, we propose to appoint a “pool” of scientific and development advisors from a range of institutions/organizations and with a range of expertise. Nominations will be received from all GLVA Stakeholders by the RMT, who make a recommendation to the SC for a consensus approval. These experts will be assembled to provide independent guidance on strategic planning, new R4D opportunities and research progress across the GLVA agenda. We expect to appoint an initial pool of 6-10 advisors on 1 to 3 year appointments. Because of the difficulty to organize for all advisors to attend all GLVA meetings, we will seek to have at least two advisors present at all physical meetings of the RMT and GLVA. One or more advisors may also be requested to participate in the semi-annual (electronically) and/or annual SC meetings. All such interactions will be formally recorded and responses documented by the SC or RMT.

Dispute resolution among GLVA partners or with external parties will be handled according to policies established by the RMT if within the domain of research-for-development (including partnerships). If disputes fall in the domain of institutional and legal responsibilities, the SC will resolve them in accordance with the principles established in the
Management of Intellectual Property

Intellectual property (IP) management is based on the overall IP policy of the Consortium of CGIAR-supported Centers, which is driven by the mission of the CGIAR and the imperative that the products of the Centers' research should be international public goods.

The Centers work with a wide range of partners, including national agricultural research systems (NARS), advanced research institutes (ARIs), civil society organizations, private sector companies, and regional and international intergovernmental organizations. The Centers produce, manage and provide access to the products of their research for use by, and for the benefit of the poor, especially farmers in developing countries.

Intellectual assets resulting from GLVA will be made available globally and publicly made available. Centers hold their in-trust collections of germplasm for the benefit of the world community, in accordance with agreements signed by Centers and the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA).

Knowledge Sharing and Communications

Knowledge sharing (KS) involves a variety of strategies and practices used to identify, create, represent, distribute, and enable adoption of insights and experiences with a wide range of stakeholders. IARCs have developed a number of innovative methods and practices over the last decade using the power of ICT. Many non-profit organizations dedicate significant resources to knowledge sharing, often as a part of their fundamental business plan.

Internally focused KS typically concentrates on management-related objectives, such as improved organizational performance, clarity about competitive advantages and innovations, and the sharing of lessons learned. In the context of GLVA, KM efforts will overlap with Monitoring & Evaluation (M&E) and will both reinforce and draw on M&E efforts.

Given the organizational complexity of GLVA, we must be willing to invest time and effort to help partners obtain and share valuable insights, reduce redundancies (increasingly rely on task specialization), increase the efficiency of R4D activities and capacity strengthening efforts, retain intellectual capital, adapt to rapidly changing operational environments and take advantage of new opportunities.

However, to be effective and oriented towards impact, KS systems require to be aligned towards the users furthest in the knowledge value chain- the smallholder farmers. The range of information producers typically is not small in agriculture R4D. A careful analysis and expert advice is needed in the design and development of viable KM systems. Over the past few decades, rapid developments in genomic and other molecular research technologies, as well as brisk advancements in information technologies, have combined to produce and enable the effective management of vast amounts of information related to molecular biology. Bioinformatics tools and geo-spatial mapping will be critical components of GLVA’s knowledge sharing efforts, but even these high-end information technologies will be oriented towards resolving practical problems arising from the management and analysis of very large amounts of agro-molecular data and information.
Agricultural R4D communication is also undergoing a transformation that is driven by the spread of high-speed Internet connectivity; the advent of digital media; the development of new tools, platforms and methodologies; and changes in the ways the world accesses and uses information. We, thus have an opportunity to implement a rapid, highly targeted and efficient transfer of research results into practice and policy – while simultaneously capturing them in peer-reviewed journals and publications.

The GLVA Director will have general responsibility for communicating on behalf of CRP partners to a wide variety of audiences, and will help establish and monitor (in concert with the GLVA Steering Committee and Regional Program Coordinators) the GLVA’s communication action plan. Implementation of that plan will occur at all levels and will be carried out by many of those involved in the R4D work, but regardless of their organizational affiliation, their communication efforts will rest on the strategic needs, interests and achievements of GLVA.

Communications will be made an integral part of the R4D process, and not be just a by-product of it. GLVA will invest in developing the communication skills of key individuals and partners – especially their ability to interact effectively with the media, particularly the internet–enabled social media. The communications work will be periodically evaluated to ensure optimum impact.

As noted earlier, advocacy on behalf of increased investments in legumes AR4D (and in markets and other needed rural infrastructure) is seen as a vital activity for GLVA. Such advocacy must be based on the best information available, and capitalize on the most effective communications technologies and pathways. This advocacy role will be fully integrated in the Knowledge Sharing and Communication plan that will be developed in the early days of implementing GLVA.

**GLVA Data Management System**

The data generated by the various partners in GLVA are one of the most important resources for research and decision making. GLVA partners will conduct a series of on-station, on-farm and lab experiments with target legumes in different agro-ecosystems, which in-turn will produce a huge amount of phenotypic, genotypic, socio-economic, climatic, agronomic, and various other forms of data of diverse nature. Hence a state-of-art, focused and strong data acquisition, storage, archiving, curation and management system will be used / developed. This data repository will be integrated with GLVA web platforms for easy access and will be publicly accessible as an international public good (IPG). The quality and integrity of data are of utmost importance, and therefore the system will provide partners visualization and validation tools to highlight and avoid common logical errors to strengthen data capture.

This database will capture raw data alongside essential experimental metadata, thereby allowing merging of multifaceted data sets, with a support to querying combinations of molecular, trait, geospatial information and passport data. This will ensure enhanced multi-lateral information archival and exchange platform among various stakeholders and more accessible legume information. Data management system will also provide an innovative sharing mechanism by which collaborators will be able to decide selectively which data set is to be shared publicly with others and when. This may be based on various conditions, such as whether the data has been published and reporting has been completed or not. Such a data management system will give partners a better opportunity to professionally organize,
use and share their data and information with a better opportunity to access wider database and legume R4D information.

In addition to this data management system, GLVA will also identify and offer users a choice of basic analysis tools via online web services for analysis of data, downloadable results and reports. On request, the system may also generate an Analysis tracking ID (AID), by which further summarization, checking and more detailed analysis or status of desired analysis can be attained which in-turn will enhance overall system efficiency.

Many times it is observed that R4D partners are not comfortable with in online submission tools, as most of these data repositories do not offer much to users apart from archiving data. Hence, there will be more emphasis user-friendly web interfaces with additional outputs, reports and summaries to partners and stakeholders. This will be achieved by adding reporting modules, maintaining enhanced interaction between stakeholders, keeping a strong component of training and capacity building of IARCs and NAREs collaborators in use of data management system. Partners will also be trained in the publication of curated data to other appropriate public databases (like NCBI) with a link to central database with the necessary metadata.

To achieve this, initially some established and publicly open legumes / crop databases management systems will be identified such as, Legume Information System (http://www.comparative-legumes.org/ ) for genomics data, Agricultural Field Experiments Information System for field and farm trials (http://js.iasri.res.in/afeis/), and desired functional collaboration and linkages will be established with them to avoid re-inventing the wheel. Ultimately, a comprehensive data management system which will be able to cater to most of the needs of legume research will be established. This system will be a great source of information for legume researchers and will make a strong base for GLVA research strategy.
11. Time Frame

GLVA initiated the proposal development process during a brainstorming session with scientists from the major core partner centers. We began with visioning of what we would like to achieve by 2020, especially looking at the impacts that we envisage in the smallholder farmers’ fields. We outlined an initial 10 year frame work, but delineated in to three phases. Phase I will be four years (2011-2014) while & Phase II and Phase III will be three years each. We then focused on the first three years to develop milestones (through 2014). Each year, the partners will conduct an extensive analysis of progress achieved relative to projected milestones and in the context of our initial priorities. Based on the results of those annual reviews, we may modify our priorities, planned activities and anticipated milestones as we go, creating a rolling three-year action plan.

As we developed this document, for ease of reference we decided to keep our 2011-2014 projected milestones close to the strategic objectives to which they relate and the R4D activities that are meant to achieve them.

GLVA will continue the extensive discussions that have already been held among the initial partners and, at the same time, bring other key partners on board to help map out specific work plans for first three years of the initiative. In developing this proposal, the current partners identified general areas where they believe collaboration can be more effective. Our focus during the first six months will be elaborating and clarifying relative roles and responsibilities of those involved in order to effectively implement collaborative efforts and more fully realize the potential efficiencies we see, and hopefully identify others. Thus, in the first six months, a detailed business plan will be developed – one that reflects our plans for mainstreaming important gender dimensions of GLVA R4D, capacity strengthening, and details regarding different R4D activities, technologies to be developed and/or promoted, and the relative roles of different partners and their contribution to achieving the objectives of GLVA. We will also hold discussions on how to enhance the value chain approach in both research and development activities. Meanwhile, we will also be developing and refining the gender research strategy, in the context of the guidelines provided recently.

12. Mitigating Risks

GLVA is innovative in a number of areas (Chapter 8) so it is likely that there will be some risks involved. Value chains for example require working productively with a range of new partners that have different values, time frames and expectations. If GLVA is unable to bridge these differences, its effectiveness may be compromised. The learning curve associated with doing business in new ways involving more diverse partners may slow our progress (at least initially). A streamlined management structure and careful selection of partners involved in GLVA, however, should help mitigate this risk, as will the goodwill and enlightened self-interest that we anticipate all partners will bring to the table.

Related to this is the need to accentuate accountability and promote ownership of GLVA. As many activities related to impact are beyond the expertise and control of our research staff, we must also emphasize the inclusion of development agencies and extension services, NGOs, the private sector companies and processors and traders, and farming communities.
in planning and implementation. Doing so may increase transaction costs, but should help to mitigate the risk of limited impact on the ground.

As alluded to in other CRPs, the main risks to all CRPs are global in nature, i.e., such things as continued global financial challenges and the resulting political pressure to cut aid financing, especially to agriculture R&D. Strong monitoring and evaluation, broad-based expert advice, and an emphasis on consensus decision-making and conflict resolution should help to ameliorate management-related risks.

Legume production systems in many developing countries are often located in areas that experience high social and political volatility, and these could affect the implementation of R&D efforts, especially adoption of interventions in targeted areas. In such countries, GLVA will emphasize local partnerships to minimize this risk. While legume production systems have always been characterized by risk, many of these risks are changing and in some cases increasing. At the same time, the capacity to manage risk has declined as a result of restricted access to resources, lack of information, land degradation and land tenure insecurity faced by the smallholder farmers. Resource conflicts characterize developing country cropping systems and could be severe in some cases (e.g. the availability and control of water resources in Central Asia). Mitigating such risks will be difficult, and will depend on the wise counsel and full participation in activities at the community level, with priorities being driven locally.

Continued government policy bias against the support of smallholder farmers in marginal areas, even in the face of growing evidence of the value and importance of their enterprises, is also an important risk factor. Efforts to speak with a unified voice to policymakers and other influencers should help reduce this risk, but policy decisions are usually not made on the basis of well-reasoned arguments or even solid scientific evidence. GLVA partners will therefore need to identify local, regional and even international ‘champions’ who have the ear of key policymakers and who might, over time, influence the course of political decisions that limit legume production, processing and marketing. Finally, important risks to longer-term sustainability of CRP3.5 Grain Legumes could include insufficient interest on the part of private sector organizations needed to push commercialization of new technologies, as well as insufficient capacity on the part of national agricultural AR4D institutions to sustain the initiative. By including public and private organizations during the early stages of research planning and implementation, we believe that sustainability risks will be diminished due to a stronger sense of ownership and accountability for success. Finally, there are risks associated with climate—erratic rainfall, prolonged droughts or floods, can affect the success of CRP efforts in the target areas, both R4D activities and adoption of technologies by smallholder farmers.
13. Monitoring and Evaluation System

GLVA will generate a number of diverse outputs, including improved crop varieties, crop management technologies, information exchange, capacity building tools and genetic and genomic resources. These outputs, which are detailed in previous sections, should result in desired outcomes that ultimately lead to the intended impacts of reducing poverty and malnutrition, enhancing livelihood security, and reducing environmental degradation.

GLVA priorities are based on suggestions in the CGIAR Strategy and Results Framework. Each partner will conduct their own internal M&E of agreed research activities. The GLVA Research Management Team (RMT) will have responsibility for ensuring that proposed outputs are delivered and that expected outcomes are successful. This will require formal, annual project evaluations, as well as mid-term and end-of-program reviews by independent experts including evaluation by end users (farmers) and consumers.

We also expect that the proposed R4D Advisory Pool (Chapter 10) will conduct focused short-term reviews and provide feedback. Given the breadth and scope of the CRP, additional experts will be commissioned to provide inputs into specific activities. These will be considered by the RMT and required adjustments will be made as needed in our research planning.

Some of the major indicators to be used for M&E include:

- Enhanced use of genetic resources and new sources of resistance to abiotic and biotic stresses, improved nutritional quality and productivity, and enhanced product quality including palatability and consumer acceptance available as international public goods;
- Cutting-edge scientific knowledge on genetics and genomics published;
- Cultivars derived from IARC germplasm released by NARS and grown on a large-scale using recommended crop management practices;
- Efficient private sector and informal seed production and delivery systems/models operating in target countries, supported by harmonized national and regional regulatory frameworks;
- Capacity-building and technology delivery frameworks enhanced to facilitate farmers’ access to validated technology such as quality seed of improved crop cultivars, crop management practices and other farm inputs;
- Farmer and consumer acceptance of final products; and
- Publication of peer reviewed research articles, curated data sets and learning materials in granulated form to support use in multiple contexts by the partners and stakeholders.

In addition, GLVA intends to incorporate into our evaluation learning processes tools that provide feedback loops so that lessons learned can be quickly adopted and incorporated in our research planning. M&E, while vital to our enterprise is not an end in itself, but rather a part of a larger effort to help set realistic priorities that ultimately lead to impact in the field without eroding the already available diversity.

Monitoring and evaluation will also be related to value addition in chains as described in Chapter 3. Relating M&E to the value chain framework connects it to development drivers that can help reveal key bottlenecks to the uptake and impact of innovations. The impact pathway for the Grain Legume Value Alliance (Figure 13.1) provides a simplified diagram of
how GLVA research objectives are expected to produce the outputs that will lead to desired outcomes on intended stakeholders (both immediate and final users) finally leading to impacts at the farm level and finally to regional and national level impacts. The monitoring and evaluation (M&E) framework is given in Table 13.1.
<table>
<thead>
<tr>
<th>M&amp;E Indicators</th>
<th>Type of output</th>
<th>Measurement</th>
<th>Method of M&amp;E</th>
<th>Implementing Agency</th>
<th>Frequency</th>
<th>M&amp;E Agency</th>
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</thead>
<tbody>
<tr>
<td>Enhanced use of genetic resources and new sources of resistance to abiotic</td>
<td>• Well characterized germplasm</td>
<td>• No. of accessions screened and characterized</td>
<td>• Field and laboratory inspection</td>
<td>IARC</td>
<td>Seasonal &amp;</td>
<td>Implementing, Executing, &amp;</td>
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<tr>
<td>and biotic stresses and improved nutritional quality, productivity and product</td>
<td>• Seed material</td>
<td>• Core and mini core sets</td>
<td>• Analysis of feedback from recipients</td>
<td>NARS</td>
<td>Annually</td>
<td>Independent</td>
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<tr>
<td>quality</td>
<td></td>
<td>• Crop productivity and nutritional composition</td>
<td></td>
<td>ARIs</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Consumer acceptance of product quality</td>
<td></td>
<td>Private Sector</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leading edge scientific knowledge on genetics and genomics published</td>
<td>• Publications</td>
<td>• Cultivar/Variety released at regional and national level,</td>
<td></td>
<td>IARC</td>
<td>Annually</td>
<td>Implementing &amp; Executing</td>
</tr>
<tr>
<td></td>
<td>• Genomic databases</td>
<td>• Performance over time</td>
<td></td>
<td>NARS</td>
<td></td>
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<tr>
<td></td>
<td>• Genetic maps</td>
<td>• No. of scientific articles published books, reports, monographs.</td>
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<td>ARIs</td>
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<td>• Website hits/downloads</td>
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<tr>
<td></td>
<td></td>
<td>• Analysis of data on performance of crop variety at different locations.</td>
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<td></td>
<td></td>
<td>• Peer review.</td>
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<td></td>
<td></td>
<td>• Classification of publications by type, author, collaborator, citation index</td>
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<td>• Website hits/downloads, website hits/downloads</td>
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Table 13.1 Monitoring and Evaluation (M&E) Framework (Process and Performance Indicators)
<table>
<thead>
<tr>
<th>M&amp;E Indicators</th>
<th>Type of output</th>
<th>Measurement</th>
<th>Method of M&amp;E</th>
<th>Implementing Agency</th>
<th>Frequency</th>
<th>M&amp;E Agency</th>
</tr>
</thead>
</table>
| Cultivars derived from IARC germplasm released by NARS and grown on a large scale along with recommended crop management practices | • Cultivar (seed material)  
• Crop management technology | • No. of improved cultivars released under different conditions,  
• Effectiveness and cost of crop management practices/technologies recommended,  
• Productivity and returns per ha  
• BC ratio  
• Area covered and % of farmers adopting technologies | • Visits to field trails, farmers’ field days and demonstration plots.  
• Analysis of field data generated.  
• Focused farmers’ group discussion | IARC  
NARS  
NGOs | Monthly & Quarterly | Implementing & Executing |
| Efficient private sector and informal seed production and delivery systems/ models established and operating in each target country, supported by nationally reformed and regionally harmonized regulatory frameworks | • Availability of breeder, foundation and certified seed | • Quantity of seed produced and distributed at right time, place, and at affordable price  
• Increased seed replacement ratio  
• Reduced transaction cost of seed distribution at agency and farmer levels | • Field visits and inspection  
• Certification/Quality accreditation  
• Seed market surveys, number of dealer/agencies involved in seed supply  
• Reduced seed cost/unit | Private Sector  
NGOs  
NARS  
IARC | Semi-Annually | Implementing, Executing & Independent |
<table>
<thead>
<tr>
<th>M&amp;E Indicators</th>
<th>Type of output</th>
<th>Measurement</th>
<th>Method of M&amp;E</th>
<th>Implementing Agency</th>
<th>Frequency</th>
<th>M&amp;E Agency</th>
</tr>
</thead>
</table>
| Capacity building and technology delivery frameworks and options enhanced to facilitate farmers’ access to validated technology such as quality seed of improved crop cultivars, crop management approaches and other farm inputs | • Enhanced capacity of human resources  
• Increased gender participation | • No. of trainings organized  
• No. of partners/collaborators/clients trained  
• Dissemination of gained knowledge  
• Gender wise receptivity  
• Impact on farmers’ fields due to capacity building | • Review of capacity building activities  
• Interactive workshops/meetings/opinion survey of beneficiaries  
• Initial adoption surveys  
• Impact analysis at farm level | IARC NARS NGOs | Annually | Implementing, Executing & Independent |
| Publication of peer reviewed research articles, curated data sets and learning materials in highly granulated form to support use in multiple contexts by the partners and stakeholders | • Publications  
• Data sets  
• Learning materials | • No. of peer reviewed articles, books, reports, monographs, policy briefs  
• No. of users of curated datasets/learning material | • Peer review  
• Classification of publications by type, author, collaborator  
• Citation index, and segregation by institution | IARC NARS ARIs | Annually | Implementing & Executing |
| Impact analysis of new technology released                                    | • Data on impacts  
• Reports on impacts | • Impact analysis using primary and secondary data  
• Sustainability of technology released | • Economic impact analysis at farmer/primary level | IARC NARS NGOs | Project Start & End | Implementing & Executing |
**Key GLVA milestones**

Milestones will serve as the central tool for the monitoring and evaluation of R4D progress and impact. Indicators listed in Chapter 5 will help to sharpen the milestone assessments. Milestones will be monitored by a special functional unit within GLVA led by a professional M&E/impact assessment specialist. Placing this unit centrally under GLVA management rather than under the R4D Objectives will increase its independence and influence on priority-setting.

The key milestones to be monitored and evaluated are listed below, by Objectives/Outputs.

**Objective 1: High value grain legumes to reduce rural poverty**

**Output 1.1: Value chains analyzed for value addition**

**Key Milestones:**

- Best opportunities offered by major legume markets (domestic or export) for value-addition to improve the incomes of smallholder farmers determined (2012).
- Opportunities for expanding new or existing legume products within these markets assessed (2012).
- Domestic or export markets that are likely to be most important for the purchase of new or existing legume products assessed (2012).
- For each specific product x market interaction, opportunities that are most likely to benefit or adversely affect women farmers, traders or consumers assessed (2013).
- Five new or existing legume products within each selected market that are most likely to benefit women and improve health and incomes prioritized (2013).
- Technologies or capacity building measures needed for expansion of these opportunities for value addition and providing feedback to other outputs assessed (2014).
- Appropriate capacity building programs for expanded market value for new or existing legume products in ways that will particularly benefit women developed (2014).

**Output 1.2: Technology for high value perishable fresh products developed and promoted**

**Key Milestones:**

- The existing processing technologies, particularly suitable for home use or small-scale operations, for leaves, and green pod/seeds documented, and the most suitable technologies selected for up scaling (2012).
- Existing processing technologies for leaves, pods or green seeds (suitable for home use or small-scale operations) that are used to add value documented and the technologies suitable for scaling up or transfer to new markets identified (2012).
- The gender implications of applying these technologies determined and technologies prioritized based on economics and social benefits (2013).
- At least 2-3 processing technologies prioritized, developed and promoted for use across legumes for the production of value added products for market demand (2014).
- Minimum of 2-3 cultivars of each legume suitable for use with these processing technologies and opportunities to breed for better processing types assessed (2014).

**Output 1.3: Technologies for high value dry seed products developed and promoted**

**Key Milestones:**

- The available processing technologies for producing high value legume-based foods, where most value is added and who benefits assessed (2012).
• The degree to which post-harvest processing of dry seed can benefit women, and under what circumstances is this more or less likely, documented (2013).
• The degree of crop and value lost due to storage pests and the available controls for storage pests and what technologies need to be developed to overcome continuing problems assessed (2013).
• Improved methods for control of storage pests in key legumes developed and the potential economic benefit from scaling these up assessed (2014).
• At least 2-3 legume cultivars suitable in each legume for complex processing of dry seed and the options for breeding more suitable types assessed (2014).
• Five varieties for high value products (e.g. high oil content in GN and SB) identified/developed (2014).

Output 1.4: Technologies for high value animal feeds and stover developed and promoted

Key Milestones:
• Breeding or processing options that are most likely to significantly increase feed grain and haulm quality to enhance returns for smallholder producers assessed and prioritized (2012).
• Markets for improved legume fodder that command premium prices determined, and breeding or simple processing options to enhance its value in such markets assessed (2012).
• Major animal feed markets for legumes assessed and the relative benefits to smallholders for supplying to these markets as compared to the human food markets determined (2012).
• Risks associated with the use of oil cake as animal feed assessed (2012).
• Selection of suitable lines or processing options to improve feed grain/fodder value in major legume feed markets implemented (2013).
• Strategies to manage Aflatoxin contamination in oil cake developed (2014)

Output 1.5: Mechanization for small-scale crop production developed

Key Milestones:
• The degree to which labor is a major constraint in smallholder legume production and the potential of increased mechanization to improve profitability documented (2012).
• The available alternatives for weed control in legumes, by smallholders identified and their relative impacts on women assessed (2012).
• Options for smallholder threshing or harvesting to improve legume profitability assessed, with particular reference to uses across legume species (2012).
• Options for improved weed control methods with wide applications across different legumes and locations; their relative impacts on women and profitability assessed (2013).
• Pilot testing of small-scale mechanical harvesting innovations performed in conjunction with partners and their implications for crop profitability and impact on women assessed (2013).
• At least 2-3 breeding lines in each legume suitable for mechanical harvesting identified/developed (2013).
• At least 4-5 sources of herbicide tolerance in each major legume identified from germplasm or through induced mutagenesis / genetic engineering developed (2014).
Output 1.6: Policy suggestions for sustainable value addition provided

Key Milestones:

- Case studies of current or past price support programs for legumes and the impact they have had on sustainable smallholder legume production documented (2012).
- Cases where investment policies have benefited the establishment of storage, processing and transport facilities for legumes and legume products that had benefited the smallholder farmers documented (2012).
- Factors affecting the beneficial impact of price support policies for different legumes determined and recommendations to policymakers developed (2013).
- Impact of food and trade policies in expanding legume trade and markets, and the impact of these on smallholder farmers documented (2013).
- Changes to food and trade policies that will help to create new markets for value added products benefiting smallholders recommended to policymakers (2014).
- Priorities for investment policies to encourage the development of processing and local value adding industries for legumes in different markets assessed (2014).

Objective 2: Productive grain legumes to secure food supplies

Output 2.1: Enhanced utilization of genetic resources in developing high yielding, broad based cultivars

Key Milestones:

- Global legume phenotyping networks formed, priority traits, methods, research partners, and number of accessions to be characterized agreed upon (2012).
- Databases and web portals on which to build are chosen, and the necessary IT expertise determined (2012).
- Trait-specific germplasm available using core/mini core, reference, and FIGS sets in at least five legumes (2013).
- Mapping populations (RILs/ AB-QTL, MAGIC lines), TILLING populations and other genetic stocks developed in all legumes for use in genetic studies (2013).
- At least one training course for NARS partners on genetic resources management conducted (2013).
- A web resource made available for open access on phenotyping protocols and standard methods to evaluate stress resistance (2014).
- Effective methods for accessing genes from the wild species of secondary and tertiary gene pools developed (2014).
- Legume genetic resources and information utilized by partners and its use assessed (2014).

Output 2.2: Novel and efficient breeding methods for cultivars development established and shared

Key Milestones:

- Whole genome sequence information available for at least one accession in CP and CB and testing of genotyping by sequencing approaches completed in at least one legume species for genome-wide selection (2013).
- High throughput genotyping platforms such as SNP established for at least 6 legumes (CB, CP, CW, PP, SB, MB) (2013).
• Diagnostic markers linked to key traits identified in CB, CP, CW, LN, MB, (2013).
• Cross-legume genomic studies of gene expression to identify genes involved in the transition from vegetative to reproductive phase completed (CB, CP, MB) (2013).
• Transgenic events for pod borer resistance, drought tolerance, and other desired traits developed and characterized in CP, CW, GN, LN, PP (2013).
• Key traits-linked markers validated and converted to cost-effective platforms for implementation in breeding programs of CB, CP, CW, LN, MB (2012-2014).
• Breeding lines with improved key agronomic traits developed using marker assisted selection (MAS) in CP, CW, MB (2014).

Output 2.3: Climate resilience cultivars with appropriate traits developed

Key Milestones:

• Best-bet sets of germplasm for each crop group evaluated for key climate change traits and rigorously evaluated using up-to-date phenotyping technologies- partner with institutions that have the appropriate equipment and screening protocols (2012).
• Comparative performance of different legume crops, including neglected species (e.g., P. coccineus, P. dumosus and/or P. acutifolius, V. subterranean, L. sativus), assessed in different environments for climate change-related traits (2012).
• Yield potential in stressful environments of underutilized species quantified in at least two countries in Africa (2013).
• Changes in relative abundance and geographical distribution of major insect pests and pathogens mapped (2013).
• Better understanding of the components and genetics of tolerance to drought and heat (2014).
• Ten breeding lines with improved tolerance to key traits required for climate change resilience, such as heat, drought and water logging tolerance, developed and shared with partners (2014).
• Ten breeding lines with improved tolerance to key biotic stresses developed and shared with NARS partners for further evaluation (2014).

Output 2.4: Improved legume cultivars (yielding at least 15% higher) with enhanced resistance/tolerance to biotic and abiotic stresses for different production systems developed

Key Milestones:

• Early- to extra-early breeding lines for short-window cropping seasons developed in CHP, PP, LN and at least 5 early- to extra-early varieties made available (2012).
• At least 200 promising elite lines carrying traits such as drought tolerance, cold tolerance, and higher nutrient-use efficiency per year across legumes distributed to NARS partners in the form of international nurseries, and compiled results made available to all partners worldwide (2012-2013).
• Ten breeding lines with at least 15% higher yield than the best available cultivars developed across legumes and shared with NARS partners (2012-2013).
• Ten breeding lines with improved resistance to key diseases and insect pests developed across legumes (2013).
• Inter-specific derivatives evaluated for food and feed (2013).
• New inbred lines and at least five hybrids made available in PP and evaluated at multiple locations in SA and SSA (2013).
• CMS and fertility restorer lines identified and hybrid seed production system developed in SB (2013).

**Output 2.5: Sustainable and efficient seed systems refined and promoted to enhance adoption of farmer-and market-preferred varieties**

**Key Milestones:**

• Five farmer-based seed production and marketing enterprises established in each of at least five countries (2012).
• At least 15 farmer-preferred legume varieties identified in the target regions by conducting PVS trials involving at least 50% women farmers in decision making (2013).
• Sufficient quantity of breeder and foundation seeds of farmer-preferred varieties produced by NARS and CG centers in the consortium (2011-2013).
• Existing public- and private-sector legume seed production and delivery systems in the target locations studied and gaps identified (2013).
• Studies on the technical efficiency of public- and private-sector legume seed production completed in at least five countries (2013).
• Impact of the small seed pack marketing strategy, particularly in bean, quantified, including gender disaggregated data on adoption (2013).
• Eco-friendly safe seed storage practices at household level developed (2014).
• National seed policies development facilitated in at least five target countries with weak seed systems (2015).
• Training provided to seed growers, including women farmers, in seed production, processing, storage and marketing (Annual).
• Associations/cooperatives of small holder seed growers formed (2013)
• Field days, training programs regional travelling workshop and other extension activities organized for knowledge empowerment of farmers in improved varieties and crop production technologies (Annual).
• Formal (public and private) seed sector integrated with informal (farmers’ seed production) seed sector (2014).
• Capacity of NARS partners to meet the demand of nucleus/breeder/basic seed (2014).

**Output 2.6: Gender-balanced research capacity of national programs enhanced**

**Key Milestones:**

• Growing of legume crops as part of home gardens, particularly involving women, demonstrated in all regions (2012-2013).
• At least 50% or more of small-scale farmers selected for demonstrating legume technologies in project countries will be women and youth farmers (2012-2013).
• Demonstrations promoting the concept of dual purpose legumes for food and feed, particularly involving women, conducted in all regions (2012-2013).
• More than five women and youth groups in each project country produce, process and market seeds of improved legume varieties (2012-2013).
• Need-based, short-term (1-4 week) training programs organized for the scientists of national systems on novel approaches in legume improvement (2013).
• At least 15 students (MSc/PhD), including at least 50% women candidates, conduct their research projects on legumes at participating CG institutes (2013).
• Scientists’ field days organized during the crop season for knowledge sharing and providing NARS partners the opportunity to select germplasm and breeding materials according to their interests (Annual).

**Objective 3: Nutritious, safe grain legumes**

**Output 3.1: Legume gene pools and varieties with enhanced nutritional value developed**

**Key Milestones:**

- Information on nutritional parameters of different legume crops inventoried and research gaps identified (2012).
- Geographic areas of highest micronutrient and protein deficiencies in women and children identified (2013).
- Target levels for genetic improvement set for different legume crops (2013).
- Genetic variability determined and a baseline is established for relevant nutrients, anti-nutrients and/or biochemical factors in CP, CW, FB, GN, GP, LN, MB, PP and SB (2013).
- Information on relationships between anti-nutritional factors and resistances to insect pest and diseases, and between nutritional traits and productivity available and shared with partners (2013).
- Genetic variability confirmed for flatulence factors (CP) (2014).
- Transgenics created with higher expression of pro-vitamin A carotenoids (GN) (2014).
- Breeding lines with a high oleic/linoleic fatty acid ratio developed in GN (2014).

**Output 3.2: Pre- and post-harvest management options to optimize nutritional value developed**

**Key Milestones:**

- Effects of fertilization, especially with Zn, are determined (LN, CP, PP) (2012).
- Integrated management technologies tested in field to reduce pre-harvest and/or post-harvest contamination of grain with mycotoxins (GN, CB, PP) (2013).
- Processing techniques assessed to reduce anti-nutrients such as tannins, vicine and convicine (FB); ODAP (GP) and RFOs (CP) (2013).
- Uses and characteristics of legumes as complementary foods for young children documented (CB, GN, CP, PP) (2013).
- Developed and validated legume-based formulations, keeping in mind the dietary requirements of young children and the undernourished (2013).
- Retention of pro-vitamin A carotenoids (LN, GN), iron and zinc (CP, LN, GN, PP, FB, SB, CP) during processing and cooking quantified (2014).

**Output 3.3: Communication networks that enhance research capacity and outcomes promoted**

**Key Milestones:**

- Protocols for field work and sampling for nutritional value established and share with partners through a workshop (CP, CB, GN, LN, PP, MB, VSB) (2012).
• Evidence based materials produced in collaboration with experts in consumer education, with focus on women as consumers and care givers (2014).
• Evidence based materials produced and shared with policy makers in five countries (2014).

Objective 4: Grain legumes for sustainable intensification

Output 4.1: Enhanced N2 fixation efficiency of legumes

Key Milestones:
• Simple, effective facilities for Rhizobium inoculum production established (2012).
• Supply chain analyzed and links in improving efficient Rhizobium inoculum supply system identified (2012).
• Efficient rural institutional set ups established to ensure access to Rhizobium inoculum for farmers (2012).
• Different ways to improve existing social networks to enhance efficiency of Rhizobium inoculum supply systems identified (2012).
• Protocols to select legume germplasm for efficient BNF developed (2013).
• Legume genotypes screened for high BNF and P use efficiency and selected genotypes tested under a wide range of environments (2013).
• Efficient Rhizobium strains for specific legume species identified and their competitiveness with indigenous Rhizobia assessed (2013).
• Genetic resources of Rhizobium and other nitrogen fixing organisms, and entomo-pathogenic and antagonistic microbes characterized and distributed (2014).
• Phenotypic and genotypic crop-specific and comparative information exploited to understand the molecular basis/pathways of abiotic and biotic stress tolerance in legumes and BNF (2014).
• Studies on Rhizobial strains, mycorrhiza, endophytes, and trace elements required for enhanced biological activity and soil health resilience evaluated (2014).
• Technologies for efficient production of Rhizobium and other beneficial micro-organisms transferred to public/private sector partners (2014).
• Genetic basis of interaction of drought and low P with BNF studied (2014).

Output 4.2: Integrated soil and crop management for sustainable intensification

Key Milestones:
• Legume varieties with enhanced ability to cause suicidal germination of Striga hermonthica, Orobanche spp. and other parasitic weeds identified (2012).
• Appropriate agronomic practices generated, evaluated, demonstrated and disseminated to enhance legume productivity in different cropping systems (2013).
• Priority areas (both current and under CC scenarios) for crop adaptation and cultivation using crop models and GIS/spatial technologies identified (Year 2013).
• Simulation models/environments to address future constraints (pre-emptive breeding) to legume production identified (Year 2013).
• Niches for new legume species identified (2013).
• Data on effects of legumes on productivity of other crops assembled and published (2014).
• Crop varieties (2 -3) with allelopathic effects on non-parasitic weeds identified (2014).
• Nutrient-use efficient varieties with resistance or tolerance to abiotic stresses developed (2014).
• Environmentally safe, farmer-friendly plant and soil health management technologies, including biopesticides developed and promoted (2014).
• Legumes varieties identified for crop intensification in rice fallow identified and promoted (2014).

Output 4.3: Policy suggestions and enhanced capacity for sustainable intensification of cropping systems with legumes

Key Milestones:
• Strategies for adaptation of N2 fixing legumes by the farmers developed (2012).
• Constraints to production and use of beneficial micro-organs and biopesticides; and associated risks assessed (2013).
• Policy framework for adoption of N2 fixing legumes by resource poor farmer advocated (2014).
14. Budget

Details on the projected GLVA budget for 2011-2013 are presented in Table 14.1. The budget presents the required level of income from CGIAR Windows and bilateral funding, and expenses by Objective and by Output, partner and expense category.

The budget was developed by initially allocating existing bilateral project budgets for ICRISAT, CIAT, ICARDA, IITA and the GCP to Strategic Objective outputs. The total required budget for each output was determined based on projected key milestones. Each output budget represents the requirements for ICRISAT, CIAT, ICARDA, IITA, the GCP, AVRDC and partners to be initially funded by GLVA. Considering that GLVA will be initiating a few new activities to achieve planned outputs, we have indicated increased budgets from year 2 to support these new activities.

Costs for gender research and analysis are budgeted separately and include scientists’ time and operating expenses across the partners. Approximately 4% (US$ 6.3M) of the total first three-year budget has been specifically allocated for gender-related research. ICRISAT, CIAT and ICARDA have gender specialists who will devote significant time to GLVA researching gender aspects of targeting, planning, design and implementation.

Given the need to effectively manage the CRP across all partners, including a number of non-CGIAR partners, a specific budget for CRP Management is proposed. This includes the costs for the CRP Director (40% for 2011 and 100% for 2012 and 2013), global coordination meetings involving partners to be held at least twice each year, regional coordination meetings twice each year, the steering committee to meet once physically each year and once virtually, and the travel and honoraria costs for advisory pool members. The total CRP management budget is 2% of the total CRP budget for 2011-2013. Efforts will be made to maintain, if not reduce, the costs of CRP management, but it will be critical to allocate funds to management during the first phase to enable the required staffing, communications and meetings.

Partners are critical for the success of GLVA and a total of 20% of the three-year budget has been allocated for them. The GCP budget (2%) is entirely for partners and an additional 18% has been identified for R4D and development partners. These funds will be used to support specific research under each Strategic Objective output based on agreed work plans. Much of the partner budget is already allocated based on existing bilateral projects, although these will be enhanced with other funding from the CRP.

Several partners, including ICAR, will also make significant in-kind contributions to GLVA. These institutes and/or programs have their own source of funding to support infrastructure, salaries and operational expenses. Through better coordination of efforts under the CRP, these opportunities will be tapped to greatly enhance the progress towards the goals of GLVA. We will also work with each partner to help identify additional funding resources to support the work of partners in the CRP. Funding for GLVA (approximately US$ 161 million over three years) will be provided by CGIAR Windows 1 and 2, and from bilateral projects already secured. Realizing that full support from the CGIAR Windows is unlikely during the first three years, efforts to secure additional bilateral support will continue, although at a reducing level each year. Over the first three years, funding from CGIAR Windows 1 and 2 is proposed to cover 68% of the total expense budget, with the remaining 32% from bilateral (secured and pending) sources.
CRP 3.5 Gain Legume Value Alliance Budget (2001 to 2013)
Amount in US$®

### Income:

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<tr>
<td>CIIFAW Window 1-2: Research</td>
<td>20,250,000</td>
<td>38,824,000</td>
<td>46,144,000</td>
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<td>579,000</td>
<td>1,567,000</td>
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<td>Bilateral Funding (secured)</td>
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<td>4,404,000</td>
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<td>20,826,000</td>
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<td>45,230,000</td>
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<td>53,990,000</td>
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**Grand Total Income: 42,235,000**

### Expenses by Objective:

**Objective 1: High Value grain legumes to reduce rural poverty**

1.1. Value chains for value addition: 1,907,000
1.2. Perishable fresh products: 2,405,000
1.3. Dry seed products: 1,489,000
1.4. Animal feed and stover: 1,526,000
1.5. Small-scale mechanization: 1,092,000
1.6. Policy suggestions for value addition: 1,231,000

**Total Objective 1: 6,198,000**

**Objective 2: Productive grain legumes to secure food supplies**

2.1. Utilization of genetic resources: 2,546,000
2.2. Novel breeding methods: 3,221,472
2.3. Climate resilient cultivars: 3,719,000
2.4. Legume cultivars for production systems: 6,975,528
2.5. Sustainable seed systems: 3,596,406

**Total Objective 2: 19,486,287**

**Objective 3: Nutritive grain legumes to nourish health**

3.1. Gene pools with enhanced nutritional value: 3,780,000
3.2. Pro- and post-harvest management: 3,672,198
3.3. Communication networks: 2,835,000

**Total Objective 3: 9,297,000**

**Objective 4: Grain legumes for sustainable intensification**

4.1. Enhanced N2 fixation efficiency: 3,465,000
4.2. Integrated soil and crop management: 3,587,406
4.3. Policy and capacity strengthening: 2,122,000

**Total Objective 4: 9,175,406**

**Total Objectives: 35,991,360**

**Gender Analysis: 1,065,000**

**CRP Management: 579,760**

**Total Expenses: 42,235,000**

### Expenses by Category:

**Expenses by Partner:**

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<td>Partners</td>
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**Total Expenses: 42,235,000**

### CRP Management Expenses:

| Global Leadership                                                      | 49,000      |
| Regional Leadership                                                   | 300,000     |
| CRP Global Coordination Meetings                                      | 19,500      |
| CRP Regional Coordination & Meetings                                  | 11,100      |
| Steering Committee                                                    | 51,500      |
| Advisory Pool                                                         | 10,200      |

**Total CRP Management Expenses: 579,760**

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List of References


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http://www.ifpri.org/pubs/newsletters/ifpriforum/if200410.htm


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Malhotra RS. 2009. The CWANA countries have two well defined seasons, namely winter and spring, and chickpea is traditionally grown in the spring season (on conserved soil moisture) as most of the local land races grown in these countries are highly susceptible to ascochyta blight and cold/frost which are the main constraints in the winter (Malhotra et al. 2009).


Olorunju PE, Kuhn CW, Demski JW, Misari SM and Ansa OA. 1992. Inheritance of resistance in peanut to mixed infections of groundnut rosette virus (GRV) and groundnut rosette assistor virus and a single infection of GRV. Plant Dis. 76: 95-100.


Appendix 1. GLVA Initial Partners: Capacities and Priorities

AVRDC

AVRDC-The World Vegetable Center improves grain legumes that are used as vegetables. This includes a global mandate for mung bean (Vigna radiata) and vegetable soybean (Glycine max). Major breeding efforts have been made on these crops for the past 40 years, with additional work on improving agronomy, nutritional value, insect and pest management, and seed production. Macro-economic studies have also been carried out on the impact of mung bean in improving crop rotations and reducing anaemia in South Asia. The center has also done selection work and marketing studies on cowpea (Vigna unguiculata), consumed for its leaves in East Africa, and some selection and entomological work on yard-long bean (V. unguiculata, spp sesquipedalis), consumed as a vegetable in South and Southeast Asia.

AVRDC’s special strengths in grain legumes are in collaborative breeding efforts involving many national partners that led to improved mung beans, and in close collaboration with national partners and industry that created the high-value vegetable soybean industry in East Asia.

AVRDC’s value-adding contributions to GLVA will be in the development of super-early high yielding legumes (e.g. mung beans that mature in less than 60 days) and in developing high value markets for legumes (e.g. vegetable soybean can return ten times as much income as grain soybean). AVRDC also brings extensive experience on improving human nutrition through high iron mung bean and school feeding programs with both mung bean and vegetable soybean. Most of AVRDC’s work has been in Asia, and a major GLVA opportunity is to expand that work into Africa. AVRDC also holds the largest international public germplasm collections of mung bean and soybean.

AVRDC’s largest impacts have been with mung bean. In partnership with 29 Asian institutions between 1984 and 2006 AVRDC developed high-yielding, short duration, disease resistant mung bean varieties that are now planted on more than three million hectares in nine countries in South and East Asia that dominate global production. They provide an estimated 1.5 million farmers with yield increases of 28 to 55% (approximately 300 kg/ha). Total production across these countries increased by 35% and mung bean consumption has increased 22 to 66 percent with documented improvements in the health of anemic women and children. AVRDC also catalyzed the vegetable soybean industry in East Asia that has provided smallholder farmers in China, Taiwan, Thailand and Indonesia with a high value export crop to Japan, and a highly nutritious crop for home consumption or local sale.

AVRDC is strongly involved on two major fronts with these crops at present. One is the spread of new strains of viral diseases of mung bean that are devastating production in major areas. The other is the promotion of vegetable soybean as a highly nutritious tropical alternative to fresh peas.

The International Center for Tropical Agriculture (CIAT)

CIAT, headquartered in Cali, Colombia holds a mandate for research on Phaseolus beans. The Phaseolus genus is of neotropical origin and CIAT is located in the center of diversity of the crop. Five cultivated species of Phaseolus are conserved in the Genetic Resources Unit (almost 40,000 accessions), although most research is directed towards Phaseolus vulgaris, the common bean.

The ecologies in which Phaseolus species evolved range from arid to tropical rainforests, so the genus offers a unique perspective on adaptations across extremes of environmental conditions – especially relevant to looming climate change. The species with which the common bean may be hybridized cover most of this range, and represent a unique reservoir of genetic diversity.

CIAT’s historical strength has been in genetic improvement. More than 300 varieties have been released by countries in Latin America and more than 170 in Africa. On both continents disease-
resistant varieties have been the primary product. In Latin America varieties with resistance to Gemini viruses have been the hallmark, while in Africa root rot resistant varieties have sustained bean production in western Kenya and neighboring countries. The most dramatic impact has resulted from the introduction of improved climbing bean varieties in central and eastern Africa, first in Rwanda where they tripled yields, and subsequently spreading to Kenya, Uganda and Tanzania. Thirty years ago Rwanda was a net importer of beans; today that country exports beans to its neighbors.

CIAT has long emphasized participatory research and farmer involvement in the selection of new varieties. CIAT also pioneered the establishment of functional regional research networks, first in Central America, followed by East-Central Africa and the Andean zone. Today the Pan-African Bean Research Alliance (PABRA) is a model for partnership and has served to jump start the Wider Impact Program – a platform for interaction among actors along the research-to-development continuum that nurtures impact pathways by facilitating communication between those who supply and those who demand new technology.

To GLVA, CIAT contributes a headquarters team of two breeders, a molecular biologist, a pathologist, an entomologist and a plant nutritionist is supported by shared-time contributions from agricultural geographers, a human nutritionist, a biometrician and statisticians. In Africa (Uganda and Malawi) CIAT contributes breeders, a pathologist, an agricultural economist, a geographer, a marketing specialist, and a seed systems specialist.

Looking ahead, climate change will bring particular challenges to bean cultivation. Central America and Mexico have always suffered periodic droughts, and meteorologists predict that the region will become progressively drier. However, beans are even more sensitive to excess moisture, and eastern Africa and the Andean zone may suffer greater average rainfall with accompanying disease pressure of root rots and other fungi. Soil fertility continues to be the biggest single constraint on bean yields, and climate change will likely accelerate the mineralization of organic matter, making such constraints even more acute. Adapting beans to problem soils will be the biggest challenge of all for increasing bean yields, and forms a major activity in CIAT's current research agenda.

Indian Council of Agricultural Research (ICAR)
The Indian Council of Agricultural Research (ICAR) is an autonomous organization under the Department of Agricultural Research and Education (DARE), Ministry of Agriculture, Government of India. ICAR is headquartered in New Delhi. With 97 ICAR institutes and 47 agricultural universities across the country, ICAR is one of the largest national agricultural systems in the world. As the apex body for coordinating, guiding and managing research and education in agriculture in the country, ICAR provides advice that informs government policies and programs on grain legume food security issues.

More than 250 scientists work on legumes in ICAR programs. ICAR institutes that work on grain legumes include the Indian Institute for Pulses Research (IIPR, Kanpur), the Indian Agricultural Research Institute (IARI, New Delhi), the Central Research Institute of Dryland Agriculture (CRIDA; Hyderabad), the Directorate of Groundnut Research (Junagadh), and the Directorate of Soybean Research (Indore). Under the All India Coordinated Research Project (AICRP) 58 research institutes (including state agricultural universities) work on chickpea, and 22 research institutes each work on pigeonpea and groundnut. Collectively these institutions address a wide range of grain legumes including chickpea (*Cicer arietinum*), pigeonpea (*Cajanus cajan*), mung bean (*Vigna radiata*), urdbean (black gram; *Vigna mungo*), lentil (*Lens culinaris*), lathyrus (*Lathyrus sativus*), common bean (*Phaseolus vulgaris*), pea (*Pisum sativum*), groundnut (*Arachis hypogaea*) and soybean (*Glycine max*). They address plant breeding, biotechnology, genetic resources (collection, evaluation and conservation), cropping systems research, integrated pest and disease management, on-farm research and informatics and postharvest technology.
ICAR has demonstrated yield increases of 30-40% at field level through improved package technologies over local practices in different legume crops. The main issues that the ICAR institutes are currently addressing include increasing and stabilizing the production of legumes, especially of crops such as pigeon pea, mung bean and chickpea (in order to address national production shortfalls and to reduce the prices of these commodities), insect pest resistance (particularly against Helicoverpa) and expanding legume cultivation in rice fallows and other niches.

ICAR works collaboratively with many CGIAR centers. Some of the strengths that the ICAR institutes that will contribute to GLVA include: (i) a large network of testing sites/locations for multi-location evaluation; (ii) capacity development for other NARS, especially from South Asia; (iii) leadership in farm machinery, mechanization, postharvest technologies, and development of novel food products; and (iv) possible coordination of activities in crops for centers not having offices in India

**International Center for Agricultural Research in Dry Areas (ICARDA)**

ICARDA conducts breeding improvement R4D on kabuli chickpea, lentil, faba bean and grasspea in the temperate zone of the developing world, and is exploring expansion into field pea (*Pisum sativum*). ICARDA holds large genetic resource collections of all these crops and carries out collection, conservation and utilization studies to enhance their utility for crop improvement. A few major accomplishments to date include the development of winter planted chickpea technology for West Asia and North Africa that more than doubles yields; improved short-duration lentil varieties that triggered an increase in production from 600,000 tons to 1.27 million tons in the last 30 years in South Asia; new faba bean varieties that have contributed to poverty alleviation in Ethiopia, Sudan and Egypt; and the release of low-neurotoxin (low ODAP) grasspea variety in Ethiopia.

Drought, cold, heat and salinity tolerance are major abiotic challenges being addressed through breeding, while soil-borne and foliar pathogens and parasitic weeds are leading biotic constraints receiving attention. This includes resistance breeding/screening and integrated pest management of leaf miner, aphids, Sitona weevils and against important viruses of grain legumes along with seed health testing, diagnostic kits for viruses, and village-level seed systems support. Conventional and molecular breeding approaches are utilized. For pests not endemic/epidemic in Syria, ICARDA relies on partnership with NARS to screen target crosses and other genetic materials. Agronomic research addresses tillage effects (till vs. no-till, irrigation vs. rainfed) on disease resistance and yield.

Major current activities focus on:

- Developing pre-breeding programs to introgress useful allele(s)/genes particularly from wild relatives;
- Increasing R4D on climate variability and development of heat, cold, and drought resistant germplasm using modern biotech approaches such as QTL and association mapping of these traits in lentil and chickpea;
- Developing disease and pest resistant varieties and IPM packages for existing and new biotic emerging threats in response to climate variability and change;
- Addressing pest problems in South Asia especially botrytis grey mold, wilt/root rot resistance and Stemphylium blight in partnership with NARS;
- A new effort to introduce pulses such as lentil into rice-fallow systems;
- Developing kabuli chickpea for East Africa (e.g. Ethiopia) to enter in the international kabuli commodity market;
- Developing different market classes of lentil and faba bean;
- Biofortification of lentil with iron and zinc and extending the work to chickpea, faba bean and pea;
- Further advancing neurotoxin (ODAP)-free breeding R4D in grasspea.
Strengths that ICARDA will contribute to GLVA include a bio-pesticide laboratory; a large collection of bio-control agents; a strong seed technology section also focusing on seed delivery systems; screening facilities for Fusarium wilt, Ascochyta blight, cold tolerance and water supply variability; a well-organized plant virology laboratory providing training and support of NARS in virus identification and diagnosis; geospatial sciences capacity that improves understanding of germplasm and targeting of breeding efforts to fit climatic and soil environments; food-feed and crop residue research including a small ruminant research unit (sheep and goats); a biotechnology laboratory that routinely transforms chickpea and lentil; a large collection of Rhizobium (1400 accessions) for BNF R4D; a legume food quality lab addressing nutritional (iron, zinc) and anti-nutritional factors such as ODAP in grasspea; and a strong international germplasm testing network with NARS.

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

ICRISAT improves chickpea, groundnut and pigeonpea crops and systems that are widespread across the tropical drylands and beyond. These crops are among the hardiest of the grain legumes against drought and heat, having evolved under conditions of high variability in rainfall, temperature and soil quality. ICRISAT holds in trust for humanity one of the world’s largest collections of grain legume genetic resources. This includes 20,140 accessions of chickpea, 15,419 of groundnut, and 13,632 of pigeonpea.

ICRISAT conducts R4D on the characterization and use of this germplasm for plant breeding, including drought and heat physiology, pathology and entomology studies supported by a strong biotechnology effort. Cropping systems R4D addresses soil, water and nutrient management, while markets, institutions and policies are also studied to enhance market-access and profits for poor farmers. All these directions are accompanied by capacity-building activities to strengthen partner institutions across the dryland tropics of Africa and Asia.

Impacts to date have been large. Fifty-four countries have released improved cultivars of groundnut (135), chickpea (116) and pigeonpea (65) using germplasm accessions and breeding materials supplied by ICRISAT, resulting in impacts estimated at over US$150 million annually in increased production. A few of these impacts are highlighted in Chapter 3. With their partners, biotechnologists in ICRISAT have constructed reference genetic maps in chickpea, groundnut and pigeonpea, and are in the process of sequencing the genomes of chickpea and pigeonpea.

In the partnership arena, ICRISAT has played a catalytic and coordinating role in the Cereals Legumes Asia Network (CLAN) since its inception. In recent years ICRISAT pioneered an important public-private partnership known as the Hybrid Parents Research Consortium (HPRC) with private-sector seed companies to which all partners contribute to advance hybrid varieties and seed supply chains. Another private-public partnership achievement is the Agri-business Innovation Platform (AIP) that fosters entrepreneurship to increase the availability of modern technology to poor dryland tropical farming communities. ICRISAT will contribute the experiences, partnerships and capacities gained in all the above areas to GLVA.

International Institute for Tropical Agriculture (IITA)

IITA improves cowpea and soybean for the sub-humid and semi-arid areas of sub-Saharan Africa. Research on the important but neglected bambara groundnut crop has recently been re-initiated. IITA aims to improve integrated farming systems, varieties, seed systems, plant health management and natural resource management. IITA also addresses postharvest value-chain activities in order to stimulate commercial demand through improved processing and marketing of grain legume products.

In view of the integrated and multiple objectives of small-scale farmers in Africa, IITA develops multiple-purpose varieties that provided grains for human food, feed for livestock and improve soil fertility. These targets include the development of efficient and effective rhizobial inoculants to enhance BNF, and integrated plant health management options. The IITA genebank holds the
World's largest and most diverse collection of cowpeas, with 15,122 accessions from 88 countries representing 70% of African cultivars and nearly half of the crop's global diversity. The gene bank also holds 1742 soybean and 1815 bambara groundnut.

In cowpea the development and dissemination of a wide range of cultivars has led to increases in production and incomes of small-scale farmers. Improved varieties have been released by 68 countries around the world. Varieties tolerant to the parasitic weeds *Striga* and *Alectra* have reduced production losses. Other technologies that have increased cowpea production include the establishment of a novel parasitoid against flower thrips in West Africa, and the development of cheap delivery systems for natural enemies of the legume pod borer.

In view of the commercial importance of soybean around the world, IITA approached the crop from a value chain perspective in Nigeria, generating major impact with partners. Keys to this success were the development and dissemination of promiscuously-nodulating varieties in concert with improved processing and utilization technologies and activities to raise public awareness of home preparation methods. Ensuring that all value chain bottlenecks were alleviated led to the emergence of a number of medium and large-scale soybean processors that added further value to the chain. IITA will contribute this learning to GLVA to assist its application to other grain legumes.

Current priorities include:

- Disease-resistant varieties targeted to a range of uses
- Improved resistance to drought and low phosphorus
- Resistance to *Maruca* pod borer
- Reducing the excessive use of synthetic insecticides
- Partnering with NGOs and private sector for the production of bio-pesticides
- Development of efficient rhizobial inoculants to increase BNF
- Improved nutritional quality, particularly for micronutrients
- Improved processing and utilization
- Crop management practices to increase productivity
- Dissemination and impact analysis
Appendix 2. GLVA Focus Regions: Brief Profiles

Central and West Asia and North Africa (CWANA)  Faba bean, chickpea and lentil are the most important grain legumes in CWANA. In general faba bean is grown in the low coastal areas, chickpea in the continental areas and lentil in the high altitude areas. Faba bean and lentil are grown during the cool rainy winters and chickpea in the late winter/early spring as the rains end and temperatures rise. These crops are usually rotated with wheat or barley.

Over the past 30 years, the chickpea and lentil area has been increasing in West Asia while faba bean and other grain legumes are declining in other parts of CWANA. Although yields are low in West Asia (0.5-1 t/ha) the sown area quadrupled from 1976 to 2008 (from 378,000 ha to 1,526,000 ha - FAO 2008). The increase in West Asia is mainly due to growing awareness of the benefits of food legumes in cereal-dominated cropping systems. It is also partly due to the adoption of new cultivars suitable for machine harvesting, and winter-chickpea technology (Ascochyta blight-resistant, cold-tolerant cultivars of kabuli chickpea).

The biotic stresses of major importance for chickpea are Ascochyta blight and Fusarium wilt while abiotic stresses are drought, cold and heat. For high-altitude areas R4D emphasizes Fusarium wilt and plant type for lentil. R4D on faba-bean is focused on yield potential, combining early maturity with heat tolerance, and resistance to biotic stresses such as chocolate spot and rust, and to parasitic weeds especially Orobanche.

Livestock are very important components of CWANA farming systems, and lentil is well integrated as an important legume for food and feed. Lentil straw has good feed value and sometimes is as valuable as the grain per unit weight. Thus high biomass productivity is an important consideration for lentil.

There have been many reasons for the decline in grain legumes in North Africa including Orobanche infestation, non-availability of improved seed, lack of suitable varieties for mechanical harvesting, low prices, high production costs and climatic stress, especially severe droughts. Losses of human capacity to conduct R4D has also taken a toll. Morocco and Tunisia were formerly exporters of food legumes but have now become importers. Faba bean in North Africa is grown on 274,000 ha, mainly in Morocco. A large component of the faba bean production is in the form of green pods, but FAO production data do not report this form of the crop. Egypt (78,000 ha) and Sudan (68,000 ha) are the other large faba bean producers (FAO 2008).
During the Soviet era food legumes were important components of farming systems in Central Asia and the Caucasus, but have since become forgotten crops. Among the GLVA grain legumes, chickpea is still grown on a modest area of about 100,000 ha followed by lentil on about 10,000 ha. Chickpea is mainly grown in Uzbekistan and Azerbaijan, and lentil in Azerbaijan, Tajikistan, Armenia, and Uzbekistan. An organized marketing chain for these crops is lacking in this sub-region, so observations of grain legume trade within the region may give a false impression of production estimates. The main R4D effort on grain legumes takes place in Azerbaijan and Uzbekistan where few cultivars had been developed during the Soviet era.

**Eastern and Southern Africa (ESA)**

Bean, groundnut, cowpea, pigeonpea and soybean are the most important legumes in the ESA region, with lesser amounts of bambara groundnut, chickpea, lentil and faba bean. Largely grown as subsistence foodstuffs, these crops are especially cultivated by women for feeding the household. Annual per capita consumption is approximately 9 kg. A limited number of commercial farmers grow soybean in South Africa, Zimbabwe and Zambia.

Continuous maize cultivation is widespread in ESA. This monoculture has led to the mining of soil nutrients and soil degradation. Drought and low soil fertility are the main constraints. Where landholdings are small, grain legumes (primarily bean, cowpea, and pigeonpea) are intercropped or rotated with maize to diversify food supplies, hedge against drought risk, generate income and combat declining soil fertility. Sole crops of groundnut and soybean are grown in rotation with maize where sufficient land and labor or machinery are available.

The area devoted to chickpea and soybean production, though small has been steadily increasing over the years in the region. Chickpea doubled in sown area over the past 30 years (from 210,000 to 420,000 ha between 1979 and 2008) to meet increasing demand in domestic and international markets.

**West and Central Africa (WCA)**

The main legumes grown in WCA are: groundnut, cowpea, soybean, common bean and bambara nut. Pigeon pea and African yam bean are also grown as home garden intercrops.

According to FAO data, average annual production and areas under the main legume crops in WCA are: groundnut (6.4 million tons on 5.3 million ha), cowpea (4.5 million tons on 10.1 million ha), soybean (610,000 tons on 660,000 ha), common bean (230,000 tons on 390,000 ha) and bambara nuts (58,300 tons on 71,000 ha).

Across WCA, both the production and land area under legumes has been increasing by 2-6% per year over the past five years. This trend is expected to continue. Grain yield in these crops have remained static and low when compared with world averages.

Apart from soybean and groundnut to lesser extent, the other legumes are grown in mixed cropping including intercropping and relay cropping with cereals (sorghum, millet, maize), other legumes and root crops such as cassava, yam and sweet potato, cotton (cowpea mainly), sugarcane, and plantation tree crops. With their increased role as cash crops, mono-cropping of the legumes is expanding in the different countries.

Women are the main producers of homestead legumes in mixed and intercrops. Where legumes are grown as field cash crops, men are more likely to be involved. Few large scale commercial farmers growing these crops in this region. Grain legume processing and retailing are carried out almost exclusively by women.

Cowpea and bambara nut are cultivated mainly in the drier sudan savanna and the Sahel regions, while groundnut is better adapted to the less harsh northern guinea savanna zone. Soybean is grown in the still moister savanna regions (southern guinea) and extending to the forest/savanna transition agro-ecology. The legume crops often occupy marginal poor farmlands. Farmers use no or little fertilizer on them and do not inoculate with rhizobium. The only input that is often used is
insecticide on cowpeas in some situations in Nigeria where such inputs could be obtained, often through cotton input supply systems. Most crop management activities are done by hand in this region, although animal traction is used in some areas.
Latin America and the Caribbean (LAC)  In Latin America and the Caribbean two grain legumes are of major importance: common bean (*Phaseolus vulgaris*) and soybean (*Glycine max*). Other legume species including another four species of cultivated *Phaseolus* as well as groundnut are also cultivated but on relatively small areas in niches of extreme heat, drought or high rainfall, rendering some of them as interesting potential components to help adapt farming systems to climate change. Several introduced legume species are important locally: cowpea in northeast Brazil, the northern coast of South America and eastern Cuba; pigeonpea in Haiti; chickpea in the Pacific coast of Mexico; and faba bean in the high Andes. For human consumption common bean is by far the most important in area and tonnage.

In general the grain legumes are cultivated by small farmers for home consumption and for sale through local and regional markets. Traditionally a large proportion of common bean area was planted with climbing or semi-climbing types in association or relay with maize; in highland areas of southern Mexico, Guatemala, Ecuador, and Peru some association with maize persists. However rising labor costs have led farmers to prefer upright bush habits that facilitate harvest. In Central America the small-seeded types of the Mesoamerican gene pool predominate, with most production in the range of 400 to 1200 m above sea level. Yields typically average around 700 kg / ha, although El Salvador now registers a national yield average of about 1000 kg/ha. In the low to mid-altitude regions Gemini viruses became the primary production limitation in the decade of the 1970s, and now are effectively controlled through genetic means. While vegetable production offers significant income for farmers with good market access, among field crops beans continue to be the best income option for small farmers.

In the Caribbean, Cuba, the Dominican Republic and Haiti are the most important producers and consumers of legumes. Here the altitudinal gradient, soil and climate determine which legumes are produced, although common bean is the legume of preference. In the Caribbean and in the Andean zone, as well as in parts of Brazil the large-seeded types that originated in the Andes are preferred.

Mexico and Brazil present extremes of production systems. In Brazil the irrigated winter planting represents about 5% of total area, while the northeast of Brazil remains one of the strongholds of poverty in the western hemisphere with more than a million hectares of bean and cowpea, out of more than 4 million ha nationwide. Mexico presents even wider variability in production, from irrigated high input agriculture on the Pacific coast, to mechanized dryland agriculture in the central plateau, to totally traditional systems in the south.

In Latin America urbanization has led to lower per capita consumption and in some cases more diet-related illnesses such as cardio-vascular disease and diabetes. Common bean area has been steady or has declined slightly, but production has increased due to gradually improving yields. However, erratic weather in Central America in recent years has led to serious production shortages, with grain buyers looking far afield to meet local demand.

Soybean production is concentrated in Brazil and Argentina and is principally in the hands of large mechanized farmers, although some technology (for example, BNF) could be of utility to other regions of the world.
Legumes in Maize based cropping systems of Latin America

Source: Farming systems map, FAO, YIB, 2001
South and Southeast Asia (SSEA)

South and Southeast Asia contains more than half of the world’s population living on less than one-third of its arable land while producing more than half of the developing world’s grain legume crop. Population pressures on land are particularly high in SEA, where grain legumes have traditionally provided a major source of food and nutritional security.

Asia is the center of origin of many important grain legumes. Asia dominates world production of several grain legumes including pigeonpea (95%), mung bean (90%) and chickpea (85%). India alone accounts for around 80% of SEA chickpea and pigeonpea production, about half of its lentils and about one third of its soybeans, groundnuts, dry peas and dry beans (mainly mung bean and urin bean). A ban on the trade of grasspea in India and Nepal due to neurotoxin concerns has been the main reason behind the drastic decline in this crop’s cultivation. In Bangladesh, grasspea still occupies first position among the pulse crops.

The sustainable legume-cereal system began to break down with the Green Revolution in the 1960s that heavily promoted increasing cereal production, as well as the rise of other cash crops responding to industrial development. Traditional legume components in crop rotations were relegated to marginal land areas. For example wheat, rapeseed, and mustard have largely replaced chickpea and lentil in the middle and northern temperate regions of India, forcing those crops southward into hotter, drier areas. Competition from maize and cotton has contributed to declines in the area of groundnut in the Philippines, Thailand and India.

The deleterious consequences of policy bias against grain legumes on national economies as well as on farming systems are being increasingly recognized in the region. India, Pakistan and Sri Lanka have become major legume importers from China, Myanmar, Thailand, Australia and Canada, creating an outflow of hard currency from the region. Efforts to cope have resulted in the breeding of high-yielding short-duration grain legume varieties tolerant to heat and drought, so that these crops could better fit into the marginal niches available in cereal rotations, often maturing on residual moisture. But this progress has not been sufficient to meet growing food demand for legumes.

Rising prosperity is also changing the legume market in economically-emergent parts of Asia. Increasing urbanization and changing food habits including growing demand for healthy convenience foods however is creating new kinds of demand that could benefit poor farmers. There is a need to diversify food products made from legumes to satisfy growing demands for such foods.
Appendix 3: GLVA Target Crops: Brief Profiles

As described in Chapter 5, GLVA will focus on ten mandate grain legume crops in the developing world: chickpea, common bean, cowpea, faba bean, grasspea, groundnut, lentil, mung bean, pigeonpea and soybean. Exploratory work will be pursued on four additional crops: bambara nut, lima bean, pea and tepary bean. Brief descriptions of these crops are below.

Mandate Crops

**Chickpea** is the world’s second-largest cultivated food legume. Developing countries account for over 95% of its production and consumption (Gaur et al. 2008). Chickpea grain is an excellent source of high-quality protein, with a wide range of essential amino acids (Wood and Grusak 2007) and high ability to fix atmospheric nitrogen. Since major consumers such as India do not produce sufficient chickpeas domestically, there are opportunities especially for East African countries to sell into this important market; indeed, sown area in ESA doubled over the past 30 years and exports accounted for about 30% of total production, indicating that these poor farmers are using chickpea for both food and to earn extra income. The area under chickpea in West Asia has also increased dramatically in the past 30 years (from 378,000 ha to 1,526,000 ha) leading to the exportation of chickpea from countries such as Turkey, Syria, and Iran. Drought stress commonly affects chickpea because it is largely grown under rainfed conditions during the post-rainy season on residual soil moisture (Gaur et al. 2008). R4D on drought tolerance has paid dividends in recent years with the improved drought tolerant chickpea cultivars. Collar rot, *Fusarium* wilt, dry root rot and *Ascochyta* blight are some of the important diseases of chickpea in the Indian subcontinent, whereas *Ascochyta* blight and *Fusarium* wilt are the most important worldwide (Chen et al., 2010). Chickpea in CWANA is traditionally grown during the rainy season to avoid ascochyta blight and cold/frost but then encounters drought conditions, reducing potential yields (Malhotra et al. 2009).

**Common bean** is the most important grain legume for direct human consumption with 23 m ha grown worldwide (Broughton et al. 2003). Approximately 12 million metric tons are produced annually, of which about 8 million tons are from Latin America and Africa (FAO, 2005). Over 200 million people in SSA depend on the crop as a primary staple, with beans contributing to diet and incomes in over 24 countries in this region alone (Wortmann et al. 1998). In the developing world bean is a small farmer crop, and in Africa is cultivated largely by women. Consumption is as high as 66 kg/year/person, and in many areas, common bean is the second most important source of calories after maize. Typical bean yields, however, represent only 20 to 30% of the genetic potential of improved varieties due to major production risks such as insect pests, diseases and drought, which – due to climate change – is increasing in severity and frequency in the region (Funk et al. 2008). Drought affects production of common beans in most of Eastern Africa, but is especially severe in the mid-altitudes of Ethiopia, Kenya, Tanzania, Malawi and Zimbabwe, as well as in Southern Africa as a whole.

**Cowpea** (*Vigna unguiculata*, Leguminosae) is the most important grain legume crop in sub-Saharan Africa (Timko et al., 2007), grown by tens of millions of smallholders. It is estimated that 200 million children, women, and men in West Africa rely on cowpea, consuming the grain daily whenever available. It is mostly grown in the hot drought-prone savannas and very arid Sahelian agro-ecologies, where it is often intercropped with pearl millet and sorghum (Hall, 2004). Cowpea is a protein-rich grain that complements staple cereal and starchy tuber crops, but also provides fodder for livestock, soil improvement benefits through nitrogen fixation, and households benefits in the form of cash and income diversity. Cowpea is highly drought-tolerant with deep roots that help stabilize the soil and dense foliage that shades the soil surface preserving moisture. Cowpea ‘on-farm’ grain yields in SSA reach only 10–30% of their biological yield potential, due primarily to insect and disease attacks and drought (Ehlers and Hall, 1997). Improved varieties are urgently needed that will help to reduce this yield gap (Hall et al., 1997).
**Faba bean** (*Vicia faba* L.) Faba bean (*Vicia faba* L.) also called fava bean, broad bean, field bean, horse bean and bell bean is an erect leafy winter or summer annual. It is one of the oldest crops domesticated in the Fertile Crescent of the Near East. It expanded around the world during Neolithic period: from Antalya (Turkey) towards Europe (Germany, Greece, France, Italy and Spain); from Egypt across North Africa and eastwards to Afghanistan and onwards to China, India and in more recent times to Latin America and North America (Canada and USA) (Cubero, 1974). In WANA faba bean is cultivated in costal Mediterranean areas with 300 mm and above annual rainfall. In China there are two major production areas, one sown in winter (mainly in the southern province of Yunnan) and the other sown in spring (in highlands stretching from Mongolia to Tibet). Faba bean is grown in northern India (Bihar, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Jharkhand, Orissa, West Bengal). In Latin America it is mainly grown in Argentina and Chile. Cultivated faba bean is used as human food in developing countries, and as animal feed (mainly for pigs, horses, poultry and pigeons) in developed countries and in North Africa. In addition to boiled grains, it is consumed as vegetable green seeds/pods, dried or canned. It is a staple breakfast food in the Middle East, Mediterranean region, China and Ethiopia (Bond et al., 1985). Faba bean has a protein content of 24-30 percent. Although the global average grain yield of faba bean has almost doubled during the past 50 years, the total area sown to the crop has declined by 56% over the same period due to the cheap availability of fertilizers (devaluing some of the short-term economic benefits of BNF) and competition with policy-favored cereal and high-value urban cash crops. The most important diseases of faba bean are chocolate spot (*Botrytis fabae* and *B. cinerea*), rust (*Uromyces viciae fabae*), Ascochyta blight (*Ascochyta fabae*), black root rot (*Thielaviopsis basicola*), stem rots (*Sclerotina trifoliorum*, *S. sclerotiorum*), root rots/damping-off (*Rhizoctonia* spp.), pre-emergence damping-off (*Pythium* spp.), bean yellow mosaic virus, bean true mosaic virus, bean leaf roll virus and bean yellow necrotic virus (van Emden et al., 1988). Among the insect pests, bruchids and aphids are important.

**Grasspea** (*Lathyrus sativus* F.) (khesari in India and Bangladesh, guaya in Ethiopia) and is a legume commonly grown for human consumption and livestock feed in Asia and East Africa. It is one of the most important food legumes in countries like Bangladesh, India and Ethiopia. It is high in protein (28-32%). It has become popular due to its high degree of adaptability under extreme drought conditions, its disease resistance under smallholder low-intensity cultivation and its low input requirement. It can withstand excessive rainfall and can be grown on land subjected to flooding, including very poor soils and heavy clays (Sinha SK, 1980). The major limiting factor of grasspea is that its seeds contain a neurotoxin (ODAP) (Kumar et al. 2010). Breeding efforts were successful in developing low and zero level ODAP lines (Kumar et al. 2011). Major pests and diseases limiting the productivity of grasspea include aphids (*Aphis craccivora*), powdery mildew (*Erysiphe polygoni* DC) and downy mildew (*Perenospora lathyri-palustris* Gaumann).

**Groundnut** (*Arachis hypogaea*), is known by many local names including peanut, earthnut, monkey nut and poor man’s nut. Though groundnut is native to South America, it is successfully grown in other parts of the world and became an important oil seed and food crop. From a nutritional point of view, groundnuts are very important in the lives of poor as they are very rich source of protein (26%) and monounsaturated fat. In addition to protein, groundnuts are a good source of calcium, phosphorus, iron, zinc and boron. While China and India are the leading producers worldwide, millions of small-holder farmers in sub-Saharan Africa (SSA) grow groundnut as a food and cash crop, which accounts for 9m ha of cultivated farmland (2007 datum). While this area is 40% of the world total, this percentage represents only 25% of the total production due to low yield (950 kg/ha, versus 1.8 t/ha in Asia). The main constraints hampering higher yields and quality in Africa are intermittent drought due to erratic rainfall patterns and terminal drought during maturation. Yield losses from drought run to millions of dollars each year (Sharma and Lavanya 2002). A drought-related quality issue is pre-harvest contamination of seeds with aflatoxin, a carcinogenic mycotoxin produced primarily by the fungus *Aspergillus flavus*, which consequently shuts out SSA groundnuts from export markets. In addition, major foliar fungus diseases like early leaf spots (ELS) and late leaf
spots (LLS) and Rust; and virus diseases like Rosette, Peanut Clump and Bud Necrosis causes devastating yield losses (50-60% yield losses by ELS—LLS, Waliyar et al., 1991; 2000; Grichar et al., 1998) and as much as 100% by rosette in epidemic years, Yayock et al. 1976., Olorunju et al. 1992).

**Lentil** (*Lens culinaris* Medikus), one of the world’s oldest cultivated plants, originating in the Middle East and spreading east through Western Asia to the Indian subcontinent. Lentil is currently grown in South America, Europe, Australia and Asia (Bangladesh, India, Jordan, Lebanon, Syria and Turkey). Lentil has a variety of different names in different countries and languages including *Masoor* (India), *Adas* (Arabic), *Mercimek* (Turkey), *Messer* (Ethiopia) and *Heramame* (Japanese) giving some indication of the breadth of its importance (Erskine et al. 2009). It is a short-statured, annual, self-pollinated, high valued crop species. The crop has great significance in cereal-based cropping systems because of its nitrogen fixing ability, its high protein seeds for human diet and its straw for animal feed. Protein content ranges from 22 to 35% and like other grain legumes its amino acid profile is complementary to that of cereals. Lentil is currently grown on 3.8 M ha worldwide (though much of this is in developed countries) with production of over 3.5 M metric tons (FAOSTAT, 2008). The major reason for its low productivity in developing countries is because the crop produced on marginal lands in semi-arid environments without irrigation, weeding or pest control. The major producers of lentil are the countries in Southern and Western Asia, Northern Africa, Canada, Australia and USA (Chen et al. 2010). The most economically important fungal diseases of lentil world wide are *Ascochyta* blight and *Fusarium* wilt; however other diseases such as anthracnose, *Stemphylium* blight and *Botrytis* blight are also economically significant. Major pests include aphids, bud weevils, cutworms, leaf weevils, pod borer, stink bugs and thrips (Chen et al. 2010).

**Mung bean** (*Vigna radiata* L.) also called as green gram or golden gram, is an ancient and well-known pulse crop. Mung bean matures in 60-65 days, faster than any other grain legume. An estimated 30-74 kg/ha nitrogen can be fixed by mung bean (IIPR, India). Mung bean contains 23.6% easily digestible protein (Kaul 1982). Mung beans are mainly cultivated in China, Thailand, Philippines, Vietnam, Indonesia, Burma, Bangladesh and India, but also in hot and dry regions of southern Europe and the southern USA. Yields are affected by several biotic and abiotic factors. Charcoal rot caused by *Macrophomina phaseolina* (Tassi) Goid is major constraint. Powdery mildew, *Cercospora* leaf spot and mung bean yellow mosaic virus (MYMV) are other economically important diseases that limit productivity.

**Pigeonpea** (*Cajanus cajan* (L.) Millsp.) is a staple grain legume in South Asian diets and is also widely grown and consumed in household gardens in Africa – and rapidly expanding as an export crop from Eastern/Southern Africa to South Asia. Household artisanal production is not well documented in the FAO database, which indicates total global area of 4.79 M ha (FAO, 2008) in 22 countries. India is by far the largest producer with 3.58 M ha although this is insufficient to meet all its consumption needs; it imports from neighbor Myanmar (560,000 ha) and other countries, notably in ESA. In Africa smallholders are most intensified for dual consumption and export in Kenya (196,000 ha), Malawi (123,000 ha), Uganda (86,000 ha), Mozambique (85,000 ha), and Tanzania (68,000 ha) (Saxena et al. 2010). With protein content totaling more than 20%, almost three times that of cereals, pigeonpea plays an important role in nutrient-balancing the cereal-heavy diets of the poor. Pigeonpea is also important in some Caribbean islands and some areas of South America associated where populations of Asian and African heritage have settled (Saxena et al. 2010). In addition to being an important source of human food and animal feed, pigeonpea also plays an important role in sustaining soil fertility by improving physical properties of soil and fixing atmospheric nitrogen. Traditional long-duration pigeonpea expresses a perennial tall bush like growth habit that conveys additional soil protection and deep-rooted nutrient recycling ability. Shorter-duration varieties will naturally have less time to provide such services. Pigeonpea is generally relay or intercropped with sorghum, cotton, maize and groundnut and thus has to compete with that associated crop for water, nutrients, sunlight and other resources. Recently, ICRISAT has developed hybrid pigeonpea cultivars that produce 35% higher yields and are currently being multiplied through the private sector for
dissemination to farmers. Major biotic stresses include diseases especially sterility mosaic, *Fusarium* wilt, and *Phytophthora* blight in the Indian subcontinent; wilt and *Cercospora* leaf spot in eastern Africa; and witches' broom in the Caribbean and Central America (Reddy et al. 1990). The major insect pests are pod fly (*Melanagramyza* sp), pod borers (*Helicoverpa armigera* and *Maruca vitrata*), and pod sucker (*Clavigralla* sp) (Joshi et al. 2001). Major abiotic constraints are drought and in some areas intermittent waterlogging.

**Soybean** (*Glycine max* L. Merr.) cultivation originated in China around 1700-1100 B.C. Soybean is now cultivated throughout East and Southeast Asia, North America, Brazil and Africa where people depend on it for food, animal feed and medicine. It is highly industrialized in developed countries, providing more than a quarter of world’s food and animal feed requirement in addition to protein (Graham and Vance, 2003). It grows well in tropical, subtropical, and temperate climates during warm, moist periods. Postharvest technologies such as oil processing have led to many new applications of this useful plant. Soybean has great potential as an exceptionally nutritious and rich protein food. It contains more than 40 per cent protein of superior quality and all the essential amino acids, particularly glycine, tryptophan and lysine, similar to cow’s milk and meat protein. Soybean also contains about 20 per cent oil including healthy fatty acids, lecithin and vitamins A and D. Soybean also contains secondary metabolites such as isoflavones (Sakai and kogiso, 2008), saponins, phytic acid, oligosaccharides, goitrogens and phytoestrogens (Liener, 1994; Oosuki and Kennelly, 2003). Soybean oil is also used as a source of biodiesel (Pimentel and Patzek, 2008). Some of the major biotic constraints include asian soybean rust, frogeye leaf spot, bacterial pustule, bacterial blight and soybean mosaic virus. Nematodes and insects such as pod feeders (stink bugs), foliage feeders, and bean flies feed on soybean plants. These wounds provide entry points for pathogens, and the plant frequently becomes susceptible to pathogenic organisms. Breeders at IITA are currently developing dual-purpose varieties that are tolerant to phosphorus-deficient soils and have enhanced capacity to kill seeds of the parasitic weed *Striga hermonthica* that attacks cereals.

**Exploratory crops**

**Bambara nut** (*Vigna subterranea* Leguminosae) or bambara bean ripens its pods underground, much like the peanut or groundnut. They can be eaten fresh or boiled after drying. Bambara bean is a rare example of a complete food. It contains such an excellent balance of nutritive factors that people can sustain life on a diet nearly of bambara nuts alone. Its protein contains more of the nutritionally essential amino acid methionine than most other grain legumes. The grains contain approximately 20 percent protein and 7 percent oil. For these reasons bambara could become an excellent tool for combating malnutrition. Nevertheless, due to its small planted area, bambara bean has received little attention from R4D institutions. A total of 101,000 ha are planted worldwide in a typical year with total production reaching some 77,000 t (FAOSTAT, 2008). Average farm yields are about 400 kg per hectare, yet under improved conditions the crop can produce ten times more than this. Because of the orphan status of this crop, varieties with stable and predictable yields under intensification are lacking. Another serious limitation is the long time needed to cook the dry seeds.

**Lima bean** (*Phaseolus lunatus*) is mainly grown for fresh vegetable consumption. It is known by a number of names, including Haba beans, sugar beans, butter beans, Guffin beans, civet beans, Hibbert beans, Pallar beans, Sieva beans, Madagascar beans, and Burma beans. Lima beans are a very good source of cholesterol-lowering fiber, as are most other legumes. In addition, the lima beans' high fiber content prevents blood sugar levels from rising too rapidly after a meal, making them an especially good choice for individuals with diabetes, insulin resistance or hypoglycemia. Lima beans are an excellent source of molybdenum and manganese. Lima beans are likewise good sources of folate, protein, potassium, iron, copper, phosphorus, magnesium and thiamin. Many factors influence yields, but weather conditions that affect flower bud development, pollination, and pod maturation have the greatest impact. Production constraints include diseases (downy mildew, root rots (*Phythium, Rhizoctonia*) and white mold (*Sclerotinia*), insects (cut worms, aphids, mites and leaf hoppers) and weed control.
Pea (*Pisum sativum* L) is grown widely throughout the world for both fresh and dry pods and grains. Peas are grown on approximately 7.32 million hectares worldwide with 20 million metric tons produced annually (FAO 2009). The major producers are developed countries (Canada, Australia, USA and EU countries) but the crop is also found on a small scale in Africa and Asia. Pea is a rich source of protein, vitamin A, vitamin C, folate, thiamine (B1), iron and phosphorus. The haulms are also used for livestock feed and have been found to be highly productive in exploratory trials at ICARDA. Pea is a self-pollinated annual herb, bushy or climbing, glabrous, stems weak, round, and slender, leaves alternate, pinnate with 1-3 pairs of leaflets. Interesting leaf type variants exist including conventional, semi-leafless and leafless. It is adapted to a wide range of climates and altitudes. Accessions of *Pisum* have been collected and maintained within several major well-characterized collections worldwide including the ICARDA gene bank (Zong et al 2009). The crop is challenged by both abiotic and biotic constraints including frost and drought particularly at the flowering stage, and diseases such as bacterial blight, powdery mildew, downy mildew, leaf spot or scab, rust and viruses. Unpredictable variation in climate poses a continuous threat to rainfed pea production, particularly in Africa and South Asia.

Tepary bean (*Phaseolus acutifolius*, Fabaceae) is an indigenous legume of arid and semi-arid regions. Other names for this native bean include Pawi, Pavi, Tepari, Escomite, Yori mui and Yori muni. Tepary beans are high in protein (23-25%). They are eaten like other dry beans, first soaked, then boiled or baked. It is more drought-resistant than the common bean (*Phaseolus vulgaris*) and is adapted well to grow in desert and semi-desert conditions. Its water requirements are low and will grow in areas where annual rainfall is less than 400 mm (16 inches). It is early maturing, with long roots that can reach down to tap soil moisture. It was recently introduced in Africa and gained importance in Sudan, northeastern Kenya, Uganda, and Botswana, where most other legumes fail because of drought and where short duration crops are often needed. Tepary bean is generally not affected by diseases in semi-arid regions except during periods when humidity is high. However it is highly susceptible to bean common mosaic virus (BCMV). In Uganda average yields are 450-670 kg dry seeds per ha where as in the US dry land farming system produce 500-800 kg/ha. With irrigation it readily produces 900-1700 kg/ha. The largest germplasm collection of tepary bean is held at CIAT. To foster tepary bean in Africa, the selection of high yielding cultivars, the development of food products (protein supplements) with a reduced odor, and the creation of marketing infrastructure are a prerequisite.
Appendix 4. Grain Legume Regional R4D Networks: Brief Profiles

A number of important regional networks that are important to GLVA’s success are described here in more detail.

**Sub-Saharan Africa**

**PABRA**

CIAT facilitates the Pan-Africa Bean Research Alliance (PABRA). PABRA was founded in 1996 and now is a consortium of regional bean networks consisting of about 350 direct and indirect partners, mainly NARS in 28 countries in sub-Saharan Africa, an international research organization (CIAT), and a number of donor organizations, Government and Non-Governmental Organizations (NGOs), sub-regional organization (SROs) such as ASARECA, SADC-FANR and CORAF, community-based Organizations (CBOs), selected rural communities, farmers (seed producers and on-farm researchers), traders and the commercial private sector. The sub-regional bean networks linked by PABRA are the Eastern and Central Africa Bean Research Network (ECABREN) with eight countries (Kenya, Ethiopia, Uganda, Rwanda, Burundi, Sudan, Eastern and west DRC, Madagascar and Northern Tanzania), the Southern Africa Bean Research Network (SABRN) consisting of 10 countries (Southern Tanzania, Mozambique, Zambia, Malawi, Lesotho, Mauritius, South Africa, Angola, southern DRC, Swazi land) and the relatively new West and Central Africa Bean Network (WECABREN) consisting of Burkina Faso, Cameroon, Central African Republic, Congo Brazzaville, Guinea Conakry, Senegal, Sierra Leone and Togo, Ghana and Mali. The regional networks are managed by regional coordinators and respond to issues and priorities of respective sub-regional organization (SROs). A network Steering Committee (SC) is made of leaders of the National Bean Programs of countries in the network who by and large are also leaders of the Legume Program. Annual work plans and budgets are proposed by the SC of each network based on regional network partnership activities. The network workplans are integrated and harmonized into PABRA workplans.

PABRA facilitates collaborative research within and between the bean networks in Africa by providing a forum for building and maintaining linkages to multiple partners and between research and development. PABRA’s five-year framework (developed by partners, based on shared vision and objectives, and a long term mutual agreement to collaborate, sharing of knowledge, resources and capabilities) has well defined performance indicators and is collaboratively implemented by NARS partners in 28 countries belonging to three regional bean networks through complementarity which PABRA harnesses through a process facilitated by the three Regional Networks and PABRA Steering Committees. The successes in beans in Africa are largely attributed to the partnership: release of several bean varieties and the reach of over 7 million households with improved bean varieties within a period of five years.

**PRONAF and NGICA on cowpea in Western and Central Africa**

Several networks were established mainly in West Africa for cowpea. The main objectives of these networks are to allow interactions among cowpea scientists in the region and to exchange improved cowpea breeding lines and crop management knowledge. RENACO (Réseau de Recherche sur le Niébé pour l’Afrique de l’Ouest et du Centre) [West and Central African Cowpea Research Network] created in covered the following countries: Benin, Cameroon, Ghana, Nigeria, Niger, Mali, Senegal and Burkina Faso. Another project PEDUNE (Protection écologiquement durable du niébé) was set up in 1997 to increase cowpea production and productivity in the Sahel and African savannas by devising ecologically and economically sustainable cowpea pest control for subsistence farmers. PEDUNE covered Benin, Burkina Faso, Mozambique, Niger and Nigeria in the pilot phase and was
expanded later to include Cameroon, Ghana, Mali and Senegal. From 2000, RENACO and PEDUNE were merged to form PRONAF (ProjetNiebe pour l’Afrique) with IFAD funding which serves nine countries: Benin, Burkina Faso, Cameroon, Ghana, Mali, Mozambique, Niger, Nigeria and Senegal. The goal of this project is to enhance livelihoods of rural poor through empowerment and gender equitable access to cowpea value chain opportunities via improved institutional arrangements, capacity building and strong linkages with NARES, countries’ IFAD investment projects, farmer’s organizations and the private sector. The current phase of the project involves the following countries: Benin, Burkina Faso, Ghana, Malawi and Nigeria.

IITA also participates in other network-like R4D partnerships on cowpea through different projects and also in collaboration with other international institutions. One example of long standing relationship is that between IITA and the USAID-supported Bean/Cowpea CRSP that recently became the Dry Pulses CRSP. IITA is involved in cowpea breeding, socio-economic and crop protection R4D.

IITA scientists are also involved in the Network for the Genetic Improvement of Cowpea for Africa – NGICA. This is a voluntary association of scientists and other stakeholders in cowpea. NGICA’s take a novel approach to maximizing the benefits of this crop in Africa – NGICA seeks to address the entire spectrum of the cowpea production and utilization system. NGICA is an informal organization made up of volunteers dedicated to the genetic improvement of cowpea worldwide. The main geographic focus is sub-Saharan Africa. The central goal is to benefit the millions of cowpea producers and tens of millions of cowpea consumers in Africa, but if the benefits can be extended further, so much the better. Because the NGICA community is international, it involves participants from North America, South America, Europe and Australia in addition to Africa. It represents disciplines ranging from plant breeding to molecular biology, from agricultural economics to public policy. We believe that traditional institutions and approaches have often become less and less relevant, and that bold, unconventional institutions and approaches are needed – particularly to take advantage of the information and biotechnology revolutions of the past decade.

**South and Southeast Asia**

*All India Coordinated Research Programs (AICRP)*

AICRP is multi-disciplinary multi-location research network spearheaded by ICAR to monitor, guide, and coordinate research on pulses in India. Many CGIAR centers participate including ICARDA and ICRISAT for the evaluation of lentil, chickpea, pigeonpea, groundnut, and grasspea. This network has identified appropriate varieties and production technologies of these crops in India.

*Cereals and Legumes Asia Network (CLAN)*

The Cereals and Legumes Asia Network (CLAN) was established in 1992, after merging the erstwhile Cooperative Cereals Research Network (CCRN) and the Asian Grain Legumes Network (AGLN). CLAN currently includes scientists and policymakers from 12 member countries (Bangladesh, China, India, Indonesia, Iran, Myanmar, Nepal, Pakistan, Philippines, Thailand, Sri Lanka, and Vietnam). It also includes interested regional and international research institutions in Asia. The Asia-Pacific Association of Agriculture Research Institutions (APAARI) has endorsed and supported the network activities over the past two decades. CLAN is co-facilitated by three GLVA partners, ICRISAT, ICARDA and AVRDC. CLAN aims to enhance production and productivity of grain legumes (as well as cereals) in Asia. Major network activities include: i) research collaboration to generate smallholder-appropriate technologies, ii) strengthening crop improvement and natural resource management research in NARS, iii) information and knowledge sharing among member countries and iv) capacity building of NARS research and development programs.

**SAVERNET and AVNET**

AVRDC coordinated five sub-regional R&D networks from the early 1990s to 2004 involving 32 countries that helped in sharing vegetable germplasm between NARS and for working on common
pest and disease problems. The networks included SAVERNET (South Asia Vegetable Research Network) in Bangladesh, India, Nepal and Sri Lanka, AVNET (Asian vegetable network) in Indonesia, Malaysia, Philippines and Thailand, and other specific networks in Southeast Asia, Central America and Africa. Most of the funding for these was provided by ADB. A network specifically for mung bean R&D operated with NARS and universities in India, Nepal, Pakistan and Bangladesh associated with a DFID sponsored project from 1997 to 2004. These networks could be revived by GLVA if resources can be found.

Central and West Asia and North Africa (CWANA)

In collaboration with national scientists across CWANA, ICARDA is leading multi-location, multi-year testing of advanced lines to identify improved germplasm through an international nursery system. Lines are evaluated against stresses such as drought, heat, cold, salinity, disease, and insects at many key sites. The information received includes performance data, meteorological data, and agronomic information, providing valuable information on the performance and adaptation of the test genotypes. Every year, ICARDA’s food legume program distributes improved germplasm to 50 countries. Thus, ICARDA’s international testing network complements national efforts for fast-tracking the release of improved germplasm for general cultivation and facilitating the design of appropriate breeding strategies for specific regions.

Regional Seed Network: The national seed sectors in the West Asia and North Africa (WANA) region are at different stages of development in terms of policy, regulation, technology, and institutions, which affects the progress of seed sector in each country and its integration both at national and regional levels. Networking between national seed programs can assist regional cooperation through the exchange of information and sharing of experiences. Since 1992, the Network is operational as the regional seed organization and the scope of its activities has increased. It is now the major ‘outreach vehicle’ of the ICARDA Seed Unit and complements other main regional activities such as training.

Nile Valley Regional Food legume Network: Three networks are being established at the regional level in Nile valley and Red Sea region. Ethiopia coordinates one network for the management of wilt and root-rot diseases of cool-season food legumes. Breeding lines and varieties from the four countries, Egypt, Sudan, Ethiopia and Eritrea and ICARDA are screened in Ethiopia (hot spot areas) and shared among countries. Egypt coordinates the network on integrated control of aphids and major virus diseases in cool-season food legumes and cereals and similar IPM options are being tested and demonstrated across participating NARS. Egypt also coordinates the network on socioeconomic studies to see the adoption and impact studies of regional projects on the livelihoods of small-holder farmers.

Maghreb Food Legumes Network: The Maghreb Food Legumes Network [Roseau Maghreb in de Recherche et Developpement des Legumineuse Alimentaires (REMALA)] was created in Tunis targeting North African countries especially Morocco, Algeria and Tunisia for setting up research and development priorities for food legumes in the region. The network comprises a steering committee and the representative members from each country, ICARDA, and European network on protein pea (link to European researchers). The network is dormant now and needs to be revitalized as the demand for food legumes in the region is increasing.
Latin America and the Caribbean

Bean networks were initiated in Central America with the PROFRIJOL network, and a second network was subsequently formed in the Andean zone as well. These networks are no longer funded but the collegial relationships established in the past are still carried forward. These include the exchange of information and joint planning, either under projects that span the region such as the AgroSalud project on crop biofortification, or through the regional agronomy meetings known as the PCCMCA (Programa Cooperativo Centroamericano para el Mejoramiento de Cultivos y Animales). Bean programs of Costa Rica, Cuba, El Salvador, Guatemala, Honduras, and Nicaragua routinely participate in the PCCMCA.
Appendix 5. Global Partners in GLVA

National Agricultural Research Systems (NARS)

1. Agricultural Research Council (ARC), Egypt
2. Agricultural Research Council (ARC), South Africa
3. Agricultural Research Council (ARC), Sudan
4. Agricultural Research Division (ARD), Swaziland
5. Agriculture Research Division (ARD), Lesotho
6. Bangladesh Agricultural Research Council (BARC), Bangladesh
7. Bureau of Agricultural Research (BAR) and Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Philippines
8. Central Food Technological Research Institute (CFTRI), Mysore, India
9. Central Institute of Agricultural Engineering (CIAE), Bhopal, India
10. Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, India
11. Central Research Institute for Field Crops (CRIFC), Turkey
12. Centre de Recherches Agronomiques de Loudima (CRAL), Congo Brazzaville
13. Centre National de la Recherche Appliquée au Développement Rural (FOFIFA), Madagascar
14. Centro Nacional de Tecnificación Agrícola (CENTA), El Salvador
15. Chinese Academy of Agricultural Sciences (CAAS), China
16. Comisión Para la Promoción de Exportaciones (PROMPEX), Peru
17. Crops Research Institute, (CRI), Ghana
18. Department of Agricultural Research (DAR), Myanmar
19. Department of Research & Specialist Services (DR&SS), Zimbabwe
20. Department of Agricultural Research Services (DARS), Malawi
21. Dirección de Ciencia Y Tecnología Agropecuaria (DICTA) and Escuela Agrícola Panamericana (EAP), Honduras
22. Directorate of Groundnut Research (DGR), Junagadh, India
23. Directorate of Soybean Research (DSR), Indore, India
24. Dryland Agricultural Research Institute (DARI), Iran
25. Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA), Brazil
26. Ethiopian Institute of Agricultural Research (EIAR), Ethiopia
27. Ethiopian Seed Enterprise (ESE), Ethiopia
28. General Commission for Agricultural Scientific Research (GCSAR), Syria
29. Indian Agricultural Research Institute (IARI), New Delhi, India
30. Indian Institute of Chemical Technology (IICT), Hyderabad, India
31. Indian Institute of Pulses Research (IIPR), Kanpur, India
32. Institut Centrafricain de Recherche Agronomique (ICRA), Republic of Central Africa
33. Institut de l’Environnement et de Recherches Agricoles (INERA), Burkina Faso
34. Institut de Recherche Agricole Pour Le Developpement (IRAD), Cameroon
35. Institut de Recherche Agronomique de la Guinée (IRAG), Guinea
36. Institut d’Economie Rurale (IER), Mali
37. Institut Des Sciences Agronomiques Du Burundi (ISABU), Burundi
38. Institut des Sciences Agronomiques du Rwanda (ISAR), Rwanda
39. Institut National De La Recherche Agronomique (INRA), Rabat, Morocco
40. Institut National de Recherche Agronomique de Tunis (INRAT), Tunisia
41. Institut National de Recherches Agronomiques du Niger (INRAN), Niger
42. Institut National des Recherches Agricoles du Benin (INRAB), Benin
43. Institut National pour l’Etude et la Recherche Agronomique (INERA), DR Congo
44. Institut Senegalais de Recherches Agricoles (ISRA), Senegal
45. Institut Togolais de Recherche Agronomique (ITRA), Togo
46. Instituto de Ciencia y Tecnología Agrícolas (ICTA), Guatemala
47. Instituto de Investigacao Agraria de Mocambique (IIAM), Mozambique
48. Instituto de Investigación Agronómica (IIA), Angola
49. Instituto Nacional Autonomo de Investigaciones Agropecuarias (INIAP), Ecuador
50. Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), Mexico
51. Instituto Nicaraguense de Tecnología Agropecuaria (INTA), Nicaragua
52. Kenya Agricultural Research Institute (KARI), Kenya
53. La Estación Experimental Agroindustrial Obispo Colombres (EEAOC), Argentina
54. Lake Zone Agricultural Research and Development Institute (LZARDI), Tanzania
55. Mauritius Sugar Industry Research Institute (MSIRI), Mauritius
56. Naliendele Agricultural Research Station (NARS), Tanzania
57. National Agricultural Research Organization (NARO), Uganda
58. National Bureau of Agriculturally Important Microorganisms (NBAIM), Mau, India
59. National Bureau of Plant Genetic Resources (NBPRG), New Delhi, India
60. National Institute of Nutrition (NIN), Hyderabad, India
61. National Cereal Research Institute (NCRI), Nigeria
62. Nepal Agricultural Research Council (NARC), Nepal
63. Pakistan Agricultural Research Council (PARC), Pakistan
64. Plant Protection Research Institute (PPRI), Hanoi, Vietnam
65. Selian Agricultural Research Institute (SARI), Tanzania
66. The Institute for Agricultural Research (IAR), Nigeria
67. Vietnam Academy of Agricultural Sciences (VAAS), Hanoi, Vietnam
68. Zambian Agricultural Research Institute (ZARI), Zambia

International Agricultural Research Centers (IARCs)
1. AVRDC - The World Vegetable Center, Taiwan
2. Bioversity International, Rome, Italy
3. Centro Internacional de Agricultura Tropical (CIAT), Columbia
4. International Center for Agricultural Research in the Dry Areas (ICARDA), Syria
5. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India/Africa
6. International Food Policy Research Institute (IFPRI), USA
7. International Institute of Tropical Agriculture (IITA), Nigeria
8. International Livestock Research Institute (ILRI), Kenya/Ethiopia
9. International Maize and Wheat Improvement Center (CIMMYT), Mexico
10. International Rice Research Institute (IRRI), Philippines
11. International Water Management Institute (IWMI), Sri Lanka

Advanced Research Institutes (ARIs)/Universities
1. Acharya N G Ranga Agricultural University (ANGRAU), Hyderabad, India
2. Aleppo University, Syria
3. Assam Agriculture University, Jorhat, India
4. Australian Centre for International Agricultural Research (ACIAR), Australia
5. Bayero University of Kano (BUK), Nigeria
6. Beijing Genomics Institute (BGI), China
7. Birsa Agricultural University (BAU), Jharkhand, India
8. Botswana College of Agriculture (BCA), Botswana
9. Bunda College of Agriculture (BCA), Malawi
10. Catholic University of Leuven, Belgium
11. Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), France
12. Centre for Legumes in Mediterranean Agriculture (CLIMA), Australia
13. Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Haryana, India  
14. Colorado State University (CSU), United States of America  
15. Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia  
16. Consejo Superior de Investigaciones Científicas (CSIC), Spain  
17. Cornell University, United States of America  
18. Department of Employment, Economic Development and Innovation (DEEDI), Queensland, Australia  
19. Donald Danforth Center, St Louis, United States of America  
20. Dry Grain Pulses Collaborative Research Program, United States of America  
21. Egerton University, Kenya  
22. Estação Nacional de Melhoramento de Elvas (ENMP), Portugal  
23. GB Pant University of Agriculture and Technology, Pantnagar, India  
24. Ghent University, Belgium  
25. Halemaya University, Ethiopia  
26. Indian Agriculture Research Institute (IARI), New Delhi, India  
27. Indira Gandhi Agricultural University (IGAU), Raipur, Chhattisgarh, India  
28. Institut National De La Recherche Agronomique (INRA), France  
29. Instituto de Investigacion y Formacion Agraria y Pesquera de Andalucia (IIFAPA), Spain  
30. Instituto Nacional de Salud Publica (INASP), Mexico  
31. Iowa State University, United States of America  
32. Japan International Research Centre for Agricultural Sciences (JIRCAS), Tsukuba, Japan  
33. Jawaharlal Nehru Agricultural University (JNAU), Jabalpur, Madhya Pradesh, India  
34. Kansas State University (KSU), United States of America  
35. Kenyatta University, Kenya  
36. Lanzhou University, China  
37. Laval University, Canada  
38. Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri, India  
39. Makerere University, Kampala, Uganda  
40. Michigan State University, United States of America  
41. Moi University, Kenya  
42. National Centre for Genome Resources (NCGR), New Mexico, United States of America  
43. National Research Centre on Plant Biotechnology (NRCPB), New Delhi, India  
44. National University of Ireland, Galway, Ireland  
45. Njala University, Sierra Leone  
46. North Dakota State University, United States of America  
47. Nottingham University, United Kingdom  
48. Orissa University of agriculture & Technology, Orissa, India  
49. Osmania University (OU), Hyderabad, India  
50. Panjabrao Deshmukh Krishi Vidyapeeth (PDKV), Akola, India  
51. Peanut Collaborative Research Support Program, United States of America  
52. Penn State University, United States of America  
53. Pulse Breeding Australia (PBA), Australia  
54. Punjab Agricultural University (PAU), Ludhiana, India  
55. Purdue University, United States of America  
56. Rajmata Scindia Krishi Vishwavidyalaya (RSKU), Gwalior, India  
57. Sokoine University of Agriculture, Tanzania  
58. Tamil Nadu Agricultural University (TNAU), Coimbatore, India  
59. Tamworth Agricultural Institute, NSW, Australia  
60. Techreen University, Syria  
61. Université Nationale de Rwanda, Rwanda  
62. University of Agricultural Sciences, Raichur, India
63. University of Agricultural Sciences, Bangalore, India
64. University of Agricultural Sciences, Dharwad, India
65. University of California, Davis, United States of America
66. University of California, Riverside, United States of America
67. University of Cordoba, Spain
68. University of Frankfurt, Germany
69. University of Georgia, United States of America
70. University of Ibadan, Nigeria
71. University of Illinois, United States of America
72. University of KwaZulu Natal, South Africa
73. University of Maiduguri, Nigeria
74. University of Makurdi, Nigeria
75. University of Nairobi, Kenya
76. University of Pretoria, South Africa
77. University of Queensland, Australia
78. University of Saskatoon, Canada
79. University of West Virginia, United States of America
80. University of Western Australia, Australia
81. University of Wisconsin, Madison, United States of America
82. University of Zimbabwe, Zimbabwe
83. USDA-ARS, Soybean Genomics Lab, BARC, United States of America
84. Victorian Agri-Biosciences Centre (VABC), Australia
85. Washington State University, United States of America

Non-Government Organizations (NGOs)
1. Africare, Washington DC, United States of America
2. Alliance for a Green Revolution in Africa (AGRA), Kenya
3. AMADEA, Madagascar
4. AME Foundation, Bangalore, India
5. BAIF Institute for Rural Development, Pune, India
6. CARE International, Switzerland
7. Catholic Dioceses Development, Kenya
8. Catholic Relief Services (CRS), United States of America
9. Centre for World Solidarity (CWS), Hyderabad, India
10. Kirkhouse Trust, United Kingdom
11. Mozambican Farmers Co-operative- for agri-trading, processing and exporting (IKURU), Mozambique
12. National Smallholder Farmers’ Association of Malawi (NASFAM), Malawi
13. One Acre Fund/Tubura Rwanda, Burundi and Kenya
14. Rural Development Trust (RDT), Anantapur, India
16. SNV, Niger
17. Sustainable intensification of maize-legume cropping systems for food security in eastern and southern Africa (SIMLESA), Africa
18. Techno Serve, Washington DC, United States of America
19. The Cooperative League of USA (CLUSA), United States of America
20. World Vision International, United States of America
Private Sector
1. Agricultural Commodity Supplies (ACOS), Ethiopia
2. Alheri Seeds, Niger
3. Asia & Pacific Seed Association (APSA)
4. Demeter Agriculture, Malawi
5. Dry Bean Producers Organization South Africa
6. Dry Land Seed Co, Kenya
7. Elfora Agro-industry Ltd, Ethiopia
8. Farm Input Care (FICA) Seed, Uganda
9. Farmers’ Link, Zambia
10. FICA Seed, Uganda
11. International Seed Testing Association (ISTA), Switzerland
12. Kamano Seeds, Zambia
14. Krishidhan Seeds Ltd., India
15. Krishna Seeds, Tanzania
16. Leldet Seeds, Kenya
17. Mahyco Seeds, India
18. Masoumin Grain Trader, Madagascar
19. Nalweya Seed Company (NASECO), Uganda
20. Nimbkar Seeds Private Ltd., India
21. PANNAR Seed (PTY) Ltd, South Africa
22. Pristine Seeds, Zimbabwe
23. Progeny Seeds, Zimbabwe
24. Rwanda Seed Company (RWASECO) Private Seed Co, Rwanda
25. Victoria Seeds Limited, Uganda
26. Zenobia Seed Co, Tanzania

Regional/sub-regional organizations
1. Asia-Pacific Association of Agriculture Research Institutions (APAARI), Thailand
2. Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Uganda
3. Association of Agricultural Research Institutions in the Near East and North Africa (AARINENA), Jordan
4. Forum for Agricultural Research in Africa (FARA), Ghana

Farmers’ cooperatives and organizations
1. Association of Seed Marketing Action Group (ASMAG), Malawi
2. Bora Dembela Farmers Cooperative Union (FCU), Ethiopia
3. Confédération des Associations des Producteurs Agricoles pour le développement (CAPAD),
4. East Province Farmers’ Cooperative (Zambia )imbaraga, Rwanda
5. Lume Adama Farmers Cooperative Union (FCU), Ethiopia
Appendix 6. Ongoing Grain Legume Project Portfolios of Core Partners

AVRDC Grain Legume Project Portfolio

I. Breeding for high methionine mung bean
Methionine and cystein are essential nutrients that must be provided through the diet and are very low in diets dominated by rice. An interspecific cross between blackgram (Vigna mungo) and mung bean (V. radiata) was used as a high methionine donor parent to improve methionine content in cultivated mung bean. Selections that had approximately 1~3 times more methionine content than the reference mung bean line NM92 were used to make subsequent backcrosses to mung bean parents from 2004 to 2008. The final best selected lines ranged in γ-glut amyl-s-methyl cysteine content from 308~626 mg/100 g and four lines produced 50~92% more of this than the reference line ‘NM92.’ The development of molecular markers will be important to make efficient selection in larger populations.

II. Selection of brushed resistant mung beans based on differential protein expression
Bruchid (Callosobruchus spp) is a serious storage pest for many cereal and legume crops. A wild species of mung bean, had been reported to be highly resistant. Using 200 recombinant inbred lines (RILs) derived from a cross of cultivated mung bean with TC1966, AVRDC has successfully mapped the bruchid resistance gene and characterized bruchid reactions for each RIL. Studies on this gene show it is related to the production of lentil lectin, associated with insect resistance in plants. Studies are continuing to further identify the mechanism of bruchid resistance and the potential application of this gene.

III. Developing male sterility and chasmogamous flower type in mung bean for hybrid seed production
In addition to radiation, interspecific crosses (Vigna radiata x Vigna radiata ssp. sublobata) have been made to find new male sterility genes or sterile cytoplasm. Spontaneous male sterile plants were found in the F3 population. The sterile plants were maintained by hand pollination with fertile plants. Mung bean normally produces cleistogamous flowers leading to self-pollination. This is a barrier to large-scale hybrid seed production. To improve the outcrossing rate in mung bean, radiation was used to change the flower morphology to a more open, chasmogamous type in which the stigma and anther emerge from the flower. Studies are continuing on purifying these lines and understanding the inheritance of this characteristic to develop female parental lines for hybrid seed production.

IV. Developing an integrated pest management package for Asian soybean rust, characterizing races and evaluating the importance of wild soybeans as alternative hosts
Asian soybean rust (ASR), caused by Phakopsora pachyrhizi, is one of the most destructive diseases on soybean production. It is spreading rapidly and causing severe damage and yield losses in Asia, South Africa, South America and the continental United States. ASR management has become a major concern for global soybean production. Wild host eradication, host resistance, and chemical control were assessed for the development of an integrated management package of ASR. AVRDC has developed eight advanced soybean lines with tolerance to ASR; however, no resistant cultivar is available. Experimental results indicate that G. soja might be a useful source for resistance breeding by interspecies hybridization. Additional molecular studies have characterized the race composition of the pathogen in Taiwan to assist in the soybean rust resistance breeding program.
V. IPM against legume pod borer on cowpea and lablab bean in Asia and West Africa
An IPM package for legume pod borer (LPB) consisting of Maruca vitrata nucleopolyhedrovirus (MaviMNPV), parasitoids (Nemorilla maculosa and Apanteles taragamae), neem, Bt, and pesticide were evaluated on yard-long bean and lablab bean. Synergistic effects between A. taragamae and MaviMNPV have been seen in trials and are being further confirmed. The efficacy of six blends of sex pheromones to control legume pod borer are also being evaluated under lab and field conditions.

VI. Sequential cropping systems with legumes and intercropping with legumes for improved productivity of vegetables in home gardens
The use of vegetable legumes in sequential cropping systems can increase productivity of vegetables in small-scale farming systems and home gardens. Experimental results from Tanzania have shown that sunhemp should be used as a green manure when amaranth and Ethiopian mustard are produced, and cowpea should be used as a green manure when nightshade is produced. Legume-vegetable intercropping trials were also conducted using vegetable cowpea and sunhemp intercropped with nightshade, Ethiopian mustard, and amaranth as model vegetables. Intercropping vegetables with appropriate legumes can significantly increase leaf yields and help reduce pesticide spraying.

VII. Developing vegetable soybean and mung bean lines with improved nutrition and flavor qualities
Basmati flavored vegetable soybeans are more popular in Asia and Africa than the traditional lines developed primarily for the Japanese market, and could increase market demand for the crop. Selection work is continuing to evaluate the best performing basmati flavored lines in multilocal trials in Taiwan, India and sub-Saharan Africa.

VIII. Integrated organic production technology for vegetable soybean
Organic vegetable soybean can attract premium prices in the Japanese market. Integrated organic production technologies were developed for vegetable soybean to guide organic farmers in Taiwan. These included variety evaluation, organic fertilization, integrated crop and soil management, integrated disease management, integrated pest management, weed control, and quality evaluation. Bioagents were used to successfully control disease. Adding Trichoderma spp. in the early growing stage significantly reduced the percentage of root rot caused by Rhizoctonia solani, while applying Streptomyces spp. effectively inhibited anthracnose on pods. Additional IPM practices for insect pests and practical means of weed control were also produced.

IX. Multi-locational testing and release of improved legume germplasm in Central Asia
Improved vegetable soybean and mung bean lines have been tested as a part of a wide range multi-year program to select improved vegetable varieties for Central Asia. In 2009 28 varieties of tomato, sweet and hot pepper, eggplant, vegetable soybean and mung bean were tested in state variety trials in Armenia, Kazakhstan, Tajikistan, and Uzbekistan. Two PhD students are conducting research on promising germplasm including vegetable soybean and a postgraduate student is working on yard-long bean in Uzbekistan. Three improved varieties of mung bean and vegetable soybean have been officially released and improved recipes developed for many vegetables, including vegetable soybean.

X. Yard-long bean insect management and yield observation trials
Yard-long bean (Vigna sesquipedalis) is one of the most important vegetable crops in southeast Asia, and is being tested in experiments in Indonesia as a screen crop to prevent whitefly spread into capsicum crops. The effects of a cover crop (Arachis pintoi) on abundances of an aphid (Aphis craccivora), a ladybird beetle predator (Menochilus sexmaculatus), predatory soil-dwelling arthropods and on yield of yard-long bean was also studied in Indonesia. Varieties and accessions
lines from across southeast Asia are being assessed in observation yield trials as a part of preliminary selection and breeding work.

XI. Postharvest technologies for priority vegetables expanded to yard long bean
Postharvest technologies to reduce losses of tomato, chili, common cabbage, Chinese kale, Chinese/green mustard, aromatic mustard, and kangkong have been developed in projects over recent years in Cambodia, Laos and Vietnam. In 2009 this was expanded to include postharvest trials on yard long bean, bitter gourd, cucumber and eggplant. These included the use of modified atmosphere packaging (MAP) with polypropylene film, evaporative cooling storage, and pre-storage sanitizing with chlorine washes.

XII. Evaluation of vegetable cowpea lines for leaf yield
Cowpea (Vigna unguiculata) has been long been cultivated as an important grain legume in sub-Saharan Africa, but it is also an important leafy vegetable in many parts of the continent. Trials are being conducted to select varieties with high leaf yields and promotion for use as a leafy vegetable.

XIII. Development of super-nodulating vegetable soybean
The Japanese super-nodulating soybean line Sakuke #4 has been crossed with high performing vegetable soybean lines develop improved lines with supernodulation. These are being evaluated for yields and agronomic traits to assess the value of this characteristic to vegetable soybean.

XIV. Nutritious vegetable seed kits for disaster response in tropical and sub-tropical Africa and Asia
AVRDC has distributed over 50,000 vegetable seed kits following disasters in Asia and Africa and demand continues to grow. Most of these contain legumes. Selections of regionally suited crops have been made that are nutritious, hardy, fast-growing, relatively free of pest and disease problems, commonly cultivated in many tropical and subtropical less-developed countries in the region, and have low input requirements. Five different seed packs have been developed for different regions with seed to be bulked up in each region. Four of these contain improved varieties of legumes – mung bean in Asia and vegetable cowpea in Africa.

CIAT Grain Legume Project Portfolio

I. Biofortified Crops for Improved Human Nutrition - Harvest Plus Challenge Program
To improve the health and micronutrient nutrition of consumers in developing countries, with priority on rural populations of Africa and Asia
Region: East-Central Africa (Rwanda and D.R. Congo)

II. Combating hidden hunger in Latin America: Biofortified crops with improved vitamin A, essential minerals and quality protein (AgroSalud)
To improve the health and micronutrient nutrition of consumers in Latin America
Region: Central America, the Caribbean, the Andean zone and Brazil

III. Fighting Drought and Aluminium Toxicity: Integrating Genomics, Phenotypic Screening and Participatory Research with Women and Small-Scale Farmers to Development Stress-Resistant Common Bean and Brachiaria for the Tropics
To improve crop productivity in crop-livestock systems including beans and forages
Region: Nicaragua, Rwanda, Malawi
IV. Improving tropical legume productivity for marginal environments in sub-Saharan Africa: Phase II
To contribute to the development of improved legume varieties in sub-Saharan Africa and South Asia by advancing molecular breeding for traits of importance in both regions
Region: Ethiopia, Kenya, Malawi, Tanzania, Zimbabwe

V. Getting back to basics: creating impact-oriented bean seed delivery systems for the poor in Malawi, Mozambique and Tanzania
To improve bean yields of small farmers by enhancing their access to improved varieties of common bean
Region: Malawi, Mozambique and Tanzania

VI. Improved Smallholder food Security, Nutrition and Income through Increased Production and Marketing of Climbing Beans
To contribute to improved food security, nutrition and incomes of resource poor farmers through climbing bean production
Region: Malawi and Mozambique

VII. Nutritional Improvement of the important pulse legume, the common bean, through the reduction of seed tannin content, for the benefits of people' diet in Africa and Latin America
To improve the nutrition of bean consumers with regard to iron and protein nutrition
Region: Africa and Latin America

VIII. Dry bean improvement and marker assisted selection for diseases and abiotic stresses in Central America and the Caribbean
To improve stability of bean yields in drought prone areas
Region: Central America, the Caribbean

IX. Students for Analysis of drought tolerance in common bean
To enhance the capacity of bean researchers in Africa
Region: Zimbabwe and Ethiopia

X. Research in molecular techniques of snap bean rust characterization
Goal:
Region:

XI. Development of "Nebraska" Farm as a Research Platform for Generation of New Crop Varieties and Cropping Systems Adapted to the Stressful Soils of Eastern and Southern Africa
To develop germplasm of common bean and other crops that are tolerant of low fertility soils.
Region: Republic of South Africa

XII. Basal root architecture and drought tolerance in common bean
To develop germplasm of common bean that combines tolerance to low available soil phosphorus and to drought
Region: Republic of South Africa, and Eastern-southern Africa in general
XIII. Supporting Nutrition and health, Food security, Environmental Stresses and Market Challenges that contribute to improve livelihood and create income resource poor small holder families in Sub-Saharan Africa
To enhance family income, food security and nutrition of small holder bean producers and consumers in East, southern and West Africa
Region: 28 countries in East, southern and West Africa

XIV. The Pan Africa Beans Research Alliance (PABRA) Phase IV
To enhance family income, food security and nutrition of small holder bean producers and consumers in East, southern and West Africa
Region: 28 countries in East, southern and West Africa

XV. Optimized Pest Management with Botanical Pesticides on Legume Cropping Systems in Malawi and Tanzania
To enhance bean yield stability and productivity through the control of insect pests of common bean
Region: Malawi and Tanzania

XVI. Improved beans for Africa and Latin America
To enhance the social impact of bean production and consumption in Latin America and Africa
Region: East, southern and West Africa and Latin America

XVII. Disease Management Technologies in Bean and Cowpea Systems
Goal:
Region:

XVIII. Evaluation of Phaseolus Bean Collection for Identification of Sources of Resistance to Root Rots under Drought Stress
To stabilize yields of common bean in drought prone areas through resistance to soil pathogens
Region: East, southern and West Africa and Latin America

XIX. Making Seed Security Response more Effective in Emergency, Chronic Stress, and Developmental Contexts
To make seed relief more effective in both the short and long terms
Region: East and southern Africa

XX. Strengthening Food Security on Drought through Biofortified Rice and Beans (Cuba and Nicaragua)
To enhance human nutrition with regard to micronutrient intake
Region: Cuba and Nicaragua

ICARDA Grain Legume Project Portfolio

I. Chickpea improvement research
Sustainable use of the biodiversity of chickpea to increase productivity and nutritional security and establish sustainable farming systems in the non-tropical dry areas
Region: Non-tropical dry areas of world

II. Faba bean improvement Research
Sustainable use of the biodiversity of faba bean to increase productivity and nutritional security and establish sustainable farming systems in the non-tropical dry areas
Region: Faba bean growing countries globally

III. Lentil Improvement research
Sustainable use of the biodiversity of lentil to increase productivity and nutritional security and establish sustainable farming systems in the non-tropical dry areas
Region: Lentil growing countries globally

IV. Grasspea improvement research
Sustainable use of the biodiversity of grasspea to increase productivity and nutritional security and establish sustainable farming systems in the non-tropical dry areas
Region: Bangladesh, Ethiopia and India

V. Evaluation and application of advanced tools for molecular breeding for drought and salinity tolerance in chickpea
To evaluate the novel tools for molecular breeding to facilitate the rapid development of new varieties with enhanced terminal drought and salinity tolerance. Direct beneficiaries of the project are molecular breeders and physiologists at ICARDA and national agriculture research systems (NARS) scientists. They will gain access to and training in the use of an innovative, easily applicable and reliable technology that, nevertheless, is highly informative and may have extreme power for predicting dehydration-stress-responses in germplasm and breeding lines. Novel concepts and functional genomics tools for breeding for stress-tolerant crops
Region: Central and West Asia and North Africa (CWANA) Region

VI. Addressing legume constraints in cereals-based cropping systems, with particular reference to poverty alleviation in north–western Bangladesh
The overall aim of this variation is to expand lentil production in Bangladesh by understanding bottlenecks where effective interventions can be made and through the development of ICM packages that will be adopted by farmers.
Region: South Asia (Bangladesh)

VII. Breeding Chickpea for Drought Tolerance and Disease Resistance
To enhance production and productivity of chickpea under Mediterranean type environments through genetic and agronomic manipulation.
Region: WANA region

VIII. Technical Assistance to Authority of Merowi Dam Area for Agricultural Development (AMDAAD)
ICARDA will provide technical assistance to AMDAAD in developing the following central research and training facilities.
Region: Sudan

IX. Development of Lentil Cultivar with High Concentration of Iron and Zinc
To assist the Collaborator in financing the implementation of its research activities under the Challenge Program as approved by the Program Advisory Committee (“PAC”).
Region: Bangladesh, India and Nepal.

X. Sustainable Water Use Securing Food Production in Dry Areas of the Mediterranean Region
Improve productivity and sustainable use of agricultural lands by developing a more diverse farming system. Supporting economic development in non-European Mediterranean countries while ensuring mutual interest and benefit with the European Union.
Region: Syria, other Mediterranean areas
XI. Lentil improvement

Bold seeded lentil varieties project:
- Development of bold-seeded genotypes (>3.0 g per 100-seeds) using local and ICARDA-supplied genetic materials (germplasm, breeding lines, segregating populations) with resistance to rust, vascular wilt and root rot, and tolerant to drought and heat.
- Identification and use of wild relatives having desirable genes, tagging of rust resistant genes to use in MAS and validation of drought tolerant transgenics.

Small-seeded and early maturing lentil varieties suitable to rice-based cropping systems:
- To develop small-seeded, early maturing genotypes with early vigor and higher biomass, and amenable for late planting.
- To incorporate resistance to rust, wilt, Stemphylium blight in genotypes suitable for rice-based cropping system.

Region: India

XII. Kabuli chickpea improvement

Identification of bold-seeded ICARDA germplasm/segregating populations under Indian conditions for yield potential, phonological adaptation, resistance to Ascochyta blight disease, drought and cold.

Region: India

XIII. Development of Conservation Cropping Systems in the Drylands of Northern Iraq

The project aims to increase crop productivity, profitability and sustainability in the drylands of northern Iraq through the development, evaluation and promotion of conservation cropping technologies involving zero-tillage, stubble mulching, improved crop cultivars and better crop management.

Region: Iraq

XIV. Sustainable Approach to Productive Maintenance of Cereal/Legume/Rangeland/ Livestock system in Southern Mediterranean Countries

Improving drought tolerance of wheat, barley, and chickpea through conventional and biotechnological approaches. Application of zero tillage system with aim to improve water retention, enhancing organic matter content and micronutrients.

Region: Mediterranean: Morocco, Algeria, Tunisia, Syria, Lebanon and Portugal

XV. Faba bean diseases (ARC Egypt)

To augment food security, alleviate malnutrition and reduce the risk of climate change through improved production technologies of faba bean Faba bean

Region: Nile Valley and North Africa

XVI. WSU Lentil Linkage (USAID)

Inheritance and mapping of genes for resistance to rust and stemphylium blight in lentil

Region: South Asia

XVII. To improve availability of safe food

Evaluation of lathyrus gene pools for ODAP neurotoxin content and for determining cross pollination rate
ICRISAT Grain Legume Project Portfolio

I. Enhancing Grain Legumes’ Productivity, and Production and the Income of Poor Farmers in Drought-Prone Areas of Sub-Saharan Africa and South Asia (TL II)
   To increase the production of tropical grain legumes in sub-Saharan Africa and South Asia by 10-20%, and ensure that they occupy an average of 30% of crop area, reaching 150 million poor, rural legume users and resulting in an annual aggregate additional value of over US$300 million.
   Region: The primary countries include Nigeria, Mali and Niger in West and Central Africa (WCA); Ethiopia, Kenya, Malawi, Tanzania, and Mozambique in Eastern and Southern Africa (ESA); and India in South Asia.

II. West Africa Seed Alliance (WASA) Seeds project
   To establish a sustainable commercial seed industry in West Africa capable of: Ensuring that farmers have affordable, timely and reliable access to adapted genetics and traits in high quality seeds and planting materials; Playing a leading role in the growth and development of viable agricultural inputs systems; Supporting the development of African agro-industry; and Supporting the policy commitment and call by African Union Leaders and NEPAD member states for the Intensification of Agriculture at the Abuja Declaration at the African Fertilizer Summit and in line with commitments to CAADP.
   Region: Ghana, Mali, Niger, Nigeria, Burkina Faso, Benin, Togo.

III. Tracking Change in Rural Poverty in Household and Village Economics in South Asia
   To decrease the incidence and severity of absolute poverty in South Asia’s semi-arid and humid tropics by markedly increasing the availability of time-series district-, household-, individual-, and field-level data.
   Region: South Asia

IV. ICRISAT Platform for Translational Research on Transgenic Crops (PTTC)
   The aim of establishing the “Platform for Translational Research on Transgenic Crops” (PTTC), will be to facilitate collaborative and coordinated approach for the translation of existing genetic engineering technologies for the development of transgenic crop varieties that can be efficiently taken through product development to commercialization
   Region: India

V. Improving tropical legume productivity for marginal environments in sub-Saharan Africa: TL I-Phase 2
   To contribute to the development of improved legume varieties in sub-Saharan Africa and South Asia by advancing molecular breeding for traits of importance in both regions.
   Region: Sub Saharan Africa and south Asia

VI. Agricultural Input Market Strengthening
   The ultimate goal of the AIMS project is to contribute to Mozambique’s Development Agenda for Rural Incomes program at USAID of promoting rapid increases in rural income (10% on average) in target areas through increased sales of agriculture production, expanded rural enterprises, and increased marketing due to improved transport infrastructure and the NEPAD/CAADP goal of 6% annual growth in agricultural output by promoting private-sector investment in agricultural input technologies and marketing. The purpose is to establish open and competitive markets and dealer networks as the primary mechanisms to improve farmer access to appropriate agricultural technologies for accelerated growth in agricultural production.
   Region: Mozambique
VII. Developing Sustainable Seed Systems to Support Commercialization of Small-scale Agriculture in Sub-Saharan Africa
Rapidly increase the adoption of the best new varieties of major food crops in sub-Saharan Africa leading to sustained growth in productivity and rural incomes for small-scale farmers.
Region: Sub-Saharan Africa (Mozambique, Ethiopia, Tanzania, Kenya, Mali)

VIII. Enhancing Chickpea Production in Rainfed Rice Fallow land (RRFL) of Chattisgarh and Madhya Pradesh States of India following Improved Pulse Production and Protection Technologies (IPPPT) under National Food Security Mission (NFSM-Pulses)
Self-sufficiency in chickpea-pulse production through increased productivity by expanding improved pulse production and protection technologies (IPPPT), and establishing village level seed system in the rainfed rice fallow lands (RRFL) in India.
Region: India (states of Chattisgarh and CRP)

IX. Taking Pigeonpea Hybrids to the Doorsteps of Farmers under National Food Security Mission (NFSM)
To increase pigeonpea production in major pigeonpea growing areas of India
Region: India

X. Program for Integrated Innovations for Improving Legumes Productivity, Market Linkages and Risk management in Eastern and Southern Africa
The goal of the project is to harness opportunities for income growth and diversification in the semi-arid areas of ESA through integrated innovations that improve productivity and market linkages for grain legumes and improve the resilience of livelihoods.
Region: Eastern and Southern Africa countries: Ethiopia, Kenya, Tanzania, and Malawi

XI. Program for Harnessing the True Potential of legumes : Economic and Knowledge Empowerment of Poor Farmers in rainfed Areas in Asia
The overall goal of the project is to improve the well being of rural poor in Asia through sustainable increases in agricultural productivity based on the wider adoption of grain legumes in rainfed cropping systems.
Region: Asia (India, Nepal, Vietnam)

XII. Support for Malawi Seed Industry Development
The goal of the ESASA Team in developing Malawi’s seed industry is to increase smallholder farmer yields and incomes through the competitive and reliable provision of high quality affordable seed to smallholder farmers, while its purpose is to support seed sector entrepreneurs.
Region: Malawi

XIII. Seed System in Legumes : Development & Popularization of 'Model' Seed Production of Major Legumes to Ensure Seed-sufficiency at the Village level
Economic empowerment and nutritional security of resource poor dryland farmers through increased legume productivity by achieving seed self-sufficiency of farmer-preferred improved varieties at the village level
Region: India (states of Madhya Pradesh, Uttar Pradesh, Andhra Pradesh and Orissa)

XIV. Centre of Excellence for High-throughput Allele Determination for Molecular Breeding
The overall goal of the proposed Centre of Excellence for High-Throughput Allele Determination for Molecular Breeding is the full utilization of modern molecular methods of genome analysis by Indian agricultural breeding programs
Region: India

XV. Sustainable Intensification of Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa (SIMLESA)
Increase food security and incomes at household and regional levels and economic development in eastern and southern Africa through improved productivity from more resilient and sustainable maize-based farming systems.
Region: Eastern and Southern Africa (countries: Ethiopia, Kenya, Tanzania, Malawi, Mozambique, Republic of South Africa, Uganda, Australia)

XVI. Maximizing Agricultural Revenue and Key Enterprises in Targeted Sites (MARKETS) – Development of the seed Value Chain
MARKETS has been working along commodity value chains to increase incomes and transform Nigerian agriculture from subsistence farming to a more commercially competitive system linked to market demand. Activities have focused on staple crops, targeting a significant number of farmers and rural households.
MARKETS will ramp up activities for staple crops to expand successful income and productivity-increasing interventions for a larger and more diverse base of agribusinesses and farmers.
Region: Nigeria

XVII. Improving farmer livelihoods and food security through enhanced legume productivity in India and Myanmar
The overall goal of the project is to empower farmers and researchers in India and Myanmar to improve livelihoods through enhanced productivity of legume crops.
Region: India, Myanmar

XVIII. BREAD: Overcoming the Domestication Bottleneck for Symbiotic Nitrogen Fixation in Legumes
The goal of the proposed research is to characterize the genetic mechanisms that underlie phenotypic plasticity for symbiosis in the agricultural context.
Region: United States, South Asia

XIX. Improving Heat tolerance in Chickpea for enhancing its productivity in warm growing conditions and mitigating impact of climate change
The overall goal of the project is to enhance chickpea production in warm growing conditions by developing heat tolerant and climate-resilient cultivars.
Region: India

XX. Assessing the dynamics of poverty and land degradation in the Sahelian countries of West Africa
The overall goal of the project is to contribute to improved rural livelihood outcomes and natural resource management in the Sahel.
Region: Sahelian West Africa

XXI. Increasing Food Security and Farmer Livelihoods through Enhanced Legume Cultivation in the Central Dry Zone of Myanmar
The aim of this project is to improve the food security, nutritional health and livelihood needs of the poor farmers and communities in Myanmar by increasing productivity of pulse and oilseed legumes.
Region: Myanmar
XXII. **Groundnut varieties improvement for yield and adaptation, human health and nutrition (funded by the McKnight Foundation)**

Reduction of poverty and improvement of food and nutrition security among smallholder farm families in mid-altitude and lowland areas of Malawi and Tanzania through investments in

Groundnut varieties improvement for yield and adaptation, human health and nutrition.

**Region:** Malawi and Tanzania

**IITA Grain Legume Project Portfolio**

I. **Nigeria Maximizing Agricultural Revenue and Key Enterprises in Targeted Sites (MARKETS)**

Improved Livelihoods in Selected Areas of Nigeria

**Region:** Nigeria

II. **Participatory Development, Diffusion and Adoption of Cowpea Technologies for Poverty Reduction and Sustainable livelihoods in West Africa (PRONAF - GIL)**

To enhance livelihoods of rural poor through empowerment and gender equitable access to cowpea value chain opportunities

**Region:** Bénin; Burkina Faso; Ghana; Malawi; Nigeria

III. **Dutch APO: Legume Agronomist - Malawi - Daniel Van Vugt**

Develop improved crop production technologies to enhance cereal and legume yields and at the same time that promote resource sustainability

**Region:** Malawi

IV. **Dutch APO: Seed systems Economist - Kano - Pieter Biemond**

Improve the availability of high quality seeds of improved varieties to smallholder farmers in West Africa.

**Region:** Nigeria

V. **Encouraging regional trade with hermetic storage for cowpea in West and Central Africa**

The vision is that within five years, 50% of the cowpea stored at the farm-level in West and Central Africa will be appropriately stored with non-chemical, hermetic storage

**Region:** Cameroon; Nigeria; Togo

VI. **Analyzing the conditions for optimizing livelihood & environmental benefits from crop residues production by smallholder peri-urban & urban livestock producers in Sudan & Sahel savannas of W. Africa**

Evaluate opportunities for livelihood improvement arising from increased use of crops residues for periurban livestock production

**Region:** West Africa

VII. **Evaluation and scaling up new chemical and biological commercial products for improving and sustaining crop yields in selected agro-ecological zones in sub-Saharan Africa (COCRPRO)**

To assist farmers in obtaining increased and stable crop yields that allow them to sustainably generate more income through marketing of their produce

**Region:** Nigeria

VIII. **Public-private partnership for innovation in soybean and cowpea value chains in Mozambique (Platform Mozambique)**

To enhance the contribution of agricultural research for development to improved rural livelihoods and reduced poverty in Mozambique
Region: Mozambique

IX. Less loss, more profit, better health: reducing the losses caused by the pod borer (Maruca vitrata) on vegetable legumes in Southeast Asia and sub-Saharan Africa.
To contribute to improving livelihoods through sustainable vegetable legume production systems in Southeast Asia and sub-Saharan Africa
Region: Sub-Saharan Africa

X. Putting Nitrogen Fixation to Work for Smallholder Farmers in Africa (N2fixAfrica)
The goals of the project are to identify niches for targeting nitrogen fixing legumes, test multi-purpose legumes to provide food, animal feed, and improved soil fertility, promote the adoption of improved legume varieties, support the development of inoculum production capacity through collaboration with private sector partners, develop and strengthen capacity for legumes research and technology dissemination, deliver improved varieties of legumes and inoculant technologies to more than 225,000 smallholder farmers in eight countries of sub-Saharan Africa.
Region: Sub-Saharan Africa

XI. Introduction of new cowpea varieties to enhance food production in semi-arid regions of Africa - AVEC-BF
To increase agricultural productivity and alleviate food shortage in semi-arid regions of Africa
Region: Africa wide

XII. Breeding for improved soybean symbiosis and rust resistance to the benefit of African farmers
To accelerate the development of soybean cultivars with an improved productivity, due to their capacity to counterbalance soil degradation and resist soybean rust disease.
Region: Mozambique and Malawi

XIII. IFAR Fellowship 2010 - Assessment of virus biodiversity in unmanaged systems in legume-growing guinea and derived Savanna...
Determine the diversity and abundance of viruses in wild hosts in unmanaged systems, and develop reliable diagnostic tools for their detection and management in Nigeria
Region: Nigeria

XIV. Development of parasitic weed control methods for world food security (NEDO project ID: 09E52502a)
Advanced Striga gesnerioides control methods developed
Region: Nigeria

XV. IPM CRSP Global Themes Regional Diagnostic Laboratories: The International Plant Diagnostic Network (IPDN)
Development of plant disease diagnostic capacity in three critical regions: West Africa, East Africa and Central America/Caribbean
Region: Bénin; Burkina Faso; Mali

XVI. Collective Action for the Rehabilitation of Global Public Goods in the CGIAR Genetic Resources System: Phase 2
Crop genetic resources and associated biodiversity are put to use in developing countries to fight poverty, enhance food security and health, and protect the environment. Creation of a comprehensive, effective and sustainable global conservation and use system
Region: Nigeria
XVII. Enhancing grain legumes productivity, production and income of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia (TL II)
To reduce poverty, hunger and malnutrition; coupled with increased incomes for better livelihoods of the poor people living in the drought-prone areas in sub-Saharan Africa and South Asia
Region: Kenya; Malawi; Mali; Mozambique; Niger; Nigeria; Tanzania

XVIII. Development and Promotion of Alectra Resistant Cowpea cultivars for smallholder farmers in Tanzania and Malawi
To improve cowpea productivity on A. vogelii infested land in Malawi and Tanzania
Region: Malawi; Tanzania

XIX. Improving tropical legume productivity for marginal environments in sub-Saharan Africa (TL I)
Phase II
To improve the productivity of four tropical legume species for SSA through the application of modern breeding approaches using the genetic resources and genomic tools developed in the first phase of the project, in close partnership with sub-Saharan Africa country and regional research institutions.
Region: Nigeria

XX. Providing for the Long-term funding of Ex Situ collections of germplasm held by IITA
Food security for today and future's generations
Region: Nigeria

XXI. G4008.17 - Application of Marker Assisted Selection for Striga Resistance in Cowpea
To increase the rapidity of cowpea breeding programs developing for well-adapted cowpea varieties containing pyramided agronomic productivity traits and sustainable resistance to disease and pest, especially Striga resistance can be generated via breeding programs in West and Central African countries using MAS.
Region: Burkina Faso; Niger

XXII. G4008.13 - Improving Drought Tolerance Phenotyping in Cowpea
Identify cowpea varieties/lines with drought resistance, and understand key physiological mechanisms contributing to their performance in the field and screen house conditions
Region: Burkina Faso; Nigeria; Senegal

XXIII. Field testing and dissemination of appropriate seed varieties and production technologies in order to increase soybean production in Manica and Tete Provinces
To increase the productivity of soybean among both smallholders and larger scale commercial farmers through increased access to adapted high-yielding soybean varieties and provision of appropriate soybean production technologies
Region: Mozambique

XXIV. Biological Foundations for Management of Field Insect Pests of Cowpea in Africa
To train our host country primary investigators on two novel natural enemies of the pod borer Maruca vitrata so they can use these strategies in their Farmer Field Schools (FFS).
Region: Nigeria
XXV. SSACP - KKM: Linking Technical Options, Policy and Market Access for Improved Land Productivity in the Sudan Savannah Zone
The overall goal is to contribute towards improving rural livelihoods, increasing food security and sustainable management of natural resources throughout sub-Saharan Africa, by adapting and promoting appropriate agricultural research for development (AR4D) approaches
Region: Nigeria

XXVI. Development of Global Strategy for the Ex Situ Conservation of cowpea and its Wild Relatives
To develop in close consultation with representatives of the relevant networks institutions and stakeholder. a strategy for the efficient and effective conservation of vigna genetic resources and identify priority collections eligible for long term support from the Global Crop Diversity Trust.

XXVII. Investigating, understanding and mapping Striga diversity to aid effective control technology development, deployment and longevity
The goal of this research project is to enable, enhance and promote the development, formulation and adoption of durable Striga control technologies in farmer's fields.

XXVIII. Molecular characterization of tropical soybean varieties, elite lines and germplasm
This study is intended to generate knowledge on the genetic structure of soybean varieties, lines and germplasm accessions of IITA. Information will be generated on the level of genetic diversity at the molecular level. The direct beneficiary from this work will be researchers involved in soybean improvement. The benefit of this work is to hasten conventional soybean improvement through the use of modern molecular genetics tools.
Region: Nigeria

XXIX. Seed recycling and Genetic degradation
Develop tool to measure genetic degradation. Determine the relation between seed recycling and genetic degradation and its effect on yield.

XXX. Metabolite profiling of IITA crops
Providing a functional research platform for plant metabolite research, for screening/profiling of the novel plant metabolites, and for the metabolite bank for the African plant resources.