ICRISAT Medium-Term Plan

2010-2012

ICRISAT
Science with a human face

International Crops Research Institute
for the Semi-Arid Tropics

International Crops Research Institute for the Semi-Arid Tropics

Medium-Term Plan 2010-12

Submitted to the Science Council

of the

Consultative Group on International Agricultural Research (CGIAR)

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International Crops Research Institute for the Semi-Arid Tropics

Medium-Term Plan 2010-12

Table of Contents

MTP Overview

Introduction

The main phase of ICRISAT's Sixth EPMR (2003-2008) was completed in February 2009. The report and recommendations have been received and ICRISAT's responses to each recommendation presented to the Science Council at their meeting in March. We have also prepared a comprehensive set of action plans for implementing each recommendation. We believe the review was very positive, indicating a successful turn-around of the Center, a critical mandate to focus on improving dryland farming systems in the semi-arid tropics of sub-Saharan Africa and South Asia, and helping to point the way towards future achievements. Given that the report was only just received and approved, and with the current CGIAR Change process underway, ICRISAT has not made significant changes in the MTP for 2010-2012, including not adding Output Targets for 2012. We have updated each MTP Project's description, the output targets for 2009-11, target and beneficiary countries, and included an impact pathway for each output. Further details are provided in each Project.

Based on the EPMR recommendations, ICRISAT plans to undertake an inclusive strategic planning process, starting in 2009, to address the EPMR recommendations, new CGIAR Strategic Objectives, Strategy and Results Framework and Mega-Program structure, and to build on ICRISAT's comparative advantages for enhancing the agricultural systems in the semi-arid tropics of Africa and Asia. This will result in a new Strategic Plan to 2020 and revised MTP.

More generally, many things have changed in the global context, including escalating world food prices, energy costs affecting interest in biofuels, and global financial crises. Each of these has increased global awareness of the important role agriculture plays in food and income security, but also places pressure of ICRISAT to evaluate how best to respond to each newly arising crisis. In addition, the CGIAR approved a plan to revitalize the system through the formation of a Consortium of Centers. This will require us to devote significant attention to helping move this important initiative forward while at the same time initiating our plans to develop a new strategic plan for the institute.

The SC commentary for MTP 2009-2011 acknowledged that ICRISAT's current project portfolio is well aligned with the System Priorities. They did request clarity of certain projects, which we have done in the specific project descriptions.

ICRISAT special project portfolio – While a few significant special projects terminated in 2008, or will terminate in early 2009, most of the research under these was either completed or will continue under newly funded projects. Several major new special projects have been approved in 2008 and early 2009 that have enhanced research efforts in most all of the MTP Projects. Especially noteworthy are those related to our social science research in Project 1, efforts to understand the role of sweet sorghum in SAT agriculture under Project 5, and the scaling up and out of our watershed successes in Project 9.

ICRISAT terminated Project 8 - With the non-approval of the OASIS Challenge Program proposal and lack of significant additional funding for the Desert Margins Project, we have terminated Project 8 in 2009. No milestones were indicated in last year's MTP, and the few activities that could be included in Project 8 are included in other MTP Projects. During the strategic planning process starting in 2009, we will carefully evaluate the role of our work that was included in Project 8 and in the proposed OASIS Challenge Program proposal.

Context

Highlights of Project Portfolio

The MTP 2009-2012 is based on the previous three MTPs and remains in accordance with the Center's current strategic plan to 2015.

The nine MTP Projects are focused across the research to development continuum that is required for improving agriculture in the SAT. **Project 1**, focusing on understanding the constraints faced by SAT farming families, provides inputs into priority setting for ICRISAT and partner research. It also ensures that impacts are achieved by guiding the impact pathways, develops improved seed systems, improves market linkages, and measures our successes through appropriate impact analyses. **Project 2** supplies ICRISAT and global research institutes the necessary genetic resources and genomic tools to ensure the most efficient and effective solutions in crop improvement, in particular promoting the use of genetic resources in crop improvement, while maintaining our mandated genetic resources for future generations. **Projects 3 to 6**, our core crop improvement projects, build from the resources developed in Project 2 and the priorities and opportunities identified in Project 1, and deliver to public and private partners improved germplasm that meets the needs to today's SAT farmers. These projects are not simply focused on crop improvement per se, but the testing new varieties under typical environmental conditions faced by farmers in the SAT, and on enabling the necessary inputs such as fertilizer, seed and credit that farmers need to be able to obtain and benefit from our improved varieties. As farmers in the SAT need options in order to improve their livelihoods, **Project 7** aims to provide such options by researching the options that high-value crops can play in SAT agricultural systems. In this project, our work starts with our mandate crops, but seeks to add options that provide additional income and food security, and doesn't require us to broaden our crop improvement efforts as the target crops are already locally available. **Project 9** addresses the critical issues of water management and land degradation so often found in the SAT. We are now seeing that our successes in watershed management and micro-dosing are being sought by our partners for scaling up and out, so our role is becoming more to facilitate and backstop such efforts by partners, and to concentrate better on strategic issues that still need to be addressed and where ICRISAT has a comparative advantage. Given that information technology is changing rapidly, and that many farmers and rural communities are using such advances to access information, we continue to enhance **Project 10** on information dissemination under efforts such as VASAT, open learning and crop concept mapping (e.g., Agropedia) to see that what we and others know doesn't just remain with us, but reaches the rural communities.

ICRISAT's expenditure for 2008 was $47.55 million, with a projected budget for 2009 of $49.02 million, an increase of $1.47 million, primarily due to new special project funding. Table 1 provides further details on the funding of each project and the System Priority focus.

New and Terminated Research

Major special projects concluded since last MTP submission – Major special projects (greater than $500,000 total budget) concluded in 2008, or expected to be completed in early 2009, include a five-year project with Belgium funding on improving livelihoods in the Sahel through the development and implementation of household-level economic decision support systems; Phase I of DFID funding to support NGOs in Zimbabwe; Phase II of the Sujala watersheds in Karnataka with funding from the Karnataka State government; USDA project through Technoserve to support improved legume production in east Africa; an IDRC project to strengthen research for development in east and southern Africa; integrated Striga management for improved sorghum productivity in ESA funded by ASARECA; and USAID-funded pilot project to develop community-based water-energy services and markets in India.

In each project, the activities were completed and results documented, or we have been able to attract additional funding to support continued research efforts.

New mainstream special projects starting since last MTP submission - Major new special projects (over $500,000 total budget) approved in 2008/2009, and that support our strategic efforts include the following.

We have strengthened our efforts in **Project 1** to investigate changes at the household level through two projects, one funded by the Bill and Melinda Gates Foundation on "Tracking Change in Rural Poverty in Household and Village Economies in South Asia", and a second project supporting the study of adaptation strategies to climate change at the household level in South Asia funded by the Asian Development Bank.

Our genetic resources efforts in SSA under **Projects 2 and 3** have been enhanced by two new special projects: a GTZ-funded project to enhance community management of crop diversity of pearl millet in West Africa; and an ACIAR-funded project to develop MAS-bred sorghum varieties using existing staygreen QTLs and by assessing sorghum germplasm for traits related to a better adaptation to the post rainy season environment, initiatives that can have potential spill-over effects to **Project 3 and 4**.

Through a joint project with the Indian Department of Biotechnology, we are establishing a platform for the translational research on transgenic crops, principally under **Project 2**, but with significant impacts on our efforts to develop and deliver transgenic crops under **Projects 3 to 6**.

Our crop improvement research under **Projects 3 to 6** continues to increase its special project support through several projects, including one addressing one of the major biotic constraints of legume production by a new project from the Indian Ministry of Agriculture focused on exploiting host plant resistance to pod borers in chickpea and pigeonpea. The release in 2008 of the first hybrid production system in pigeonpea is being scaled up by an Indian Ministry of Agriculture project to develop improved parental lines for pigeonpea hybrids. Another Ministry of Agriculture of India project focuses on the improvement of chickpea production in rainfed rice fallow land. An IFAD project helps us to continue our efforts to improve legume production by poor farmers in rainfed areas of Asia.

Our research in the use of sweet sorghum as a multi-purpose crop for food, feed, fodder and fuel in **Project 5** is enhanced by three projects: one from the EU with CIRAD as the Lead Institute, a second from India under the National Agricultural Initiative Program, and a third from IFAD.

In **Project 6**, an ACIAR project to improve post-rainy season sorghum to meet the growing demand for grain and fodder in India has been initiated with partners in the Indian national program and Australian universities.

We continue to scale-up and out our community-based watersheds research in **Project 9** through newly supported projects from the Indian Ministry of Agriculture on macro-management of community watershed systems. Two projects from the Sir Dorabji Trust in India are now supporting our work in increasing agricultural productivity of farming systems in central India and to improve livelihoods in two States of India through community watersheds.

Slower than Expected Progress in Previous MTP

The expected funding of the major activities (e.g., Phase II of the Desert Margins Program) proposed in MTP Project 8 "Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources, particularly at the Desert Margins of the Sahel and the drylands of ESA" has not been received, nor is forecast to be received in 2009. In addition, the

proposed OASIS Challenge Program was not approved. For these reasons, ICRISAT has elected to terminate Project 8 in the MTP 2010-2012 and allocate any remaining activities under this project to other MTP Projects.

Changes in Collaborative Arrangements

ICRISAT continues to participate significantly in all the current CGIAR Challenge Programs (Generation, Harvest Plus, Water and Food and FARA Africa). In the Generation Challenge Program, we are providing leadership to the chickpea Grand Challenge Initiative and are providing molecular genotyping support to a number of developing countries programs through our Genotyping Services Laboratory. We continue to coordinate the major project on Legume Improvement in SSA and Asia with CIAT and IITA funded by the Bill and Melinda Gates Foundation. Starting in 2009, ICRISAT will coordinate a new Bill and Melinda Gates Foundation project on "Tracking Change in Rural Poverty in Household and Village Economies in South Asia" that will enhance on village level studies research in partnership with IFPRI, IRRI and national programs in South Asia.

Alignment with System Priorities

The SC commentary for MTP 2009-2011 has acknowledged ICRISAT's current project portfolio is well aligned with System Priority goals. The accordance of the work proposed with the respective priorities is described in each project narrative.

Non-System Priority Activities

One of ICRISAT's continuing projects (Project 10) is The Virtual Academy for the African and Asian SAT and its linkages with the Global Open Food and Agriculture University (GOFAU). This is a vital institutional tool in ensuring that ICRISAT's IPG technologies attain the broad exposure that they deserve. ICRISAT prefers in the current plan to continue to give this effort Blue Skies Project status within the context of the CGIAR Systems Priorities. New research activities include ICRISAT's partnerships in the Agri-Science Park @ ICRISAT and with AVRDC.

Center Financial Indicators

ICRISAT continues to maintain a strong financial position and has achieved a budget surplus for 2008. All Center Financial Indicators are presently within CGIAR-accepted approved levels. As of the end of 2008, we have reserves totaling $15.827 million, short-term solvency (liquidity) of 170 days, and long-term solvency (adequacy of resources) of 127 days, both favorable compared with the CGIAR's recommended acceptable ranges.

ICRISAT's current estimate for 2009 financing is US$49.02 million, an increase of US$1.47 million from 2008. As our estimated unrestricted funds are expected to remain essentially the same as 2008, this increase is due to the successful attraction of new special project funding. We continue to have a good success rate for project approvals and have implemented a full-cost recovery program for all projects starting at the beginning of 2008. We are devoting more efforts to attract larger (and longer term) projects to reduce administrative burdens on the institute, although smaller grants are targeted for specific areas and donors.

Table 1. ICRISAT Projects Budgets 2008-2009

MTP Project	Expenditure Estimate $ 2008	Expenditure Estimate $ 2009	System Priority
1. Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	$6.399M	$6.555M	5 (A-D)
2. Sustaining biodiversity of sorghum, pearl millet, small millets, groundnut, pigeonpea and chickpea for current and future generations	$5.546M	$5.895M	1 (A-B)
3. Producing more and better food at lower cost of the staple cereals and legumes of the WCA SAT (sorghum, pearl millet and groundnut) through genetic improvement	$7.460M	$7.408M	2 (A-C)
4. Producing more and better food at lower cost of the staple cereals and legumes of the ESA SAT (sorghum, millets, groundnut, pigeonpea and chickpea) through genetic improvement	$5.064M	$4.735M	2 (A-C)
5. Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (sorghum, pearl millet and pigeonpea) through genetic improvement	$3.198M	$3.525M	2 (A-C)
6. Producing more and better food at lower cost of staple open-pollinated cereals and legumes in the Asian SAT (sorghum, millets, pigeonpea, chickpea and groundnut) through genetic improvement	$5.475M	$6.091M	2 (A-C)
7. Reducing rural poverty through agricultural diversification and emerging opportunities for high-value commodities (HVCs) and products	$3.842M	$3.975M	3 (A,B,D)

8. Poverty alleviation and sustainable management of water, land, livestock and foret resources, particularly at the desert margins of the Sahel and the drylands of ESA (SSA Desert Margins Program SWEP)	$0.864M	-	4 (A,D)
9. Poverty alleviation and sustainable management of water, land, livestock and forest resources through sustainable agro-ecological intensification in low- and high-potential environments	$6.055M	$6.765M	4 (A,C,D)
10. The Virtual Academy for the African and Asian SAT	$1.646M	$1.781M	Blue Sky
Development, Stand-alone training, New research areas	$1.998M	$2.287M	Development
TOTAL	**$47.547M**	**$49.017M**	

Project Portfolio

ICRISAT-1: Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT

Project Overview and Rationale

MTP Project 1 provides the essential social science context for ICRISAT research. This project attempts to understand the complex challenges and emerging constraints facing agriculture in the semi-arid tropics with the aim to identify multi-faceted interventions that encompass innovations in policy, institutions and new technologies that improve productivity and market access for the poor. It employs a mix of qualitative and quantitative approaches to identify livelihood strategies, technology adoption and impact pathways and analysis of pro-poor policies and development strategies for improving productivity and marketing of agricultural produce. The strategic assessments for agricultural and economic growth in the SAT region - the dynamics of rural livelihoods, nature and the determinants of poverty, as well as commodity and market trends in increasingly global markets, and input supply and access constraints - are vital to inform and direct future investments in the SAT. The project will focus on mapping the complex development pathways and alternative livelihood options and the institutional innovations for improving access to agricultural technologies and markets to identify policy options and inform interventions to address poverty, vulnerability, marginalization and social exclusion in the semi-arid tropics. The project has the following four specific objectives that are in line with the mandate, goals and objectives of the Center as a whole.

1. Evaluate and develop innovative adoption and impact pathways and policy options for expanding access and utilization of new technologies for smallholder producers, and enhance the conduct and performance of knowledge intensive rural institutions (e.g. extension service) through impact studies that also contribute to accountability and priority setting.
2. Develop and promote strategies that enhance market access and competitiveness of dryland commodities for smallholder farmers/agro-enterprises and food safety for consumers.
3. Examine, develop and promote strategies for strengthening rural institutions and pro-poor institutional change to reduce vulnerability of smallholder livelihoods.
4. Analyze the effectiveness of agricultural and rural development strategies and identify development pathways and policies that facilitate poverty reduction and livelihood protection under chronic and transitory emergencies.

The target eco-region for MTP Project 1 is the semi-arid tropics of sub-Saharan Africa and Asia. In this project, ICRISAT is both a primary and secondary research provider. ICRISAT also plays a bridge-broker-catalyst role in this project articulating a vision for the future of dryland agriculture that will make a difference to the livelihoods of people in the SAT. It plays a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs. The remainder is unchanged from MTP 2007-2009 and MTP 2008-10.

ICRISAT is a leader in this research area and is well poised as a major player in developing strategies, policies and innovations in the semi-arid tropics. It works in an interdisciplinary and partnership mode and produces international public goods by using micro- and macro-level analysis to inform policy development and decision making.

Strategic research for identifying pro-poor policy and institutional innovations to improve access to agricultural technologies, markets and services will require a systematic analysis of

the future outlook for dryland agriculture, targeted research priorities and impact evaluation methodologies which are developed and shared with national and sub-regional research systems. Along with advanced methods for impact assessment of both first and second-order impacts of agricultural interventions, participatory monitoring and evaluation models will be developed and shared with partners. In addition a coalition approach (e.g. public-private partnerships) applying principles of innovation systems for better coordination and delivery of grain and input marketing services and rural finance to smallholder farmers will be documented and promoted as specific exemplars for generating valuable models and IPGs from this area of research.

Impact Pathway

The impact pathway developed for ICRISAT MTP Project 1 is an essential part of project monitoring and evaluation which enables a learning process throughout the Project 1 cycle. This impact pathway systematically outlines a hierarchy of outcomes that contributes to attaining the Project's ultimate development goal, that is, improved livelihoods of the people in the semi-arid tropics. The pathway shows a hierarchy of outcomes and how these outcomes at different levels ---outputs/activities, outcomes, impacts --- are expected to contribute to the Project 1 sub-goals and ultimate development goal. Getting all research partners and stakeholders to be aware and to agree to this impact pathway facilitates the learning process and will ensure a common understanding of what the project is trying to achieve. This understanding is crucial for an effective delivery of project outputs to the target users and beneficiaries of ICRISAT research products.

Impact from improving incentives for technology generation, access and use, we assume, will come through enhanced commercial investment in, for example, seed production and marketing as a result of reduced transactions costs faced by the private sector as a result of seed trade harmonization. Our efforts in the creation and capacity development, for example, of the West African Seed Association are designed to mitigate this risk. For crops that are less commercially attractive including groundnut that is bulky, perishable and has a low seed multiplication rate the development of independent foundation seed enterprises set up as units of public utility with the authority to take business decisions, the financial autonomy that will allow the full recuperation and use of proceeds from seed sales, and provide the necessary accountability to whatever governance mechanism is decided upon, we assume, will improve access to publicly developed germplasm and we provide capacity development to help ensure this. These units will support community-based seed production, and the development of seed entrepreneurs both of which are expected to improve impact from public-breeding efforts.

The ICRISAT Project 1 Impact Pathway articulates the essential phases in achieving the overarching development goal of improved livelihoods for the SAT poor. Six sub-goals are identified: food security, income augmentation, reduced vulnerability, improved quality of life, market-led transformation, inclusiveness and gender equity. The outputs-outcomes-impacts phases are systematically outlined. This is illustrated in Figure 1.1 in the 2008-2010 MTP. For the research outputs to have an effective influence on the achievement of higher level purposes and goals, a holistic inclusive network of partners/actors/participants is conceptualized and illustrated by a network pathway for Project 1 (Figure 1.2 as presented in the 2008-2010 MTP). This is developed to identify the players and their interactions throughout the research and development process. This instrument provides a visual perspective of the transformation of knowledge into action through effective evaluation and reflective learning, the key to successful implementation of a project, and to generating significant impact through project activities and dissemination of results.

Alignment to CGIAR Priorities

The research proposed in this project is in specific accordance with System Priority 5 'Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger'. It specifically covers priorities 5A, 5B, 5C and 5D.

Outputs Description

Changes from Previous MTP
Output 4 is an on–going output with intermediary outputs achieved in previous years (model adaptation to SAT crops, training etc.).

Output 1: **Best innovative practices and mechanisms for harmonization and utilization of seed-related and biosafety regulations and policies suitable for the specific conditions of the SAT piloted, promoted and adopted with new knowledge shared with partners**

Description:

A key intervention point is in developing strategic options and best practices for seed systems development in the SAT and supportive policies that facilitate trading and marketing of seeds across national boundaries, including harmonization of seed regulations and policies, especially variety evaluation and release procedures, seed certification, phytosanitary procedures and plant variety protection. This has the advantage of creating new incentives in terms of better economies of scale and scope for the emergence and participation of the private seed industry in seed supply and marketing. This will complement the weaker public sector seed enterprises in the region and create opportunities for farmer entrepreneurs and small rural agro-enterprises to participate in the seed production and marketing in rural areas.

ICRISAT and its partners can hope to achieve an enhanced policy and institutional environment for accelerated investment in SAT agriculture that would contribute towards generation and adoption of better suited technologies and increase in farm incomes and nutritional security for the poor. This may be achieved through a strategy that focuses on the following output targets for 2010:

2010 1.1.1: Best practices for harmonization of seed-related regulations and policies suitable for the specific conditions of the ASARECA and SADC regions promoted

This research area is closely linked to that of Projects 3-6 but as a global generic policy issue it is felt it would be better to address it as a whole in Project 1 rather than to disarticulate it between 4 other projects.

Alignment to CGIAR Priorities : 5A: Improving science and technology policies and institutions;

Output 2: **Ex-ante and ex-post impact studies conducted on representative ICRISAT NARS innovations for the SAT to enhance accountability and facilitate priority setting**

Description:

An output will be produced from this initiative including intensive capacity building through collaboration with SAT Asia and Africa national and international researchers. Policy dialogues with governments on research priorities, institutional innovations and policy will be catalyzed. These efforts are summarized in three output targets namely:

2009 1.2.1: Ex-post impact studies on conservation farming and micro-dosing in Zimbabwe to be completed

2009 1.2.1: Ex-post impact studies on sorghum and pearl millet in Nigeria; sorghum and pearl millet for poultry feed in Asia

2010 1.2.1: Early adoption studies on chickpea, pigeon pea and groundnut in selected countries

Alignment to CGIAR Priorities : 5A: Improving science and technology policies and institutions;

Output 3: **Database and new methodologies addressing the impact of bio-physical and social science research developed**

Description:

The need for global information on mandate crops and associated livestock and the place of the SAT in the WTO arena. World market price information of mandate crops and associated livestock and supply-demand projections would help in more informed decision making on research resource allocation and their implications for small-scale farmers in relation to global market trends. An output will be produced from this initiative including intensive capacity building through collaboration with SAT Asia and Africa regional and international researchers. Dialogues with governments on policy options and suitable interventions will be catalyzed.

2009 1.3.1: Impact assessment master classes in Asia completed and documented

2010 1.3.1: Impact pathways approach applied in ICRISAT planning and monitoring and evaluation process for enhancing relevance of R and D interventions in the SAT

2011 1.3.1: Updated impact database shared in the website

2011 1.3.2: Impact evaluation methodologies tackling social processes and capacity building, along with lessons learnt from analysis of impact pathways developed and shared with national and sub-regional agricultural systems

2011 1.3.3: Lessons learnt from analysis of impact pathways of representative ICRISAT NARS

Alignment to CGIAR Priorities : 5A: Improving science and technology policies and institutions;

Output 4: **Current agricultural growth trends and future outlooks for the SAT analyzed and shared with key stakeholders**

Description:

The main purpose of this output is to generate viable projections for ICRISAT mandate crops and competing crops using the advanced IMPACT-WATER Model. This partial equilibrium model can be used to generate forecasts for production, consumption (food and feed) and trade under various scenarios like drought, yield and income changes and trade policy changes. These efforts are summarized in two output targets namely:

2009 1.4.1: Regional/Global economic outlook (supply, demand, trade, prices) report of ICRISAT mandate legumes

2011 1.4.1: Global/Regional outlook (supply, demand, trade, prices) reports of ICRISAT mandate crops

Alignment to CGIAR Priorities : 5A: Improving science and technology policies and institutions;

Output 5: **Investment and policy options for increasing agricultural productivity and mitigating climatic related shocks identified and shared with key stakeholders.**

Description:

As per Output 1.2. These efforts are summarized in four output targets namely:

2009 1.5.1: Development domains report for southern Africa

2010 1.5.1: Policy options for increasing agricultural productivity to mitigate HIV susceptibility

2010 1.5.2: Constraints, challenges and opportunities for regional cooperation in R and D and alternative regional research and development strategies in southern Africa report

2011 1.5.1: Adaptation strategies and layers of resilience to climatic related shocks in Asia documented

Alignment to CGIAR Priorities : 5A: Improving science and technology policies and institutions;

Output 6: **Strategies for increasing competitiveness through identifying preferred market traits and introducing quality control systems to meet social, food safety and environmental standards for dryland crops established and promoted**

Description:

In the coming decade, whether smallholder producers in the SAT would be able to invest in new agricultural technologies and escape poverty would depend on their ability to access domestic, regional and international markets for their produce by making necessary adjustments to meet growing quality standards and improving efficiency in production and marketing. Efficiency in production would depend on their ability to access and exploit the best available technology and inputs. Market access requires access to demand and price information in different markets, seasonal patterns of supply and price changes, credit, and availability of essential services. Given the complex factors that limit the functioning and efficiency of markets in rural areas, diverse policies and institutional arrangements can be employed to make markets work for the poor. Vertical coordination of production and marketing arrangements to improve economies of scale and reduce transaction costs will be critical. This is already evident in the region through cooperatives, producer organizations, and contract farming, whose role is likely to increase in the coming years. Linking producers directly to the upper part of the value of chain can shorten the supply chain, reduce the role of intermediaries (and transaction costs), and raise farm-gate prices while prices to poor consumers remain low.

As demand for a consistent supply of homogenous and quality products increases, there will be growing demand for private sector participation in agriculture through contract farming and other arrangements. This may also pose new threats and opportunities for small farmers in the SAT. While it may create monopolistic behavior and further marginalize less competitive and unorganized poor farmers in low potential areas, it may provide reliable market outlets and access to inputs, skills and technologies for some producers that will improve production efficiency. Future research will need to identify efficient strategies and equitable mechanisms for linking producers to markets and enforcing such contracts, while also protecting the livelihoods of marginal farmers under transitory and chronic poverty.

ICRISAT efforts will focus on the following elements:

– Mapping values chains and identifying profitable marketing channels and outlets
– Understanding the existing grading and quality control systems and effects on prices
– Determinants of smallholder market participation and marketed surplus
– Policies and institutional arrangements for better coordination of production and marketing to enhance competitiveness

The research strategy focuses on the following output targets:

2009 1.6.1: Value chains and preferred market traits identified for selected tradable legumes (chickpea, pigeonpea and groundnut) in selected markets

2010 1.6.2: Preferred market traits identified for livestock (in southern Africa) and dryland cereals in WCA region

2011 1.6.4: Determinants of smallholder market participation and marketed surplus of grains in selected markets in ESA, WCA and SA

2011 1.6.4: Policy briefs outlining the strategies for establishing quality-based agricultural marketing systems for selected dryland commodities in ESA, WCA, and SA

Alignment to CGIAR Priorities : 5B: Making international and domestic markets work for the poor;

Output 7: **Institutional innovations for reducing transaction costs and improving coordination in input and output market chains for dryland commodities in domestic and international markets identified and promoted**

Description:

As per Output 1.6.

Whereas market reforms and liberalization polices in the last few years have opened opportunities for market-led agricultural development in Africa, transforming largely subsistence oriented smallholder production systems into commercial enterprises has remained to be a major challenge. The lack of sufficient market infrastructure and supporting institutions in rural areas has stifled the degree of market participation and competitiveness of smallholder farmers. This has opened greater opportunities for leveraging rural institutions to overcome market failures, reduce entry barriers and enhance smallholder access to input and output markets.

The research strategy focuses on the following output targets:

2009 1.7.1: Innovative arrangements for better coordination of production, access to inputs and services, and output marketing (for selected legumes (ESA), and ruminants in ESA) along the value chain for reducing transaction costs identified and communicated

2010 1.7.1: Policy recommendations for improving market institutions, linkages and coordination for selected commodities developed and shared with policy markers and partners

2010 1.7.1: Synthesis of lessons and experiences on role of producer organizations to improve markets for small producers in Africa

2011 1.7.1: Synthesis of pilot market and institutional innovation studies in Asia using coalition approach completed

Alignment to CGIAR Priorities : 5B: Making international and domestic markets work for the poor;

Output 8: **Policies and strategies that enhance agricultural diversification into high value products (e.g., legumes, livestock, biofuels, vegetables, etc) to harness emerging demand opportunities and facilitate agribusiness enterprises developed and promoted**

Description:

As per Output 1.6.

2010 1.8.1: Research report on economic feasibility of diversification using legumes and/or livestock (ESA) completed

2011 1.8.1: Research report on economic feasibility of diversification into high value products with emphasis on biofuels (ESA, Asia) and vegetables (WCA) completed

2012 1.8.1: Policy options and recommendations for stimulating diversification of agro-enterprises into high value commodities defined and shared with policy makers and partners

Alignment to CGIAR Priorities : 5B: Making international and domestic markets work for the poor;

Output 9: **Alternative institutional innovations to strengthen rural institutions that facilitate and enhance adoption of technological and market innovations and policy recommendations developed and shared with partners.**

Description:

Priority 5C. Improving Rural institutions and their governance

Priority 5C, Specific goal 1: Identify mechanisms for the strengthening of producers organizations and for modes of participatory research

Priority 5C, Specific goal 2: Identify new forms of partnerships with NARS, the private sector, public extension agencies, NGOs and producers organizations, and public agencies from other sectors, such as environment and health to enhance the conduct and impact from agricultural research

ICRISAT is faced with the challenge to identify broad lessons and strategies that facilitate the emergence of viable farmer organizations and institutions that facilitate access to essential services, namely markets and agricultural innovations, and help mitigate vulnerability to shocks or support local agricultural recovery efforts. ICRISAT is working closely with different kinds of farmer organizations in various countries. ICRISAT has also taken initial steps in the understanding of how such rural organizations evolve and function and how they can provide effective services especially in relation to marketing groups, farmer cooperatives and other commercially-oriented farmer enterprises.

This research will involve the following area: Characterization of selected rural institutional arrangements in selected countries including their potentials for improving farmer access to markets and agricultural technologies for income growth and reducing vulnerability to shocks, e.g. drought.

The output target for 2011 is:

2011 1.9.1: Policy report on impact of rainfall insurance and recapitalization of cooperatives in India

Alignment to CGIAR Priorities : 5C: Improving rural institutions and their governance;

Output 10: **Livelihood, institutional and policy options for investment and risk management for SAT poor developed and promoted with associated capacity building for partners**

Description:

Almost a billion people in SAT Asia and Africa are still engaged in small-scale agriculture. The past years have seen an increasing focus on the diversity of livelihood strategies employed by rural households. Farming remains important but rural people are looking for diverse opportunities to improve food security, livelihood resilience, and stabilize their incomes. Farmers vulnerability and their adaptation through coping mechanisms depend on their assets (physical, natural, financial, human, and social), and are influenced by institutions, the external environment and broader economic trends such as market prices and shocks including drought.

ICRISAT and its partners aim to maximize the impact of agricultural research by improving research and development options to reduce rural poverty and vulnerability in Asia and sub-Saharan Africa. To achieve this, ICRISAT will focus on mapping complex development pathways and alternative livelihood options to help make critical interventions to address poverty, vulnerability, marginalization and social exclusion. In particular, this will involve:

- Understanding the dynamics of poverty in the SAT and monitoring changes; identify options for the rural poor to access, acquire, protect (in the case of shocks) and use assets to improve their livelihoods and use the information to inform future R and D strategies
- Improving characterization of the rural poor (assets, context, depth and duration of poverty, vulnerability, basic needs, and choice of livelihood strategies) in relation to SAT agriculture.
- Analyzing uptake pathways of improved technologies and natural resource management practices and participation in higher-value product markets Determining specific opportunities or niches for ICRISAT to make a difference to the welfare of the SAT poor to include trade-offs underlying investments in crops and livestock, farm and non-farm rural employment and enterprise, migration and remittances, labor efficiency and greater human disease burden including HIV/AIDS, market interventions and policy changes.
- Assessment of returns to alternative livelihood and resource management strategies, and evaluation of approaches to improve ex-ante risk management through livelihood diversification, formal and informal insurance mechanisms, financial and in-kind savings, futures and forward markets, and improved market information systems
- Analysis of the effectiveness of public sector assistance programs and rural development strategies to improve livelihood resilience and reduce poverty

Outputs produced from this initiative include intensive capacity building through collaboration with SAT Asia and Africa regional and international researchers. Policy dialogues with governments on improving rural livelihoods and social protection interventions will be catalyzed.

Alignment to CGIAR Priorities : 5D: Improving research and development options to reduce rural poverty and vulnerability;

Impact Pathways by Output

Output 1: Best innovative practices and mechanisms for harmonization and utilization of seed-related and biosafety regulations and policies suitable for the specific conditions of the SAT piloted, promoted and adopted with new knowledge shared with partners

Seed is arguably the most important input in agriculture. Intervention in improving seed policies begin by going through the policy cycle, i.e., data collection®data analysis®policy dialogue®implementation with regard to seed evaluation release and registration, seed certification, phytosanitary regulations, import-export procedures, bio-safety regulations and others. The results [OUTPUTS] are agreements on new rules of the game about how to do business more efficiently and effectively. This then leads to [OUTCOMES a] changes in national

seed laws, regulations, rules, policies and procedures. When these changes are effected they in turn lead to [OUTCOMES b] increased flow of better quality seed, increased choices of seed by farmers, increased productivity and production for crops. At the end of it all [IMPACT] we realize increased food security and better nutrition, increased regional seed trade and therefore more income to seed sector participants and overall increase in agricultural and national gross domestic product.

Output 2: Ex-ante and ex-post impact studies conducted on representative ICRISAT NARS innovations for the SAT to enhance accountability and facilitate priority setting

In the process of documenting ex-post impact using both primary and secondary data, ICRISAT believes that it is possible to derive insights that can help better inform ex-ante priority assessment and provide grounds for additional investment in the resultant research portfolio. Ex-post impact assessment of research boosts the confidence of scientists, research managers and stakeholders and makes a case for enhanced support for research. Information obtained during the process of impact evaluation can also help in research prioritization. For example, data from primary field studies provide a good basis for reasonable estimates of parameters, which are used in the priority-setting exercise. The essential impact assessment information includes: (i) levels and speed of adoption, and reasons for adoption/non-adoption of technology; (ii) farmers' perceptions of desirable traits or features of technology options; (iii) on-farm gains due to alleviation of biotic and abiotic constraints; and (iv) infrastructural, institutional and policy constraints in facilitating technology exchange.

Two categories of impact data may be developed. The first is a set of primary data on adoption and related variables generated from formal and informal on-farm surveys. The second is a set of secondary data based on documentation (published and nonpublished reports). On-farm reconnaissance and formal surveys may be primarily aimed at continuously assessing the extent of adoption of improved technology from the secondary database. This confirms the extent of utilization of improved technologies by farmers in the target regions. Research lag is a major parameter determining the present value of research, and the cost of miscalculating it in terms of erroneous priority ranking can be significant. Verification of research and adoption lags used can be accomplished by crosschecking data from various sources.

Farmers' opinions on important constraints as well as their perceptions of desirable cultivation and management technology options may also be generated from primary surveys. These farmers' perspectives provide the following information: (a) they identify the constraints and research opportunities; (b) they provide an empirical basis for the expected ceiling levels of adoption, i.e. technologies introduced in an environment characterized by significant bottlenecks to adoption cannot be expected to have high adoption ceilings unless these constraints are addressed; and (c) they identify the research options that directly address the users' needs and are most likely to be adopted.

Estimates of yield losses due to important constraints and on-farm gains due to improved technology are also vital pieces of information for deciding research priorities. Impact studies can be used to validate estimates of expected yields. Furthermore, the estimates generated from these surveys (i.e., yield gains or unit cost reductions) also provide a way of predicting the potential supply shift, a necessary parameter for estimating potential impacts in cost/benefit analyses.

Another important outcome from impact studies is the assessment of researchers' perceptions or constraints, which can be technological, institutional, infrastructural and policy. Two aspects are relevant for seed policy and priority setting: (a) standard variety release procedures of breeders' selecting materials that can make it through the formal release system; and (b) criteria for varietal release do not necessarily match farmers' needs and preferences.

While ex-post experience is not the panacea when revalidating earlier ex-ante assessments, ex-post experience at best can inform the ex-ante process, hopefully in a way that helps

minimize the moral hazards associated with scientists' estimates of their expected outputs and milestones.

Output 3: Database and new methodologies addressing the impact of bio-physical and social science research developed

The eventual outcomes of this output are anticipated to be new knowledge and database on impact. This impact assessment explores the development of new methodologies and development of database on impact and their adoption by all stakeholders, and assesses the contribution of the project to the achievement of these final outcomes and consequent benefits.

Using the example of the case of sorghum research in India through a project by ACIAR, it is projected that the impact assessment leads to many of the outcomes specified, such as increased use of genetically modified or higher-yielding sorghum by farmers. The aim of the ACIAR project was to develop the capacity to insert genes into sorghum in India. This was achieved by developing a tool called the particle inflow gun (PIG) and training Indian scientists in its use. However, a number of other steps must be completed before genetically modified sorghum can reach farmers' fields. Outputs include enhanced genetic transformation techniques, capability to incorporate different gene types into sorghum, sorghum tissue culture transformation book, compilation of databases and improved analytical tools for multi-environment trials. Once outputs have been generated by the research process, the innovation process becomes important, i.e., the dissemination of information and the application of the research outputs. These are through training courses, publications like handbooks and manuals, information dissemination to extension agents and farmers and enhancing the capacity of the social and bio-physical scientists. The outcome of this process is the adoption of technologies or the acquisition of knowledge by new users. Improved analytical methods and ability to use genetically transformed sorghum; for farmers the outcomes will be change in water table or land regeneration, increased area planted, among others. Outcomes in this case are also measured in terms of increases in yield, productivity, and/or production and capacity of the scientists enhanced in undertaking such impact assessments.

Similarly in West Africa, through a project implemented by NARS and ICRISAT from 2003 to 2007, the GSP (Groundnut Seed Project), a number of outputs and outcomes have been achieved. The objective of the project was to promote groundnut varieties using participatory approaches and strengthen seed production and delivery systems in 4 groundnut producing countries in West Africa namely Mali, Niger, Nigeria and Senegal. More than 200 farmer participatory variety trials have been implemented, more than 3000 farmers have been trained in seed production techniques, and more than 40 farmers' associations and small-scale producers have been empowered and strengthened in seed production techniques. This has resulted in the production of 108 tons of foundation seed and 300 tons of certified seed.

This research and development intervention led to the diffusion of 20 varieties of which more than 10 have been adopted in these countries and more precisely in project sites. In Niger for example, the area cultivated to new varieties increased by 14% in Niger, 44% in Mali and 31% in Nigeria. Adopters have benefited from reduction in unit costs of production (estimated to 11% about in Niger, 10% in Mali and 11% in Nigeria) and increased in yields (estimated to about 43% in Niger, 24% in Mali and 51% in Nigeria) resulting in significant income gains (estimated to about 73% in Niger, 66% in Mali and 111% in Nigeria).

In addition to this intervention, 10 NARS economists have been trained in Impact assessment methodologies within the project.

Output 4: Current agricultural growth trends and future outlooks for the SAT analyzed and shared with key stakeholders

Inputs: Fine tuning the model to generate authentic projections based on expert knowledge from crop improvement scientists, and current data.

Outputs: Region and country wise projections on key variables for ICRISAT mandate crops. Sensitivity analysis of the projections under varying scenarios (drought, yield and income changes, trade policy etc.).

Outcomes: Partners in Semi-Arid Tropics show informed decision making for identifying development targets for SAT regions and commodities.

Adopter level changes: Effective supply and demand projections for SAT mandate crops and associated livestock based on scientific information will lead to more informed research resource allocation and research priority setting by commodities and regions. Policy makers use the information for making informed policy decisions.

Community level impacts: Better targeting of interventions and technologies benefiting the SAT farmers.

Output 5: Investment and policy options for increasing agricultural productivity and mitigating climatic related shocks identified and shared with key stakeholders.

Initial engagement is the identification and assessment of the most likely policy interventions in raising productivity, food security and nutrition, trade and incomes. Of great concern is also the probability that an intervention will contribute to the two targets of the Comprehensive African Agricultural Development Program (CAADP)—increasing investment in agriculture at a level of 10% of the agricultural GDP and maintaining a growth rate in agriculture of 6% and higher. This is then followed by data collection in the chosen areas, analysis and generating [OUTPUTS]-a set of viable options that can be [OUTCOMES] discussed in various relevant forums at highest level of government—nationally and regionally to determine specific areas where investments or changes in investment are needed. When Action is taken to implement these investments, the results are [IMPACTS] increased productivity in the selected sectors, increased food security and nutrition as well as better management of the environment.

The project entitled, “Vulnerability to climate change: Adaptation strategies and layers of resilience” aims to provide science-based solutions and pro-poor approaches for adaptation of agricultural systems to climate change for the rural poor and most vulnerable farmers in semi-arid regions of Asia especially of Bangladesh, India, Pakistan, Sri Lanka ,The Peoples’ Republic of China (PRC), Thailand and Vietnam. The overall objective of the project is to identify and prioritize the sectors most at risk and develop gender equitable agricultural adaptation and mitigation strategies as an integral part of agricultural development in the most vulnerable areas.

The focus of the project is on ground level realities linked or integrated with macro level factors to evolve adaptation strategies that will address the issues of vulnerability in the most vulnerable sites of semi-arid tropics (SAT) and develop various layers of resilience. The outcomes from the project are: Improved understanding of climate variability and adaptation-coping strategies of the rural poor in SAT region; Best practices and institutional innovations for mitigating the effects of climate change; and Strategies to address socioeconomic problems relating to changing weather patterns and availability of a range of initiatives for their alleviation and Policy options.

The pathways of adoption include the use of VLS longitudinal data for R and D and policy influence on economic development; policy dialogues to influence decision makers; enhanced capacity of the social and biophysical scientists and information dissemination on adaptation strategies and layers of resilience. The outcome from this project accrue to all.

Output 6: Strategies for increasing competitiveness through identifying preferred market traits and introducing quality control systems to meet social, food safety and environmental standards for dryland crops established and promoted

This research is expected to generate the following outputs, outcomes and impacts:

Outputs:

- Market linkages, value chain maps and strategies for reducing transaction costs and expanding market access for selected legumes and cereals
- Best practices and policy options for introducing market-based grading and quality control systems to meet consumer preferences in selected markets
- Synthesis of lessons on role of producer organizations to improve farmer access to markets and technologies
- Policies and strategies that enhance participation of smallholders in agricultural markets through leveraging producer organizations to overcome market impediments
- New opportunities for poverty reduction and incentives for smallholder farmers to adopt profitable and market-led agricultural technologies

Outcomes:

- Farmer organizations and small-scale producers will benefit from market opportunity identification and expanded market outlets that reduce transaction costs
- The supply chain for dryland commodities will be differentiated by grades and quality standards opening opportunities for value addition and increased competitiveness of small producers
- Smallholder farmers will benefit from stronger producer organizations that improve marketing services and access to basic inputs for increasing adoption and agricultural productivity
- Policy makers and planners will take steps to implement policies for increased integration of small producers into value chains and better coordination of grain production and marketing

Potential impacts:

- Enhanced market participation and integration of smallholder producers into markets that would contribute to income growth and food security
- Enhanced ability to respond to the challenges and seize opportunities from globalization in meeting consumer preferences for food safety, social and environmental standards
- Reduced entry barriers and improved competitiveness of smallholder producers and agro-enterprises
- Better prices and higher incomes for smallholder producers from improved market linkages
- Increased smallholder ability to manage production and market risks through stronger market institutions that will reduce vulnerability of rural livelihoods

Output 7: Institutional innovations for reducing transaction costs and improving coordination in input and output market chains for dryland commodities in domestic and international markets identified and promoted

Under this output on Institutional innovations for reducing transaction costs and improving coordination in input and output market chains for dryland commodities in domestic and international markets identified and promoted, the impact pathway is [resented using the example of the coalition approach for promoting sorghum in poultry feed in Asia. The coalition approach is a model to link different institutional players for a speedier and sustainable dissemination of technology for small-scale producers. It is also a process in which distinct/independent entities/institutions work together as a single unit for the common goal with synergistic effect while keeping their identity. The activity was undertaken jointly in collaboration with the stakeholders [research institutions such as ICRISAT, Agricultural

Universities, SRI (China), FCRI (Thailand)] and final users namely, NARES, NGOs, seed and grain suppliers, input suppliers, grain storage agencies, credit agencies, poultry feed manufacturers, farmer and poultry federations and finally farmers. The outputs include the coalition building itself, improved crop production technologies, higher yields, innovations in input supply and marketing chains, dissemination and scaling out of the coalition approach. These outputs lead to outcomes at the farmer level such as access to cheaper credits, market intelligence, reduced risk and use of quality inputs. The outcomes ofr the other stakeholders involved in this activity included availability of grain to the end users (eg. poultry industry), credit uptake and assured grain quality. The impact felt at the community level were both socioeconomic in nature and also environment. Increase in income, better health and education for children and reduced use of chemical fertilizer and pesticides are some of them.

Output 8: Policies and strategies that enhance agricultural diversification into high value products (e.g., legumes, livestock, biofuels, vegetables, etc) to harness emerging demand opportunities and facilitate agribusiness enterprises developed and promoted

Production and marketing risks are recurrent in the Semi-Arid Tropics. Agricultural diversification is an essential risk coping mechanism that allows consumers to smooth their consumption and ensure a consistent supply of a portfolio of products by producers. Limited diversification into high value crops where countries have comparative advantages has constrained the competitiveness of SAT agriculture and the opportunity to gain from trade.

Agricultural diversification towards high-value commodities can be a potential tool for poverty alleviation in developing countries. To harness this potential the following elements are critical to scaling-up diversification are: (i) production base that can deliver high value marketable surplus, (ii) physical infrastructure (roads, electricity, communication, refrigerated transport, cold chains, etc.) that can facilitate commodity flows between production and markets, (iii) efficient interactions between key supply chain players to reduce transaction costs (iv) investment in product processing and conservation for value addition, and (v) an enabling regulatory and legal framework to enhance the capacity of the public sector and encourage private sector investment in agribusiness.

Diversification of agriculture towards high-value agriculture will impact various stakeholders (including farmers, processors, traders and consumers) on the supply chain for high-value food commodities. At the upstream farmers will be benefited in terms of enhanced income and employment opportunities and become more competitive. At the down stream consumers will benefit in terms of improved product quality and value, better availability and lower prices of these commodities. Other stakeholders like traders and processors will also benefit from reduced transaction costs and can exploit higher margins for their activities and services. On the whole impact of high-value agriculture will be felt economy-wide in terms of enhanced opportunities for income and employment for rural workers.

In dynamic development, adaptive responses between producers and policy makers are necessary, to enhance communication among the value chain players. This will allow identification of key challenges in agricultural production, processing and marketing, and how strategically best to address them, e.g., better coordination of supply and demand, regular volumes of sales, quality requirements. Improved communication will support further product diversification and capturing new market opportunities, e.g., niche and export markets. It will also contribute to identify future research needs that respond to the identified challenges, and enhances technology transfer and adoption.

Harmonization of policies and decision making processes will enable poorer farmers in producing high value products, improving livelihoods and environmental benefits. It also includes the question on nexus between high value products, market development and development. This will ensure integration of pro poor product and market development approaches, e.g., protection against market risk, safety net strategies, smart subsidies and

infant industries. The role of quality standards in excluding small scale farmers from product diversification, eg traceability and sanitary standards, will be addressed.

Output 9: Alternative institutional innovations to strengthen rural institutions that facilitate and enhance adoption of technological and market innovations and policy recommendations developed and shared with partners.

A research project will be carried out to understand vulnerability of SAT farmers to climate change and the various adaptation mechanisms and layers of resilience they have developed through time. Specific focus on the role of rural institutions in adaptation will yield the following outputs:

- Characterization of existing rural institutions in selected SAT villages and their linkages
- Documentation of the role of existing rural institutions in climate change adaptation
- Alternative institutional arrangements for facilitating adaptation to climate change

The lessons learnt and conclusions drawn from the study, if effectively scaled up and out are expected to result in increased awareness among NARES, NGOs, policy makers, credit agencies, producer organizations and farmers on the potential of local institutions in promoting adaptation. It is expected that this will result in increased participation of farmers, improved governance of and linkages between rural institutions and changes in policies, laws and regulations.

The outcomes will be higher productivity and reduced vulnerability of farmers to climatic shocks because of enhanced collective action, access to markets, insurance and credit, external interventions, information and adaptation technologies as well as effective legislation.

Ultimately, socio-economic and environmental impacts are expected to be realized in the form of increased incomes to farmers, reduced incidences of climatic-shock associated farmer suicides and forced migration, reduced rates of environmental degradation and stronger rural institutions in the SAT resulting in improved rural livelihoods and reduced levels of poverty.

Output 10: Livelihood, institutional and policy options for investment and risk management for SAT poor developed and promoted with associated capacity building for partners

The impact pathways for the study on tracking change in rural poverty in household and village economies in South Asia and West Africa encourages going beyond the scope of a single sub-project or output target. The research outputs so developed and identification of the stakeholders and beneficiaries outside the project needs to use these outputs to achieve developmental outcomes and impact.

ICRISAT social science research has engaged stakeholders worldwide in Village Level Studies (VLS) to understand rural poverty dynamics with focus on the SAT. In partnership with IRRI, NCAP, and NARS, NGOs and State Universities and Think Tanks from India and Bangladesh in Asia, IER and INRAN from West Africa, this study has significance in providing valuable insights on rural development pathways in meeting the Global Development Challenges. This understanding of village-level information and ground realities can act as an important catalyst in accelerating development. It provides a working knowledge of rural economy which can point to ways in which the development of rural livelihood pathways can be earlier achieved. Building on this and the belief of the Bill and Melinda Gates Foundation (BMGF) as well as IDRC - to break the cycle of hunger and poverty, better information will enrich all efforts to improve the plight of small farmers in sub-Saharan Africa and South Asia – the Village Dynamics Study lead by GT-IMPI is an influential tool in giving voice to the least powerful in the society.

The ultimate purpose which is envisioned through this study is to decrease the incidence and severity of absolute poverty in South Asia's semi-arid and humid tropics as well as West Africa

Semi-Arid Tropics by markedly increasing the availability of time-series district-, household-, individual-, and field-level data. It seeks to improve the quantity and quality of time-series meso- and micro-data so that decision-making is based on evidence on impacts on the poor. In Asia, the project is driven by three initiatives: the compilation of longitudinal household, individual, and field data over five years in 42 villages in India and Bangladesh, the assembly of secondary meso-level agricultural data into integrated data bases for distribution, and the nurturing of policy and data analysis, and capacity building. In West Africa, the project is driven by 2 initiatives: the compilation of longitudinal household, individual and field data over 3 years in 20 villages in Niegr and Burkina Faso and the data analysis and capacity building.

This multi-disciplinary study builds on the unique databases already developed and will add considerable value to them. It will provide a distinctive social science laboratory to address contemporary issues related to institutional, policy and technological changes and their actual past and potential scope to benefit the poor. It will also allow for innovative quantitative and qualitative analysis of rural poverty that offers new insights into producing a forward looking and policy oriented knowledge base and decision support system.

The project/study has the ability to magnetize the best and brightest in the social sciences globally to conduct research on the most impoverished regions of the developing world and establish a longitudinal panel data for the two countries in Asia (India and Bangladesh) and 2 countries in West Africa (Niger and Burkina Faso), will further serve as an exemplar for other national programs in developing countries. Having the opportunity that the VLS approach affords to periodically revisit the same households and villages over cropping seasons and years is an exciting prospect for practitioners and researchers alike. The potential for dynamic ground truthing is a fertile environment for the generation of ideas.

International Public Goods

Methodologies, tools and other IPGs that have applicability beyond one nations borders.

The projects outputs are often globally derived, building on ICRISAT's strengths throughout the SAT and it delivers clear examples of international public goods (IPGs).

These are:

- Village Level Studies (VLS): overall methodology, risk preferences, estimation of time preference, research and policy findings. The VLS database which has been historically a vital IPG used by international partners from the broadest spectrum
- Research evaluation and impact assessment (REIA): methodology, training modules
- Future outlooks and development opportunities in SAT agriculture identified through strategic assessments
- Institutional innovations for reducing risks and transaction costs in input and output markets
- Ways to linking market and livelihood analysis with priority setting and technology design
- Decision tools and models for evaluation of options for sustainable intensification and diversification of SAT agriculture
- Producers and consumers' preferences for dryland legumes and cereals in intermediate and end user markets and implications for technology design
- Seed policy options to facilitate policy harmonization, market development and trade to ensure sustained access to quality seed of improved varieties by farmers

Elaboration of Partners Roles

The national program partners participate in project planning and implementation as well as in training and capacity building. The evolving network of social scientists adapts methods developed by ICRISAT while policy makers use alternative development pathways particularly for pro-poor policies and risk management strategies. Higher degree students will be

associated with most aspects of this project. Economists, policy makers, and think- tanks for development policy analysis in WCA (Burkina Faso, Mali, Niger, Nigeria, Senegal), ESA (Ethiopia, Kenya, Malawi, Mozambique, South Africa, Tanzania, Uganda, Zimbabwe), and Asia (Bangladesh, China, India, Indonesia, Japan, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam) are part of the evolving network of social scientists working on the SAT. They take decisions informed by studies on diffusion, adoption and impacts, market prospects and outlooks. Advanced research institutes are closely involved in addressing methodological and empirical issues as well as cutting edge analytical methods for both macro and micro level assessments. Scientists from other disciplines within and outside ICRISAT obtain feedback information on insights on village economies to aid in the design and development of SAT technologies. The above partners are also directly collaborating to improve priority setting and resource allocation. Our new initiative on innovation systems involve close partnerships with the private sector, NGOs and farmers organizations who assist in identifying profitable marketing channels among alternative options that reduce transaction costs for seeds systems and dryland tradable coarse grains. Ultimately as policy makers better understand the consequences of policy and institutional constraints, they more effectively identify appropriate interventions and formulate pro-poor policy for farmers in the SAT.

In terms of ICRISAT's most strategic alliances: CIAT, IFPRI, IITA, ILRI, IRRI, and IWMI partner with ICRISAT through its global expertise on adoption and impact studies,marketing, innovation systems, and village level studies; Iowa State University (a world leader in international seed science issues) and the WASA (West African Seed Alliance) and ESASA (East and Southern African Seed Alliance) Consortia (supporting commercialization of small scale agriculture in SSA) and NASFAM (Malawi) are critical to work under the CGIAR Priority 5 in Africa and NCAP (the Indian National Center for Agricultural Policy), other national program partners in India and Bangladesh are key partners in Asian and VLS activities owing to its extensive domestic reach in South Asia and long experience of collaboration with ICRISAT (particularly Priority 5D).

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**Best innovative practices and mechanisms for harmonization and utilization of seed-related and biosafety regulations and policies suitable for the specific conditions of the SAT piloted, promoted and adopted with new knowledge shared with partners**	Public, private seed industry, partners, policy makers, farmer and regional seed organizations in the SAT, Iowa State University	Partners and policy makers internalize in 2008 and take initial steps to harmonize in 2009 seed related, biosafety and seed system protocols in the SAT (particularly at regional level) which enhances the utilization and market and non-market based exchange of germplasm to promote agriculture	The regulation of the seed industry, particularly when harmonized at a regional level has a very great influence on farmers access to improved genetic material which should be substantively beneficial. Easier replication of research findings in areas with similar agro-climatic conditions
Target 2010: Policy strategies	1.1.1 Three Best practices for harmonization of seed-related regulations and policies suitable for ASARECA regions documented and promoted			
Output 2	**Ex-ante and ex-post impact studies conducted on representative ICRISAT NARS innovations for the SAT to enhance accountability and facilitate priority setting**	Research partners, policy makers, NARES, SAT farmers, ICRISAT management and donors	Research partners and policy makers take better informed, innovative, science-based, decisions on alternative investment opportunities for improving agricultural productivity, incomes and employment and sustainability in the semi-arid regions	ICRISAT research management, NARES and other stakeholders demonstrate enhanced research efficiency, priority setting and resource allocation based on systematic impact analysis.

	Outputs	Intended Users	Outcome	Impact
Target 2009: Practices	1.2.1 Ex-post impact studies conducted on micro-dosing in Zimbabwe - deleted			
Target 2009: Materials	1.2.2 Ex-post impact studies on sorghum and pearl millet in Nigeria; sorghum and pearl millet for poultry feed in Asia			
Target 2010: Materials	1.2.1 Early adoption studies on chick pea, pigeon pea and groundnut in selected countries			
Output 3	**Database and new methodologies addressing the impact of bio-physical and social science research developed**	Research partners, policy makers, NARES, SAT farmers, ICRISAT management and donors	Research partners and policy makers take better informed, innovative, science-based, decisions on alternative investment opportunities for improving agricultural productivity, incomes and employment and sustainability in the semi-arid regions	NARES and other stakeholders demonstrate enhanced research efficiency by using projected impact pathways; and knowledge is more freely available from their securely preserved databases.
Target 2009: Capacity	1.3.1 Impact assessment master classes in Asia completed and documented			
Target 2010: Policy strategies	1.3.1 Impact pathways approach applied in ICRISAT planning and M and E process for enhancing relevance of R and D interventions in the SAT			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Other kinds of knowledge	1.3.1 Updated impact database shared in the website			
Target 2011: Other kinds of knowledge	1.3.2 New methodologies tackling impact on social processes (social capital and networks), capacity building and policy developed			
Target 2011: Other kinds of knowledge	1.3.3 Lessons learnt from analysis of impact pathways of representative ICRISA–NARS innovations			
Output 4	**Current agricultural growth trends and future outlooks for the SAT analyzed and shared with key stakeholders**	ICRISAT management, NARES partners, traders, processors, market agents.	Partners show informed decision making for identifying development targets for SAT regions and commodities	Effective supply and demand projections for SAT mandate crops and associated livestock based on more scientific information have led to more informed research resource allocation and research priority setting by commodities and regions.
Target 2009: Other kinds of knowledge	1.4.1 Regional/global economic outlook (supply, demand, trade, prices) report of ICRISAT legume crops			
Target 2011: Other kinds of knowledge	1.4.1 Regional outlook (supply, demand, trade, prices) reports of ICRISAT mandate crops			standards for the benefit of small scale farmers

	Outputs	Intended Users	Outcome	Impact
Output 5	**Investment and policy options for increasing agricultural productivity and mitigating climatic related shocks identified and shared with key stakeholders.**	Research partners, policy makers, NARES and SAT farmers	Research partners and policy makers take better informed, innovative, science-based, decisions on alternative investment opportunities for improving agricultural productivity, incomes and employment and sustainability in the semi-arid regions	NARES demonstrate much enhanced research efficiency
Target 2009: Practices	1.5.1 Three Development domains report for southern Africa			
Target 2010: Policy strategies	1.5.1 Policy options for increasing agricultural productivity to mitigate HIV susceptibility			
Target 2010: Policy strategies	1.5.2 Constraints, challenges and opportunities for regional cooperation in R and D and alternative regional research and development strategies in southern Africa report			
Target 2011: Policy strategies	1.5.1 Adaptation strategies and layers of resilience to climatic related shocks in Asia documented			
Output 6	**Strategies for increasing competitiveness through identifying preferred market traits and introducing quality control systems to meet social,**	Policy makers, farmer organizations, traders, small-scale producers, agro-enterprises, market agents, processor and the private sector.	Farmer organizations and policy makers and planners take innovative and scientifically-informed decisions and implement policies that enhance the	The marketing industry harmonized at a regional level contributes greatly to the transformation of agricultural performance in SAT countries. Improved

	Outputs	Intended Users	Outcome	Impact
	food safety and environmental standards for dryland crops established and promoted		competitiveness, product quality and profitability of farmers, agro-enterprises, market agents and processors and facilitate enhanced national, intra-regional and global trade	competitiveness of agricultural produce from SAT countries in the global market.
Target 2009: Materials	1.6.1 Preferred market traits identified for selected tradable legumes in three regions -- ESA, WCA and Asia			
Target 2010: Policy strategies	1.6.1 Preferred market traits identified for livestock (in southern Africa) and dryland cereals in WCA region			
Target 2011: Policy strategies	1.6.1 Three Policy options for establishing quality-based agricultural marketing systems for selected legumes, livestock and cereals identified and communicated to policy makers and partners			
Output 7	**Institutional innovations for reducing transaction costs and improving coordination in input and output market chains for dryland commodities in domestic and international markets identified and promoted**	NARES partners, traders, processors, market agents, small-scale crop and livestock producers	Partners show informed decision making for SAT regions and commodities and assist small-scale producers of both crops and livestock to demonstrate enhanced technical know-how, reduced-risk production strategies, institutional linkages, bargaining power; access to	The marketing industry harmonized at a regional level contributes greatly to the transformati on of agricultural performanc e in SAT countries. Improved competitiveness of agricultural produce from SAT countries in the global market

	Outputs	Intended Users	Outcome	Impact
			niche markets, reduced transaction costs and reduced market risk.	
Target 2009: Practices	1.7.1 Innovative arrangements for better coordination of production, access to inputs and services, and output marketing (for selected legumes in ESA and ruminants in ESA) along the value chain for reducing transaction costs identified and communicated			
Target 2010: Policy strategies	1.7.1 Policy recommendations for improving market access, linkages and coordination for selected commodities developed and shared with policy makers and partners			
Target 2011: Policy strategies	1.7.1 Synthesis of pilot market and institutional innovation studies in Asia using coalition approach completed			
Output 8	**Policies and strategies that enhance agricultural diversification into high value products (e.g., legumes, livestock, biofuels, vegetables, etc) to harness emerging demand opportunities and facilitate agribusiness enterprises developed and**	NARES partners, traders, processors, market agents, small-scale crop and livestock producers	Farmers adopt diversification options that enhance system productivity and profitability Partners show informed decision making and assist small-scale producers of both crops and livestock to demonstrate enhanced technical know-how, reduced-risk production strategies,	Agribusiness enterprises stimulated through high value products (e.g., legumes, livestock, biofuels, vegetables, etc); Emerging demand opportunities are met by smallholders

	Outputs	Intended Users	Outcome	Impact
	promoted		institutional linkages, bargaining power; access to niche markets, reduced transaction costs and reduced market risk	
Target 2009: Policy strategies	1.8.1 Research report on economic feasibility of diversification using legumes and livestock (ESA) completed			
Target 2011: Policy strategies	1.8.1 Research report on economic feasibility of diversification into high value products with emphasis on biofuels (ESA, Asia) and vegetables (WCA) completed			
Target 2012: Policy strategies	1.8.1 Policy options and recommendations for stimulating diversification of agro-enterprises into high value commodities defined and shared with policy makers and partners			
Output 9	**Alternative institutional innovations to strengthen rural institutions that facilitate and enhance adoption of technological and market innovations and policy recommendations developed and shared with partners.**	Policy makers, planners, extension and market agents and agencies for social protection.	Policy makers, planners, extension and market agents realize the potentials of alternative institutional options Means for mutual knowledge transfer between rural farmers and research centers (coalition approach)	Development has occurred within a context in which rural institutions are newly strong and functional in the SAT resulting in improved rural livelihoods. SAT farmers utilize alternative institutional options to foster production and markets for their produce

	Outputs	Intended Users	Outcome	Impact
Target 2011: Policy strategies	1.9.1 Policy report on the impact of rainfall insurance and recapitalization of cooperatives completed in India			
Output 10	**Livelihood, institutional and policy options for investment and risk management for SAT poor developed and promoted with associated capacity building for partners**	Researchers, policy makers, planners, extension and market agents and agencies for social protection	Advanced research institutes, universities and students are using the dataset for studying the long-term poverty dynamics. Policy makers and development planners are using these recommendations to out and upscale technology interventions. The rural households are seen using the prioritized investment options. Policy makers and development planners in SAT Africa and Asia sensitized and are using the recommendations. Financial institutions develop risk mitigating products	Testing and development of new economic theories in development economics using the dataset Better income and employment opportunities for the SAT poor Improvements in the returns on the investments for the poor in the SAT Households in the SAT benefited by the change in policies Less variations in the income streams for the SAT poor
Target 2009: Practices	1.10.1 Panel dataset on village and household economies in West Africa (2004-2006) fully documented			
Target 2009: Practices	1.10.2 Report on rural livelihoods in the context of relief programs in Zimbabwe			
Target 2010: Practices	1.10.1 Database and documentation of Changes in household			

	Outputs	Intended Users	Outcome	Impact
	economies on SAT Asia based on the VLS panel data from 1975-2007 completed; VLS webpage developed			
Target 2010: Practices	1.10.2 Report on rural livelihoods in West-Africa Completed			
Target 2010: Practices	1.10.3 Report on Research and development options for West- African SAT Agriculture completed			
Target 2010: Capacity	1.10.4 Uptake pathways of SAT technologies documented based on case studies and shared with national program partners in Asia			
Target 2011: Policy strategies	1.10.1 Policy brief on Investment options for the rural poor in West- African SAT published			
Target 2011: Policy strategies	1.10.2 Report on household economies in SAT Asia (2001-2009) completed			
Target 2011: Policy strategies	1.10.3 Analysis of alternate investment options and their trade-offs completed and accessible to rural poor in Asia			
Target 2011: Policy strategies	1.10.4 Policy package elements on risk management strategies			

	Outputs	Intended Users	Outcome	Impact
	for mitigating the impact of risks inherent in rainfed agriculture (under a Ph. D dissertation on social networks and technology innovations) developed and shared with partners in SAT			
Target 2012: Practices	2009-2012: 1.10.1 Gathering longitudinal data on households, individuals and fields in 42 selected villages in years 1-5 of the project			
Target 2012: Practices	2009-2012: 1.10.2 Assembly of secondary agricultural meso-level data into an integrated database updated, expanded in coverage, extended in geographic area and decentralized in level of aggregation			
Target 2012: Practices	2009-2012: 1.10.3 Capacity building for NARS scientists and regional scientists in the design and execution of household panel surveys, data processing technologies and time-series panel data analysis			
Target 2012: Practices	2011-2012: 1.11.1 Database and documentation of VLS baseline data for SAT India, East India and Bangladesh; VLS information portal developed			

ICRISAT-2: Sustaining biodiversity of sorghum, pearl millet, small millets, groundnut, pigeonpea and chickpea for current and future generations

Project Overview and Rationale

This research, through its active custodianship of a large proportion of the world's germplasm, is delivering IPGs annually as its responsibility to the world community has been defined by FAO to be "in perpetuity". ICRISAT claims that 100% of this project's activities are encapsulated within the CGIAR System Priorities. ICRISAT is involved with the System-wide Genetic Resources Program (SGRP) in developing policies and practices for managing, acquiring and making available genetic resources that are consistent with international agreements. Knowledge, technologies and information on genetic resources is shared with other partners for sustainable use of biodiversity.

The target ecoregion, the beneficiaries and end users
The project has a global responsibility within ICRISAT's MTP for effective conservation and utilization of the biodiversity of mandate SAT staple crops and small millets. The immediate beneficiaries of this research are the institute's own researchers, varied research and development partners: including NARS and private sector scientists involved in genetic resources conservation and crop improvement. The end users are farmers; village communities, and consumers benefiting from enhanced yields, nutritious diets and more secure annual incomes.

Is the center the primary or secondary research provider?
The center is a primary research provider in this project. It has been a major contributor to the Generation Challenge Program and is continuing to play this role. Amongst much other work, for example, in 2006 three thousand accessions of a chickpea composite collection were genotyped using SSR markers in collaboration with ICARDA.

Is it a catalyser, facilitator, enabler and/or advocate to influence the impact pathway and thus to ensure outcomes and impact
The germplasm conserved in the genebank is the primary source of basic germplasm for the scientists at ICRISAT and many NARS and private sector companies worldwide. ICRISAT also plays the role of enabler and facilitator – the international status of this collection is guaranteed by the in-trust agreement between FAO and ICRISAT. Our obligations to FAO and the International Treaty on Plant Genetic Resources for Food and Agriculture require that we set the highest standards for conservation of staple and under-utilized species and assist in the conservation of, and access to, the germplasm and provide related information to the global R and D community.

Comparative and complimentary advantage of the project activities
ICRISAT is well placed to organize information and legal germplasm exchanges between partners from different countries. It has excellent germplasm conservation facilities at Patancheru, India and improved infrastructure for managing the genetic resources at its regional genebanks. Also, ICRISAT has a comparative advantage of working on system-wide projects with other CG centers on genetic resources management and information sharing.

Playing a catalytic, facilitating, enabling or advocacy role complementary to the center's research role and their contribution to IPGs
Computerized documentation systems enable rapid dissemination of information to users as well as assist curators to manage collections more efficiently. ICRISAT has been an active participant in the System-wide Information Network on Genetic Resources (SINGER), and a participating member in the other regional networks and contributes to CG sponsored activities related to development and implementation of genetic resources exchange protocols. Thus, we ensure our knowledge is made freely available worldwide.

Impact Pathway

Newly acquired germplasm and germplasm with incomplete data are characterized and data is recorded on morpho-agronomic traits, facilitating greater use by researchers. Data is transferred to the SINGER database facilitating greater access by the global community. Evaluation of core and mini core collections of staple crops and finger millet for agronomic traits and various biotic and abiotic stresses to identify trait specific germplasm will result, we assume, in enhanced use of germplasm by the breeders to develop high yielding cultivars with a broad genetic base. Population structure and extent of linkage disequilibria are studied in the core/mini core and composite collections using SSR markers. Devising strategies e.g. association mapping for utilizing the existing allelic diversity in plant breeding programs and sharing this with partners is an important activity. A reference set for each crop would be selected, and conserved for future use in crop improvement by partner breeders. Molecular characterization of trait specific germplasm will help in identifying genetically diverse parents for use in mapping and in breeding programs to develop cultivars with a broad genetic base. The mini core and reference sets are shared with the global scientific community, particularly with the partners specified below and we offer capacity development where appropriate in all these areas especially for higher degree students in biotechnological issues to mitigate possible risk of under, or inappropriate, use. An Impact Pathway Problem Tree and Network Map were developed for this project and are shown in the 2008-2010 MTP document.

Alignment to CGIAR Priorities

The research proposed in this project is in accordance with System Priority 1A -- Specific goals 1 to 5 and Priority 1B -- Specific goals 1 to 3. In addition, the research activities will harmonize with the five new specific goals of the draft Priority 1A Framework Plan as below:

1. Policies and strategies are in place to enable collaborative action within a global system for the conservation and use of CGIAR crops

2. Plant genetic resources for food and agriculture, including endangered and potentially useful germplasm, are conserved and disseminated within the context of the global system

3. Diversity within priority global collections of crops and related wild species is assessed in order to add value and enhance use

4. Genetic and genomic stocks within and outside the CGIAR System for priority crops are assembled, developed conserved and distributed

5. Information systems are developed to enhance the accessibility and usefulness of genetic resources, and to promote the global system

Outputs Description

Changes from Previous MTP

The project structure for ICRISAT was re-worked newly in 2006 and has not changed in 2007 or 2008. The outputs have not changed. However, there has been change in the output targets as 2008 2.1.2 and 2008 2.1.3 cannot be fully achieved as the availability of new, unique germplasm proved to be more restricted than was originally envisaged. In addition, 2008 2.2.2 has been deferred by one year as capacity development is only possible once germplasm collections are finally assembled. Likewise, 2009 2.4.1 is deferred to 2011 but in compensation two additional intermediary output targets are declared to show that work is progressing satisfactorily in this specific area (2009 2.4.1 and 2010 2.4.3). We have also added 2011 2.2.1, 2.3.3, and 2.3.4. The output target 2009 2.4.1 is now 2.4.1 for 2011 and output target 2.4.4 for 2010 is now 2.4.3 for 2011.

Output target 2008 2.2.1 with less than 50% achievement has been retained for 2009 as 2.2.4.

Output target 2008 2.3.2 with more than 75% achievement has been retained for 2009 as 2.3.2.

Output target 2011 2.3.3 has been modified slightly, to reflect changes suggested during discussions with team members.

Output target 2010 2.4.4 changed to 2011 2.4.3.

Output 1: **Germplasm of staple crops assembled and conserved and germplasm characterized and documented for utilization and knowledge shared with partners**

Description:

Collection/assembly, conservation, characterization/evaluation and exchange of plant genetic resources (PGRs) is one of the main objectives of ICRISAT to ensure that germplasm accessions are accessible to researchers worldwide. Currently, the ICRISAT genebank holds 108,881 germplasm accessions of its mandate crops (sorghum, pearl millet, chickpea, pigeonpea and groundnut) representing contributions from 141 countries.

New germplasm will be assembled and characterized, evaluated for useful traits, and regenerated for conservation and distribution at Patancheru and three regional genebanks in Africa. Germplasm databases are updated for utilization.

Alignment to CGIAR Priorities : 1A: Promoting conservation and characterization of staple crops;

Output 2: **Germplasm of six small millets assembled and conserved germplasm characterized / evaluated and documented for utilization and knowledge shared with partners**

Description:

Besides germplasm of sorghum, pearl millet, chickpea, pigeonpea, and groundnut (staple crops), ICRISAT also conserves, characterizes, and promotes the utilization of six small millets (finger-, foxtail-, barnyard-, kodo-, little-, and proso- millet) that have regional and location-specific importance and are classified as under-utilized crops. ICRISAT genebank is holding 10,193 accessions (5,949 finger millet, 1,535 foxtail millet, 842 proso millet, 743 barnyard millet, 658 kodo millet, and 466 little millet) of these crops from 50 countries.

New germplasm is assembled and characterized, evaluated for useful traits, and regenerated for conservation and distribution at Patancheru and three regional genebanks in Africa. Germplasm databases are updated regularly for utilization.

Alignment to CGIAR Priorities : 1B: Promoting conservation and characterization of underutilized plant genetic resources;

Output 3: **Core, and mini-core collections and trait specific germplasm identified and evaluated and composite collections and reference sets developed and genotyped for utilization and new knowledge shared with partners**

Description:

Core and mini core collections
To enhance the utilization of large germplasm collections in crop improvement programs

diversity using phenotypic traits was studied in the entire collection (about 17, 000 accessions) and a core collection (10% of entire collection) consisting 1,956 accessions and representing chickpea diversity was developed at ICRISAT. The size of core collection was still unwieldy for convenient exploitation by the crop improvement scientists and to overcome, a mini core collection (10% of core, 1% of entire collection) consisting 211 accessions representing the diversity of collection was developed.

Composite collection and reference set

The composite collection of chickpea consisting 3,000 accessions was developed based on available phenotypic, characterization, evaluation, geographic origin, and taxonomic data under Generation Challenge Program (GCP). The composite collection included 2271 cultivated (including 1956 core collection accessions) and three wild genotypes from ICRISAT and 709 cultivated and 17 wild accessions from ICARDA representing the diversity of two global collections. The composite collection was molecularly profiled using 50 SSR markers in collaboration with ICARDA (ICRISAT 35 SSR, ICARDA 15 SSR) to discern the diversity and population structure. A reference set consisting 300 genetically most diverse accessions has been established.

Activities Exemplar

One of the 2012 Output Targets (2012 2.3.5 to 2.3.7) declared is “Mini core and reference sets of staple crops and small millets evaluated to identify trait specific germplasm”. This results in several activities which were reported, with internal milestones in the Center’s Archival Report for 2007 (available at http://www.icrisat.org/). Several other activities and milestones also contributing to this Output Target were reported elsewhere in the report.

The activities of Output target 2012 2.3.6:

- Evaluate mini-core and reference collections for resistance to important biotic stresses
- Evaluate mini-core and/or reference collections for important abiotic stresses
- Investigation of genetic diversity of chickpea and groundnut reference sets and assessing its relevance with drought avoidance root traits

2007 Milestones:

- Groundnut, pigeonpea and chickpea mini-core collections screened for salinity tolerance
- ^{13}C in chickpea analyzed at JIRCAS
- Trait specific germplasm of chickpea multiplied for distribution to partners on request

2008 Milestones:

- Mini-core and reference collections of chickpea germplasm evaluated for resistance to AB, BGM, wilt, collar rot and dry root rot under controlled environment and field conditions
- Chickpea mini-core salinity evaluation data analyzed

2009 Milestones:

- Chickpea reference set phenotyped for root traits in PVC cylinders (120cm height)
- Ten chickpea lines identified, which show consistent high water use efficiency (WUE) as well as high yield in two locations
- Chickpea reference set genotyped with 100 SSR markers
- Reference set of chickpea multiplied for distribution to partners on request

2010 Milestones:

- Reference sets of chickpea, pigeonpea, and groundnut evaluated for salinity tolerance
- Candidate gene diversity for mining drought tolerant alleles analysed in chickpea reference set (300 accessions)

2011-2012 Milestones:

- Diversity analyzed for molecular markers and markers associated with root traits identified

The reports for 2007 and 2008 internal milestones provide detailed information on the progress towards achieving this Output Target. Due to greatly reduced size and availability of large amount of diversity, the mini core collection of chickpea is becoming popular with national program scientists in identifying trait specific germplasm for use in their breeding

programs. The chickpea mini core was evaluated at ICRISAT Centre and by NARS partners at different locations in India, Japan, Canada, Mexico and Ukraine. These evaluations have resulted in identifying several trait specific germplasm for agronomic traits, resistant sources for important pests and diseases and drought and salinity. These results have been published in several refereed journal articles and in Archival Reports.

In collaboration with JIRCAS, a significant correlation between the water use efficiency (WUE) and DELTA^{13}C (leaf carbon discrimination) of chickpea has been showed, which means that the estimation of WUE by using DELTA13C technique is possible. Currently, DELTA13C analysis for chickpea mini core collection is on-going to evaluate the genetic diversity of WUE.

Using 50 SSR markers data on the composite collection, a reference set consisting of 300 genetically most diverse accessions using a simple matching distance matrix was selected. The reference set captured 1360 (78%) of the 1741 alleles detected in the composite collection, and possessed high gene diversity (0.540 to 0.999).

Evaluation of the reference set for resistance to pod borer, Helicoverpa armigera, using the detached leaf assay method suggested that there is considerable variation in the reference set for resistance/susceptibility. In 2008, we evaluated chickpea reference set/mini core collection at ICRISAT and NARS locations and identified accessions with specific adaptation under different conditions, late-sown, irrigated, and rainfed and trait-specific lines for early-maturity, higher seed yield, and large-seeded kabuli types.

Seed multiplication of chickpea reference set accessions and trait specific germplasm identified during these experiments is in progress.

Alignment to CGIAR Priorities : 1A: Promoting conservation and characterization of staple crops; 1B: Promoting conservation and characterization of underutilized plant genetic resources;

Output 4: **Genetic diversity and population structure of staple crops and small millets assessed and mapping populations, RILs developed and DNA extracts assembled, conserved and distributed and new knowledge shared with partners**

Description:

Genetic diversity and population structure of the staple crops and finger and foxtail millets assessed and data sets of composite collections genotyping made available globally. Development of genomic resources for SAT crops. Molecular genetic maps developed for legume crops. Broadening the genetic base of legumes through wide crosses. DNA extracts of mini core collections and/or reference sets of mandate crops and finger and foxtail millets conserved for utilization. Assemble RILs and mapping populations of staple crops for utilization. Agriculturally beneficial micro-organisms from diverse environments assembled, characterized and distributed for utilization.

Alignment to CGIAR Priorities : 1A: Promoting conservation and characterization of staple crops;

Impact Pathways by Output

Output 1: Germplasm of staple crops assembled and conserved and germplasm characterized and documented for utilization and knowledge shared with partners

Newly acquired germplasm of staple crops and germplasm with incomplete data are characterized and data is recorded on morpho-agronomic traits, facilitating greater use by

researchers. Databases are updated regularly and data transferred to the SINGER database to facilitate greater access by the global research community.

Output 2: Germplasm of six small millets assembled and conserved germplasm characterized / evaluated and documented for utilization and knowledge shared with partners

Newly acquired germplasm of six small millets and germplasm with incomplete data are characterized and data is recorded on morpho-agronomic traits, to facilitate greater use of germplasm by researchers. Databases are updated and data transferred to the SINGER database facilitating greater access by the global research community.

Output 3: Core, and mini-core collections and trait specific germplasm identified and evaluated and composite collections and reference sets developed and genotyped for utilization and new knowledge shared with partners

Evaluation of core and mini core collections of staple crops and finger millet for agronomic traits and various biotic and abiotic stresses to identify trait specific germplasm will result in enhanced use of germplasm by the breeders to develop high yielding cultivars with a broad genetic base. A reference set would be selected, and conserved for future use in crop improvement by breeders. Molecular characterization of trait specific germplasm will help in identifying genetically diverse parents for use in mapping and in breeding programs to develop cultivars with a broad genetic base. The mini core and reference sets are shared with the global scientific community. We offer capacity development where appropriate in all these areas especially for higher degree students. We expect that mini core and reference sets will enhance use of germplasm in crop improvement programs.

Output 4: Genetic diversity and population structure of staple crops and small millets assessed and mapping populations, RILs developed and DNA extracts assembled, conserved and distributed and new knowledge shared with partners

Population structure and extent of linkage disequilibria are studied in the mini core and reference sets using SSR markers. Devising strategies such as association mapping will enhance use of existing allelic diversity in plant breeding programs.

International Public Goods

- Safely conserved germplasm and DNA collections of ICRISAT mandate crops and small millets
- Knowledge base shared on characterization and evaluation of conserved germplasm
- Improved methods and practices for enhanced utilization of existing collections
- Improved facilities and operational procedures on managing collections
- Improved knowledge and techniques on germplasm access, manipulation and utilization for partners
- Sub sets of germplasm and improved methods for research and crop breeding to reduce risks to food security

Elaboration of Partners Roles

The principal partners in the project are: National Germplasm Repositories, SGRP Partners, NARS and State Departments for assembling unique germplasm and Parties to the Convention on Biological Diversity (CBD) and the International Treaty on Plant Genetic Resources for Food and Agriculture (IT- PGRFA), Bioversity International, Local governments in different countries, Collaborating NARS and Universities in collecting endangered germplasm. For preservation, safety duplication and knowledge dissemination of germplasm partners include ICARDA, the

partners in the SWEP - System-wide Genetic Resources Program (SGRP) SINGER and ICIS, the Generation CP and the Svalbard repository. Partners for multi-location evaluation of germplasm include collaborating NARS in Asia (India, China, Vietnam, Thailand, and Japan) and Africa (Kenya, Malawi) and universities for staple crops; and the MS Swaminathan Research Foundation (MSSRF) for small millets in India, Kenya, Tanzania, and Uganda. For genotyping and molecular characterization – Other CG centers (ICARDA, IRRI), Generation CP Partners (EMBRAPA, CAAS) Advanced Research Institutions (CIRAD), The Indian Department of Biotechnology and universities (TAMU, USA; University of Hohenheim) (see accompanying network diagram). Population structure and extent of linkage disequilibria are studied in the germplasm collection. Devising strategies e.g. association mapping for utilizing the existing allelic diversity in plant breeding programs is an important activity. Newly acquired germplasm and germplasm with incomplete data are characterized and data is recorded on morpho-agronomic traits, facilitating greater use by researchers. Data is transferred to the SINGER database facilitating greater access by the global community. Evaluation of chickpea, groundnut and pigeonpea core and/or mini-core collections for biotic and abiotic stresses and for agronomic traits is carried out to enable identification of trait specific diverse and agronomically superior germplasm for use in crop improvement by partner breeders. Core collection of pearl millet was augmented by including 501 accessions to represent diversity in the global collection. Core collections of sorghum, pearl millet and finger millet are being evaluated for morpho-agronomic traits, data is analyzed and representative mini core collections are developed for sharing with partner breeders. Composite collections of five mandate crops will be genotyped using micro- satellite markers. The diversity of the composite collections will be assessed and a representative reference set for each crop selected, and conserved for future use in crop improvement by partner breeders. Reference collections will be made available for research to the global scientific community, particularly to the partners specified below.

Key Strategic Alliances: Specifically with the SGRP for its long collaboration on conservation, the Generation CP partners by providing early access to germplasm, information and cutting edge biotechnological techniques and the Indian Department of Biotechnology for exploitation of germplasm through its network of associated research institutions and generous funding support.

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**Germplasm of staple crops assembled and conserved and germplasm characterized and documented for utilization and knowledge shared with partners**	SGRP, Other CG centers, Generation CP partners, Parties to CBD and IT, NARS, Crop Diversity Trust, Universities, ARIs and the Svalbard repository	i) Germplasm safely conserved for present and future use, and ii) Partners have the most up-to-date knowledge and secure access to the largest collection of well-characterized genetic diversity of five SAT staple crops in the world and use this internationally to improve the efficiency and effectiveness of their breeding programs.	Risks to food security in the SAT are strongly reduced as crop researchers have had access to diverse germplasm to develop improved broad genetic based cultivars; and ii) Biodiversity is sustained for current and future generations.
Target 2009: Other kinds of knowledge	2.1.1 Priority areas for sorghum/groundnut for collection and assembly determined in collaboration with NARS and with associated capacity development			
Target 2009: Other kinds of knowledge	2.1.2 Staple crops germplasm databases updated and uploaded to website for global use			
Target 2010: Materials	2.1.1 Germplasm of staple crops assembled and conserved for utilization at regional genebanks in Africa (Bulawayo, Nairobi and			

	Outputs	Intended Users	Outcome	Impact
	Niamey)			
Target 2010: Materials	2.1.2 85% of germplasm characterized and documented for utilization			
Target 2011: Materials	2.1.1 Germplasm of staple crops regenerated (2000 accessions) for conservation and distribution			
Output 2	**Germplasm of six small millets assembled and conserved germplasm characterized/evaluated and documented for utilization and knowledge shared with partners**	Parties to CBD and IT, Crop Diversity Trust, SGRP, Bioversity International, Generation CP partners, NARS, Universities, ARIs and the Svalbard Repository	i) Germplasm safely conserved for present and future use, ii) Partners have the most up-to-date knowledge and secure access to the largest collection of well-characterized genetic diversity of six small millet crops of SAT in the world and use this internationally to improve the efficiency and effectiveness of their breeding programs, and iii) Small millets germplasm with desirable traits including high grain quality known.	i) Risks to food security in the SAT are strongly reduced as crop researchers have had access to diverse germplasm to develop improved broad genetic based cultivars, and ii) Biodiversity of six small millets is sustained for current and future generations
Target 2009: Materials	2.2.1 Gaps in finger millet collection identified and potentially filled in at least two countries in ESA			
Target 2009: Other kinds of knowledge	2.2.2 Germplasm databases of			

	Outputs	Intended Users	Outcome	Impact
	small millets updated			
Target 2009: Other kinds of knowledge	2.2.3 Priority areas identified for foxtail, little, kodo, proso and barnyard millet for collection/assembly in collaboration with NARS			
Target 2009: Other kinds of knowledge	2.2.4 Passport, characterization and evaluation data of small millets germplasm documented (less than 50% achieved during 2008)			
Target 2010: Other kinds of knowledge	2.2.1 Databases of small millets germplasm updated for utilization			
Target 2010: Materials	2.2.2 Germplasm of six small millets assembled and conserved with 50% of germplasm characterized/ evaluated for desirable traits and documented for utilization			
Target 2011: Materials	2.2.1 Germplasm of small millets supplied on request			

	Outputs	Intended Users	Outcome	Impact
Output 3	**Core, and mini-core collections and trait specific germplasm identified and evaluated and composite collections and reference sets developed and genotyped for utilization and new knowledge shared with partners**	Other CG centers, Generation CP Partners, ARIs, NARS and Universities	i) Partners have the most up-to-date knowledge on diversity of germplasm available in core and mini core collections, trait-specific germplasm and representative reference sets and use this to improve the efficiency of their breeding programs	i) Precision of germplasm evaluation has been enhanced. ii) Risks to food security in the SAT have been strongly reduced by robust, informed, efficient trait-based breeding programs
Target 2009: Materials	2.3.1 Mini-core collection of pigeonpea germplasm evaluated for resistance to wilt and sterility mosaic diseases under controlled environment and field conditions			
Target 2009: Materials	2.3.2 Mini core collections of chickpea, groundnut, and pigeonpea evaluated in multilocations in Asia (greater than 75% achieved during 2008)			
Target 2010: Practices	2.3.1 New reference sets of			

	Outputs	Intended Users	Outcome	Impact
	chickpea, groundnut, pigeonpea and sorghum germplasm (300 accessions each) established and evaluated for utilization			
Target 2011: Materials	2.3.1 Foxtail millet core collection evaluated for resistance to blast			
Target 2011: Practices	2.3.2 Diversity analyzed for molecular markers and markers associated with drought related (root traits) in chickpea identified			
Target 2011: Materials	2.3.3 Pearl millet mini core collection evaluated for resistance to downy mildew			
Target 2011: Materials	2.3.4 Sorghum mini core or reference set screened for root traits			
Output 4	**Genetic diversity and population structure of staple crops and small millets assessed and mapping populations, RILs developed and DNA extracts assembled, conserved and distributed and new knowledge shared with partners**	Other CG centers, GCP Partners, NARS, Universities and ARIs	Partners use the most up-to-date knowledge on available genetic diversity, population structure, mapping populations and reference sets of staple and small millet crops to improve the efficiency and effectiveness of their breeding programs	Enhancement of breeding efficiencies after assessing and exploiting allelic diversity, maintenance of usable germplasm, and use of mapping populations, mini core collection and reference sets has resulted in an enhancement of the productivity and quality of

	Outputs	Intended Users	Outcome	Impact
				ICRISAT mandate crops in the SAT
Target 2009: Practices	2.4.1 Genetic diversity and population structure of finger millet composite collection assessed and reference set (300 accessions) established			
Target 2010: Materials	2.4.1 DNA extracts of chickpea and groundnut mini-core collections of germplasm conserved for utilization			
Target 2010: Other kinds of knowledge	2.4.2 Datasets for groundnut and pigeonpea, composite collections genotyping made available globally via the internet			
Target 2010: Practices	2.4.3 Genetic diversity and population structure of foxtail millet composite collection assessed and reference set (200 accessions) established			
Target 2011: Other kinds of knowledge	2.4.1 Data sets of composite collections of finger millet and foxtail millet genotyping made available globally via the internet			
Target 2011: Practices	2.4.2 Molecular genetic maps and consensus maps based on SSRs,			

	Outputs	Intended Users	Outcome	Impact
	DArTs and EST-based markers developed for chickpea, pigeonpea and groundnut			
Target 2011: Materials	2.4.3 Agriculturally beneficial micro-organisms assembled for utilization with associated capacity development			

ICRISAT-3: Producing more and better food from the staple cereals and legumes of the west and central African (WCA) SAT (sorghum, pearl millet and groundnut) through genetic improvement

Project Overview and Rationale

ICRISAT sees its research as a positive contribution which its research is making to the MDGs in a region where food and nutritional security is regularly threatened. The research from this project is regionally oriented towards the large number of Sahelian countries from Senegal to Chad and owing to the consistency of environments across a broad swathe of west Africa the results from this project are used widely as IPGs and there is the strong likelihood of future spillover from this research from Sahelian country to Sahelian country and into comparable environments in Sudan, Ethiopia and the Horn of Africa.

The target ecoregion, the beneficiaries and end users
The target ecoregion is the semi-arid tropics of west and central Africa, specifically the Sahelian, Sudanian and northern Guinea savannah zones of agricultural production. The immediate beneficiaries of this research are our varied research and development partners from the NARES, the NGO and CBO communities and professional farmer organizations. We are also trying to assist the few private sector seed enterprises, as well the input suppliers in general. The end users are village communities benefiting from more secure and nutritious staple food production and more secure annual incomes, as well as more and better quality crop residues for increased animal production.

Is the center the primary or secondary research provider?
The Center in this project is often the primary research provider especially in the area of hybrid cereals but can also adopt a secondary role especially when farmer participatory breeding and seed systems development is employed as a research mechanism. However funding of most NARS has been decreasing, thus numbers of staff have been leaving, and only few national breeding programs remain fully operational in WCA. Higher degree student support is one way in which ICRISAT is trying to redress this problem.

Is it a catalyser, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact
ICRISAT, in this project under System Priority 2 plays multiple roles. It has recently re-oriented its cereal improvement research to focus on photoperiod-specific agro-ecological zones with the key issue being the need to develop photoperiod sensitivity in varieties so that they are specifically adapted to specific rainfall zones in the WCA SAT. Some other examples for such regionally zone specific problems are the abundant presence of the parasitic weed Striga, or low levels of soil phosphorus availability in the drier Sahelian/ Northern Sudanian zones. Thus collaboration with NARES which share similar agro-ecozones is natural and efficient and enables progress from joint selection, which no partner alone could achieve, under the present conditions of resource availability and scientific research capacity. Farmers of the WCA-SAT are increasingly organizing themselves into associations for increased economic benefits, enhanced political representation, and for improving information exchange. ICRISAT has diversified is research by adding nutrition issues to its agricultural production agenda in his project. In this case ICRISAT's role is a catalyser for new partnerships, as well as addressing new goals for interdisciplinary research. ICRISAT will thus play both catalytic and facilitating roles amongst these very different partners as appropriate.

Comparative and complementary advantage of the project activities
ICRISAT plays a leading role in the West and Central African region for the genetic enhancement of pearl millet, sorghum and groundnut. One key advantage of ICRISAT's regional approach in WCA is the capacity to undertake priority setting and implementation of research and technology development on an agro-ecological basis by targeting the

predominant production systems that cut across the entire West-and Central African region. ICRISAT plays a key role in fostering regional collaboration to achieve the critical mass required for effectively addressing specific production zone research issues that exceed the capacity of individual NARS, as well as ICRISAT. The ICRISAT team in WCA is well placed to organize information and legal germplasm exchanges between partners from different countries. ICRISAT's pro-poor stance is also highly valued for its work on participatory approaches to plant breeding, enabling ICRISAT and their partners to address priority needs and specific pro-poor opportunities for genetic enhancement.

Playing a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs
ICRISAT will play research, catalytic, facilitating and enabling roles amongst a wide range of very diverse partners as appropriate. A key initiative with new dimensions is the West African Seed Alliance which focuses on a) regional harmonization of laws and regulation for seed trade in WCA, as well as direct and indirect support to the private sector involved in the delivery of agricultural inputs in the large sense. These roles are necessary to ensure that public goods can be created and scaled up to fully international public goods. It should be recognized that there is little incentive for NARS partners at a local or national level to either consider the regional or international implications arising from research projects. Nor are they willing necessarily to share their knowledge outputs were ICRISAT not playing this role and ensuring that such knowledge reaches the public domain in easily accessible form.

Alignment to CGIAR Priorities

The research proposed in this project is in accordance with System Priority 2 A (yield) with both its specific goals 1 and 2, priority 2B (selected abiotic stress: drought) and priority 2C (nutritional quality and safety). This project will also address tangentially Priority area 3B as for all three crops the crop residues are an economically important component, primarily used for animal production. ICRISAT claims that 100% of this projects activities are encapsulated within the CGIAR System Priorities. It is in accordance with the Framework Plans of Priority 2B and 2C and in particular will address increased use of genetic resources, will use marker assisted selection and will use a more holistic modeling approach (see also Project 9) at a landscape level to try to overcome the challenges of unpredictable and severe drought (see the related projects 5 and 6 Alignment Sections for a fuller analysis). In particular for Biofortification and Biodetoxification issues it will address issues highlighted in the 2C framework plan as follows:

- Develop and provide access to new nutritious staple foods that are proven efficacious and meet the supply and demand needs of poor farmers who supply food to a growing population of hungry
- Expand understanding of micronutrient malnutrition and the chronically hungry, where they live, what they eat, and how biofortified crops can best be used to improve micronutrient status
- Increase substantially the body of knowledge on how staple foods and their components affect population micronutrient status
- Contribute or adapt new methods, protocols, equipment and related technologies to global agriculture and nutrition research in the developed and developing world
- Strengthen national research systems in agriculture and health in the developing world to support the development of nutritious biofortified crops in response to targeted needs

Outputs Description

Changes from Previous MTP

From the previous MTP only minor changes where made, to more precisely target outputs for the coming 2-3 years. Output 3.4 was reworded so as to include all work on seed system development and understanding ongoing in West-Africa, not only that of the West African Seed Alliance.

Farmers and consumers in the semi-arid tropics of West and Central Africa, depending on sorghum and pearl millet as their staples and groundnut for a range of purposes, face a number of basic issues that limit production, productivity increases, food security as well as nutrition and health.

1. Increasing demands on the natural resource base: A number of abiotic, biotic and socio-economic constraints limits pearl millet, sorghum and groundnut production and marketing in WCA.

2. Increasing intensification of sorghum production systems: Sorghum, and to a lesser extent pearl millet production systems are intensifying. Sorghum begins to benefit from inputs such as fertilizers, either as residuals from cash crops such as cotton or with direct application. Farmers are also increasingly harvesting stover for controlled feeding of livestock.However the increase of fertilizer prices, and the difficulties in the cotton sector have reduced fertilizers availability, as well accessibility severely over the last two seasons.

3. SAT the home of the poor -- Food security, nutritional and health status remain low: High child mortality, low life expectancy and poor women's health are distressingly common issues throughout the region. Farming in WCA is primarily labor limited and thus the poor health status of the potential workforce seriously compromises agricultural productivity.

4. Emerging markets for cereal grain: Increasingly sorghum and pearl millet grain are important as an income source as well as for food sufficiency, while groundnut is a key source of income, primarily for women farmers. Poor infrastructure, institutional framework, price variability, and farmer cash flow problems however represent significant challenges. Farmer organizations are undertaking collective marketing of grain and seeing increased opportunities for animal and poultry feed (These issues are linked to research in Project 1).

Overall, it must be noted that there is a strong need for integrated solutions towards production intensification and marketing, focusing on the opportunities and constraints of specific agro-ecological regions and farming systems. The strategy to increase groundnut, pearl millet and sorghum production and marketing in WCA is based on integrated genetic and natural resource management (IGNRM). Breeders and geneticists cooperate with systems agronomists, animal scientists and socio-economists to develop sustainable, integrated solutions and to profit from positive genotype x management interactions.

The pearl millet breeding research as a component of the IGNRM approach will focus on the Sahelian and northern Sudanian zones, sorghum improvement research focuses on the Sudanian and to a lesser extent on the northern Guinea savannah zones. Groundnut improvement is focusing on areas with sandy soils in both the Sahelian and Sudanian zones. The research will pursue the following four focal areas of research that encompass many of the ongoing and emerging activities largely in accordance with the System priorities.

- Exploitation of heterotic relationships between different germplasm pools of sorghum and pearl millet
- Development of tools and methodologies for effective implementation of genetic enhancement research within an INGRM approach across the region
- Addressing specific nutrition and health concerns through targeted crop improvement

- Supporting regional, national and local efforts at improving the availability of quality preferred seeds to farmers in West-Africa

Output 3.1 - Changes in this MTP are the inclusion of two output targets for 2011, one for making sorghum hbrids available to partners, and the other on on pearl millet hybrid parents, specifically creating the first seed parents based entirely on West-African germplasm.

Output 3.2 - The output target focusing on sorghum lines and varieties with specific values added now includes activities on sweet sorghum variety and hybrid testing, as well as product development . Five outputs were added for 2011, for enhacing grounut breeding populations for multiple traits, including drought tolerance completing one cycle of recurrent selection in one broad based sorghum population, the identification of two downy mildew resistant pearl millet varieties, refining variety adaptation maps for sorghm and pearl millet, and improving the understanding of sorghum and pearl millet insect pests.

Output 3.3 - The output target on early adoption of crop management practices that help to reduce groudnut contamination with aflatoxin was rescheduled for 2009. New output targets for 2011 added include the assessment the groundnut mini-core collection for tolerance to Aspergillus flavus and afltoxin contamination, the identification of new groundnut varieties resistant to aflatoxin contamination, as well as the identification of sorghum and pearl millet varieties with increased iron and zinc contents, and improved bioavailability.

Output 3.4 - With the somewhat broadend scope of the output we included an additional output target, which brings together the various projects, and activities on seed system assessments as well as monitoring and evaluation of seed dissemination efforts by ICRISAT and its partners.

Output 1: **Heterotic relationships identified within sorghum and pearl millet germplasm adapted to WCA conditions and appropriate broad-based breeding populations and hybrid parents and knowledge made available to NARS and other partners in order to maximise genetic gain from selection**

Description:

Priority 2A, Specific goal 1: Enhance capacity and efficiency of genetic improvement programs through approaches linking characterization and use

Priority 2A, Specific goal 2: Identification of pro-poor traits

Identification of heterotic pools among locally adapted, nutrient-efficient, photoperiod-sensitive genetic materials of sorghum and pearl millet landraces and available improved materials is the main target of this research. It is expected that the use of genetically distinct heterotic pools in both population and hybrid breeding will enhance heterozygosity and therefore hybrid vigour in the new cultivars. This in turn is expected to result in higher yield and stability due to enhanced individual buffering. The heterotic grouping comprises a detailed phenotypic and genotypic (using molecular markers) characterization of pearl millet and sorghum genetic resources and breeding materials from all over WCA and combining ability studies of selected, genetically diverse materials.

The research looks towards two 2011 output targets of: 2011 3.1.1 Six new sorghum hybrids for at least 2 countries in West Africa identified, release relevant information as well as parental seed made available to partners; and 2011: 3.1.2 Five pearl millet inbred lines, and 2 populations with high general combining ability backcrossed into male-sterility inducing A4 cytoplasm.

Alignment to CGIAR Priorities : 2A: Maintaining and enhancing yields and yield potential of food staples;

Output 2: **Improved methodologies developed for integrating breeding of groundnut, sorghum and pearl millet populations and varieties with crop management strategies to overcome key environmental and socio-economic constraints and making them available with new knowledge to partners**

Description:

The development and initial implementation of a regionally coordinated strategy for population improvement and participatory variety selection for groundnut, pearl millet and sorghum will be based on improved understanding of the specific requirements for crop adaptation to specific production systems. Regional integration is expected to enhance breeding efficiency, since the target countries share the similar agro-ecological zones.

Environmental characterization, GIS-based adaptation mapping (modelling of genotype x environment interactions) and development of a mega-environment concept will be a key activity of this project. The advantages of such regional targeting are:

- The use of spill-over effects by transferring gain from selection made at one site to other target sites that belong to the same mega-environment
- Information for choosing, artificially creating and weighting of selection environments for improvements of selection efficiency
- The development of maps and eventually a handbook of varietal adaptation for sorghum, pearl millet and groundnut varieties in WCA

Given the highly variable beginning of the rainy season, photoperiod sensitivity is a key adaptation trait for both sorghum and pearl millet in WCA, as it assures flowering at the more predictable end of the rainy season, independent of the highly variable date of planting. Improving our understanding of the physiology of photoperiodicity in West-African sorghum and pearl millet will help to identify tools for improving selection efficiency for combining zone-appropriate photoperiod response with higher yielding ability, specifically an increased sink size. Development of allele-specific markers for photoperiodic sensitivity of flowering time of pearl millet and sorghum will be one approach we shall pursue.

Similarly we will be testing the efficiency of dynamic genepool management for linking in-situ conservation of pearl millet and sorghum genetic resources with the development of pearl millet and sorghum populations and open-pollinated varieties with specific adaptation to predominant production constraints. In this approach, sub-samples of adapted, but highly diversified populations are grown in contrasting sites within each adaptation zone. Natural, farmer and breeders selection for specific adaptation will act on the subpopulations. One focal point will be adaptation to poor soil fertility. In addition, each sub-population is also a potential cultivar and source of variation for specific characters or adaptation traits.

Groundnut breeding will maintain its focus on combining multiple disease resistances into cultivars with a range of flowering dates. In addition the groundnut team has started to put into place a systematic effort to improve drought tolerance screening.

The output targets for 2011 are:

2011 3.2.1: At least two new breeding populations of groundnut with enhanced multiple attributes available for testing and selection by NARS

2011 3.2.2: Improved cycle of at least one sorghum broadbased population produced by random-mating superior progenies

2011 3.2.3: At least 2 downy mildew resistant open pollinated varieties of pearl millet made available to partners with release relevant information

2011 3.2.4: Refined adaptation maps for at least 10 sorghum and pearl millet varieties available for use by partners

2011 3.2.5: Understanding of dry land cereal pest dynamics enhanced for at least two priority species across WCA, and used in adaptive IGNRM research targeting at least two countries

Alignment to CGIAR Priorities : 2A: Maintaining and enhancing yields and yield potential of food staples;

Output 3: **Crop management, Aspergillus flavus resistant groundnut varieties and post-harvest technologies to reduce aflatoxin contamination in food and feed products, as well as micronutrient rich cereal varieties and processing techniques to improve bio-availability developed, tested and made available to partners with new knowledge in the SAT of WCA**

Description:

Priority 2C, specific goal 1: Increase the content of micronutrients in the edible parts of crop plants through improved biotechnologies and breeding

Priority 2C, specific goal 2: Evaluation of bio-fortification strategies and introduction of the best means to enhance the diets of nutritionally disadvantaged populations in developing countries

Priority 2C, specific goal 3: To reduce the content of constitutive or microbial toxins in selected staples that affect quality, food safety and human health

Many West-and Central African countries, especially the land-locked ones rank among the lowest in the Human Development Index. Sorghum and pearl millet provide the main staple foods for over 100 million people living in this region. These crops are an important source of micronutrients in this region, providing one third to one half of Fe needs/person/day. Malnutrition remains a serious problem. An additional dietary challenge of growing concern is the widespread presence of mycotoxins in a wide variety of foods. Aspergillus flavus that produces aflatoxin in groundnut is widely distributed in nature. Therefore, aflatoxin contamination in staple diets is another major cause for malnutrition and can directly and indirectly affect food security, health and livelihoods of people in WCA. ICRISAT focuses its research on developing technologies to improve nutrient and vitamin uptake and providing safety measures to decrease risk of food and feed contamination by aflatoxins. This can be achieved through an Integrated Genetic and Natural Resource Management (IGNRM) approach by developing vitamin (betacarotene) and micronutrient (iron and zinc) rich, aflatoxin tolerant cultivars, and implementing appropriate pre- and post-harvest technologies that reduce the risk of aflatoxin contamination in food/feed, and increase the bioavailability of key minerals and vitamins. Research addressing these particular specific goals is summarized through three output targets for 2011 namely:

2011 3.3.1: 2-3 farmer-and market preferred groundnut varieties tolerant to aflatoxin contamination identified for dissemination by at least two NARS in WCA

2011 3.3.2: Mini-core Groundnut collection phenotyped for tolerance to A. flavus and aflatoxin contamination

2011 3.3.3: Two sorghum and pearl millet varieties with increased iron and zinc content, and low content of anti-nutritional factors available for cultivation in at least two countries in WCA

Alignment to CGIAR Priorities : 2C: Enhancing nutritional quality and safety;

Output 4: **High quality seed of adapted, released varieties of sorghum, pearl millet and groundnut accessible and affordable to small scale farmers in a timely manner through networks of agro-input dealers, seed entrepreneurs and breeders, both public and private by focusing on sustainable breeder and foundation seed production and creating an enabling agricultural environment for regional seed trade in West Africa**

Description:

Priority 2A, Specific goal 1: Enhance capacity and efficiency of genetic improvement programs through support to production and storage of breeder seed

Priority 5B: Making international , domestic and local seed markets work for the poor
Specific goal 2: Improve the marketing environment for smallholders by improving the efficiency of domestic markets

Priority 5C: Rural institutions and their governance
Specific goal 2: Identify new forms of partnership with NARS, the private sector, public extension agencies, NGOs and producers organizations, and public agencies from other sectors, such as environment and health to enhance the conduct and impact from agricultural research

The research on seed system development is focused on improving the speed and spread of impacts that can be expected from the other research conducted in this project. Research will focus on the following key issues:

1. Improved understanding of seed dissemination pathways of new varieties under different scenarios, e.g. in areas where participatory variety selection has been conducted, in areas, where farmers rarely access seeds from outside sources, in areas, where markets are an important source of seeds for small scale farmers, etc.
2. Strengthening the capacity of seed entrepreneurs to identify appropriate varieties for commercialization, and to produce or contract and market seed successfully
3. Strengthen the capacity of public sector breeders to enhance availability of breeders' seed of preferred varieties
4. Facilitate the development of harmonized seed trade and quality control regulation across West Africa

ICRISAT has developed several of partnerships for seed system development that cover a wide range of approaches, target zones, types of varieties and institutional environments and target groups of farmers. ICRISAT scientists are part of collaborative arrangements between farmer organizations, development NGO's and national researchers focusing on seed issues, such as the McKnight Foundation West –African community of practice, or the legumes seeds groups formed by the Tropical legumes 2 project.

ICRISAT is also the founding member of the West Africa Seed Alliance (WASA) which facilitates access by commercial seed companies, farmer associations, cooperatives and other interested parties to improved seed developed through public or private research investments. WASA provides technical advice on seed production, seed business development services, and facilitates access to seed processing and storage technology. It focuses on increasing the demand for high-quality foundation and certified seed of farmer preferred varieties. Wasa also

supports the development of an agro-dealer network for general input supply, output marketing and information dissemination to ensure that farmers have reliable, timely access to affordable high-quality seeds and complementary inputs and information through commercial channels.

The team will focus efforts on harmonizing seed legislation, variety release procedures, seed certification and seed import export procedures manuals to facilitate regional seed trade. This policy dialogue involves policy makers from ECOWAS, UEOMA, and CILSS member countries. This will be complemented by research efforts to map variety adaptation zones, as a tool to facilitate varietal choice for seed producers, dealers, as well as farmers. The two output targets for 2011 are namely:

2011 3.4.1: Enhanced availability of foundation seed to satisfy requests from certified seed producers, especially with linkages to product markets in Ghana, Mali, Niger and Nigeria

2011: 3.4.2 Seed dissemination channels assessed in at least one country in WCA

Alignment to CGIAR Priorities : 2A: Maintaining and enhancing yields and yield potential of food staples;

Impact Pathways by Output

Output 1: Heterotic relationships identified within sorghum and pearl millet germplasm adapted to WCA conditions and appropriate broad-based breeding populations and hybrid parents and knowledge made available to NARS and other partners in order to maximise genetic gain from selection

The key to achieving anticipated impact from the output from the identification of heterotic groupings for more efficient hybrid development in WCA is close collaboration with, and thus strengthening the capacity of, NARS researchers to identify superior hybrids and releasing them. Seed production techniques for these photosensitive materials will also be jointly developed with NARS scientists, and interested private sector investors, including farmer managed seed cooperatives and enterprises. We expect that the release of superior hybrids will increase private investment in the seed sector in key sorghum growing countries in West and Central Africa. Farmers will benefit from the purchase of these seeds with higher grain yields, and with higher incomes as a surplus over household needs is more likely to be produced. We assume that cereal prices in WCA will actually become less volatile in the near future, due to rises in world market prices for coarse cereals, as well as due to increasing demand in regional markets, and lastly due to increasing demand specifically for food processing for specific uses in specific countries. We further assume that socio-economics research collaboration with development projects to improve farmers negotiating powers through enhanced group/cooperative marketing skills will also be successful, so that farmers will able to generate income from surplus cereal production. Capacity development is provided to help ensure such assumptions are realized.

All the outputs target new knowledge sharing. In all cases the impact will only be possible if this knowledge is understood and applied by relevant partners, especially the NARS, NGOs, development personnel and Farmer Organizations. We thus place particular importance on ensuring that knowledge is created jointly, and owned by all our key partners, who contribute to its creation and testing.

Output 2: Improved methodologies developed for integrating breeding of groundnut, sorghum and pearl millet populations and varieties with crop management strategies to overcome key environmental and socio-economic constraints and making them available with new knowledge to partners

For output 2 we envisage that the impact pathway for groundnut varieties and open pollinated varieties of sorghum is similar, except that the involvement of the private sector in seed production and dissemination will not be the same. Seed diffusion will also be possible through organized farmer group efforts, through targeted NGO or development projects, or through the local seed systems per se, however at a slower rate. For millet this is unlikely to be successful, unless a serious and continuous investment is made into production of pure seed stocks, due to the outcrossing nature of pearl millet.

The speed and rate of impact will depend on innovations in the seed systems that farmers can use (see output 3.4). Progress from selection depends on successful multi-location trails. Thus, the partnerships with NARS working in the same agro-ecology, as well as with farmer organizations interested in testing varieties are necessary. We further assume that the research stations remain managed in a manner that allows quality trials to be conducted. Capacity development on breeding techniques etc. are provided where appropriate. An unpredictable risk could come from serious droughts, or atypical invasions of insects, like locusts. We expect that our work on tools and methods for breeding new varieties will have similar pathways to impact.

Impact on improved yields, and increased resilience, for poor farming households will also come from involvement in Farmer Field Schools geared towards experiential learning about Striga management, and improved marketing skills. We expect that farmers will be able to use the FFS results to increase productivity in their fields, and improve their capacity for group marketing. We expect that NGO partners and collaboration with large development projects will facilitate large scale impacts.

All the outputs have important components of sharing new . Impact will only be possible if this knowledge is used by relevant partners, especially the NARS, NGOs, development personnel and Farmer Organizations. We thus place particular importance on ensuring that knowledge is created jointly, and owned by all our key partners, who contribute to its creation and testing.

This principle of shared ownership also applies to the new germplasm, varieties or hybrids, whenever possible. However the key impact pathway for new seeds needs to be a commercial seed system but this is very far from being established in all West-Africa countries, except Nigeria. This project thus collaborates closely with Project 1 to identify policy and market changes that could facilitate private investments in seed supply, as well as low cost options for enhancing the traditional seed system with respect to its capacity to access and disseminate new germplasm.

Output 3: Crop management, Aspergillus flavus resistant groundnut varieties and post-harvest technologies to reduce aflatoxin contamination in food and feed products, as well as micronutrient rich cereal varieties and processing techniques to improve bio-availability developed, tested and made available to partners with new knowledge in the SAT of WCA

The nutrition impacts expected from Output 3, both reduced aflatoxin contamination, as well as increased iron and zinc status will be achieved in part through adoption of more appropriate varieties, and thus follow the pattern for impact described under output 3.2. However, the new varieties alone will probably not achieve this impact. Farmers, specifically women farmers will have to also learn about the advantages of these varieties in human, and especially in children's consumption. In addition the women will have to learn about improved crop management techniques (post-harvest treatments for groundnuts) or specific processing techniques to improve the bioavailability of existing micronutrients. To achieve these impacts collaboration with development partners is essential. For the micronutrient work the partners have to have the capacity to successfully address child nutrition issues. We expect that the use of local radios will be very supportive in generating impact from bio-fortification, and introducing new techniques to reduce aflatoxin contamination.

For achieving the desired impact from the work on aflatoxin contamination it will also be necessary to : (1) improve scientists' understanding of household perception of Aflatoxin

contamination, (2) to facilitate appropriate policies that provide incentives to consume and trade aflatoxin free products. This entails broad collaboration among NARS, networks, NGOs, CG centers, and ARIs. The impact of technologies will depend on using the right approach for sharing the knowledge generated. Appropriate knowledge sharing tools/mechanisms such as ICT, media, TV, radio, meetings, workshops, advisory and expert panels, farmer to farmer exchange of information and technologies will be used. Training of scientists, technicians, farmers and NGOs will help in up-scaling technologies.

Output 4: High quality seed of adapted, released varieties of sorghum, pearl millet and groundnut accessible and affordable to small scale farmers in a timely manner through networks of agro-input dealers, seed entrepreneurs and breeders, both public and private by focusing on sustainable breeder and foundation seed production and creating an enabling agricultural environment for regional seed trade in West Africa

The impact pathway expected for output 4 targets the functioning of the private sector for improving input availability, as well enhancing other forms of interaction between crop improvement research and existing seed system components. It is expected that through a regional legislation seeds of preferred varieties can be marketed across the West-African Region. It is expected that this will encourage private sector investments in seed production and marketing, and in the long-term in varietal development. Generally input availability at the farmer level shall improve, through the strengthening of the capacities of local retailers and increased trust between farmers and retailers.

Sharing new knowledge is integral for the success of this output. The expected impacts will only be possible if this knowledge is understood and applied by relevant partners, especially the NARS, Farmer Organizations, private seed sector, NGOs, development personnel and. We thus place particular importance on ensuring that knowledge is created jointly, and owned by all our key partners, who contribute to its creation and testing.

This principle of shared ownership also applies to the new germplasm, varieties or hybrids, whenever possible. However the key impact pathway for new seeds needs to be a commercial seed system but this is very far from being established in all West-Africa countries, except Nigeria. This project thus collaborates closely with Project 1 to identify interventions, policy and market changes that could facilitate private investments in seed supply, as well as low cost options for enhancing the traditional seed system with respect to its capacity to access and disseminate new germplasm.

In the medium term, establishment of a sustainable seed production and delivery system at the village level will facilitate the spread of new crop varieties particularly among smallholder farmers. This will occur if the NARS establish a sustainable scheme to ensure breeder seed production and that governments support policies to encourage local seed supply systems and private sector intervention in the seed industry. In the research pathway, farmers have to be involved at the onset of variety development through participatory approaches. NARS will need to institutionalize participatory variety selection. As farmers adopt new varieties, we expected that yields at the farm level (20 – 30%) increase. This will likely lead to unit reduced cost of production (at least 10%) and thus lead to increased profit per unit. This will generate impacts on household income, increase food security, and household resilience.

We expect that facilitating regional trade of high quality seed and planting materials will improve availability of farmer preferred seeds across West Africa. The main obstacles to regional seed trade are the non-harmonized procedures of variety release or registration and inappropriate quarantine pests lists. We expect to increase the number of available varieties in each country, and relevant information about these varieties needed both by seed companies and farmers, through the development of a web-bases variety catalogue. With the regional harmonized regulations, varieties registered in the regional catalogue are authorized to be traded in all the seventeen countries provided they meet phytosanitary and certification requirements. The review and update of national laws/decrees to conform with the regional agreements is expected to increase both intra-regional and inter-region seed trade. The

regional harmonized quarantine pests list will increase cross-border trade by reducing the time spent at borders, and unnecessary expenses in controlling non-issue pests in seed lots. The overall impact on the enabling agricultural environment will be important because the development and implementation in each country of procedure manuals for variety release and registration, for seed quality control and certification and seed import-exports which will create a sound business atmosphere and attract the involvement of private seed companies.

The lack of a reliable supply of quality foundation seed from NARS breeders is a major constraint to the development of local-level seed production capacity by farmers' associations and small seed companies. WASA will work with NARS breeders to improve their technical capacity in maintenance breeding, and assist them in the development of business plans so that maintenance breeding costs can be supported through seed sales. Improved seed quality and better business management practices will stimulate the development of seed production capacity further down the seed chain, and the increased availability of quality seed at affordable prices will increase the effective demand for formal sector seed.

International Public Goods

- Tools methods and institutional arrangements for effective farmer participatory variety development for sorghum, pearl millet and groundnut
- Information and knowledge about characteristics of previously underutilized germplasm of sorghum and pearl millet
- Broad based breeding populations improved for specific traits and adaptations to major agro-ecological zones of WCA
- Breeding methods (molecular and phenotype based) methods for improving Striga resistance in pearl millet and sorghum
- Training manuals for improving bioavailability of iron and zinc in children's diets in West-Africa
- Breeding methods for improving bioavailability of iron and zinc in sorghum and pearl millet
- Tools for effective participatory technology adaptation and diffusion for specific production conditions in pearl millet and sorghum systems, e.g. FFS for integrated Striga management
- Information on structure of variability in regional sorghum and pearl millet germplasm on different levels of differentiation: regions, countries, villages, and intra-varietal (in collaboration with projects 2 and 9)
- Knowledge on improving grain yield potential of photoperiod sensitive sorghum and pearl millet hybrids and varieties
- Seed production techniques established for photoperiod sensitive sorghum hybrids
- Training manuals for breeders, technicians, development workers on hybrid breeding, seed production, integrated Striga management options, participatory recurrent selection, and for control of aflatoxin contamination in groundnuts
- Training manuals on seed production, certification, import-export, marketing including business development skills

Elaboration of Partners Roles

For the research on heterotic patterns the key partners are IER (Mali, sorghum , pearl millet and groundnut); INRAN (Niger, pearl millet, groundnut); INERA (Burkina Faso, sorghum and pearl millet); IAR, Nigeria (sorghum, groundnut); LCRI , Nigeria (pearl millet) and Senegal (ISRA, sorghum, pearl millet and groundnut). The NARS partners provide much of the genetic material, testing facilities, inputs into planning, and developing joint strategies. The key ARI partners who are primarily responsible for the development genetic marker techniques and analyses are the University of Hohenheim, CIRAD, Cornell University, and IRD, each with specific expertise for specific crop and methodological issues. CIRAD is a key partner for research on adaptation, and photoperiod response in sorghum and pearl millet, as well as biosafety issues.

A number of farmer organizations are investing in this research by joining in selection and variety testing activities for a wide range of traits, and conditions. Their inputs are the key to adapting breeding targets to meet primary farmer needs. The collaboration with large investment development projects funded through IFAD, as well as other development projects, are central to the effort of reaching more farmers more quickly.

The Helen Keller Foundation is a key partner in the nutrition research, and we are working intensely with the University of Wageningen, and other Harvest-Plus Challenge program partners. The Systems Wide Livestock program (with ILRI) is a partner in addressing specific issues related to improving feed value of crops residues, and generally crop livestock integration in Sahelian and Sudanian zone agro-ecologies. The mycotoxin research involves the same NARS partners in all the countries, for testing components of integrated management of Aspergillus flavus and synergies between them. The University of Georgia supports these efforts. The Water and Food Challenge program (Volta consortium) are partners and in future the African CP is likely to play a role. ICRISAT in WCA has recently entered into the West African Seed Alliance as the lead member, together with the African Seed Trade Association, Iowa State University Seed research Center, and the international NGO CNFA. The planned work is a concerted effort at improving seed commercialization in West Africa as a whole, not limited to ICRISAT crops only.

Key Strategic Alliances: CIRAD (expertise in sorghum breeding, entomology, crop physiology), Hohenheim University (expertise to support breeding methods) and Wageningen University (expertise to support efforts on human nutrition, and Striga research), University of Georgia on pearl millet pathology and breeding, as well as Striga genetics, Michigan State University on integrating natural and genetic resources management. African Seed Trade Association, Iowa State University, CNFA and others as part of WASA.

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**Heterotic relationships identified within sorghum and pearl millet germplasm adapted to WCA conditions and appropriate broad-based breeding populations and hybrid parents and knowledge made available to NARS and other partners in order to maximise genetic gain from selection**	NARES, ARIs and private sector breeders and seed producers	Strengthened partners (NARES, private sector) change their breeding strategy, and make productive hybrids regionally available in WCA	Farmer staple cereal production has increased, and stabilized, contributing to increased annual incomes, and system resilience though adoption of new hybrids. Commercial seed and breeding enterprises have been established successfully
Target 2009: Materials	3.1.1 Initial heterotic groupings for sorghum and pearl millet hybrid breeding for WCA established and publication drafted			
Target 2010: Materials	3.1.1 Five new pearl millet and five sorghum inbred lines with good combining ability identified and characterized; seed made available to partners with associated capacity development for developing hybrid cultivars			
Target 2011: Materials	3.1.1 Six sorghum hybrids for at least two countries in West Africa identified, release relevant information as well as parental seed made available to partners			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Materials	3.1.2 Five pearl millet inbred lines, and 2 populations with high general combining ability backcrossed into male-sterility inducing A4 cytoplasm			
Output 2	**Improved methodologies developed for integrating breeding of groundnut, sorghum and pearl millet populations and varieties with crop management strategies to overcome key environmental and socio-economic constraints and making them available with new knowledge to partners**	NARES and private sector breeders and NGO/CBOs, Alliance, PGRA, SLP, Generation CP, Africa CP partners and VASAT Consortium partners (project 10) in the WCA SAT	NARES in WCA work together, involving farmer associations, private sector, and NGOs whenever appropriate to identify and release superior varieties using modern tools as appropriate	Increasing and stabilized productivity of staple crops in a range of eco-systems, and production contexts has been achieved through the availability of well-adapted, genetic diverse varieties and participatory methodologies which have helped farmers to identify their most promising options
Target 2009: Other kinds of knowledge	3.2.1 First availability of allele-specific molecular markers for genes controlling photoperiod sensitivity of flowering time in pearl millet and sorghum			
Target 2009: Materials	3.2.2 One new genepool of pearl millet with reduced Striga susceptibility available for testing in West African breeding programs			
Target 2009: Other kinds of knowledge	3.2.3 Knowledge of adaptation and initial regional adaptation maps for 5 sorghum and pearl millet varieties each made			

	Outputs	Intended Users	Outcome	Impact
	available and disseminated with associated capacity development to WCA partners			
Target 2010: Other kinds of knowledge	3.2.1 Tools for farmer participatory recurrent selection tested for pearl millet and sorghum with partners with associated capacity development in different agro-ecologies. (associated with PRGA SWEP)			
Target 2010: Capacity	3.2.2 Two NARS empowered to breed groundnut varieties with multiple attributes, including drought resistance.			
Target 2010: Materials	3.2.3 Three high yielding, well adapted sorghum varieties with at least one trait adding value to the harvest (stover quality, sweet juicy stems, brewing quality) identified for dissemination to farmers in two countries in WCA			
Target 2011: Materials	3.2.1 At least two new breeding populations of groundnut with enhanced multiple attributes available for testing and selection by NARS			
Target 2011: Materials	3.2.2 Improved cycle of at least one sorghum broadbased			

	Outputs	Intended Users	Outcome	Impact
	population produced by random-mating superior progenies			
Target 2011: Materials	3.2.3 At least 2 downy mildew resistant open pollinated varieties of pearl millet made available to partners with release relevant information			
Target 2011: Other kinds of knowledge	3.2.4 Refined adaptation maps for at least 10 sorghum and pearl millet varieties available for use by partners			
Target 2011: Other kinds of knowledge	3.2.5 Understanding of dry land cereal pest dynamics enhanced for at least two priority species across WCA, and used in adaptive IGNRM research targeting at least two countries			
Output 3	**Crop management, Aspergillus flavus resistant groundnut varieties and post-harvest technologies to reduce aflatoxin contamination in food and feed products, as well as micronutrient rich cereal varieties and processing techniques to improve bio-availability developed, tested and made available to partners with new knowledge in the SAT of**	NARES breeders, Harvest + CP partners, agronomists, animal scientists and private sector processors and the VASAT Consortium for dissemination (Project 10)	Partners adopt new breeding, agronomic and processing practices which improve food and feed quality	Improved nutrition of rural and urban populations has been brought about through consumption of new nutrient dense staples, and mycotoxin free groundnuts and secondary products Reduced aflatoxin contamination will generate social benefits and a net gain ranging from $ 0.56 to 4.25

	Outputs	Intended Users	Outcome	Impact
	WCA			million.
Target 2009: Practices	3.3.1 A report on early adoption of crop management practices to reduce Aflatoxin contamination available			
Target 2010: Practices	3.3.2 ELISA testing lab set up at ICRISAT-Bamako			
Target 2011: Materials	3.3.1 2-3 farmer-and market preferred groundnut varieties tolerant to aflatoxin contamination identified for dissemination by at least two NARS in WCA			
Target 2011: Materials	3.3.2 Mini-core Groundnut collection phenotyped for tolerance to A. flavus and aflatoxin contamination			
Target 2011: Materials	3.3.3 Two sorghum and pearl millet varieties with increased iron and zinc content, and low content of anti-nutritional factors available for cultivation in at least two countries in WCA			
Output 4	**High quality seed of adapted, released varieties of sorghum, pearl millet**	Breeders, seed technicians, seed lab analysts, seed producers, seed dealers and	National variety release and seed certification process management manuals	Registered private certified seed producers list established and improved

	Outputs	Intended Users	Outcome	Impact
	and groundnut accessible and affordable to small scale farmers in a timely manner through networks of agro-input dealers, seed entrepreneurs and breeders, both public and private by focusing on sustainable breeder and foundation seed production and creating an enabling agricultural environment for regional seed trade in West Africa	other private stakeholders	developed and private stakeholders and seed regulatory agency staff trained for the use of these manuals in Mali, Ghana and Nigeria based on regional agreements. Science based plant quarantine pest list of seed of sorghum, millet, groundnut etc. developed and adopted by the West African countries and the seed import-export process manuals developed for Mali , Nigeria, Ghana	seed uses and yield increases
Target 2010: Capacity	3.4.1 Improved agricultural enabling environment established for marketing high quality seed of sorghum, millet groundnut, etc. between West African Countries			
Target 2011: Capacity	3.4.1 Enhanced availability of foundation seed to satisfy requests from certified seed producers, especially with linkages to product markets in Ghana, Mali, Niger and Nigeria			
Target 2011: Other kinds of knowledge	3.4.2 Seed dissemination channels assessed in at least one country in WCA			

ICRISAT-4: Producing more and better food from staple cereals (sorghum and millets) and legumes (groundnuts, chickpea and pigeonpea) at lower cost in the eastern and southern African (ESA) SAT through genetic improvement

Project Overview and Rationale

The use of improved varieties with inbuilt mechanisms to tolerate and resist many of the biotic and abiotic stresses faced by farmers in the ESA SAT is often cited as the easiest and most cost effective form of technology change in smallholder production systems. Yet, in ESA, gains from crop improvements have not been fully exploited to date. A number of key constraints hinder development, dissemination and adoption of improved varieties. Firstly, the focus of crop improvement is still national, rather than regional yet most national research institutes do not have adequate resources to pursue a full range of strategic, applied and adaptive research for each priority problem associated with ICRISAT's mandate crops. Secondly, breeders have not adequately tapped traits of economic importance available in local germplasm to develop market - and end user-preferred quality and nutritious cultivars that provide good yields under biotic and abiotic stresses. In addition, for new varieties to make an impact at the farm level, viable seed systems are a prerequisite and should be linked to Integrated Genetic and Natural Resource Management (IGNRM) approaches that enhance productivity, and translate these into profitability through product market linkages and partnerships to encourage farmers to sustainably invest in productivity enhancing technologies and inputs.

This project places an emphasis on improving and strengthening the efficiency of breeding and cultivar evaluation for ICRISAT crops across the ESA region while conserving and making maximum use of the natural genetic resource base. This will be achieved through new regionally-based institutional networking arrangements which integrate traditional crop breeding, biotechnology and farmer participation. To facilitate adoption and impact from technological changes, scientific inputs and technical support will be provided to public and private sector institutions spearheading the harmonization of seed regulations and policies as well addressing biosafety issues in ESA. The project outputs are regionally oriented and their IPG nature also spills over into ICRISAT's west and central African and Asian projects (Projects 3 and 6).

The target ecoregion, the beneficiaries and end users
The target ecoregion is the SAT of ESA. The immediate beneficiaries are NARS breeders from both public and private sectors, agronomists and social scientists, our partners in the Alliance centers, the Water and Food CP, Harvest Plus and African CPs, NGOs and CBOs involved in agricultural research, extension and small scale, private sector marketing and seed entrepreneurs. The end users are small scale farmers and village communities.

Is the center the primary or secondary research provider?
The Center in this project can be either the primary or secondary research provider depending on circumstances. NARS crop improvement programs in ESA are becoming increasingly weak due to poor allocation of resources by governments and low number of scientists with varying strengths to carry out breeding activities. The weaker NARS will therefore rely on the Center for semi-completed and finished breeding products while the stronger NARS may be able to develop the products independently or be provided with segregating populations. In most cases the center becomes the primary source and provider of materials.

Is it a catalyser, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact
ICRISAT is a catalyser in the field of plant breeding and biotechnology in the ESA region, north of the Republic of South Africa. As a facilitator, ICRISAT is working with NARS scientists in crop improvement and management of genetic resources to develop improved varieties for its mandate crops in ESA. ICRISAT ESA is also an enabler and/or advocate in that it assists the

SADC-FANR and ASARECA based public and private partners to establish and pursue efficient regionalized breeding programs that integrate biotechnology, farmers participation and use of local germplasm of ICRISAT mandate crops.

Comparative and complementary advantage of the project activities
ICRISAT is well placed to organize information and legal germplasm exchanges between partners from different countries. It has highly trained interdisciplinary research teams at several locations across the SAT that are well positioned to implement regionally coordinated projects in partnership with NARS and other partners. ICRISAT ESA has demonstrated the justification for pursuance of regionalized crop improvement and regional variety registration. This was a key achievement and it has been adopted by the two Sub regional organizations- ASARECA and SADC FANR as an approach to enhance research efficiency in the face of diminishing human and financial resources.

In the field of biotechnology, ICRISAT has developed many markers linked to important traits related to enhanced performance under biotic and abiotic stresses in the SAT for all its mandate crops (Project 2). Some of the markers are being applied in ESA to introgress beneficial traits into locally adapted varieties through marker-assisted backcrossing (MAB).

Playing a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs
ICRISAT, in this project under System Priority 2, recognized that crop breeding and variety release systems remain largely focused on national markets while seed markets are becoming increasingly globalized. However, breeding programs are poorly staffed and under-funded in relation to the number of each country's crop breeding challenges. Geographic Information System (GIS) analyses are used to delineate the region into recommendation domains based on lengths of growing periods (LGPs) as well as by distribution of biotic and abiotic stresses. Multiple variety releases demonstrate the potential adaptability of these varieties across country borders. Using grain yield data from Multi- Environment Trials (METs) conducted over a span of 15 years, allowed stratification of 39 SADC test sites into 6 groups according to their similarity of line-yield differentiation. This provided an objective basis (IPG) for selection of a few representative benchmark test sites for efficient regionalized variety testing through the Lead NARS approach targeting regional variety registration, especially for sorghum and millet in ESA. The center has demonstrated a modus operandi for enhancing efficiency in crop improvement by engaging stronger NARES in product development and providing a platform for sharing products and information across the region. This has facilitated farmers' quick access to new improved varieties and addressed constraints of small scale seed markets. ICRISAT's genetic improvement products remain largely in the public domain and no exclusivity is given to any individual partner even where partnerships involve the private sector. Products can therefore be easily accessed for utilization resulting in measurable impact.

Impact Pathway

ICRISAT in ESA, in collaboration with NARS partners in the two sub regional organization (ASARECA and SADC FANR) have collaborated in identification of regional challenges that impact on crop productivity and set crop improvement priorities. The priority setting exercise was rigorous for sorghum and millets and involved a broad range of stakeholder groups in ECA along the crops value chain. This was possible because of the presence and functioning of the Eastern and Central Africa Sorghum and Millet (ECARSAM) network. With different approaches used for other crops, regional crop breeding priority areas have been determined as well. Public and private sector breeders through capacity development in the region are adopting regionalized breeding approaches (through task networks) to improve efficiency and cost effectiveness in development, regional testing and release of improved cultivars. Through this approach, breeders are also more willing to take on broader regional crop improvement agenda; share regional breeding responsibilities, germplasm products, knowledge and low cost diagnostic tools with traders and processors to ensure food safety. For example, the taking on of a new breeding theme on improvement of the long season photoperiod sensitive sorghums was a result of the understanding of existence of this niche with unique sorghum genetic resources and interest of farmers for this particular germplasm. Similarly for pigeonpea,

understanding of modulation of flowering as influenced by photoperiod and temperature has permitted ICRISAT breeding program to develop varieties and target to agro-ecologies where they are most likely to reach their yield potential Crop breeding efforts will provide farmers in this environment niche with improved and adaptable germplasm for sorghum and other pigeon pea. The availability of the BECA facility provides capacity building on Marker Assisted Selection and other biotechnology techniques. The facility enables NARSs participation in integration of biotechnology tools and participatory approaches to further enhance breeding efficiency of ICRISAT mandate crops in the ESA region.

Diversified and improved germplasm of mandate crops that combine high yields, resistance to biotic and abiotic stresses and some with enhanced micronutrient contents and reduced mycotoxin contaminations will be available to breeders for further evaluation, to seed producers for marketing across the region and to farmers especially women farmers for ensuring improved health, nutrition and food security of family members. The availability improved materials will include those of sweet sorghum germplasm and other high value crops like finger millet and kabuli chickpea to address new global challenges and needs. Energy security, for example, is a growing concern because of uncertainties in supply coupled with sharp increases in prices because of geopolitical tensions and weather disturbances in oil producing countries. A vital assumption in the broad sharing of germplasm is that the new International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) will enable, rather than hinder the regional flow of improved germplasm to create impact across the ESA countries. This does not look particularly encouraging at present, and makes the role of ICRISAT along the impact pathway, and as an honest broker, of more importance than previously anticipated.

The delineation of agro ecological zones, identification of recommendation domains and breeding themes and areas of technology targeting will provide maps with information on regional cultivar adaptation. The implications are that outputs of a breeding program in one country can potentially be adapted and adopted in similar environments in other countries. These results increase potential interest of commercial seed companies/ entrepreneurs in variety multiplication and distribution enhance adoption and generate impact and returns from investments to breeding programs. However methodical regionalized breeding targeting specific environments at regional level while gaining from increased acreage summed across countries will produce greater potential economic benefits from higher yields on a wide geographic crop area. Maps of the region showing zones of adaptation of specific (widely adapted) our mandate crops can strengthen regional seed security and accelerate the spread of improved varieties, reducing the cost of research programs, and speeding the delivery of benefits to farmers. Another important implication is the targeting of relief seed. These maps make it is easy to identify what varieties are adapted to the afflicted areas, identify where else in the region those varieties are grown, and where seed might be sourced. In future, it may also be possible to set up a regional seed security system wherein seed stocks of regionally important varieties could be held as a regional reserve. In ESA region, and with support from the Alliance for a Green Revolution in Africa (AGRA) program, a number of seed companies and agro dealers are being established. These will facilitate increased dissemination of improved cultivars for enhanced adoption to increase productivity and impact.

To create impact, the policy environment has to be conducive and supportive especially for seed systems and other productivity enhancing inputs. A number of seed systems models have been tested and are being promoted to provide farmers with varying options to access quality seed of improved varieties. The adoption of these models requires revisions of current seed regulations and policies. ICRISAT ESA has provided scientific justification to the pursuance of on going seed policy and regulation harmonization in the region. The renewed thinking on how to develop and evaluate varieties targeting much larger areas (AEZ) across the region will stimulate regional seed markets and create larger impacts from improved varieties. The endorsement of regional variety registration by SROs in the ESA region is a success that will promote and support regional seed markets. The establishment of another class of seed Quality Declared Seed will enable trained communities and farmers organizations to multiply and market seed at community level where certified seed can not be easily availed. Improved varieties alone will not achieve the required increased productivity and profitability to create

the impact that is required. Farmers will need to integrate improved crop cultivars with on farm water management and soil fertility enhancing technologies to improve crop productivity. Enabling policies on seed will link with technology and policy developments in other projects (projects 1, 7, 8,9) to support availability of inputs such as fertilizer. Links will be created to product markets to improve profitability and hence contributing to achieving the CGIAR, NEPAD and MDG goals.

ICRISAT in collaboration with other alliances is integrating biotechnology approaches in its crop improvement programs. Informed policy decisions will be made on the deployment of transgenics in the ESA region based on results from studies to understand the impacts of gene flow for environmental risk/safety assessments.

Generation and dissemination of knowledge, promotion of tools and methods to ensure that farmers produce and market quality and safety assured products should improve profitability if premium prices can be paid for enhanced quality and safe products. This should ultimately result into farmers improved livelihood derived from impacts of technological changes.

Alignment to CGIAR Priorities

The research proposed in this project addresses System Priority Area 2 in the Eastern and Southern Africa (ESA) semi-arid tropics (SAT) through genetic improvement. Within this priority area, the focus will be on (i) system priority 2A which aims to increase yield and also consider pro- poor traits (pests, diseases and Striga), (ii) system priority 2B which addresses abiotic stresses (drought) and (iii) 2C which focuses on enhancing nutritional quality and safety. Within 2C, emphasis will be laid on improving nutritional quality of sorghum, pearl and finger millet through bio-fortification. Linkages will also be established with the on going Harvest Plus Challenge Program as well as with other global initiatives. In addition, 2C will address food safety concerns, especially aflatoxin in groundnuts. It is anticipated that a combination of conventional and biotechnology tools and methods will be used. Environmental safety, especially biosafety and risk assessment, issues will therefore be covered in this project. Genetic enhancement of selected high value crops (2D), particularly sweet sorghum, for ethanol production will be conducted in collaboration with Project 5.

ICRISAT claims that 100% of this projects activities are encapsulated within the CGIAR System Priorities. It is well aligned to the objectives of Framework Plans 2B and 2C (see the related projects 5 and 6 for a fuller analysis) but in particular for Biofortification Biodetoxification issues. It will address issues highlighted in the framework plan as follows:

- Develop and provide access to new nutritious staple foods that have proven efficacious and meet the supply and demand needs of poor farmers who supply food to a growing population of hungry
- Contribute or adapt new methods, protocols, equipment and related technologies to global agriculture and nutrition research in the developed and developing world
- Strengthen national research systems in agriculture and health in the developing world to support the development of nutritious biofortified crops in response to targeted needs
- Enable scientists and policymakers to recognize the utility of agriculture and biotechnology in improving the health and well being of the populace

Outputs Description

Changes from Previous MTP
Output 4.4 - Propose a revised output statement to clearly reflect what is being done and what has been done and will be achieved.

Output 1: **Sustainable regional breeding networks that integrate conventional and biotechnology tools established and associated capacity building implemented**

Description:

Priority 2A: Maintaining and enhancing yield and yield potential of food staples

System Priority 2A, Specific goal 1: Enhance the capacity and efficiency of genetic improvement programs through approaches linking characterization and use

System Priority 2A, Specific goal 2: Identification and development of pro-poor traits

Breeding programs in ESA are poorly staffed and under-funded. The use of characterized local germplasm to tap end users and economically important traits is limited. Similarly, application of biotechnology tools to increase breeding efficiency has been constrained by insufficient infrastructure and capacity. Characterization of ESA environments using GIS and combined with demonstrated evidence of spillover of varieties across the region, justifies the pursuance of regionalized breeding approaches. NARS partners, through their sub-regional organization and in collaboration with IARCs and other ARIs have identified the need to improve the efficiency in agricultural research. The ICRISAT-ESA crop improvement teams in collaboration with breeders in ASARECA and SADC is pursuing regionalized crop improvement approaches through task networks on breeding for challenges such as drought, adaptation traits (eg. photoperiodism) and biotic stresses (e.g. Striga) that cut across a number of countries. Biotechnology tools will be deployed in transferring resistance into farmer preferred varieties and this will be linked to capacity building of NARS scientists in Marker Assisted Selection (MAS). This approach will increase crop breeding efficiency through the use of novel tools and methods as well as the utilization of available human resources through task network to implement regionalized breeding activities. The approach will also provide informed decisions for germplasm and breeding material sharing across similar AEZ and across target regions. Enhancing available GIS maps on varietal adaptation in ESA will contribute to regional variety testing and registration. This will enhance regional seed markets to improve farmers access to seeds of improved varieties. Enhanced capacity will ensure sustainability in crop breeding to address regionally identified challenges and pro- poor traits to increase the yield of food staples.

Alignment to CGIAR Priorities : 2A: Maintaining and enhancing yields and yield potential of food staples;

Output 2: **Improved germplasm and parental lines of adaptable sorghum, pearl millet, pigeon pea, chickpea and groundnut that are resistant to chronic biotic stresses and meet end user preferences developed and disseminated with new knowledge to partners**

Description:

Priority 2A: Maintaining and enhancing yield and yield potential of food staples

System Priority 2A, Specific goal 1: Enhance the capacity and efficiency of genetic improvement programs through approaches linking characterization and use

System Priority 2A, Specific goal 2: Identification and development of pro-poor traits

The focus will be on technological options that enhance yield and productivity with genetic resistance to major pests and diseases problems and good grain quality for human consumption, including traits preferred by the consumers and markets. Important biotic stresses and pro poor traits that limit productivity have been identified for each crop. We will focus on developing genetically diverse materials that are resistant to Striga, midge and stem borers for sorghum; downy mildew for pearl millet; groundnuts leaf diseases (early and late leaf spots) and rosette; and Fusarium wilt, Phytophthora blight and Helicoverpa and Maruca pod borers for pigeonpeas. The strategy will include use of local and farmer preferred germplasm sources, biotechnology tools and participatory approaches to improve efficiency in

breeding and associated capacity building to partners. In collaboration with private and public partners, dissemination models of seed of different categories will be studied and used to enhance adoption and impact from improved germplasm. This output will be informed to a large extent by the strategic approaches indicated in output 1 for determining extent of key constraints and also areas for technology targeting and for potential scaling out and spillover.

Activities exemplar

One of the 2010 Output Targets (2010 4.2.3) is, Striga resistance transferred to farmer-preferred sorghum varieties using MAS. This results in an activity at the center which is reported, with its internal milestones in the Center Archival Report for 2007 (available at www.icrisat.org).

The activity is to Transfer Striga resistance in sorghum to elite African cultivars using marker-assisted selection.

2007 Milestone: SSR derived markers more tightly linked to Striga resistance in sorghum identified and mapped

2008 Milestone: Striga resistance transferred to at least 3 farmer preferred sorghum varieties using marker assisted selection

2009 Milestone: Three elite farmer varieties from three countries carrying 1 to 3 QTLs evaluated through a participatory approach

2010 Milestone: Multi-locational trials of at least three farmer preferred sorghum varieties carrying one to three Striga resistance QTLs performed

2011 Milestone: At least one farmer preferred sorghum variety carrying one to three Striga resistance QTLs is proposed for release in at least one country and nucleus seed is available for production of subsequent seed classes.

The report for the 2007 internal milestone provides additional details of the precise activities undertaken and it was, SSR derived markers more tightly linked to Striga resistance in sorghum identified and mapped. Significant progress has been made in identifying molecular markers for Striga resistance in sorghum under field conditions by ICRISAT over the last 10 years. Five genomic regions (quantitative trait loci, QTL) associated with stable Striga resistance from the resistant line N13 have been identified across a range of 10 field trials in Mali and Kenya, and through two independent samples of a mapping population involving this resistance source.

Flanking microsatellite or Simple Sequence Repeats (SSR) markers to the QTL are available for use in marker-assisted selection (MAS). MAS studies have, amongst others, revealed that the tighter molecular markers are linked to the target QTL, the more efficient the MAS procedure tends to be. The five QTL for Striga resistance on sorghum LGs 1, 2, 5 and 6, are positioned on genomic intervals flanked by SSR markers, ranging in size from 13 to 56 cM. These intervals correspond to approximately 5.7 to 24.5 Mb, using a total sorghum genetic map length of 1713 cM (Menz et al., 2002) and a sorghum genome size of 750 Mb (Arumaganathan and Earle, 1991). The average gene content of 76 ORFs/Mb, implies that with the transfer of the Striga QTL from N13 to the FPSVs, many additional genes with possible negative effects on the phenotypes will be unintentionally transferred.

MAS using markers more tightly linked to the Striga resistance QTL will reduce the impact of linkage drag and thereby increase chances of farmer adoption of the FPSVs enriched with Striga resistance. The activity aims to utilize molecular markers tightly linked to Striga resistance Quantitative Trait Loci (QTL) in marker-assisted selection (MAS) and farmer-participatory selection in order to move Striga resistance from resistant donor (N13) to susceptible Farmer Preferred Sorghum Varieties (FPSV) from Eritrea, Kenya and Sudan. The

activity builds upon the products, BC2S2 lines, generated through the BMZ project entitled Arresting the scourge of Striga on sorghum in Africa by combining the strengths of marker-assisted backcrossing and farmer-participatory selection. A total of five FPSVs from Kenya, Eritrea and Sudan were selfed twice following two backcross generations (BC2S2) and resulted in numerous lines with up to four Striga resistance QTLs. Four BC2S2 lines with 3 and 4 Striga resistance QTLs were provided to Nairobi University (Kenya) and they have been backcrossed to the local variety Ochuti to generate the BC3F1 population. In Sudan, several lines with 1, 2 and 3 QTLs have been backcrossed to the local varieties Tabat and BC3F1 seeds have been generated.

Alignment to CGIAR Priorities : 2A: Maintaining and enhancing yields and yield potential of food staples;

Output 3: **New knowledge of the QTLs for the stay green and drought tolerance traits confirmed, and marker assisted selection efficiency improved, and specific abiotic stress tolerant varieties and associated knowledge for sorghum, pearl millet and groundnuts developed and disseminated in ESA with associated capacity development**

Description:

Priority 2B: Tolerance to selected abiotic stresses

In SAT of ESA, drought, soil acidity, salinity, cool temperatures and low nitrogen and phosphorus are the serious abiotic stresses that crops are exposed to, leading to severe yield losses. Photoperiod sensitivity is another important adaptation trait. Photoperiod sensitive sorghum materials also have uniquely hard endosperm grains characteristics. However, drought is the most serious single abiotic stress as it is highly unpredictable, and varies in intensities and frequencies. In addition to developing early maturing short season sorghum and millet varieties that are adaptable and have end user traits, we will introgress stay green a secondary trait for selecting for terminal drought tolerance by integrating conventional, biotechnology (MAS for introgressing stay green QTLs) and participatory approaches. We will integrate drought tolerant /early maturing varieties of sorghum, millets and groundnuts with tested water management technologies to increase crop water productivity and maximize benefits from crop improvement. In collaboration with a physiologist in project 3, studies on the physiology of photoperiodicity of ESA and WCA sorghums will be conducted to determine selection approaches for improving the long season photoperiod sensitive materials of ESA. Diversified germplasm using photoperiod sensitive materials as well as other improved sorghum varieties targeting the photoperiod sensitive AEZ will also be developed.

Research results for addressing drought as an important abiotic stress is summarized in output target for 2009 as, Field evaluations of drought tolerance of stay-green sorghum lines evaluated using a farmer-participatory approach in Kenya.

Alignment to CGIAR Priorities : 2B: Improving tolerance to selected abiotic stresses;

Output 4: **Progress in knowledge for use in developing nutritionally (micronutrient) enhanced cereals (sorghum and millets) using conventional and biotechnological approaches, and advances on studies to establish environmental risk assessments for transgenic sorghum**

Description:

Priority 2C: Enhancing nutritional quality and safety

Priority 2C, specific goal 1: Increase the content of micronutrients in the edible parts of crop plants through improved biotechnologies and breeding

Priority 2C, specific goal 2: Evaluation of bio-fortification strategies and introduction of the best means to enhance the diets of nutritionally disadvantaged populations in developing countries

Millions of people in ESA are among the billions of people in developing countries who suffer from an insidious form of hunger known as micronutrient malnutrition and this is a result of diets poor in bio-available vitamins and minerals. Three micronutrients, Fe, Zn and beta-carotene, are widely recognized as limiting especially for people whose diets are heavy on cereals such as sorghum and millets. Strategic and applied research efforts by global alliances including ICRISAT are in progress to biofortify staple crops.

Exploitation of genes for essential nutrients, through biotechnology and conventional plant breeding, offers a promising route for improving the quality of crop foods. The use of biotechnology, in particular, to create genetically modified organisms (GMOs) has the potential to design foods with specific attributes. However, environmental risks and safety associated with deployment of transgenics need to be understood to inform the development of biosafety regulations. In collaboration with other ICRISAT regional and global alliances, the focus of research is to develop cereals and legumes breeding lines with increased levels of micronutrients to deliver Recommended Dietary Allowances (RDAs) of vitamins, amino acids and minerals. This will include understanding natural variability for grain densities of Fe and Zn and their relationship with other morpho - agronomic characteristics. Transgenic approaches are also being tested in sorghum to improve protein quality and digestibility, increase iron and zinc availability and increase levels of Vitamin A and E. The potential for gene flow to wild related species and to landraces is certain to be the top concern of authorities in the assessment of environmental safety of transgenic sorghum. In collaboration with other alliances, ICRISAT is conducting studies to generate data on gene flow in sorghum. The information is needed to inform the regulators and the public in general about issues and concerns related to safety/risks of deploying transgenics and hence contribute to the evolution of the regulatory policy environments.

Research results addressing the two specific goals are summarized as output targets for:

2009: Relationship among important micronutrients determined in sorghum to inform breeding strategies

2010: Documentation for risk/safety assessment for GM regulatory needs

Alignment to CGIAR Priorities : 2C: Enhancing nutritional quality and safety;

Output 5: **Technological options and knowledge to reduce aflatoxin contamination at different stages of the groundnut crop cycle developed and disseminated to partner NARES, traders and processors in ESA with associated capacity building for enhanced food and feed quality**

Description:

Priority 2C, specific goal 3: To reduce the content of constitutive or microbial toxins in selected staples that affect quality, food safety and human health

Advances in developing high yielding and nutritious foods can be overshadowed and reversed by the presence of mycotoxin in a variety of foods and can adversely affect food security, health and livelihoods of people in ESA. The toxigenic strains of Aspergillus flavus and A. Parasiticus produce aflatoxins, which are toxic, carcinogenic, and immuno - suppressive. To tackle micronutrient contamination, ICRISAT emphasizes on Integrated Genetic and Natural Resource Management (IGNRM) techniques involving developing crop handling techniques and mycotoxin tolerant cultivars of mandate crops. Current efforts are on establishing facilities and developing protocols for isolation and testing of mycotoxins. Subsequent efforts will be to promote adoption of low cost technologies for reducing aflatoxin contamination especially in groundnuts and other staples and high value crops grown in ESA. Capacity building of farming

communities and agricultural advisors is also provided to promote appropriate pre and post harvest technologies that reduce the risk of food/feed contamination with mycotoxin while integrating broad knowledge and information sharing.

Research addressing this specific goal is summarized in two outputs targets for 2010 specifically for sorghum and groundnuts

2010: Role of variety/genotype contribution to aflatoxin control documented in Sorghum and groundnut in ESA

2010: Pre-harvest and post harvest aflatoxin control measures implemented in at least 2 countries on an annual basis by 2010

Intended users and outcomes: Public breeders will experience improved efficiency in their crop improvement programs, and by pooling resources, be able to address an increased number of breeding targets across the region. In ESA there are at least 5 breeding networks that are operational in ASARECA with one NARS providing leadership and facilitating sharing of germplasm products. NARES and private sector breeders are collaborating in breeding and screening for pests, Striga and disease resistance, drought, adaptation traits e.g. photoperiodism and are looking into the potential of hybrids. Partner breeders can use the available germplasm for further selection and testing for adaptability and acceptability. The BECA facility is being strengthened and used by NARS scientists to enhance capacity for biotechnology. NARES agronomists, breeders, pathologists, traders, food processors and health experts access and promote germplasm of nutritionally enhanced and safe to use crops. Regulatory bodies in SADC and ASARECA make informed bio-safety policy decisions based on knowledge of environment risks and safety analyses from gene flow studies. Partner breeders accept proof of concept of the feasibility of conventional breeding aided by MAS and transgenics and incorporate higher nutritional standards into their breeding goals. It is assumed that funds for breeding activities within the NARES continue to be forthcoming. It is also assumed that the new role of the Bill and Melinda Gates Foundation in agriculture will help assure the promotion of such activities. The recent approval (May 2007) of the major multi-year project for legume research by the Bill and Melinda Gates Foundation through the Generation CP, of which ICRISAT is a substantive beneficiary, is evidence that this assumption will be achieved.

Biotechnology and transgenic crops have provided new opportunities for global food security and new developments in life sciences. However, the release and use of transgenic products and possibilities of transgene escape through gene flow from genetically modified (GM) crops to their wild relative species may potentially cause environmental biosafety problems. When alien transgenes escape to, and express normally in weedy or wild relatives of transgenic crop species, transgenes may persist and disseminate within the weedy or wild populations through sexual reproduction and/or vegetative propagation. It is imperative, therefore, to assess the extent of gene flow between cultivated crops and their wild relatives under field conditions. Subsequently, studies on out-crossing rates and the distance pollen flows are important in order to assess potential risks of transgene contamination.

Exploitation of genes for essential nutrients, through biotechnology and conventional plant breeding, offers a promising route for improving the quality of crop foods. The use of biotechnology, in particular, to create genetically-modified organisms (GMOs) has the potential to design foods with specific attributes. Enhanced nutritional quality of crops may be achieved by enabling the capacity of the plant to synthesize vitamins, to take up minerals with greater efficiency, or by reducing anti-nutrient factors such as phytates or tannins that can make nutrients unavailable as well as lower food palatability. Crops with enhanced qualities such as high -carotene, high levels of minerals and Vitamins have the potential to alleviate chronic problems of malnutrition in ESA.

Alignment to CGIAR Priorities : 2C: Enhancing nutritional quality and safety;

Impact Pathways by Output

Output 1: Sustainable regional breeding networks that integrate conventional and biotechnology tools established and associated capacity building implemented

ICRISAT in ESA, in collaboration with NARS partners in the two sub regional organization (ASARECA and SADC FANR) have identified regional challenges that impact on crop productivity and set crop improvement priorities. Public and private sector breeders are adopting regionalized breeding approaches (through task networks) to improve efficiency and cost effectiveness in development, regional testing and release of improved cultivars. The main inputs are breeding teams that are deploying integrated crop improvement approaches that include conventional breeding, biotechnology and participatory approaches. Genetic resources especially those that are farmer preferred are the key ingredients in the crop improvement program as sources of resistance to stresses and sources of quality attributes. The availability of the BECA facility provides capacity building on Marker Assisted Selection and other biotechnology techniques. The facility enables NARS participation in integration of biotechnology tools and participatory approaches to further enhance breeding efficiency of ICRISAT mandate crops in the ESA region. The main products/outputs include information and maps of crop and variety adaptation zones across the regions and for the targeted stresses; improved varieties of sorghum, millets, groundnuts, pigeon pea and chickpeas at different stages of development such. Other outputs include nucleus and breeder seed of released cultivars that may be supplied for further multiplication and accompanying information published for the scientific community and also for the farming groups. The process of variety release is for scaling up the germplasm products and that of dissemination and availability of different seed classes is to facilitate adoption. The resulting outcomes are 1) breeders' capacity is enhanced and those breeders participating in task networks are able to routinely develop new breeding materials and to continue and sustain crop improvement activities for the specific stresses 2) Farmers engaging in participatory variety selection get knowledge about improved varieties, have better chances to access improved germplasm. Seed industry are able to market appropriate varieties to the mapped adaptation areas and this is across a wider region and NGOS are able to supply appropriate relief seed to the needy communities. Ultimately, the impact is that farmers growing improved varieties of ICRISAT mandate crops will experience increased productivity for increased food security and improved livelihood.

Output 2: Improved germplasm and parental lines of adaptable sorghum, pearl millet, pigeon pea, chickpea and groundnut that are resistant to chronic biotic stresses and meet end user preferences developed and disseminated with new knowledge to partners

The focus for this output is on technological options that enhance yield and productivity from genetic resistance to major pests and disease problems and good grain quality for human consumption, including traits preferred by the consumers and markets. This output will be informed to a large extent by the strategic approaches indicated in output 1 for determining extent of key constraints and also areas for technology targeting and for potential scaling out and spillover. Important biotic stresses and pro poor traits that limit productivity in ESA have been identified for each of the five mandate crops. The main inputs include agronomic and botanical characterization of identified sources of biotic resistances from minicore and reference sets to facilitate their utilization in breeding. Germplasm screening against insect-pests and diseases carried out in collaboration with entomologists and pathologists. Grains tested for nutritive value such as protein, micronutrients contents in cereals, cooking time and farmer/market preferences and evaluation of elite germplasm from various ICRISAT breeding programs for traits of agronomic importance to enhance greater germplasm sharing between ICRISAT and ESA NARS. The main outputs/products are genetically diverse materials (germplasm and parental lines) that are resistant to Striga, midge and stem borers for sorghum; downy mildew for pearl millet; groundnuts leaf diseases (early and late leaf spots) and rosette; and Fusarium wilt, Phytophthora blight and Helicoverpa and Maruca pod borers for pigeonpeas. In collaboration with private and public partners, dissemination models of seed of different categories will be studied and used to enhance adoption and impact from improved germplasm. As outcomes, farmers' knowledge about varieties will be improved through participation in organized Field days, open days, and seed fairs targeting promotion, release

and registration for scaling up of the best varieties and hybrids to enhance productivity and profitability. Farmers' opportunity to access to better germplasm will also be enhanced. The scientific community will be informed about new tools, methods and products through publications in peer reviewed journals and presentations in workshops and conferences. The impact will be for breeders whose effectiveness will be enhanced by employing better tools and methods in crop improvement using available genetic resources. Farmers who will use improved germplasm that are resistant to key biotic stresses will be impacted as they will get improved productivity and better nutritious foods and ultimately enhanced food security, income and health.

Output 3: New knowledge of the QTLs for the stay green and drought tolerance traits confirmed, and marker assisted selection efficiency improved, and specific abiotic stress tolerant varieties and associated knowledge for sorghum, pearl millet and groundnuts developed and disseminated in ESA with associated capacity development

Crop adaptation to climatic conditions is an important attribute for adaptability and productivity. Drought is the most serious single abiotic stress as it is highly unpredictable, and varies in intensities and frequencies. In addition to developing early maturing short season sorghum and millet varieties that are adaptable and have end user traits, the main inputs for this output is introgression of stay green -a secondary trait - for selecting for terminal drought tolerance. The approach integrates conventional and biotechnology techniques especially MAS. Other inputs include studies on physiology of photoperiodism as well as integration of drought tolerant varieties with water management options to enhance productivity. The products/output include drought tolerant varieties of sorghum for evaluation with water management options, groundnut breeding populations for GRD,ELS and rust, groundnut working collection as a basis for MAS, QTLs for stay green, knowledge on photoperiodism and enhanced capacity on integrated breeding approaches (QTLs introgression and selection). The outcome is that partner breeders will be able to use the stay green QTL to enhance efficiency and effectiveness in breeding for sorghum drought tolerance. The knowledge around photoperiodism will increase efficiency in developing improved varieties adaptable to that agro ecology and production environment. The strengthened BECA facility is used and breeders' capacity is enhanced to integrate molecular technology in crop improvement. The impact will be improved speed and cost effectiveness in developing and release of varieties with abiotic stress tolerant traits and farmers will experience increased productivity.

Output 4: Progress in knowledge for use in developing nutritionally (micronutrient) enhanced cereals (sorghum and millets) using conventional and biotechnological approaches, and advances on studies to establish environmental risk assessments for transgenic sorghum

Three micronutrients, Fe, Zn and beta- carotene, are widely recognized as limiting especially for people whose diets are heavy on cereals such as sorghum and millets. The main inputs include strategic and applied research efforts to identify Fe and Zinc dense germplasm and use conventional approaches in developing improved varieties of micronutrient enriched staple crops. However, phytic acid in the seed binds Fe and Zn and become unavailable The key input is to use transformation tools to increase Fe and Zn availability by removing phytic acid through blocking its production. Studies are conducted to understand environmental and agricultural risks (using conventional and molecular technology) and socio economics effects of sorghum crop-to-wild gene flow to enable effective decision-making regarding the testing and the introduction of GM sorghums. The main products are molecular markers for use in gene flow studies, socio economic understanding on wild and weedy sorghum, information on hybrid fitness and proof of concept on the use of different approach to enhance micronutrients in sorghum; knowledge and information that support development and execution of biosafety policies and harmonization of seed regulations and policies. The key outcome are that with breeders' knowledge on genetics of micronutrient development of varieties with nutritional attributes will be enhanced; regulatory needs will be determined and policy makers will make scientific-based informed decisions on how to handle transgenic sorghums in Africa. The ultimate impact is increased nutrition for those who will use micronutrient dense varieties and implications of gene flow on sorghum genetic resources will provide conservation in the midst of transgenic development era.

Output 5: Technological options and knowledge to reduce aflatoxin contamination at different stages of the groundnut crop cycle developed and disseminated to partner NARES, traders and processors in ESA with associated capacity building for enhanced food and feed quality

Advances in developing high yielding and nutritious foods can be overshadowed and reversed by the presence of mycotoxin in a variety of foods and can adversely affect food security, health and livelihoods of people in ESA. The main inputs are development of reliable aflatoxin testing facilities in the countries where this work will be undertaken (Kenya and Malawi). Once these facilities have been established laboratory staff will be trained in the ELISA technique for analyzing aflatoxin samples. The staff will then be assisted to develop a business plan to determine the cost of analyzing samples so that the facilities can be operated on a full-cost recovery basis. With the functioning laboratories, the products will be a sampling protocol and low cost diagnostic tool and data to inform institutional and policy changes on how to sample groundnuts at harvest and in storage to determine the level of aflatoxin contamination, and these levels will be related to the management practices used by the farmers from where the samples were collected, and by the assemblers storing groundnuts. Results from the analysis will be synthesized and published as policy briefs which will then be distributed to different stakeholders along the value-chain. The main outcome is that researchers and extension staff will use this information to design a range of different management interventions. With enhanced capacity provided in aflatoxin management to farmer associations and to traders, lower levels of contamination will be found. The impact is increased food safety for a better health and enhanced livelihood.

International Public Goods

- Tools for establishing new institutional arrangements to operationalize regionalized crop improvement task networks to increase crop breeding efficiencies
- New tools and methods for improving efficiency in crop breeding, molecular markers and transgenic events
- Proofs of concepts for integrating conventional, biotechnology and participatory approaches for introgression of novel traits
- Improved germplasm products - finished and semi finished for open pollinated varieties and hybrids (parents and hybrids) for the major production systems in ESA
- Low cost diagnostic tools and data to inform institutional and policy changes (linked to Project 2)
- Capacity building and training modules on MAS, breeding and selection, mycotoxin management
- New and tested alternative seed delivery models to provide farmers with options for accessing quality seed of improved varieties
- Knowledge and information that support development and execution of biosafety policies and harmonization of seed regulations and policies

The IPGs are in the public domain and no exclusivity is given to any individual partner even where partnerships involve the private sector. The target eco-region is the SAT of ESA, including other agro ecologies where the ICRISAT mandate crops are important. ICRISAT has unmatched experience in this eco-region where the majority of the poor and undernourished live. The partnerships and intended users are NARES, Alliance and CP partners, sub Regional Organizations (SROs) such as ASARECA and SADC FANR and networks as well as private sector breeders and seed production companies and alliances e.g. AFSTA, NGOs such as Africa Harvest and CBOs who leverage resources for crop improvement and also use the materials to deliver finished products. Capacity will be developed in all areas, where appropriate including support of higher degree student research. Partnership is also extended to other Centers, especially in circumstances where a system approach is imperative in addressing cross cutting issues such as Striga, seed and biosafety policy issues. The end users of this project include breeders in private and public institutions in the ESA, but the ultimate end users are small scale farmers and village communities who need to use the technologies to increase productivity and enhance their income. The project will deliver outcomes and impact through the following outputs.

Elaboration of Partners Roles

The major partners, who are also beneficiaries are governments and NARES in Sub Regional Organization in SADC and ASARECA. NARS partners from eight countries in Eastern and Central Africa concerned with sorghum and millets crop improvement. Others include consortium members of the African Biofortified Sorghum [ABS] project with partners from institutions in the north e.g. Dupont/Pioneer, University of California Berkley and others in the south like FARA, CSIR and ARC South Africa and AATF. Others include partners in the Generation Challenge Program and Harvest Plus CP. There are close collaborations with NGOs such as CRS and also private sector organizations e.g. seed and food processing industries. The IGNRM work targeting improved crop water productivity and linked to markets for profitability through the Challenge Program Water for Food include CGIAR partners such as CIMMYT, CIAT and IWMI; the NARES of Mozambique, Zimbabwe and Republic of South Africa as well as ARC and private organizations like Progress Mills in RSA to facilitate market linkages. For marker assisted selection approaches to crop improvement, ICRISAT is providing the technical guidance and facilities through the BecA platform for all genotyping activities, whilst the NARS partners in participating countries do the backcrossing into their farmer preferred varieties. The NARS research partners consist of KARI (Kenya), ARTC (Sudan) and breeders in the national breeding programs of Mali, Eritrea, Ethiopia, Tanzania, Rwanda, Burundi and DR Congo. Partners outside the region include the University of Hohenheim and CIRAD. Financial support is also provided by BMZ (Germany), ASARECA, GCP, Rockefeller Foundation and BecA. For genetic engineering, the most important partner is KARI in Kenya, which will initially provide the facilities for the research, which will later be moved to the BecA platform. An Impact Pathway Problem Tree and Network Map were developed for this project and are shown in the 2008-2010 MTP document.

Key Strategic Alliances: ASARECA Regional NARS partners (for local collaboration in cereal breeding) and members of the BecA consortium (eg. KARI and ILRI for infrastructure to support biotechnology research).

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**Sustainable regional breeding networks that integrate conventional and biotechnology tools established and associated capacity building implemented**	NARES and private sector breeders and seed production companies, NGOs, CBOs and Alliance partners	Private and public sector partners throughout ESA gain access to materials with diversified genetic bases and use these for further evaluation under targeted agro environments and improved efficiency of their biotechnology and breeding programs and to release improved varieties with resistance to diseases and integrated in the production systems for improved productivity and profitability for small-holder farmers. The BECA facility is strengthened and is used by NARS scientists to build their capacity in modern breeding methods.	Farmers growing ICRISAT mandate crops have experienced increased productivity and enterprise profitability. Food quality has been improved due to enhanced nutritional value and reduced aflatoxin contamination in groundnuts and there growing acceptance for the use of GMOs throughout the ESA region
Target 2009: Materials	4.1.1 At least 3 high-yielding medium duration pigeon pea cultivars adapted to southern African cropping systems developed and available with associated capacity development to NARS partners in Tanzania and Malawi			
Target 2009: Materials	4.1.2 Groundnut variety adaptation trials including on farm variety tests conducted and			

	Outputs	Intended Users	Outcome	Impact
	monitored in ESA countries			
Target 2009: Materials	4.1.3 At least 3 high-yielding chickpea cultivars adapted to ESA cropping systems tested by NARS in Ethiopia, Kenya and Tanzania			
Target 2010: Materials	4.1.1 At least one medium and one long duration pigeonpea variety released in two countries of ESA			
Target 2010: Capacity	4.1.2 At least 2 M.Sc students from ESA trained in pigeonpea and chickpea breeding 1 MSc each in groundnut breeding and seed systems and 2000 farmers trained in their production and management			
Target 2010: Materials	4.1.3 At least 500 kg of breeder seed and 10 t of seed of pigeonpea and chickpea produced to support on farm trial and demonstrations in 4 ESA countries			
Target 2010: Materials	4.1.3 At least one medium and one long duration pigeonpea variety released in two countries of ESA			
Target 2010: Materials	4.1.4 At least 200 kg of breeder seed of sorghum and or millet availed to two ESA countries			

	Outputs	Intended Users	Outcome	Impact
Target 2010: Materials	4.1.5 At least 500 kg of breeder seed and 10 t of seed of pigeonpea and chickpea produced to support on farm trial and demonstrations in 4 ESA countries			
Target 2011: Materials	4.1.1 Groundnut Varietal Adaptation Trials including On-farm variety tests conducted and monitored in ESA countries			
Target 2011: Materials	4.1.2 At least 500 kg of breeder seed and 10 t of seed of pigeonpea and chickpea produced to support on farm trial and demonstrations in 4 ESA countries			
Output 2	**Improved germplasm and parental lines of adaptable sorghum, pearl millet, pigeon pea, chickpea and groundnut that are resistant to chronic biotic stresses and meet end user preferences developed and disseminated with new knowledge to partners**	NARES and private sector breeders and seed production companies, NGOs, CBOs, Africa CP and Alliance partners	Private and public sector partners throughout ESA gain access to materials with diversified genetic bases and use these for further evaluation under targeted agro environments and improved efficiency of their biotechnology and breeding programs and to release improved varieties with resistance to diseases and integrated in the production systems for improved productivity and profitability for small-holder farmers. The BECA facility is strengthened and is used by NARS	Farmers growing ICRISAT mandate crops have experienced increased productivity and enterprise profitability. Food quality has been improved due to enhanced nutritional value and reduced aflatoxin contamination in groundnuts and there growing acceptance for the use of GMOs throughout the ESA region

	Outputs	Intended Users	Outcome	Impact
			scientists to build their capacity in modern breeding methods	
Target 2009: Materials	4.2.1 Three elite farmer varieties of sorghum from three countries carrying 1 to 3 QTLs for striga resistance evaluated through a participatory approach			
Target 2009: Capacity	4.2.2. At least two NARS availed with sweet sorghum germplasm and accompanying knowledge and tools for evaluation			
Target 2009: Materials	4.2.3 6 newly improved pigeonpea cultivars disseminated through participatory methods in ESA			
Target 2009: Capacity	4.2.4 Capacity building through training of local scientist on Integration of molecular markers in crop improvement held at BecA			
Target 2009: Capacity	4.2.5 Groundnut Breeding activities (and associated phenotyping facilities) initiated in at least one research station in Malawi and Tanzania			
Target 2009: Materials	4.2.6 At least 1 t breeder seed of 3 released farmer/market preferred groundnut varieties in ESA produced annually			

	Outputs	Intended Users	Outcome	Impact
	from 2008 to 2011 as source for foundation seed for collaborating NARS and other partners			
Target 2009: Practices	4.2.7 Format for seed company business plan developed with training manual using the Malawi case study			
Target 2009: Materials	4.2.5 GRAV CP transgenic groundnuts evaluated in a confined greenhouse trial for resistance to Groundnut Rosette Disease			
Target 2009: Materials	4.2.6 Locally adapted pigeonpea varieties evaluated for genetic transformation using Agrobacterium strains marker genes and different promoters and at least one scientist trained			
Target 2009: Materials	4.2.7 Locally adapted groundnut varieties evaluated for genetic transformation using 4 Agrobacterium strains, marker genes and different promoters. At least one scientist trained			
Target 2009: Materials	4.2.3 4 improved chickpea cultivars disseminated through participatory methods in ESA			
Target 2010: Materials	4.2.1			

	Outputs	Intended Users	Outcome	Impact
	Performance and adaptability of bristled pearl millet ICMV221 evaluated for the first time in ESA to reduce chronic bird damage			
Target 2010: Materials	4.2.2 Striga resistance transferred to farmer-preferred sorghum varieties using MAS			
Target 2010: Materials	4.2.3 Best sources of groundnut rosette virus resistance and vector resistance introgressed in preferred varieties using molecular markers			
Target 2010: Materials	4.2.4 Segregating long duration pigeonpea populations with large grain and resistance to fusarium wilt developed			
Target 2010: Other kinds of knowledge	4.2.5 Multi-locational trials of at least three farmer preferred sorghum varieties carrying one to three Striga resistance QTLs conducted			
Target 2010: Materials	4.2.6 Segregating medium duration pigeonpea populations with large round grains and traits associated with insect pest tolerance developed			
Target 2010: Materials	4.2.7 At least 5 kg nuclear seed of each of 15 varieties in			

	Outputs	Intended Users	Outcome	Impact
	Regional Trials produced annually from 2008 to 2011 as source for breeder seed and entries for collaborative trials with NARS in ESA			
Target 2010: Materials	4.2.8 At least 1 ton breeder seed of 3 released farmer/market preferred groundnut varieties in ESA produced annually from 2008 to 2011 as source for foundation seed for collaborating NARS and other partners			
Target 2010: Capacity	4.2.9 Format for seed company business plan developed with training manual using the Tanzania and Ethiopia case studies			
Target 2011: Materials	4.2.2 At least 5 kg nuclear seed of each of 15 sorghum and millet varieties in Regional Trials produced annually from 2008 to 2011 as source for breeder seed and entries for collaborative trials with NARS in ESA			
Target 2011: Materials	4.2.3 At least 1 t breeder seed of 3 released farmer/market preferred varieties in ESA produced annually from 2008 to 2011 as source for foundation seed for collaborating NARS and other partners			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Materials	4.2.4 Best sources of groundnut rosette virus resistance and vector resistance introgressed in preferred varieties using molecular markers			
Target 2011: Materials	4.2.5 At least one farmer preferred sorghum variety carrying one to three Striga resistance QTLs is proposed for release in at least one country and nucleus seed is available for production of subsequent seed classes			
Target 2011: Other kinds of knowledge	4.2.1 Fine mapping of sorghum midge resistance QTL completed			
Output 3	**New knowledge of the QTLs for the stay green and drought tolerance traits confirmed, and marker assisted selection efficiency improved, and specific abiotic stress tolerant varieties and associated knowledge for sorghum, pearl millet and groundnuts developed and disseminated in ESA with associated capacity development**	NARES and private sector breeders, Alliance and Generation/Water CP partners, NGOs and CBOs	From 2009, partner breeders are able to use germplasm developed with ICRISAT and increase their efficiency and cost effectiveness in breeding for drought and photosensitivity in sorghum, pearl millet, chickpea and groundnut. The BECA facility is strengthened and is used by NARS scientists to build their capacity in modern breeding methods	Improved speed and cost effectiveness has been achieved in the release of abiotic stress trait-specific varieties throughout ESA which has improved productivity and profitability of small-scale dryland cropping enterprises.
Target 2009: Materials	4.3.1 (carried over from 2008) Efficiency and effectiveness of			

	Outputs	Intended Users	Outcome	Impact
	MAS for stay-green in sorghum determined			
Target 2009: Materials	4.3.2 At least one new breeding population each for GRD, ELS and rust resistance for ESA by 2009			
Target 2010: Materials	4.3.1 Efficiency of staygreen QTL introgressed into farmer preferred varieties through MAB determined in Ethiopia			
Target 2010: Other kinds of knowledge	4.3.2 Field evaluations of drought tolerance of stay-green sorghum lines evaluated using a farmer-participatory approach in Kenya			
Target 2010: Materials	4.3.3 At least 1 backcross population for each farmer preferred variety incorporating one or more sources of disease (GRD, ELS, rust) resistance or drought tolerance for use in marker assisted backcross improvement			
Target 2011: Materials	4.3.1 Segregating populations of sorghum for both photoperiod sensitivity and stay green evaluated using molecular markers			

	Outputs	Intended Users	Outcome	Impact
Output 4	**Progress in knowledge for use in developing nutritionally (micronutrient) enhanced cereals (sorghum and millets) using conventional and biotechnological approaches, and advances on studies to establish environmental risk assessments for transgenic sorghum**	NARES agronomists and breeders; NGO/CBO; GM regulatory bodies Harvest + and Africa CP partners	Partners accept proof of concept of the feasibility of conventional breeding and transgenic approaches for crop improvement using biofortification of mandate crops. NARS breeding programs incorporate improved nutritional standards as desirable goals	Improved varieties and breeding materials that combine high yield potential with enhanced micronutrient contents and resistance to biotic and abiotic stresses as well as adaptation to environment have become available to farmers thus resulting in the improved health of malnourished SAT communities.
Target 2009: Other kinds of knowledge	4.4.1 Heritability and correlations among important micronutrient traits determined in sorghum			
Target 2009: Other kinds of knowledge	4.4.2 Knowledge from geneflow studies of non-transgenic sorghum generated and provided with associated capacity development to national regulators			
Target 2009: Other kinds of knowledge	4.4.3 Farmers' knowledge on wild and weedy sorghum and implications for cultivated sorghum documented with associated capacity development for at least 2 ESA countries			
Target 2009: Other kinds of knowledge	4.4.4 Out crossing rates between sorghum and wild species determined			
Target 2010: Other kinds of	4.4.1			

	Outputs	Intended Users	Outcome	Impact
knowledge	Documentation for risk/safety assessment for GM regulatory needs drafted			
Output 5	**Technological options and knowledge to reduce aflatoxin contamination at different stages of the groundnut crop cycle developed and disseminated to partner NARES, traders and processors in ESA with associated capacity building for enhanced food and feed quality**	NARES agronomists, breeders and pathologists; policy makers, traders, processors and health professionals	Partners use low-cost diagnostic tools and make these available widely to NARES, traders and processors for monitoring human exposure to aflatoxins, and mycotoxin contamination in foods and feeds. Partners promulgate the risks of aflatoxin contaminated food and feed throughout ESA and subsequent action is taken to promote adoption of low cost technologies for reducing aflatoxin contamination in groundnut and other staple and high value crops grown in diverse farming systems	Human and animal health has been improved and enhanced market opportunities have occurred through increased production of high quality food and feed free of aflatoxin or with low aflatoxin content.
Target 2009: Other kinds of knowledge	4.5.1 Atoxigenic strains of A. flavus isolated from ESA soils			
Target 2009: Capacity	4.5.2 At least 3 trainers available in quality on-farm seed production and maintenance in at least 2 ESA NARS			
Target 2009: Capacity	4.5.3 Farmer Field School concept used with participatory farmer variety selection in adaptive trials to provide input into groundnut breeding and promote aflatoxin control			

	Outputs	Intended Users	Outcome	Impact
	practices in 2 ESA countries from 2009			
Target 2009: Capacity	4.5.4 Business plan developed for mycotoxin testing facility with associated training manuals			
Target 2010: Policy strategies	4.5.1 Role of variety/genotype contribution to aflatoxin control documented in Sorghum and groundnut in ESA			
Target 2010: Practices	4.5.2 Pre-harvest and post harvest aflatoxin control measures implemented in at least 2 countries in an annual basis by 2010			
Target 2011: Capacity	4.5.1 Farmer-friendly literature in vernacular languages (Swahili and Chichewa) on improved groundnut varieties and integrated crop management technologies available to farmers in Malawi and Tanzania			

ICRISAT-5: Producing more and better food at lower cost from staple cereals and legume hybrids in the Asian SAT (sorghum, pearl millets and pigeonpea) through genetic improvements

Project Overview and Rationale

Sorghum and pearl millet are important cereal sources of dietary energy, and pigeon pea is an important source of dietary protein in much of the Asian SAT. Sorghum and pearl millet are also valuable as fodder crops (both green forage and stover). Pigeonpea is also now recognized for its potential as a valuable forage crop. Asia is a major region for these crops, growing sorghum on 11.7 M ha, which is 28% of the global area under this crop. Pearl millet is cultivated on 12 M ha (42% of the global area). Pigeonpea, though cultivated on only 4 M ha, accounts for 90% of the global area under this crop. Productivity of all these crops is low (700-900 kg ha-1) in the SAT Asian region (as well as in other SAT regions) due to the low yield potential of farmer cultivars and numerous biotic and abiotic constraints. Synthesis of research results over the years has shown that both in sorghum and pearl millet, hybrids have 25-30% grain yield advantage over improved open-pollinated varieties of comparable maturity. There have been continuing productivity gains both in sorghum and pearl millet, largely due to the adoption of high-yielding hybrids. In pigeon pea, improved varieties have been developed and released, but the productivity has remained stagnant so far, either due to lack of their significant and repeatable yield advantage over locals, or due to lack of adoption. Pigeonpea hybrids have shown at least similar grain yield advantage over improved open-pollinated varieties as observed in sorghum and pearl millet. Development of commercially exploitable cytoplasmic-nuclear male-sterility (CMS) in pigeonpea now offers the promise of enhancing its yield potential through hybrid technology. ICRISAT's research on these crops in Asia is oriented to complement those of the NARS and the private sector by restricting its role to the development of advanced breeding lines and hybrid parents, leaving the hybrid development, testing and release to NARS and the private sector. There is limited research collaboration with NARS in key strategic research area as well. This approach has proved highly productive as reflected in the rapid and extensive uptake of ICRISAT-bred improved germplasm and potential hybrid parents of both sorghum and pearl millet by NARS and the private sector for hybrid development. The uptake of such materials in pigeonpea by NARS and the private sector has now started.

The target eco-region, the beneficiaries and end users
The target eco-region is SAT Asia, which also comprises the arid zone of India and Pakistan with large areas under pearl millet. The immediate beneficiaries of this research will be researchers in NARS and the private sector in Asia, Alliance and Generation/ Harvest + CP partners. The end users will be farming communities and seed agencies engaged in seed and grain production, urban consumers and traders, feed and food manufacturers and dairies.

Is the center the primary or secondary research provider?
ICRISAT-Patancheru has evolved into a center of excellence for hybrid parental research in all three crops (sorghum, pearl millet and pigeonpea). Thus, it is a primary supplier ofstrategic research outputs and intermediate breeding products that are pertinent to the target region in Asia and are having significant spillover effects worldwide.

Is it a catalyser, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact
ICRISAT plays multiple roles depending on the issues it addresses and the development stage of its own and of its research partners. For instance, in pigeonpea hybrid research, ICRISAT is currently playing a direct active role in developing high-yielding hybrids with farmer-acceptable traits, and coordinating their field evaluation and release through NARS and private sector. At the same time, ICRISAT is playing a catalytic role with NARS and the private sector through capacity building (including visits to their programs) to enhance the pace of hybrid development and release. Another example of a direct active role ICRISAT is playing at present

is to develop parental lines with high levels of salinity tolerance and high grain iron and zinc content in sorghum and pearl millet, and demonstrate the potential of such lines in hybrid development. ICRISAT conducts scientist field days, bringing together scientists from various research centers to enable them select breeding materials and discuss on-going and emerging research issues, thus playing facilitator and enabler roles. The scientist field days also provide opportunities to ICRISAT to seek feedback on the usefulness of ICRISAT's research products, and the prevailing and emerging preferences of farmers. This knowledge helps ICRISAT to reorient its research programs to align with emerging regional priorities.

Comparative and complementary advantage of the project activities
ICRISAT has numerous comparative advantages over other institutions in the region, in terms of well-informed and rapid access to genetic resource in its genebanks. ICRISAT's Patancheru location imparts a natural advantage over many organizations due to the favorable climatic conditions that allow 2-3 crops per year and hence rapid generation turn over. In an era of tightly defined Intellectual Property Rights, the exchange of germplasm and breeding lines is highly restricted across countries. ICRISAT has a real and demonstrable comparative advantage in the area of facilitation of germplasm exchange.

Playing a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs
ICRISAT's direct and active role in hybrid research generates a broad range of IPGs, in terms of efficient breeding and screening techniques and strategic research information; molecular markers and QTLs; genetic and cytoplasmic stocks; and improved breeding lines and hybrid parents.

Alignment to CGIAR Priorities

The research proposed in this project falls under System Priority 2 in four specific research areas: These include: Maintaining and enhancing yield potential (2A), Tolerance to selected abiotic stresses (2B), Enhancing nutritional quality and safety (2C) and Genetic enhancement of selected high-value species (2D namely sweet sorghum for ethanol production). It also has components falling under priority 3B as all these crops are essentially dual purpose food/feed. The outputs and output targets from this project are firstly regionally based but owing to the upstream nature of its breeding methods, such as its innovative use of new systems of male sterility, it has substantive IPG spillover potential at global level. 100% of the research in the project accords with Systems Priorities. It is in accordance with currently available framework plans for 2B and 2C: in the SP2B area the top priority for the CGIAR should be research and germplasm enhancement activities on enhancing abiotic stress tolerances for rainfed drought-prone cropping systems and production systems with supplementary irrigation or prevalence of extreme high temperatures. It was considered that where there were realistic options for addressing other abiotic stresses through improved agronomic practices, the CGIAR should only pursue genetic improvement activities that were completely embedded in natural resource management projects; for example, salinity tolerance in Asia. ICRISAT will increase the use of genetic resources, enhance the understanding of the underlying genetics, improve phenotyping systems, study gene and trait interactions, seek to break the association between abiotic stresses and reduced yield, use marker assisted selection, attempt to provide combined resistances to stress and where possible, undertake an holistic approach to crop improvement and provide associated capacity building (See Framework Plan 2B).

The Framework Plan indicates that the HarvestPlus Challenge Program on micronutrient enhancement is central to research on system priority 2C (Enhancing nutritional quality and safety) and one challenge at hand is to better integrate biofortification with other research aspects of nutritional quality and safety that are also underway with CGIAR institutions, such as research on microbial toxin reduction and resistance.

ICRISAT's research proposals are in direct accordance with this proposal. The 2C Framework Plan also has a bulleted list of activities and Project 5 will principally contribute to the following which are selected from the list:-

- Develop and provide access to new nutritious staple foods that are proven efficacious and meet the supply and demand needs of poor farmers who supply food to a growing population of hungry
- Contribute or adapt new methods, protocols, equipment and related technologies to global agriculture and nutrition research in the developed and developing world
- Strengthen national research systems in agriculture and health in the developing world to support the development of nutritious biofortified crops in response to targeted needs
- Enable scientists and policy makers to recognize the utility of agriculture and biotechnology in improving the health and well being of millions

Outputs Description

Changes from Previous MTP

Output 5.1 - Most of the MTP output targets remain unchanged with the exception of three outputs. The output target 2010:5.1.1. SO will be achieved a year later as the levels of shoot fly and grain mold resistance in lines identified stable for these traits are not high, although some promising lines are under conversion. Output target 2008: 5.1.1. PM was partially achieved due to lack of completion of the skeleton linkage map, which is likely to be completed in 2009. Output target 2009.5.1.3 PM will be delayed by a year because of the lack of fund to support holding the training course. Funding proposals will be developed to hold this course in 2010, which may be delayed by another year if the funding proposals do not succeed. A new output target 2011: 5.1.4 SO was added which seeks to standardize screening techniques for aphid resistance in sorghum. The transgenic research on stem borer resistance in sorghum was shifted to the Center Project 6.

Output 5.2 - There is no change in the output targets except for 2009: 5.2.2 SOPM which will be achieved two years later in 2011. Screening for foliar disease resistance is under way and it will be completed in 2009, but the materials identified for resistance need to be validated for these traits as well as for sweet stalk traits.

Output 5.3 - There is no change in the output targets except for output target 2008: 5.3.1 SOPM where the core collection of pearl millet is to be re-evaluated in 2009 to validate the previous results obtained initially from colorimetric characterization.

Output 1: **Hybrid parents and breeding lines of sorghum, pearl millet and pigeonpea with high yield potential and pro-poor traits in diverse and elite genetic backgrounds made available to defined partners with associated knowledge and capacity building in the Asian SAT**

Description: **2A: Enhancing and maintaining grain and fodder yield**
While improving yield potential, key farmer-preferred adaptation and quality traits, mostly related to maturity, and grain size and colour (cooking quality as an additional trait in pigeon pea) are taken into account. Genetic improvement of resistance to major diseases and insect pests is an integral part of yield improvement as it enhances the stability of production, and reduces the cost of production by reducing/avoiding pesticides to control diseases and insect pests. Grain mold, stem borer and shoot fly in sorghum; downy mildew in pearl millet; and wilt, sterility mosaic and pod borer in pigeonpea are the major biotic constraints that will be addressed through genetic improvement. Resistance to downy mildew in pearl millet, and to wilt and sterility mosaic in pigeon pea are mandatory, since hybrids lacking these traits can not be successfully cultivated in most regions. Marker-assisted selection (MAS) appears promising for the genetic improvement of shoot fly resistance in sorghum and downy mildew resistance in pearl millet; and its efficiency will be tested for other traits like heat, drought and salinity tolerance, and micronutrient contents.

Alignment to CGIAR Priorities : 2A: Maintaining and enhancing yields and yield potential of food staples;

Output 2: **Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeonpea with improved tolerance to abiotic stresses, made available to partners with associated knowledge and capacity building in SAT Asia**

Description: **2B. Tolerance to selected abiotic stresses**
Sorghum, pearl millet and pigeonpea are among the most drought tolerant crops because of their evolution in moisture-deficient environment. Drought and salinity are the two most serious abiotic stress factors, causing significant yield losses in all three crops. Phosphorus (P), after nitrogen, is the most critical nutrient deficiency stress factor, causing yield losses and it appears to be implicated closely in drought tolerance. Pearl millet is being increasingly grown as an irrigated summer season crop in parts of Gujarat and Rajasthan states of India, where air temperatures during flowering time in some areas can go as high as 42 degree C. Most of the hybrids fail to set seed under such conditions and ways to circumvent this constraint are being examined.

Alignment to CGIAR Priorities : 2B: Improving tolerance to selected abiotic stresses;

Output 3: **Germplasm and improved breeding lines with high and stable grain Fe and Zn content in sorghum and pearl millet hybrid parents made available to specific partners with associated knowledge and capacity building**

Description:

2C. Enhancing nutritional quality and safety
While 800 million people are classified as undernourished worldwide, the number of people affected by "hidden hunger" is two-and-a-half times that size. Three micronutrients, Fe, Zn and ß-carotene, are widely recognized as limiting by the World Health Organization (WHO). SAT Asia is a major region suffering from the deficiency of these micronutrients. Biofortification research efforts on staple food crops have been initiated and it is expected to further expand in the coming years. Hybrid parents research in sorghum and pearl millet concentrates on grain iron and zinc contents, and conducts both strategic and applied research.

Activities Exemplar

For Output target 2012 5.3.1 Effectiveness of recurrent selection for grain Fe and Zn content in pearl millet demonstrated, the following activities and milestones have been developed for internal monitoring.

2007 Milestone: Information on genetic gains from one cycle of recurrent selection for grain Fe and Zn, and its effect on grain yield and agronomic traits in two open-pollinated varieties (AIMP 92901 and GB 8735) generated

2008 Milestone: Effectiveness of one cycle of recurrent selection for grain Fe and Zn in AICMP 92901 and GB 8735 documented

2009 Milestone: Information on genetic gains from one cycle of recurrent selection for grain Fe and Zn and its effect on grain yield and in agronomic traits in two additional populations (CGP and GGP) generated

2010 Milestone: Effectiveness of one cycle of recurrent selection for grain Fe and Zn content in CGP and GGP documented

2011 Milestone: Information on genetic gains from second cycle of recurrent selection for grain Fe and Zn, and its effect on grain yield and agronomic traits in a commercial variety (ICTP 8203) generated

2012 Milestone: Effectiveness of two cycles of recurrent selection for grain Fe and Zn contents in ICTP 8203 documented

Earlier research results showed that the heritability of grain Fe and Zn was high and there was highly significant positive correlation between Fe and Zn, and that there was either positive or no correlation of Fe and Zn with grain size. As a consequence, recurrent selection for grain Fe and Zn is likely to be fairly effective, with no adverse effect on grain yield. This hypothesis is being tested on five populations which have been identified having high levels of grain Fe and Zn.

Two open-pollinated varieties (GB 8735 released in several countries in the Western and Central Africa, and AIMP 92901 released in India) for which the progenies bred for restorer line development were available, were used for an initial pilot study. From amongst the 50 progenies evaluated in each populations, nine progenies with high grain Fe and Zn content were selected separately from both AIMP 92901 (81.5-104.0 mg kg-1 Fe and 57.0-68.0 mg kg-1 Zn) and GB 8735 (78.5-104.5 mg kg-1 Fe and 57.0-59.5 mg kg-1 Zn), and random mated (half diallel) in the 2006 post rainy season. The C1 cycle bulks produced from progenies selected for high iron content [C1 (Fe)], and the one produced from progenies selected for high zinc content [C1 (Zn)], and original bulks (C0) of both the populations were evaluated for grain yield and agronomic traits in four replications during the 2006 rainy and 2007 post rainy seasons. The grain samples produced from both the seasons were analyzed to estimate Fe and Zn contents. The differences among the population bulks and their interaction with the environments were highly significant (P less than 0.01) both for grain Fe and Zn contents.

In addition, 100 S1 progenies from each of the three populations (CGP, ICTP 8203 and GGP bulk) were evaluated during the 2007 post rainy and rainy seasons to initiate recurrent selection. Grain samples of ICTP 8203 progenies from the 2007 post rainy season have been sent to CIP, Peru for comparative grain Fe and Zn estimation through NIR (Near Infra Red) Reflectance. Grain samples (25g each) from the remaining two populations evaluated during the 2007 post rainy season and rainy season are yet to be analyzed for Fe and Zn content. ICTP 8203 is a commercial open-pollinated variety grown on 0.3 million ha in India. This variety has been found to have high levels of grain Fe and Zn content. While a preliminary assessment of the effectiveness of recurrent selection to improve Fe and Zn content will be made from the 100-progeny trial mentioned above, a much larger recurrent selection program has been planned to develop its improved version with high grain Fe and Zn content, and perhaps increasing its grain yield level as well. For this, 570 plants were selfed in a breeder seed production plot during the 2007 rainy season and S1 seeds were tested for Fe content using the Perls Prussian Blue staining method. Based on the staining results, 303 S1 progenies staining deep to medium-blue (and hence likely to have high Fe content) were selected, which will be evaluated for grain Fe and Zn content using precision analysis. The progenies identified for high Fe will be random mated to produce C1 bulk, which will be subjected to another cycle of recurrent selection to produce C2 bulk. These improved bulks will be compared with the original bulk (Co) in replicated multilocational trials to assess the magnitude of genetic gain for Fe and its effect on grain yield and other agronomic traits.

Alignment to CGIAR Priorities : 2C: Enhancing nutritional quality and safety;

Output 4: **Sweet sorghum improved breeding lines with high and stable sugar and biomass made available to specific partners as hybrid parents with associated knowledge and capacity building**

Description:

2D. Genetic Enhancement of selected high-value species

In recent years, juice from sweet sorghum (Sorghum bicolor) stalks has emerged as a viable source for bioethanol production. Sweet sorghum is similar in appearance and agronomic performance to grain sorghum. It grows rapidly, is photosynthetically efficient due to its C4 metabolism, and is widely adaptable. The difference is that sweet sorghum stores much of its

photosynthate as sugar in the stalks, although it also gives reasonable grain yields. Normal grain sorghum is already grown on 11.7 million hectares in dryland Asia (28% of global sorghum area) and on 23.4 million hectares in Africa (55% of global sorghum area), and sweet sorghum could fit into these areas, producing more biomass and grain if yield enhancing technologies were stimulated by biofuel market incentives.

A crop of sweet sorghum takes about 4.5 months, and can be followed by a ratoon crop (natural second re-growth from stubble after the first crop is harvested). Together, a 1 ha of the main and ratoon crops require about 8,000 cubic meters (m3) of water, whether from rainfall or irrigation. This is less than one-fourth of that required by one crop of sugarcane (12-16 months duration and 36,000 m3 of water per crop). Sweet sorghum is grown from seed, which is less laborious than the stem cuttings used to plant sugarcane, and can be more easily mechanized. Because of this major water saving, less fertilizer, labor, and other inputs, the cost of one hectare of sweet sorghum cultivation (main + ratoon crop in 9 months) is 60% lower than for sugarcane (one crop in 9-12 months). Since poor farmers are less likely to have access to irrigation water and the capital needed to bear the cultivation costs of sugarcane, this means that sweet sorghum is more accessible to poor farmers in less water-endowed areas. Even though the ethanol yield per unit weight of feedstock is lower for sweet sorghum, the much lower production cost for this crop more than compensates, so that on the bottom line sweet sorghum still ends up with a competitive cost advantage (US$0.29 to produce one liter of ethanol from sweet sorghum, versus US$0.33 for ethanol from sugarcane). These costs of course will vary somewhat depending on a range of local production factors. Sorghum exhibits hybrid vigor and, in addition to higher biomass, good hybrids also express early maturity and photoperiod insensitivity, which means they mature over roughly the same number of months regardless of the time of year they are planted. This valuable trait allows sorghum to be planted over a wider range of planting dates as long as irrigation water is available, providing a steadier supply of feedstock to ethanol processing facilities.

Because of these strong advantages, sweet sorghum hybrid parents and hybrids are receiving high priority to help produce more feedstock per drop of water and unit of energy invested. Sorghum has an added advantage for hybrid breeding: a high ratio of seeds produced per seed planted. This makes hybrid seed production highly cost- and labor efficient, which are especially important considerations for regions like Africa. The juice and sugar productivity from sweet stalks and grain productivity potential of some of the sweet sorghum hybrids developed at ICRISAT are high. Selected hybrids are on average superior by 55% in per-day ethanol productivity and 109% superior for grain yield productivity compared to the check variety SSV 84. These results indicate the feasibility of improving stalk sugar yield (and hence ethanol yield) through hybrid breeding.

Market and constraints analysis are underway to assess the potential of sweet sorghum as a source of ethanol within a semi-arid environment. See: ICRISAT Archival Report for 2007 at www.icrisat.org.

Alignment to CGIAR Priorities : 2D: Genetically enhancing selected high-value species;

Impact Pathways by Output

Output 1: Hybrid parents and breeding lines of sorghum, pearl millet and pigeonpea with high yield potential and pro-poor traits in diverse and elite genetic backgrounds made available to defined partners with associated knowledge and capacity building in the Asian SAT

While the uptake of sorghum and pearl millet breeding lines and parental lines of hybrids with high yield potential (both grain and stover) and resistance to key biotic constraints continues to be high, and newer hybrids based on these continue to be produced, released and marketed for rainy season cultivation, lack of high levels of resistance to grain mold, stem borer and shoot fly in sorghum, and frequent breakdown of resistance to downy mildew in pearl millet,

we assume, will remain some of the greatest challenges. We assume that development of productive hybrid parents and breeding lines for the post rainy season in sorghum, and for the arid zone of north-western India in pearl millet will be somewhat slower processes than for the relatively better-endowed rainy season ecology because (i) there is less genetic variability in the germplasm having specific adaptation to these agroecologies, and (ii) NARS and the private sector have placed less emphasis, in terms of resource allocation, for hybrid development and testing.

With a pioneering role in developing parental lines of hybrids with more stable cytoplasmic-nuclear male sterility, ICRISAT continues to have the leading edge and provides capacity development (including in the support of higher degree student research) in demonstrating the yield advantages of hybrids over varieties in pigeonpea, and have also developed a fully economic seed production technology for this crop. With the hybrid yield advantage over varieties being at least as much as in sorghum and pearl millet, rapid adoption of pigeonpea hybrids is expected (especially in the early and medium-maturity groups), the more so considering the growing shortage and rising prices of pigeonpea in India. We assume the large Indian national deficit in pulse production will continue in the short term. However, ICRISAT and its partners are making a large effort to ensure that this assumption is eventually invalidated. The Indian Council of Agricultural Research (ICAR) Institutes, State Agricultural Universities (SAUs), and private seed companies (PSCs) in India, are major partners in, and major beneficiaries of, the research products and scientific information. In recent years, forage quality and quantity research (done in partnership with NARS and ILRI) has received relatively greater attention than in the past. Scientist Field Days to promote dissemination of breeding products and new/refined technologies, and consultation meetings to invite partners views and feedback on new challenges and opportunities, and ways to strengthen the partnerships, including capacity building for their participation in impact assessment, are held in alternate years. Research information and products are also disseminated through presentation of paper/posters in conference, symposia and workshops; research articles in peer-reviewed journals and in ICRISAT reports. The impact of ICRISAT research is measured in terms of the existing on-farm diversity of hybrids based on ICRISAT-bred materials, increased capacity of NARS and the private sector (reflected in wider and more productive germplasm base of their programs and enhanced skills), and increase in productivity of these crops and the associated livestock.

Output 2: Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeonpea with improved tolerance to abiotic stresses, made available to partners with associated knowledge and capacity building in SAT Asia

Almost entire work,limited to sorghum and pearl millet, under this output is in the strategic research area to generate better understanding of abiotic stress tolerance and to identify sources of tolerance for use in breeding programs. The NARS and the private sector, though interested in drought and heat tolerance research, allocate little or no resources to these research areas, and hence depend largely on ICRISAT to generate strategic research outputs and identify/develop improved breeding lines and hybrid parents with tolerance to these traits, which they can use in their hybrid breeding programs. Both NARS and private sector, the more so the latter, are active collaborators in these research areas in terms of evaluating ICRISAT-bred lines. Research on salinity tolerance and P acquisition efficiency is currently of no interest to the NARS and private sector in Asia. ICRISAT conducts salinity research in collaboration with the International Center for Biosaline Agriculture (ICBA) for identifying salinity tolerant lines and populations. ICBA undertakes on-station and on-farm testing of the materials under saline conditions in the Middle East to identify lines and populations adapted to such conditions, and for dissemination of materials identified tolerant to soil salinity. It is assumed that as the awareness of the impact of salinity in the major pearl millet growing regions of Asia builds up over time and the need for addressing this problem through genetic improvement is realized, the knowledge and materials generated from the current research will find applications in the breeding programs in the major pearl millet growing regions of Asia in the longer term. The knowledge generated from P acquisition research on pearl millet will be an important input to guide the breeding program for this trait in the Western and Central Africa.

Output 3: Germplasm and improved breeding lines with high and stable grain Fe and Zn content in sorghum and pearl millet hybrid parents made available to specific partners with associated knowledge and capacity building

Till 2008, NARS and the private sector had shown no interest in biofortification research. However, due to recent promising results from ICRISAT research in sorghum and pearl millet, the more so in pearl millet, there is now better appreciation of the Fe and Zn in nutritional security and its implication in genetic improvement for these micronutrients.

NARS and some of the seed companies have now shown interest in conducting joint research with ICRISAT for the genetic enhancement of Fe and Zn content in pearl millet, with their roles largely confined to conducting field trials of ICRISAT-bred materials for the next 2-3 years to evaluate them for grain yield potential, DM resistance, and Fe and Zn contents. Such a network program would permit ICRISAT to identify lines stable for high levels of Fe and Zn and then to use them in breeding program at ICRISAT. This research strategy would gradually build higher levels of Fe and Zn content in ICRISAT-bred materials which NARS and seed companies would select during the Scientists Field Days held at ICRISAT for use in their own hybrid breeding programs.

Output 4: Sweet sorghum improved breeding lines with high and stable sugar and biomass made available to specific partners as hybrid parents with associated knowledge and capacity building

Germplasm accessions and hybrid parents developed for grain and/or forage development have so far been used to develop sweet sorghum hybrid parents. Now, sweet stalk sources are being increasingly used for this purpose. Other activities include the development and application of best-bet practices of cultivation of sweet-stalk sorghum and capacity development of stakeholders, scientists of national programs—both public and private seed sectors and NGOs and entrepreneurs in villages and distilleries that are interested in using the sweet-stalk sorghum for production of ethanol. It is assumes that these technologies will be used by national program scientists—both public and private seed sectors—and the impact will be generated by linking farmers with the distilleries, enhanced skills of farmers and NGO staff in cultivation of sweet sorghum, enhanced entrepreneur skills development among farmers, and private sector players in byproduct development and NGOs, enhanced knowledge of government officials on policy changes required to promote ethanol production, and ethanol production from sweet-stalk sorghum.

International Public Goods

- Breeding products of all three crops, tested in and released for specific eco-regions in India and for agro-ecologies with parallel adaptation worldwide
- Sorghum and pearl millet breeding products and research information related to hybrid parents and hybrid development
- Pigeonpea hybrid technology start-up support in Asia (eg. in India, China and the Philippines)
- Hybrids with high seed yield in pigeonpea, high sugar yield in sorghum, and high forage yield both in sorghum and pearl millet for potential technology testing rather than product development
- The parental lines of potential hybrids and improved breeding lines with high yield potential and resistance to biotic stresses (grain mold, stem borer, and shoot fly in sorghum; downy mildew in pearl millet; and wilt and sterility mosaic in pigeonpea) and apparent grain quality traits
- Breeding lines, hybrid parents, improved populations and gemplasm with high forage yield, and high levels of salinity tolerance and grain iron and zinc contents in sorghum and pearl millet; high-temperature tolerance and P-uptake efficiency in pearl millet; seed parents and restorers of diverse CMS systems in all three crops
- Mapping populations and QTLs for drought and salinity tolerance (with project 2), grain Fe and Zn in sorghum and pearl millet. Information on the efficiency and effects of QTLs pyramided for drought tolerance in sorghum, and drought tolerance and downy mildew resistance in pearl millet, and genetics of CMS systems and trait-associations in all three crops

Elaboration of Partners Roles

In hybrid parents research under this project, partner roles are very well defined with little overlap. ICRISAT will largely undertake targeted germplasm evaluation and introgression into elite genetic backgrounds, generate improved breeding lines and hybrid parents using multiple research tools, and undertake strategic research in the areas of screening techniques and breeding methodologies to enhance breeding efficiencies. ICAR and SAU partners collaborate in evaluating trait-based nurseries (also pigeonpea hybrids and forage hybrids of sorghum and pearl millet) annually constituted at the partners requests under the umbrella of the ICAR-ICRISAT Partnership Research Projects. NARS and the PSC partners (including National and State Seed Corporations) will make use of ICRISAT-bred materials either directly in hybrid development, or in breeding their own parental lines of hybrids, which they will test, release and market. It is assumed that in creating their own hybrids from any single ICRISAT parent, the seed company will be creating a novel product and thus gaining its own IPR. These partners will also provide technical inputs in terms of the emerging new challenges and opportunities with respect to changing agricultural systems and farmers/consumers preferences. They are now becoming increasingly involved in impact assessment, resource mobilization, and capacity building (both as partners and as resource persons). For example, 40 PSCs now support hybrid parents research of these crops in a consortium framework through financial contributions under a 5-year (renewable) agreement to address the core research agenda of the institute and place all the breeding products and research information in the domain of IPGs. Our other partners include ARIs (eg. National Institute of Nutrition, India, sharing project resources; and University of Georgia, USA, using their own resources) who provide basic research components or provide services in the areas requiring specialized expertise and/or expensive capital items. Other international research centers, such as ILRI partner with us in forage quality analysis and research, and ICBA partners with us in salinity tolerance testing of lines both in pot culture and in saline locations. These partners are also involved in resource mobilization through joint project proposal development to support these research activities. Partnerships have recently expanded beyond SAT Asia, into China (pigeonpea) and Central Asia (sorghum and pearl millet), who will initially be recipients of crop technologies, with the prospects being favorable of them developing into active partners

for resource mobilization and resource-sharing in the medium term. This project is linked to the SLP SWEP.

Key Strategic Alliances: Hybrid Parents Research Consortium for access to their information and marketing networks, ICAR for partnership and support with a large range of Indian research institutions, ILRI/SLP and ICBA (for support on livestock feed and salinity issues respectively).

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**Hybrid parents and breeding lines of sorghum, pearl millet and pigeonpea with high yield potential and pro-poor traits in diverse and elite genetic backgrounds made available to defined partners with associated knowledge and capacity building in the Asian SAT**	NARS breeders, private seed companies and ARI, Generation CP, SLP SWEP, and Alliance partners	NARS and private sector partners use hybrid parents in the development of their own hybrids and these are successfully evaluated in multi-location yield trials Breeding lines are utilized to diversify the genetic base of partner breeding programs	Higher-yielding and more genetically diverse hybrids have been bred and released for specific target niches. Sustained annual growth in productivity in sorghum and pearl millet has occurred and pigeonpea hybrids are grown on at least 100,000 ha in Asia by 2015
Target 2009: Other kinds of knowledge	5.1.1 SO Insect-host genotype-natural enemy interactions and mechanisms of resistance and inheritance clarified (associated with the SP-IPM SWEP)			
Target 2009: Materials	5.1.2 SO Dual-purpose foliar disease resistant forage/sweet sorghum hybrid parents developed (associated with the SLP SWEP)			
Target 2009: Capacity	5.1.3 SO More than 25 scientists and technicians trained in sorghum improvement through an international training course			
Target 2009: Other kinds of knowledge	5.1.4 SO Two major putative QTL for stem borer resistance identified			

	Outputs	Intended Users	Outcome	Impact
Target 2009: Practices	5.1.5 SO Techniques to screen for resistance to aphids and shoot bug standardized			
Target 2009: Materials	5.1.1 PM Two improved populations of pearl millet with high forage yield potential developed			
Target 2009: Other kinds of knowledge	5.1.2 PM Virulence changes in Indian pearl millet downy mildew populations characterized			
Target 2009: Materials	5.1.3 PM At least five each of blast and rust resistance sources identified			
Target 2009: Capacity	5.1.5 PM Two PhD scholars complete their dissertation research			
Target 2009: Materials	5.1.1 PP At least 15 high-yielding pigeonpea hybrids and a short-duration determinate male-sterile line made available to NARS partners			
Target 2009: Other kinds of knowledge	5.1.2 PP Elite pigeonpea hybrid parents characterized for important agronomic traits and molecular diversity			
Target 2009: Other kinds of knowledge	5.1.4 PM QTL mapping of downy mildew (DM) resistance in five F6 RIL populations completed (Skeleton linkage map which			

	Outputs	Intended Users	Outcome	Impact
	could not be completed in 2008 will be completed to identify the QTL for DM resistance)			
Target 2010: Other kinds of knowledge	5.1.3 SO Two F RIL 6 populations developed and QTL for traits associated with grain mold resistance identified			
Target 2010: Capacity	5.1.2 SO At least 30 scientists participate in Sorghum Field Day and select more than 300 breeding lines			
Target 2010: Materials	5.1.1 PM At least 5 each of pearl millet seed and restorer parents adapted to arid conditions developed			
Target 2010: Other kinds of knowledge	5.1.2 PM Genetics of four diverse CMS systems documented			
Target 2010: Capacity	5.1.3 PM More than 30 scientists develop pearl millet research and development skills through an international training course			
Target 2010: Other kinds of knowledge	5.1.5 PM Effect of putative QTLs identified for stover yield and quality on these traits in two genetic backgrounds assessed			
Target 2010: Other kinds of	5.1.1 PP			

	Outputs	Intended Users	Outcome	Impact
knowledge	Consensus molecular marker and genetic linkage maps developed and shared with partners			
Target 2010: Materials	5.1.2 PP At least three short-duration determinate male-sterile lines and 10 hybrids made available to NARS partners			
Target 2010: Capacity	5.1.3 PP Two Masters students and 50 scientists and technicians from NARS and private sector trained in pigeonpea breeding			
Target 2010: Capacity	5.1.4 PM More than 50 scientists participate in Pearl Millet Field Day and select more than 600 breeding lines			
Target 2011: Materials	5.1.1 SO At least six high- yielding and large- seeded male- sterile lines with resistance to shoot fly and grain mold (3 each) developed (The levels of SF and GM resistance are not high in the stable lines but some promising material is under conversion)			
Target 2011: Other kinds of knowledge	5.1.2 SO Relationship between grain and stover yield heterosis and genetic diversity of parental lines assessed			
Target 2011: Other kinds of	5.1.3 SO			

	Outputs	Intended Users	Outcome	Impact
knowledge	Two putative QTLs for traits associated with grain mold resistance identified from two mapping populations			
Target 2011: Materials	5.1.1 PM At least 40 improved breeding lines with resistance to blast and rust (20 each) developed			
Target 2011: Other kinds of knowledge	5.1.2 PM Recurrent selection response for stover quality assessed			
Target 2011: Other kinds of knowledge	5.1.3 PM Relationship between grain and stover yield heterosis and genetic diversity of parental lines documented			
Target 2011: Materials	5.1.1 PP Seven medium-duration male-sterile lines made available to NARS and private sector for use in hybrid development			
Target 2011: Capacity	5.1.2 PP One PhD scholar and 35 scientists and technicians from NARS and seed sector trained in pigeonpea breeding			
Target 2011: Other kinds of knowledge	5.1.4 SO Techniques to screen for aphid resistance standardized			
Target 2011: Materials	5.1.1 SO Atleast four large-seeded			

	Outputs	Intended Users	Outcome	Impact
	postrainy season-adapted male-sterile lines developed.			
Output 2	**Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeonpea with improved tolerance to abiotic stresses, made available to partners with associated knowledge and capacity building in SAT Asia**	NARS breeders, private seed companies, ARI, ICBA, ILRI, Generation CP and Alliance partners	NARS and private sector consortium partners make initial use of improved breeding lines with tolerance to abiotic stress factors in breeding programs	Adoption by farmers of high-yielding hybrids with improved abiotic stress tolerance by 2015 has improved productivity and profitability substantially in dry and salt affected areas in Asia
Target 2009: Other kinds of knowledge	5.2.1 SOPM Physiological mechanisms explaining the stay-green trait dissected in sorghum near-isogenic lines with stay-green QTLs			
Target 2010: Other kinds of knowledge	5.2.1 SOPM Relationship between yield under terminal drought stay-green and root-related traits established in sorghum			
Target 2010: Materials	5.2.2 SOPM At least three pearl millet lines/parental lines with flowering-period heat tolerance at air temperatures exceeding 42ºC identified (new output target)			
Target 2010: Other kinds of knowledge	5.2.3 SOPM Mapping and introgression of stay-green QTLs into elite			

	Outputs	Intended Users	Outcome	Impact
	parental lines, and assessment of their effects on hybrid performance completed			
Target 2011: Materials	5.2.2 SOPM Dual-purpose stay-green and foliar disease resistant forage/sweet sorghum hybrid parents developed (partly associated with the SLP SWEP) (The screening for foliar disease resistance is underway. The material need to be validated for sweet stalk traits and foliar disease resistance)			
Target 2011: Other kinds of knowledge	5.2.1 SOPM Relationship between yield under terminal drought and root-related traits established in pearl millet			
Target 2011: Materials	5.2.2 SOPM At least four parental lines of sorghum and six parental lines and populations of pearl millet with salinity tolerance developed/identified			
Output 3	**Germplasm and improved breeding lines with high and stable grain Fe and Zn content in sorghum and pearl millet hybrid parents made available to specific partners with associated knowledge and capacity building**	NARS breeders, private sector partners, ARIs, ILRI, Harvest + and Alliance partners	High grain Fe and Zn content lines used by partners in breeding programs	Farmers have increased product quality and nutritional value of pearl millet and sorghum in SAT Asia by 2015, thus reducing malnutrition amongst disadvantaged SAT communities

	Outputs	Intended Users	Outcome	Impact
Target 2009: Materials	5.3.1 SOPM At least five sorghum germplasm hybrid parental lines with high Fe (greater than 50 ppm) and Zn (greater than 40 ppm) identified and made available to partners			
Target 2009: Other kinds of knowledge	5.3.1 SOPM Variability of Fe and Zn in core collection of the germplasm assessed in pearl millet (Large number of core germplasm accessions screened for grain Fe and Zn contents. It needs validation)			
Target 2010: Other kinds of knowledge	5.3.2 SOPM Comprehensive information on genetics of grain Fe and Zn content in sorghum and pearl millet generated			
Target 2011: Materials	5.3.1 SOPM At least 10 germplasm accessions of sorghum from core collection with greater than 60 ppm grain Fe and greater than 40 ppm Zn content identified			
Target 2011: Materials	5.3.2 SOPM At least six improved breeding lines of pearl millet with greater than 90 ppm grain iron and greater than 60 ppm Zn developed			
Target 2011: Materials	5.3.3 SOPM At least two high-yielding hybrids of pearl millet with greater than 70 ppm Fe and			

	Outputs	Intended Users	Outcome	Impact
	greater than 50 ppm Zn developed			
Output 4	**Sweet sorghum improved breeding lines with high and stable sugar and biomass made available to specific partners as hybrid parents with associated knowledge and capacity building**	NARS breeders, private sector partners, ARIs, and Alliance partners including ILRI and the SLP SWEP	Highly sweet hybrid parental lines used by partners in breeding programs	Sweet sorghum has become an economically viable, pro-poor biofuel
Target 2009: Capacity	5.4.1 SO More than 25 farmers training in sweet sorghum ethanol value chain	NARS breeders, private sector partners, ARIs, and Alliance partners including ILRI and the SLP SWEP.	Highly sweet hybrid parental lines used by partners in breeding programs	Sweet sorghum has become an economically viable, pro-poor biofuel
Target 2010: Materials	5.4.1 SO First generation of improved hybrid parents available to consortium partners for testing with associated capacity development (associated with the SLP SWEP)			
Target 2011: Capacity	5.4.1 SO More than 25 scientists trained in sweet sorghum hybrid parents development through an international training course			

ICRISAT-6: Producing more and better food at lower cost from staple open-pollinated cereals and legumes in the Asian SAT (sorghum, pigeonpea, chickpea and groundnut) through genetic improvements

Project Overview and Rationale

This project is extremely relevant for the semi-arid tropics (SAT) in Asia, where many farmers either cannot afford to buy hybrids and depend on seed of improved cultivars. There is little possibility of developing hybrids for commercial exploitation in chickpea and groundnut in the near future. Even in the case of sorghum and Pigeonpea, where commercial hybrids are available, nearly 30 to 40% area will continue to be under open-pollinated varieties. Varieties will also continue to be popular with farmers because of their fodder value or specific adaptation requirements (nearly 5.5 million ha in sorghum). ICRISAT mandate crops are important for food and nutritional security under rainfed subsistence farming conditions in Asia, which provide sustenance to the largest number of poor people in the world. Globally, Asia accounts for nearly 80% of the area in chickpea (~10 m ha), 90% in pigeonpea (~4 m ha), 55% in groundnut (~13 m ha), 35% in pearl millet (~12 m ha), and 25% in sorghum (~11 m ha). The pro-poor outputs of this project, although regionally oriented, have the potential to have spillovers for major impacts on the MDGs in Africa and other regions, as Asian bred chickpea and pigeonpea varieties are well adapted in eastern and southern Africa (links to Project 4), and thus, are seen by ICRISAT as producing both Substantive Public Goods (SPGs) and IPGs for food and nutritional security in the SAT. The project is in full accordance with ICRISAT's strategic plan and concentrates, where possible, on upstream pre-varietal release research, while the downstream elements are executed in full collaboration with partner NARS in Asia and SSA.

The target eco-region, the beneficiaries, and end users
The main target is the SAT in Asia. However, the other regions in Asia, where these crops are grown or have potential to be grown, will also benefit from the outputs of this project. Some of the outputs from this project will also have spill over effects in Africa [sorghum, pearl millet, and groundnut in East, southern and West Africa (links to Project 3 and 4), and groundnut, chickpea and pigeonpea in East and southern Africa]. The immediate beneficiaries of the outputs of this project are crop improvement scientists in NARES, public and private seed companies and Alliance and CP partners, the SLP SWEP, NGOs and CBOs. The end users and ultimate beneficiaries of the products of the project are the small-scale farmers of Asia (also SSA), the food processing industries, the dairy and livestock industry, and the poor rural and urban consumers.

Is the center the primary or secondary research provider?
ICRISAT is the primary or co-primary research provider, depending upon the strength of the NARES, the seed industry, and the NGOs.

Is it a catalyst, facilitator, enabler and/or advocate to influence the impact pathway and thereby ensures outcomes and impact
ICRISAT plays all of these roles for sustaining the chain of developing, high yielding pest and drought resistant cultivars, and seed production and distribution systems. It plays both a catalytic and enabling role by supplying nucleus and breeder seed to public/private sector seed agencies. ICRISAT also plays a strategic role through capacity building and by making available improved techniques in crop improvement and biotechnology, germplasm, and breeding materials to public and private institutions in the SAT. ICRISAT also plays a facilitator role by managing and coordinating networks that bring NARES breeders and other scientists together on a common platform. By demonstrating the benefits of participatory research and development, ICRISAT is able to influence the policies and practices in agricultural research and development at the local, national, and regional levels. ICRISAT also keeps the momentum going for research in these crops (particularly with respect to host plant resistance

to biotic and abiotic stresses), which usually requires a long-term regional effort, that only a stable international institution can provide.

Comparative and complementary advantage of the project activities
Framework Plan 5 B states that The CGIAR centers have a comparative advantage in many aspects of abiotic stress research because of their germplasm collections, their capacity for genetic, molecular and physiological dissection of complex traits, and their potential to conduct multidisciplinary plant improvement programs for specific target environments. Similarly, the CGIAR is considered a credible convener and coordinator, as a natural leader and nucleation point, of international research consortia and networks across disciplines, sectors and regions (both developed and developing). ICRISAT is adopting such a role and sees its comparative advantage in its well-established competence in genetic enhancement involving conventional breeding, marker-assisted selection, and genetic engineering; phenotyping for resistance to insect pests, and disease, tolerance to abiotic stresses, development of diagnostic tools for mycotoxins and viruses, bioinformatics supported by multidisciplinary teams of experienced scientists having informed access to world collection of germplasm, excellent laboratory, greenhouse, and field facilities; and the necessary infrastructure supported by competent staff to carryout high quality research.

Further, ICRISAT has excellent rapport with all the NARES in the region, and complements the stronger NARES such as India and China in carrying out joint research and development, and also helps in bringing together the stronger and the less developed NARES. ICRISAT- ILRIs collaboration in developing dual-purpose varieties of sorghum, pearl millet, groundnut, and pigeonpea is trend-setting as these CGIAR centers complement each other in their respective areas. The international public good (IPG) nature of ICRISAT's products gives it an added advantage to collaborate with public and private sector institutions, NGOs, CBOs, village self help groups, and is seen to be politically neutral, and acceptable to all in the SAT. The Institute has noted the SCs desire (2006 Commentary) for ICRISAT to delegate its strategic stress-resistance breeding of non-hybrid crops to strong national programs in Asia such as India and China. ICRISAT believes that this is an unsafe rationalization and does not accord with the reality on the ground experienced by ICRISAT, and clearly articulated to the institution by its NARS partners. Suffice to say that the transfer of improved genetic material (in both hybrids and non-hybrids) does not occur easily across national boundaries from the strong to the weak NARS without the impetus and active involvement of ICRISAT. India and China evidently are strong NARS capable of fully independent breeding programs in crops such as rice and wheat. However, this position is less demonstrably clear for the more minor crops and in providing resistance to the extremely virulent and fast mutating pathogens capable of causing chronic epidemics (downy mildew in millet, Ascochyta blight in chickpea, etc.) against which ICRISAT provides a continuing bulwark for resource-poor farmers. There remains a continuing demand for ICRISAT's strategic trait-specific and pest and disease resistant breeding material from both large and small NARS partners and we believe this is a vital strategic role for ICRISAT.

Impact Pathway

We assume that high-yielding cultivars (often dual-purpose food/feed) with resistance/tolerance to biotic/abiotic stresses, adaptation to diverse agro-ecosystems, technologies, knowledge, and capacity building of the NARES and the private sector delivered through networks will help translate research outputs into outcomes. Scientists field days, training programs for evaluating germplasm, breeding materials, mapping populations, and transgenic plants for resistance to insects, diseases, and drought; tissue culture and transformation, marker-assisted selection, mycotoxin and pathogen detection, and support of higher degree students will help in capacity building to overcome this risk and improve NARS abilities in accelerated crop improvement in SAT Asia. We also assume that the NARES, public and private seed industry, and NGOs will select the improved material/technologies developed by ICRISAT, and test and release/use the varieties/technologies for adoption by the farmers. Other recipients of technologies and germplasm include partners in the Generation and Harvest Plus Challenge Programs, ILRI, ICBA and the ARIs. This will further help in the development and transfer of technology to the poor farmers growing these crops under rainfed, subsistence farming conditions globally in general, and Asia in particular, and help

improve crop productivity, food security and nutrition, and increase farm incomes in Asia and other regions in the SAT. The VASAT Consortium will be a major player in information dissemination (Project 10). A Network Map has been developed for this project and is shown in the 2008-2010 MTP document.

Alignment to CGIAR Priorities

This project is in accordance with System Priority 2A- Specific Goal 2 (pro-poor traits), Priority 2B (selected abiotic traits), and Priority 2C (nutritional quality and safety). It focuses on open-pollinated varieties of staple cereals (sorghum and pearl millet) and self- pollinated varieties of legumes (pigeonpea, chickpea, and groundnut), and nutritional quality and safety as international public goods. It also includes the work under system priority 3B (income increase from livestock), as all these crops are essentially dual-purpose food/feed crops. It is in accordance with currently available framework plans for 2B and 2C: in the SP2B area the top priority for the CGIAR should be research and germplasm enhancement activities on enhancing abiotic stress tolerances for rainfed drought-prone cropping systems and production systems with supplementary irrigation or prevalence of extreme high temperatures. It was considered that where there were realistic options for addressing other abiotic stresses through improved agronomic practices then the CGIAR should only pursue genetic improvement activities that were completely embedded in natural resource management projects; for example, salinity tolerance in Asia. ICRISAT will increase the use of genetic resources, enhance the understanding of the underlying genetics, improve phenotyping systems, study gene and trait interactions, seeks to break the association between abiotic stresses and reduced yield, uses marker assisted selection, attempts to provide combined resistances to stress, and where possible, undertakes an holistic approach to crop improvement and associated capacity building (See Framework Plan 2B).

For Priority 2C, the Framework Plan indicates that the HarvestPlus Challenge Program on micronutrient enhancement is central to research on system priority 2C (Enhancing nutritional quality and safety) and one challenge at hand is to better integrate biofortification with other research aspects of nutritional quality and safety that are also underway with CGIAR institutions, such as research on microbial toxin reduction and resistance. ICRISAT's research proposals are in direct accordance with this proposal. The 2C Framework Plan also has a bulleted list of activities, and Project 6 will principally contribute to the following which are selected from the list:

- Develop and provide access to new nutritious staple foods that are proven efficacious and meet the supply and demand needs of poor farmers who supply food to a growing population of hungry
- Contribute or adapt new methods, and protocols related technologies to global agriculture and nutrition research in the developed and developing world
- Strengthen national research systems in agriculture and health in the developing world to support the development of nutritious biofortified crops in response to targeted needs
- Enable scientists and policymakers to recognize the utility of agriculture and biotechnology in improving the health and well being of millions

Outputs Description

Changes from Previous MTP

The project structure for ICRISAT was re-worked in 2006 and has not changed since then. The outputs have changed slightly.

Problem analysis, identification of specific problems that can be tackled by research focused on specific objectives

Output 6.1 - The outputs have not changed since the project structure was re-worked in 2006, except for slight change in the timeline of some output targets.

Output 6.2 - The outputs have not changed since the project structure was re-worked in 2006, except for slight change in the timeline of some output targets.

Output 6.3 - The outputs have not changed since the project structure was re-worked in 2006, except for slight change in the timeline of some output targets.

Output 1: **Improved germplasm and varieties of sorghum, pigeonpea, chickpea and groundnut with pro-poor traits and associated advanced knowledge of breeding methods and capacity building made available to partners internationally**

Description:

Priority 2A, Specific Goal 2: Identification and development of pro-poor traits

Crop (and system) productivity in the SAT remains low due to several biotic and abiotic stress factors. The major constraints to increase crop productivity for sustainable crop production in different crops are discussed below, along with research interventions to alleviate these stresses.

Sorghum: Need to develop varieties with resistance to grain molds, shoot fly, stem borer, aphids, and terminal drought. In addition, there is need to develop dual-purpose cultivars with pearly white grain and adaptation to different agro-ecosystems. Introgression of genes for resistance to different stresses/quality traits from the cultivated germplasm and wild relatives, marker-assisted selection for resistance to shoot fly, stem borer, and grain molds, and genetic engineering for resistance to stem borer are the major areas of research focus to alleviate these stresses. It is also necessary to identify sorghum lines which are able to thrive under low fertility conditions, in particular low P soils.

Groundnut: Need to have varieties with resistance to late leaf spot (LLS), rust, aflatoxin, peanut bud necrosis, peanut stem necrosis, leaf miner, and thrips; combined with high oil content, confectionery traits, and local adaptation to diverse agroclimatic conditions. Exploitation of cultivated germplasm and wild relatives for resistance genes/quality traits, and marker-assisted selection for resistance to leaf diseases, and genetic engineering for resistance to leaf diseases, viruses, and aflatoxins are the major interventions to alleviate these stresses.

Chickpea: Need to develop varieties with resistance to Fusarium wilt (mandatory), Ascochyta blight, Botrytis gray mold, and Helicoverpa. In addition, there is a need to develop extra-large seeded kabuli types responsive to inputs and adaptation to a wide range of environments. Major emphasis has been placed on exploitation of cultivated germplasm and wild relatives for resistance to diseases and Helicoverpa, and marker-assisted selection for resistance to Ascochyta blight, wilt, and Helicoverpa, and genetic engineering for resistance to Helicoverpa.

Pigeonpea: Need to develop varieties with resistance to Fusarium wilt, sterility mosaic disease, and Helicoverpa in medium-, short-, and extra-short maturity, and with adaptation to a wide range of environments. Exploitation of cultivated germplasm for resistance to diseases, and wild relatives for resistance to Helicoverpa, and genetic engineering for resistance Helicoverpa are the major focus of research to alleviate these stresses.

Alignment to CGIAR Priorities : 2A: Maintaining and enhancing yields and yield potential of food staples;

Output 2: **Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate drought and salinity tolerance breeding and germplasm of legume mandate crops and associated capacity building made available to partners internationally**

Description:

Priority 2B: Tolerance to selected abiotic stresses

Among the abiotic stresses, drought is the most significant constraint due to limited and unpredictable nature of rainfall in the SAT. Salinity is, next to drought, among the most severe abiotic stresses in Asia, in particular in irrigated areas where continuous irrigation has increased the levels of salt in agricultural lands. Salinity will become even more prominent with climate change.

Drought: Drought avoidance (which we encapsulate in either a better water use or a better water capture) is the major trait that needs to be addressed to stabilize and improve the production of varieties in sorghum, pearl millet, groundnut, and chickpea in Asia. The major emphasis has been placed on marker-assisted selection for tolerance to drought, using a trait-based approach where both water capture and water use efficiency are the main targets. To improve these traits, a transgenic approach is also used in groundnut and chickpea, where the use of transcription factor and few other genes involved in drought response is showing promising results. Transgenics are also useful to understand the physiological response of plants to drought, generating a knowledge that can be applied to drought research on germplasm.

Salinity: Soil salinity is another limiting factor for improving crop productivity. Legumes, in general, are more sensitive to soil salinity than cereals. The salinity problem is increasing in many areas where poorly-managed irrigation is a common practice. Exploration of a large set of representative germplasm in all mandate crops of ICRISAT has indicated a large variation for salinity tolerance, and that breeding for salt tolerance is possible. Being a complex trait, the breeding of salt tolerant varieties would benefit from marker-assisted selection.

Activities Exemplar

One of the 2011 Output Targets (2011 6.2.2 CP) declared for chickpea is Transgenic DREB/P5CSF events available for introgression into locally adapted germplasm in India.

This results in an activity at the center which is reported, with its internal milestones in the Center Archival Report for 2008.

The activity is Develop and evaluate chickpea transgenic events for enhanced tolerance to drought stress

2008 Milestone: At least 8 promising transgenic events of chickpea containing DREB1A or P5CSF genes identified and their drought tolerance characterized under contained greenhouse conditions

2009 Milestone: Three promising transgenic events of chickpea identified for drought tolerance and characterized under contained field conditions

2011 Milestones: Transgenic DREB/P5CSF transgenic events available for introgression into locally adapted genotypes

The report for the 2008 internal milestones provides additional detail of the precise activities undertaken and was: Genetic engineering of chickpea for enhanced tolerance to water stress was previously carried out using the osmoregulatory P5CSF129A gene and DREB1A transcription factor that acts as a major “switch” triggering a cascade of genes in response to a given stress. Forty-eight chickpea events with 35S:P5CSF129A and 18 events carrying rd29A:DREB1A were developed and advanced to subsequent generations. Southern analysis of the tested events indicated a low copy number (1-2 copies) in the 35S:P5CSF129A transgenics, whereas most of the events carrying rd29A:DREB1A had only a single copy of the transgene. The phenotyping of 10 selected transgenic events each of rd29A:DREB1A and 35S:

P5CSF129A in T5 generation was carried out in dry-down experiments in lysimetric system under greenhouse conditions, where several events exhibited a diversity of stress response patterns, especially with respect to the NTR-FTSW relationship and water use efficiency. The transgenic events differed in response of NTR to FTSW, where their transpiration started declining at lower FTSW values (drier soil) under drought stress. This pattern was essentially the same as observed in the previous dry-down experiments. Five transgenic events (P8, RD10, RD9, RD7 and RD2) along with the nontransformed control were evaluated for their response to terminal drought conditions in greenhouse. The component traits of yield were studied viz., cumulative transpiration, TE, yield (shoot, pod and seed) and HI. However the results indicated no significant differences across transgenic lines as well in comparison to C235 both under well-watered and terminal drought conditions. All the genotypes showed a similar response to terminal drought stress under these conditions. We plan to repeat this experiment in the next season for assessing the component traits and the root responses of these selected events. Seed multiplication and maintenance of desirable transgenic events in T6 generation has been carried out and the plants are being characterized at molecular level to ascertain homozygosity. Additional marker free transgenic events of chickpea carrying rd29A:DREB1A are also being produced.

Alignment to CGIAR Priorities : 2B: Improving tolerance to selected abiotic stresses;

Output 3: **Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate biofortification and biodetoxification breeding, improved germplasm of pearl millet, sorghum, groundnut and pigeonpea crops and associated capacity building made available to partners internationally**

Description:

Priority 2C: Enhancing nutritional quality and safety

Food security and malnutrition are a serious problem amongst a large number of the poor in the SAT. ICRISAT is focusing its research on developing technologies that improve the nutritional quality and vitamin status of its mandate crops. Introduction of crop varieties with high Fe, Zn, and beta-carotene concentrations will complement existing approaches to combat micronutrient/vitamin deficiency among the poor in Asia SAT. To reduce mycotoxin contamination, ICRISAT emphasizes integrated crop management involving resistant cultivars, biological control, appropriate pre- and post-harvest technologies that reduce the risk of contamination by mycotoxins, and genetic engineering for resistance to aflatoxin; and development of low-cost diagnostic tools for monitoring mycotoxins in food and feed. Emphasis has also been placed on developing environmental friendly pest management technologies, use of transgenic crop for pest management and their bio-safety to the non- target organisms.

Alignment to CGIAR Priorities : 2C: Enhancing nutritional quality and safety;

Impact Pathways by Output

Output 1: Improved germplasm and varieties of sorghum, pigeonpea, chickpea and groundnut with pro-poor traits and associated advanced knowledge of breeding methods and capacity building made available to partners internationally

We would develop breeding materials with improved yield potentials and enhanced resistance to abiotic and biotic stresses and market-preferred seed traits through conventional and biotechnological (marker-assisted breeding and transgenic technology) approaches and make these available to the NARS partners and public and private seed industries in Asia and other SAT regions globally. The technologies associated with the development of improved breeding materials and knowledge for their use will also be provided to partners. This will strengthen their research capabilities in developing improved germplasm. We assume that the partners

would further evaluate the breeding materials at their locations for local adaptations, resistance to diseases and insect-pests and quality and release selected lines through their national systems. The improved cultivars will reach to the farmers through the systems already in place and have impacts on the productivity, farm income and livelihood of farmers.

Output 2: Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate drought and salinity tolerance breeding and germplasm of legume mandate crops and associated capacity building made available to partners internationally

Biotechnological and conventional tools are being developed and used in development of drought and salinity tolerant materials. These tools and improved germplasm will be made available to the partners (NARS, private and public seed industries) in the SAT countries. There is a big component of capacity building on development and application of biotechnological tools in this Output Project. We assume that the partners will have enhanced capabilities to use these technologies and improved germplasm. Improved germplasm will be released by the partners using standard procedures. Drought and salinity are the major constraints to production of these crops in the SAT and the cultivars tolerant to these traits would be readily adopted by the farmers. We expect that the adoption of these cultivars would be rapid and lead to enhancement in productivity and income of farmers.

Output 3: Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate biofortification and biodetoxification breeding, improved germplasm of pearl millet, sorghum, groundnut and pigeonpea crops and associated capacity building made available to partners internationally

Improved genetic materials with enhanced nutrients (high Fe, Zn and beta-carotene) and associated technologies would be transferred to the partners of Harvest Plus Challenge program and other NARS partners. The integrated crop management practices for reducing contamination of mycotoxins will also be passed on to the partners. The knowledge empowerment of partners in development and transfer of improved technologies has been given due consideration in this Output Project. This will help is dissemination of technologies to the farmers. ICRISAT will also provide technical guidance to NARES partners in farmer-participatory evaluation of technologies and strengthening seed systems. These will enhance adoption of technologies and help improve productivity of these crops, food security and nutrition, and increase farm incomes in Asia and other regions in the SAT.

International Public Goods

- Cultivars with resistance to biotic and abiotic stresses, improved yield, and adaptation to diverse agro-ecosystems
- Protocols for evaluation of germplasm, breeding materials, mapping populations and transgenic crops for resistance to insect pests, diseases, and drought
- Protocols for genetic transformation of chickpea, pigeonpea, sorghum, and groundnut, and genetically modified plants with resistance to Helicoverpa in chickpea and pigeonpea, drought in groundnut and chickpea, and aflatoxin and viruses in groundnut
- Mapping populations for major insect pests, diseases, and drought in sorghum, chickpea, pigeonpea, and groundnut
- Molecular markers and QTLs for resistance to insect pests, diseases, and drought in sorghum, chickpea, pigeonpea and groundnut
- Knowledge of mechanisms and inheritance of resistance to biotic and abiotic stresses
- Diagnostic tools for mycotoxins and viruses, and management of Aflatoxin contamination
- Technologies for pest management and IPM modules, knowledge of the usefulness of transgenic crops for pest management, and their biosafety to the nontarget organisms

Elaboration of Partners Roles

The roles and responsibilities of partners will vary depending up on the nature of collaborative activities. In the case of Priority 2 B and 2 C, ARIs would provide products and technologies,

e.g., JIRCAS has provided the DREB gene construct, Michigan State University will provide a gene for aflatoxin resistance, and the National Institute for Nutrition will analyze samples for beta-carotene and methionine contents. ARIs would also take up researchable issues of mutual interest where we lack infrastructure and facilities. Our principal ARI partners in the Generation Challenge Program are CIRAD (France) and EMBRAPA (Brazil), and our principal partners in the Harvest Plus Challenge Program are a range of Indian Council for Agricultural Research institutes and universities. ILRI will assist in feed quality assessment (priority area 3B) and ICBA in salinity testing. The World Vegetable Center will assist in comparator studies on indigenous legume vegetables (eg. mung bean).

In the case of conventional breeding products (Priority 2 A), NARS from SAT Asia would facilitate evaluation for local adaptation including diseases and pest resistance screening in hotspot locations and provide feedback on the performance of materials and interface with farmers. They will also take the lead in getting the promising materials released through the national/ provincial systems, and produce Breeder and other categories of seed for formal/informal seed production chain to enable farmers to cultivate improved varieties. They will also assist in technology dissemination and product diversification. The rice-wheat consortium SWEP is a partner for the introduction of legumes into cereal monocrops in the Indo-Gangetic plain. The SP-IPM is associated with insect resistance studies, while VASAT will help in information dissemination (Project 10).

Key Strategic Alliances: ICAR for partnership and support with a large range of Indian research institutions, ILRI/SLP and ICBA (for support on livestock feed and salinity issues, respectively). The Harvest Plus and Mycotoxin consortium for their expertise and techniques in biofortification and biodetoxification.

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**Improved germplasm and varieties of sorghum, pigeonpea, chickpea and groundnut with pro-poor traits and associated advanced knowledge of breeding methods and capacity building made available to partners internationally**	NARS, SWEPs, ARIs, public and private seed companies, self-help groups, universities, and the farmers in Asia SAT.	Increased yields, reduced losses due to biotic stresses, improved capacity of NARS for accelerated crop improvement as a result of availability of improved lines, interspecific derivatives, mapping populations, QTLs linked to biotic stresses, and transgenic plants	Reduced risk of food insecurity and nutritional quality, and environment conservation through the use of high yielding insect and disease resistant cultivars, and improved seed systems
Target 2009: Materials	6.1.1 CP 10 Kabuli chickpea breeding lines with extra large seed (greater than 50 g 100 seeds^{-1}) and high resistance to fusarium wilt developed			
Target 2009: Other kinds of knowledge	6.1.1 PP Molecular characterization of wilt/sterility mosaic resistant and susceptible germplasm/breeding lines to identify diverse parents for developing mapping populations			
Target 2009: Materials	6.1.2 PP 15 new sources of resistance to wilt and sterility mosaic virus identified and made available to partners			
Target 2009: Materials	6.1.3 PP At least 10 germplasm/ breeding lines with resistance to Helicoverpa identified and made available to partners			

	Outputs	Intended Users	Outcome	Impact
Target 2009: Materials	6.1.1 GN 10-15 new high yielding lines with resistance to diseases and quality and adaptation traits identified and made available to NARS			
Target 2009: Materials	6.1.1 CP 15-20 new high yielding FW resistant desi and kabuli chickpea breeding lines made available to NARS			
Target 2009: Other kinds of knowledge	6.1.1 PP 25-30 pigeonpea lines tested multilocationally for their stability to wilt and sterility mosaic resistance in India			
Target 2009: Other kinds of knowledge	6.1.2 CP 20-30 sources of resistance to FW, BGM, and AB tested for stability across locations and pathotypes in Asia			
Target 2010: Materials	6.1.1 SO Two F7 sorghum RIL mapping populations (350 each) available for genotyping and assessment of yield, quality, and sugar content			
Target 2010: Other kinds of knowledge	6.1.1 CP 1-2 promising Bt transgenic events identified and characterized for insect resistance in strip trial			
Target 2010: Materials	6.1.2 CP Interspecific derivatives (10) with enhanced resistance to AB, BGM, and Helicoverpa			

	Outputs	Intended Users	Outcome	Impact
	identified and made available to partners			
Target 2010: Materials	6.1.1 GN 6-8 high yielding dual-purpose groundnut varieties in a range of maturity groups with resistance to chronic biotic constraints available for release and commercialization			
Target 2010: Materials	6.1.2 PP 1-2 promising Bt transgenic events of pigeonpea identified in strip trials			
Target 2010: Materials	6.1.1 SO Genetically diverse sorghum breeding lines (10) for high yield and large grain size with resistance to grain mold made available to partners			
Target 2010: Materials	6.1.2 GN Two transgenic events with resistance to TSV used for introgression into locally adapted groundnut genotypes			
Target 2011: Materials	6.1.1 GN Five stable interspecific derivatives of groundnut with resistance to LLS tested on farmers' fields			
Target 2011: Materials	6.1.2 GN Three mapping populations for LLS and two for confectionary traits developed			

	Outputs	Intended Users	Outcome	Impact
Target 2011: Materials	6.1.1 CP Breeding lines (10) with combined resistance to Fusarium wilt and *Helicoverpa* identified			
Target 2011: Other kinds of knowledge	6.1.1 CP Physico-chemical mechanisms of resistance to Helicoverpa identified and nature of inheritance studied			
Target 2011: Other kinds of knowledge	6.1.2 CP QTLs for Helicoverpa resistance identified from Cicer arietinum x C. reticulatum RIL population			
Target 2011: Materials	6.1.3 PP 10-15 genetically diverse large-seeded vegetable type breeding populations and lines for further selection developed			
Target 2011: Materials	6.1.1 SO Ten sweet sorghum lines with high biomass and resistance to shoot pests and foliar diseases developed			
Target 2011: Materials	6.1.1 GN At least 10 transgenic events with resistance to PBNV characterized under greenhouse conditions			
Target 2011: Other kinds of knowledge	6.1.1 CP Reference collection characterized for Helicoverpa			

	Outputs	Intended Users	Outcome	Impact
	resistance			
Output 2	**Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate drought and salinity tolerance breeding and germplasm of legume mandate crops and associated capacity building made available to partners internationally**	NARS, universities, SWEPs, ARIs, and public and private seed companies in Asia SAT.	Partners worldwide strengthened for conducting research on drought and salinity tolerance, have access to information and techniques to reduce losses due to abiotic stresses, and improved capacity for crop improvement to develop crops with tolerance to drought and salinity as a availability of improved lines with drought tolerance, mapping populations, OTLs linked to drought, and transgenic plants with drought tolerance	Reduced risks to food insecurity through availability of drought tolerant cultivars in SAT Asia
Target 2009: Materials	6.2.1 GN 6-8 dual purpose groundnut varieties with high biomass and improved haulm digestibility identified and promoted for drought prone areas in Asia (collaboration with ILRI)			
Target 2009: Other kinds of knowledge	6.2.1 CP QTLs for drought avoidance and root traits validated			
Target 2009: Materials	6.2.2 GN Three transgenic DREBIA events with drought resistance identified			
Target 2009: Materials	6.2.1 PP A set of pigeonpea genotypes suitable to breed for salinity			

	Outputs	Intended Users	Outcome	Impact
	tolerance identified			
Target 2009: Materials	6.2.1 SO Five sorghum varieties with salinity tolerance developed			
Target 2010: Materials	6.2.1 GN One to two farmer-preferred drought tolerant varieties identified in partner countries			
Target 2010: Materials	6.2.1 CP MABC derived drought tolerant lines available from 2-3 locally adapted cultivars			
Target 2011: Materials	6.2.2 GN 15-20 introgressed transgenic lines of groundnut evaluated under water-limiting conditions			
Target 2011: Other kinds of knowledge	6.2.1 CP QTLs for salinity tolerance in chickpea identified			
Target 2011: Materials	6.2.1 CP Transgenic DREB/P5CSF events transgenic events available for introgression into locally adapted genotypes			
Output 3	**Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate biofortification and**	NARS, SWEPs, universities, ARIs, and public and private seed companies in Asia SAT	Partners worldwide strengthened for conducting research on insect pests, diseases and mycotoxin to pathogens, and transgenic plants with pest and pathogen	Risks of malnutrition, aflatoxin contamination, pesticide use, burden of pests and pathogens reduced substantially in Asia SAT through application of

	Outputs	Intended Users	Outcome	Impact
	biodetoxification breeding, improved germplasm of pearl millet, sorghum, groundnut and pigeonpea crops and associated capacity building made available to partners internationally		and mycotoxin resistance. Increased productivity through better crop managemen t as a result of availability of resistant varieties, IPM packages, information on usefulness of transgenic crops in IPM, and increased adoption of transgenic crops as result of availability of information on bio- safety of transgenic crops to non-target organisms. managemen t, and have access to information and techniques to reduce losses due to biotic stresses, and improved capacity for crop improvement to develop crops with tolerance to biotic stresses as a result of availability of improved germplasm, monitoring tools, precise phenotyping of mapping populations, molecular markers and QTLs linked	integrated crop production technologies
Target 2009: Other kinds of knowledge	6.3.1 FORT Pigeonpea psy1 events with beta-carotene identified			
Target 2009: Materials	6.3.4 DTOX 8-10 elite aflatoxin resistant lines identified and made available to NARS			
Target 2009: Capacity	6.3.5 IPM Rural stakeholders trained in biopesticide production and utilization			
Target 2009: Capacity	6.3.6 CAP			

	Outputs	Intended Users	Outcome	Impact
	Nucleus/Breeder seed production of ICRISAT-bred advanced breeding lines released in partner countries undertaken on request from NARS			
Target 2009: Capacity	6.3.6 CAP Farmers' field days, as and when needed, organized at special project locations			
Target 2009: Capacity	6.3.6 CAP NARS scientists' field days in sorghum, pigeonpea, groundnut, and chickpea organized			
Target 2009: Capacity	6.3.6 CAP Farmer-participatory varietal selection trials conducted on legumes to enhance adoption of improved cultivars			
Target 2009: Capacity	6.3.6 CAP Farmer-friendly literature on crop management and seed production technology published and distributed to NARS			
Target 2010: Materials	6.3.2 DTOX Five promising transgenic events of groundnut with PNLOX13S gene for A. flavus resistance identified			
Target 2010: Materials	6.3.1 FORT At least 8 groundnut candidate psy1 events with beta- carotene selected for contained field trial			

	Outputs	Intended Users	Outcome	Impact
Target 2010: Capacity	6.3.5 CAP Training courses in application of molecular markers in crop breeding programs conducted for NARS staff			
Target 2010: Capacity	6.3.5 CAP At least 20 Ph.D. students, apprentices and technicians trained in various aspects of crop improvement, biotechnology			
Target 2011: Materials	6.3.1 FORT Bioavailability studies with 2-3 selected beta-carotene transgenic events carried out			
Target 2011: Materials	6.3.4 DTOX Ten interspecific derivatives of groundnut evaluated for A. flavus resistance and promising lines identified			
Target 2011: Policy strategies	6.3.5 IPM Bio-safety of transgenic crops to non-target organisms assessed			
Target 2011: Capacity	6.3.5 CAP Training courses in mycotoxin detection technologies conducted for NARS staff			
Target 2011: Capacity	6.3.5 CAP Training course on screening for resistance to Helicoverpa organized			

ICRISAT-7: Reducing Rural Poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and Products

Project Overview and Rationale

The project will develop and disseminate technologies to increase production of high-value commodities such as fruit and vegetables, livestock and trees for biodiesel. Above 80% of this projects activities are encapsulated within the CGIAR System Priorities.

Target ecoregion, beneficiaries and end users
The target ecoregions are the semi-arid tropics in west and central Africa, eastern and southern Africa, and Asia. The immediate beneficiaries are our various R and D partners: NARESs; NGOs and CBOs involved in rural development, small-scale private marketing enterprises and development investors. The end users of technologies developed by the project are farming communities, who will benefit from more diverse, nutritious diets and higher and more stable incomes.

Is the center the primary or secondary research provider?
ICRISAT with its partners such as AVRDC is often the primary research provider.

Is it a catalyzer, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact
ICRISAT aims to catalyze broadly based consortia for watershed development in Asia and elsewhere. The research is proof-of-concept at the end of the first stage which is imminent with two major output targets are due for achievement in 2007: Sahelian Eco-farm. First proof of concept tested and validated in Sahelian countries and report published and Exemplar watershed studies completed in four Asian countries and reports published. Strategies for outcomes and impact will be re-assessed (MTP 2009-2011) in the light of these critical reports.

Comparative and complementary advantages of project activities
ICRISAT is well placed to undertake strategic research for sustainable management of natural resources, facilitate information flows and legal germplasm exchanges between partners from different countries. Partnership in a new strategic alliance with the World Vegetable Center is expanding rapidly with joint appointment of staff now at three ICRISAT locations. ICRISAT's pro-poor research orientation is also highly apposite for its work on biodiesel, which is often well suited to the most marginal land that often supports a large number of the poor and are the cause of degradation of soil and water resources in watersheds due to its spatial location. The concept therefore of a high-value crop is therefore deemed to be relative to the remaining options in the environment.

Playing a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs
A decade of research is expected to produce a generic strategy for watershed development and management. These strategies are key IPGs and have the potential to benefit nearly one billion poor people in the SAT. Our efforts will ensure that local and national public goods can be scaled up to regional and fully international public goods. It should be recognized that partners at local or national level have little incentive to consider the regional/international implications arising from the research. Nor are they necessarily willing (or able) to share knowledge and outputs, without the strong support and facilitation role played by ICRISAT.

Alignment to CGIAR Priorities

The proposed research is in specific accordance with System Priorities 3A, Specific goals 1 and 2 (Fruit and Vegetables), 3B (Livestock) and 3D (Trees). For SP 3A The ultimate expectation in this framework plan is that operational and functional cells demonstrating the potential of high-value fruits and vegetables for getting people out of poverty, and improving nutrition would have been established in selected areas, as a guide to the further expansion of work in this area. ICRISAT's plans strive to achieve the expectation put forward. For 3B Income opportunities in more adaptive (marginal) systems are likely to be part of more diversified strategies in which incomes from livestock is one component of the strategy (linked to SP 4D). In such systems, a mix of institutional and policy innovations and technologies need to be combined to support communities to develop a range of market and non-market, livestock and non-livestock livelihood options. This sentence reasonably summarizes ICRISAT's overall research approach which is aimed specifically at small-holder owners in relatively marginal environments in which the tradeoff between intensification and the preservation of environmental services is a major issue being addressed. A similar pro- poor approach is adopted for research under SP 3D.

Outputs Description

Changes from Previous MTP
The project structure for ICRISAT was re-worked newly in 2006 and has not changed in 2007 or 2008. The outputs have not changed. However, Output 7.3 is in the gradual process of migration from Project 7 to Project 9 Output 9.5 to better accord with the Systems priorities: Projects match. In addition, a substantive number of new output targets have been declared as a result of the SC commentary requiring more detail in this project (See Logframe).

Problem analysis, identification of specific problems that can be tackled by research focused on specific objectives

These are described by specific goal as below:

Priority 2A, Specific goal 1: Identify key species for research and assess their factor and product markets

Priority 2A, Specific goal 2.: Enhance production of selected fruit and vegetables through improvement of farming systems

Output 7.2.1 on inventory of alternative watershed practices for four Asian countries documented and made available globally, which are fully achieved during 2008. The evidence based results were documented through comprehensive assessment of watershed programs and manual on best bet management practices.

Output 7.4 - Added in log frame under 7.4 for 2009

Output 1: **African Market Garden technology strategy and knowledge database, developed, tested and promulgated with associated capacity development regionally in the SAT of the Sahel in collaboration with AVRDC and ICRAF and assessed in comparison with existing and new potential dryland alternatives**

Description:

West and Central Africa
Water availability due to low and variable rainfall, high temperatures and evaporation is a key limiting factor to rainfed agriculture in the Sahel. Water retention technologies and more efficient water use are necessary for increasing productivity. Farm enterprises are generally limited to a few staple crops; opportunities clearly exist for introducing new crops and production systems. Food security and poverty can be addressed by increasing farming system

efficiency, diversifying into higher value crops, opening new markets and adding value to farm products. Traditional food plants such as fruit and oil seed trees, pulses and leafy vegetables have the potential, but technical and scientific support (e.g. for domestication) is needed.

Development of more efficient farming systems
The African Market Garden (AMG) is a low-pressure drip irrigation system particularly suitable for small farmers. It has all the advantages of conventional drip irrigation systems at a fraction of their cost. The Sahelian Eco-Farm (SEF) is an integrated dryland tree-crop- livestock system for millet-based production systems. Three versions of the SEF are being tested, in partnership with the NARES of Burkina Faso (INERA) and Ghana and with pilot farmers in Niger.

Crop diversification
Improvement of traditional crops and native plants and identification of new income-generating crops includes Acacia Senegal, traditional leafy vegetables, Hibiscus sabdifara, watermelons, Ziziphus mauritiana, dates, fruit trees and heat tolerant vegetable varieties.

Alignment to CGIAR Priorities : 3A: Increasing income from fruit and vegetables;

Output 2: **New approaches and technological options to create a strategy to diversify SAT systems using available water resources efficiently to grow high-value commodities that increase incomes for disadvantaged households identified and promoted with associated capacity building by consortium partners to Government agencies, donors, NGOs, and CBOs.**

Description:
Asia
Diversification in Asia
Rural welfare in South Asia remains highly dependent on agriculture. However, there is also a trend away from the traditional SAT crops like sorghum and pearl millet, towards high- value and tradable commodities. When technological options exist, small farmers through diversification move into new products and can often capture market opportunities. ICRISAT-Asia is using an integrated genetic and natural resource management approach at catchment scale, and has been able to sustainably enhance livelihoods through the introduction of high-value, fruit, vegetables and value-added plant products through enhanced water use efficiency measures. ICRISAT also has growing expertise in the area of agriculture and energy, particularly in the provision of substitutes or blending agents for petroleum. Potential proof of concept for use of environment-friendly alternative sources of energy using ethanol from sweet sorghum to use as energy source will be undertaken.

Development of sustainable and efficient farming systems

ICRISAT is involved in the following research areas associated with specific goal 2:

1. Sweet sorghum for ethanol production (See Project 5)
2. Systems diversification through vegetables and fruits
3. Systems diversification with medicinal and aromatic plants
4. Biological nitrification inhibition in sorghum rhizosphere soil

Alignment to CGIAR Priorities : 3A: Increasing income from fruit and vegetables;

Output 3: **Environmental impacts of livestock intensification reduced during droughts and the dry season by developing and promoting alternative feed and fodder strategies in crop-livestock systems with associated capacity building**

Description:

Priority 3B, Specific goal 2: Management of the intensification in livestock production is improved to limit the negative impacts on the poor and the environment

The impact of livestock on natural resources will be described within different policy environments and agro-ecosystems, with reference to biodiversity and primary and secondary productivity. The need for dry season feed and fodder will be quantified and prioritized based on its potential impact within agro-ecological zones using participatory selection of alternative feeding strategies with poor farmers. Improved land use strategies are to be developed with stakeholders to reduce risk and vulnerability and recommendations on policy reform will be formulated.

Alignment to CGIAR Priorities : 3B: Increasing income from livestock;

Output 4: **Opportunities for the market exploitation of biodiesel tree products by the poor promoted with associated capacity building**

Description:

Priority 3D, Specific goal 1: Improve the opportunities for the market exploitation of a range of tree products by the poor

Determining the options of very poor people (including the landless) to exploit the growth of biodiesel tree species and their agronomy on common or low quality land resources. The SC Commentary on the 2007-2009 MTP has queried the IPG nature of this highly pro-poor research activity (point d). ICRISAT believes that it is well placed to generate IPGs from this activity not only from the critically needed information on the genetic potential and likely economic agronomy of biodiesel trees but also on how the landless and other highly disadvantaged population groups can have a policy-friendly environment created for them to ensure that they can benefit from the usufruct rights from tress planted on low quality common land. Demand for such quantitative and policy information appears to be widespread in S. Asian countries at present and ICRISAT is seen as an honest broker from which such knowledge can be accessed with confidence.

Output Target 2012 7.4.1 Potential proof of concept for use of environment-friendly alternative sources of energy using biodiesel as an energy source

- We will undertake research in the following areas to achieve the output target by 2011
- Evaluation and documentation of *Jatropha* and *Pongamia* accessions and development of high yielding lines
- Standardization of agronomic practices for *Jatropha* block plantations
- Assessment of deoiled cake of *Jatropha* and *Pongamia* as a source of nutrients and organic matter
- Development of institutional model for rehabilitating degraded lands and decentralized rural energy system

Pongamia pinnata, a leguminous tree adapted to wetter wastelands; and Jatropha curcas, a more drought-tolerant shrub adapted to well-drained wastelands are widely grown as boundary plants in many Asian and African countries. They produce fruits containing 25-35% oil suitable for use as bio-diesel. No systematic efforts have been made to evaluate and document the existing variability in seed sources of both theses species. Similarly, recommendations for agronomic management practices are not yet available for *Jatropha* and *Pongamia* cultivation. ICRISAT has initiated systematic studies on understanding the potential and performance of these species under dryland situations. Oilcake is a by-product after extraction of oil and is a potential source of soil nutrients and organic matter. Four kilograms of seed of *Pongamia* or *Jatropha* render about three kilograms of cake after oil extraction.

Degraded and marginal lands that are not suitable for food production may be options for planting with biofuel crops without substantive food security tradeoffs. In south Asia Common Property Resources (CPRs) in the villages are frequently degraded and usually only act as catchment areas for watershed run-off. An institutional model for rehabilitating degraded with biodiesel crops and decentralized energy system in rural areas to benefit small farmers and

vulnerable groups are being evaluated and documented.

Activities exemplar:

New approaches and technological options to create a strategy to rehabilitate degraded lands in SAT systems using biodiesel crops and decentralized energy system in rural areas are being formulated. It is expected that this will lead to increased income for very poor rural households and promote carbon sequestration and help maintain environmental quality.

Activities:
(1.1) Documenting variability in oil content and test weight in Jatropha and Pongamia accessions
(1.2) Field evaluation of elite accessions for seed and oil yield
(1.3) Development of high yielding lines

Milestones:
(1) 2008: Variability of Jatropha and Pongamia accessions assessed
(2) 2009: Elite accessions for higher oil identified
(3) 2011: Elite accessions evaluated under field conditions
(4) 2011: High yielding accessions made available

Activities:
(2.1) Establishing trials for standardizing plant density, fertilizer schedule and after cultivation practices (pruning and harvesting)
(2.2) Conducting studies on water requirement and nutrient removal of Jatropha and Pongamia under block plantations
(2.3) Evaluating microbial diversity under block plantations of Jatropha and Pongamia
(2.4) Quantifying C sequestration and replacement potential of biodiesel plantations

Milestones:
(1) 2009: Water requirement of Jatropha and Pongamia determined
(2) 2010: Carbon sequestration potential via returning oilcakes, litter fall and roots assessed
(3) 2011: Agronomic practices standardized

Activities:
(3.1) Field evaluation of deoiled cake of Jatropha and Pongamia as source of N and organic matter
(3.2) Conducting studies on nutrient release and use pattern of deoiled cake

Milestones:
(1) 2010:Crop productivity and soil quality assessed

Activities:
(4.1) Evaluating institutional model with usufruct rights to communities for rehabilitating degraded lands with biodiesel crops and decentralized energy system in rural areas

Milestones:
(1) 2011: Model available to involve community participation for rehabilitating degraded lands and biodiesel value chain for increasing incomes

Alignment to CGIAR Priorities : 3D: Promoting sustainable income generation from forests and trees ;

Impact Pathways by Output

Output 1: African Market Garden technology strategy and knowledge database,

developed, tested and promulgated with associated capacity development regionally in the SAT of the Sahel in collaboration with AVRDC and ICRAF and assessed in comparison with existing and new potential dryland alternatives

The two stated outputs of this project have similar impact pathways. Rural poverty, exacerbated by lack of agricultural diversity, is endemic throughout large areas of the SAT. It is our assumption that on station and on-farm site specific research are the first necessary steps towards finding solutions to farmers caught in the poverty trap. Much of the testing and institutional development associated with proof-of-concept of the African Market Garden and Watershed Consortia, has been completed. Research papers have been, and will continue to be, published as source material from which effective articulation of generic strategies and their refinement for upscaling and advocacy can be achieved.

Research and capacity development in this subject area has been conducted for nearly 10 years, in partnership with NARES, NGOs, CBOs and the private sector, specifically in West Africa and South Asia. ICRISAT will encourage partners to now adopt a stronger advocacy role both nationally and with regional political organizations, to ensure policy support for these development strategies, leading to international and MDG scale impact. We assume this will occur as success in this area is already apparent in the policies of the Indian Government. Efforts under Projects 1 and 10 help to mitigate the risks associated with this assumption. ICRISAT will continue to play a vital role in this process, as a technology Product Champion, capacity developer and knowledge disseminator. Collaboration with ICRISAT's VASAT initiative will accelerate dissemination and multiply the IPG benefits in order to reach the expected very large number of potential beneficiaries.

Output 2: New approaches and technological options to create a strategy to diversify SAT systems using available water resources efficiently to grow high-value commodities that increase incomes for disadvantaged households identified and promoted with associated capacity building by consortium partners to Government agencies, donors, NGOs, and CBOs.

The primary constraints to food security in developing countries are low productivity per unit area, which further exacerbated by shrinking land and water sources available for cropping. Under these circumstances, crop diversification can be useful means to increase crop put under different settings of available resources either broadening the system adding more crops or introducing high value crops aiming at enhancing net returns per unit of input. We hypothesize that diversifying system with high value crops and efficient management practices increases economic returns thereby improving livelihood of the farmers

Identifying suitable high value crops for target regions: The primary step in advocating system diversification is to identifying inventory of crops suitable for particular regions, which is established based on pilot studies through introducing high value crops based on market availability or demonstrating evidence based results already available for the regions. The results from the pilot studies and demonstrations are systematically compiled and documented for scaling up.

Efficient crop management practices for enhancing productivity in high value crops: Intensification of crop productivity is the next step once suitable high value crops identified for the particular region. In our experience, it is revealed that balance nutrition for crops is the simplest way to improve crop productivity. Similarly, balanced nutrition studies will be evaluated in high value crops for higher productivity

Promoting environment friendly pest management practices in high value crops: In general, high value crops consume larger quantity of pesticides as it fetches premium price for the produce which is free from pest and diseases. The indiscriminate use of pesticides results in pesticide residues in the produce more than the prescribed critical level, which affects both

environment and human health. In this context, package of IPM will be evaluated along with available indigenous technologies for residue free produces.

Decentralized energy model based on straight vegetable oil (SVO): The activity is based on the diversification of marginal and degraded lands (not used for arable cropping) with the tree borne oil seed crops especially Jatropha and Pongamia. The model works on the concept of local production to consumption system addressing energy security in the local settings. The concept will be designed involving local communities considering the availability of raw materials for oil extraction and private partners for technical backstopping on the power generation. The processes and learnings are systematically documented in the pilot model, which further evaluated for economic feasibility and sustainability

Knowledge dissemination on high value crops: It builds local Capacity of NARS partners and government extension officials on the high value crops aligning with market demand, economic returns and employment generation.

Output 4: Opportunities for the market exploitation of biodiesel tree products by the poor promoted with associated capacity building

Jatropha curcas and Pongamia pinnata are promoted as source of bio diesel due to the global price escalation of fossil fuels. Common Property Resources (CPRs) which are marginal and degraded lands also referred as revenue lands in South Asia acting as catchment areas for watershed run-off. In few cases, it is the main source for livestock grazing and fuel wood for local communities. However, poor maintenance of these lands becomes degraded and barren, which are not doing any service to the local communities. ICRISAT place Jatropha curcas and Pongamia pinnata as suitable candidates for rehabilitating these lands and making the source of income for the communities who depend on these lands for livelihood. We hypothesize that establishing Jatropha curcas and Pongamia pinnata plantations in CPRs with suitable government polices and thereby improving the livelihood of the local communities by harvesting benefits from the plantations

Assessing yield potential of *Jatropha curcas* and *Pongamia pinnata*: Jatropha and Pongamia are wild plants, which lack systematic studies of their performance in terms of oil content and seed yield under block plantations. The wide distribution of these plants across the regions shows its adaptability and genetic variation. Hence primary activity is to assessing the variability of these plants for few traits of economic interest and evaluating of these plants for field performance with different plant density and levels of inputs.

Impact assessment of bio fuel system: Socio economic and environmental impact assessment is the final step for evaluating the system for which suitable indicators are developed by carefully delineating boundary of the project. The important by product of the system is deoiled cake comprising of three fourth of the raw material used for extracting the oil which will be studied for recycling as manure developing appropriate method.

Institutional arrangement for sustaining the plantations in CPRs: Community participation is very important for nurturing the plantations established in CPRs. Institutional mechanisms has to put in place to recognize local communities as stakeholder of the project and they should foresee the benefit of the project. In other words, it is necessary to develop confidence among local communities so that “ownership” of the project established.

To achieve: Consortia of government department, NGOs and communities constituted, where pilot model of establishing bio diesel plantations are undertaken in CPRs with technical backstopping from ICRISAT. It is not enough to merely planting of bio diesel crops which definitely goes in hand with soil water conservation measures for placing good plant stand. Government department provide suitable mechanism for realising benefits emanated from CPRs as they are having authority on CPRs. NGOs works for mobilizing community for the initiative and facilitating with communities. ICRISAT translates the technical knowledge gained

from on station work on Jatropha and Pongamia into the project for maximizing the productivity. The pilot model will be available for planting bio diesel crops in degraded lands while nurturing the production on sustainable basis with the involvement of communities.

International Public Goods

The most important IPGs from this research that will benefit large number of poor people residing in the developing SAT and also contribute significantly for improving livelihoods thru efficient use of scarce water resources.

· Biodiesel-tree based systems for degraded lands will contribute to mitigating effects of global warming and also develop adaptation strategies for building resilience of natural resources and human resources to face the future challenges including due to climate change
· Farmer options for attaining further crop and livestock diversification products expanded
· Vegetable/fruit varietal selections with adaptation to harsh Sahelian environments
· Proof of concept that date/vegetable or vegetable/fruit systems are profitable and sustainable at small farmer level where access is possible to water for trickle irrigation
· Economic demonstration of diversified, water harvesting based, dryland crop systems on station with sufficient replicability to warrant regional upscaling
· Improved land use strategies developed for dryland, animal and tree-based
· systems to reduce risk and vulnerability, with recommendations on policy reform
· BNI assay method for sorghum standardized and made available to the NARSs
· Decentralized energy system model to improve rural livelihoods and protect the environment
· Participatory model to rehabilitate degraded lands and improving livelihoods of landless and women
· Identified good sources of Jatropha and Pongamia along with good agronomic practices for biofuel production

Elaboration of Partners Roles

In WCA our principal research partners are Ben Gurion University, The World Vegetable Center (will be responsible for vegetable breeding and cultivar selection), ICRAF (collaboration on Pomme de Sahel), and the NARS of Ghana, Senegal, Niger, Mali and Burkina Faso. All provide services in kind that substantially contribute to project outputs and success. OASIS and the DMP SWEP are also dissemination partners for this technology and likewise the VASAT Consortium (Project 10).

In Asia a range of partners contribute in kind: CRIDA (India), BAIF (Indian NGO that helps with livestock issues), several State Governments in South and Central India, the NARSs of Thailand, Vietnam, the Philippines and China. JIRCAS through a collaborative project sponspored by the Ministry of Agriculture, Forestry, and Fisheries, Government of Japan is a partner for the BNI project. IWMI has been a supporter though the Comprehensive Assessment and ILRI through the Systems-wide Livestock program. In addition, the government of India provides financial support for the Agri-Business incubator, through which Rusni Distilleries became a close partner; and a range of governments are, or are proposing to, support biofuel research. GTZ is supporting PPP biodiesel initiative in Asia to support farmers and IFAD is supporting biofuel research in Asia and Africa.

Key Strategic Alliances: The World Vegetable Center for expertise in vegetable breeding, ICAR (CRIDA) for techniques and experience in dryland agriculture in south Asia and ILRI for expertise in crop-livestock interactions.

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**African Market Garden technology strategy and knowledge database, developed, tested and promulgated with associated capacity development regionally in the SAT of the Sahel in collaboration with AVRDC and ICRAF and assessed in comparison with existing and new potential dryland alternatives**	NARES and NGO/CBO agronomists and breeders, the World Vegetable Center, VASAT consortium, Oasis, the DMP SWEP, Alliance and Africa CP partners	Strengthened partners (NARES, universities, CBOs and private sector) diffuse AMG and Sahelian Eco-farm technology and improved vegetable seeds regionally in WCA and the strategy is adopted by farmer enterprises with access to water	Farmer annual income, system resilience and food production has been increased though adoption of new technologies and crop diversification systems. Improved nutrition of rural and urban populations through greater consumption of fruit and vegetables has occurred. Traders and exporters have benefited from greater competitiveness in local, regional and international markets
Target 2009: Policy strategies	7.1.1 Authoritative AMG strategy published and advocacy campaign for policy amendment completed (associated with the DMP SWEP)			
Target 2009: Materials	7.1.2 Single plant selections of Okra and hot pepper made and distributed to partners for testing			
Target 2009: Practices	7.1.1 (carried over from 2008) Documentation of processes and learnings on African Market Garden for Sahelian countries			
Target 2010: Materials	7.1.1 F2 heat tolerant population of sweet pepper advanced and material selected with			

	Outputs	Intended Users	Outcome	Impact
	partners			
Target 2011: Materials	7.1.1 At least one tomato line with better fruit quality than ICRI-Xina identified and seed available for further rainy season testing by partners			
Output 2	**New approaches and technological options to create a strategy to diversify SAT systems using available water resources efficiently to grow high-value commodities that increase incomes for disadvantaged households identified and promoted with associated capacity building by consortium partners to Government agencies, donors, NGOs, and CBOs.**	NARES, NGO and CBO agricultural communities, local governments and the private sector, IARCs, WVC, OASIS, DMP-SWEP	Approaches and technological strategies to increase incomes through diversifying SAT systems using high-value commodities incorporated in policies and implementation guidelines by government agencies, NARES, and donor agencies in India, Thailand, Vietnam, Southern China, and Philippines for strengthening their sustainable research and development programs	Participatory research and development (PR and D) approaches to improve the livelihoods of the landless and small farmers through rehabilitating degraded lands and diversifying SAT systems have been developed and promoted in the SAT areas of India, Thailand, Vietnam, China and the Philippines. Incomes of the farmers in target rainfed areas using available water to grow high-value commodities has been shown to have the potential to be increased by 50%.
Target 2009: Capacity	7.2.1 Capacity building for partners in crop diversification and the implementing of IGNRM practices			
Target 2009: Practices	7.2.2 Balanced nutrient management options for vegetable cultivation evaluated			
Target 2010: Other kinds of	7.2.1			

	Outputs	Intended Users	Outcome	Impact
knowledge	Potential proof of concept for use of environment-friendly alternative sources of energy using biodiesel straight vegetable oil (SVO) to use as energy source			
Target 2011: Practices	7.2.1 Monitoring and management of pesticide residues and impact of IPM established			
Target 2011: Policy strategies	7.2.3 Impact of diversification with high-value crops assessed and documented in two countries			
Target 2011: Practices	7.2.2 Assay method for BNI detection in sorghum fields standardized			
Target 2011: Practices	7.2.3 Decentralized energy model based on use of SVO in stationery engiens for power generation established in one village			
Output 3	**Environmental impacts of livestock intensification reduced during droughts and the dry season by developing and promoting alternative feed and fodder strategies in crop-livestock systems with associated capacity building**	NARES, NGOs, CBOs and policy makers, Alliance and Water CP, ILRI and SLP SWEP partners	Reduced impact on natural rangeland degradation understood by government extension services, private sector, NGOs and CBOs. More sustainable policies developed that acknowledge the tradeoffs within livestock and mixed crop-livestock systems	Partners have helped small-scale farmers throughout the SAT, to adopt new sustainable feeding strategies to reduce livestock mortality during droughts, improve animal condition and increase both livestock and crop production

	Outputs	Intended Users	Outcome	Impact
Target 2009: Practices	7.3.1 Need for dry season feed and fodder quantified and prioritized based on potential impact within agro-ecological zones, through participatory selection of alternative feeding strategies			
Target 2009: Practices	7.3.2 Improved land use strategies developed with all stakeholders to reduce risk and vulnerability, with recommendations on policy reform			
Target 2010: Capacity	7.3.1 Capacity building of stakeholders (farmers, NGOs, NARS scientists) to implement improved NRM practices for intensifying and diversifying existing livestock and crop-livestock systems undertaken			
Target 2011: Capacity	7.3.1 See Project 9 logframe			
Output 4	**Opportunities for the market exploitation of biodiesel tree products by the poor promoted with associated capacity building**	NGOs and government policy makers, ICRAF	Degraded wastelands are shown to be an economic asset for the poor and government policy is amended accordingly	The very poor have seen a potential way out of poverty that is economically and politically highly desirable
Target 2009: Materials	7.4.1 Identified superior accessions of Jatropha in terms of test weight and oil content are			

	Outputs	Intended Users	Outcome	Impact
	inducted for field evaluation			
Target 2009: Practices	7.4.2. Water requirement studies is undertaken on Jatropha to establish water balance in catchment's areas when Jatropha is planted			
Target 2010: Practices	7.4.1 Proof of concept that biodiesel trees are an economically and socially viable product for very poor and landless communities when granted usufruct rights on low quality non-titled land	NGOs and government policy makers, ICRAF	Degraded wastelands are shown to be an economic asset for the poor and government policy is amended accordingly	The very poor have seen a potential way out of poverty that is economically and politically highly desirablengly
Target 2010: Practices	7.4.2. Field evaluation of deoiled cake as source of nitrogen in field crops			
Target 2011: Practices	7.4.1 Recommendations for suitable agronomic practices for the block plantation of trees with potential for use as sources of biodiesel			

ICRISAT-8: Poverty alleviation and sustainable management of water, land, livestock and forest resources, particularly at the desert margins of the Sahel and the drylands of ESA (SSA Desert Margins Program SWEP)

Project Overview and Rationale

The project has been terminated

ICRISAT-9: Poverty alleviation and sustainable management of land, water, livestock and forest resources through sustainable agro-ecological intensification in low- and high potential environments of the semi-arid tropics of Africa and Asia

Project Overview and Rationale

The project builds on ICRISAT's existing NRM portfolio of land, water and crop-livestock management options; supported by the development and use of new tools such as systems simulation and climate forecasting; and use of farmer-participatory approaches that integrate genetic and non-genetic solutions.

Target ecoregion, beneficiaries and end-users
The target ecoregions are the SAT of sub-Saharan Africa and Asia, covering parts of 55 developing countries. These regions are home to some 1.4 billion people, 45% of the worlds hungry and 70% of the world's malnourished children. The immediate beneficiaries of this research are our R and D partners: NARES breeders, agronomists, socio-economists, climatologists and water management specialists; NGOs and CBOs involved in rural development; and private sector input suppliers. The end users are rural communities benefiting from better food and nutritional security and higher, more stable incomes. The SC commentary on the MTP 2007-2009 quotes an ICRISAT 2003 EPMR recommendation concerning the devolving of INRM activities to NARS in Asia. However, it does not take into account the fact that ICRISAT only accepted that this support should no longer be provided from core funds. Yet, ICRISAT has maintained that if special project funding for this research area were available in Asia, then it would continue its efforts in this field. It transpires that ICRISAT is now able to demonstrate substantive IPGs in this area after some years of proof of concept research. Moreover, ICRISAT's recent CCER in this area strongly recommends continued and even expanded effort in this field of research in Asia as it has now a unique opportunity to show impact with its partners and to make a substantive contribution to the MDGs.

Is the center the primary or secondary research provider?
ICRISAT will be the primary research provider in the development and use of new tools such as systems simulation and climate forecasting, and farmer-participatory approaches that integrate genetic and non-genetic solutions. It plays a secondary role in the support and coordination the Watersheds Consortia in India, and the emerging consortia of national, regional and international organizations that will evaluate the agricultural implications of climatic variability and climate change.

Is it a catalyzer, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact
ICRISAT acts as a catalyzer/facilitator and enabler of the consortium to examine the agricultural implications of current climate variability and future climate change. At national levels, ICRISAT plays the role of enabler and facilitator in the development and evaluation of IGNRM interventions that help rural households improve food security and cope with climate variability. These interventions are implemented through a range of donor-funded projects and two NRM-focused Global Challenge Programs, Water and Food and Sub-Saharan Africa.

Comparative and complementary advantages of project activities
Strong networks (the Water and Food CP with ICRISAT and watershed consortium in Asia) are in place. ICRISAT has considerable expertise in linking participatory research and development with simulation modeling, and in IGNRM work, including collaborations with leading modeling teams and bridging yield gaps on farmers' fields. These experiences form the basis of ICRISAT's current work on climate risk. ICRISAT and ASARECA coordinate a consortium of 15

national, regional and international organizations with a program on Investing in rainfed farming systems of sub-Saharan Africa: evaluating the agricultural implications of current climatic variability and planning for future climate change.

Playing a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs
ICRISAT's approach is to use local test sites to develop proof-of-concept. Results are then scaled out, often to a selection of target countries. Ultimately, generic models are developed from this experience, combining local-scale results and insights into research-for- development strategies with regional, continental and even global applicability.

Impact Pathway

The development of impact pathways within ICRISAT's IGNRM focused Centre Project 9 is crucial part of delivering the projects outputs to the right people in the semi-arid tropics at the right time in ways which improve utilization of what is produced (associated with the INRM SWEP and the Consortium for Spatial Information [CSI] and the VASAT consortium). Unlike traditional crop improvement research, where there is considerable documented evidence of impacts, there is a dearth of evidence of both overall and specific outcomes, and intermediate impacts of Integrated Natural Resource Management (INRM) research. However, we assume that a lack of documented evidence does not necessarily mean a lack of impact; rather it is often difficult in the short term to attribute the direct impacts/benefits. A major problem with the majority of INRM technologies/interventions is the inadequate understanding of performance in locations outside where they were originally developed. Many proven technologies and approaches have ot been widely spread, and only small bright spots have been achieved. A limited understanding of best-bet options for different eco-regions, opportunities and circumstances facing local people increase the risk to investments and highly reduce overall productivity and productivity of IGNRM technologies and interventions. An Impact Pathway Problem Tree and Network Map were developed for this project and are shown in the 2008-2010 MTP document.

Evaluation procedures have been formalized for different types of agricultural research and different groups of stakeholders. While they may be partly adequate for some types of research, such as genetic enhancement, the evaluation approaches commonly used are far from adequate and often entirely inappropriate for measuring the impact of INRM research. Unlike germplasm technologies, the impact of INRM technology occurs only indirectly. These benefits are often multi-faceted, encompassing economic, environmental and social gains across space and time usually extending far beyond the project cycle, and therefore outside the scope of a conventional evaluation that looks at a specific time frame linked to the project life cycle in a linear fashion. Thus, to measure the full impact of Project 9s outputs, ICRISAT and its partners (See Network Pathway) are developing a more iterative and in addition to traditional economic indicators. To do this we have to resolve a host of methodological issues: the techniques and tools used, discount rates to be applied, how to apportion impact among different (planned and unplanned) outcomes and factors external to the project. Such a process involves the full range of stakeholders as evaluators. It involves a conscious effort to reflect, share ideas and perspectives during (not after) the evaluation, and re-orient the evaluation process to better reflect the different perspectives of stakeholders.

Four factors contribute to this reflective learning process and are the corner stones of ICRISAT's IGNRM impact pathways these are stakeholder participation, systems approach to evaluation, timing of the evaluation and an iterative approach to investigation.

Alignment to CGIAR Priorities

The proposed research is in accordance with Priority 4A Integrated land, water and forest management at landscape level, specific goal 1; Priority 4C Improving water productivity, specific goal 1; and Priority 4D Sustainable agro-ecological intensification in low- and high-potential areas, specific goals 1-6 and 8. ICRISAT claims that greater than 80% of this projects activities are encapsulated within the CGIAR System Priorities.

In the case of Priority 4C (4A and 4D are not yet available), it states *Rainfed farming covers most of the worlds croplands (80%), and produces most of the worlds food (60%). Poverty is particularly concentrated in tropical developing countries in rural areas where rainfed farming is practiced. Current productivity is generally very low (yields generally 2 to 4 folds lower than achievable potential yields in the SAT). Even in the SAT, there is generally enough water to double or often quadruple yields in rainfed farming systems. The challenge is to reduce water related risks rather than coping with absolute scarcity of water. With small investments large relative improvements in agricultural and water productivity can be achieved in rainfed agriculture*. Project 9 recognizes the latent potential of the rainfed semi- arid tropics to become much more productive and to provide much greater resilience to farming enterprises. Water issues are a convenient entry point to the improvement of such systems but are only one of several entry points. Soil fertility and new varieties are other important examples used by the Project.

This is recognized by the 3C Framework plan *ICARDA and ICRISAT focus on dryland systems development through integrated water management, along with associated technologies. The latter centers may prove integral to the development of crop varieties and hybrids suitable for use in rainfed agricultural systems, and valuable input into the design of supporting management systems*.

ICRISAT therefore practices integrated genetic and natural resource management for the improvement of complex crop-livestock and socio-economic systems and in Project 9 adopts a suitable holistic approach. It acts locally but thinks globally and seeks the best ways to scale-up research results from a field to watershed and thence to landscape level. Thereby it seeks to create effective IPGs from LPGs. It represents the most downstream elements of the ICRISAT research pipeline and yet this research is as highly sophisticated and ultimately challenging as any in the institute's research portfolio and finally it helps our partners deliver the very development progress that is the *raison d'être* of ICRISAT's research being.

Outputs Description

Changes from Previous MTP

The outputs have changed in response to the SC commentary on the MTP 2008-2010. Substantial additional detail has been provided with respect to output targets, particularly with respect to climate change issues. Activities associated with Systems Priority 3B are in the process of migration from Project 7 to Project 9 as this seems to be a more rational fit with the Project: Systems Priorities balance. Additional information has been provided on Activity Exemplars and Impact Pathways.

Problem analysis, identification of specific problems that can be tackled by research focused on specific objectives

Agriculture and livelihoods in the SAT evolved under the influence of biotic (pest and disease incidence) and abiotic constraints. The most binding abiotic constraints are related to water scarcity and poor soil fertility (macro-nutrient deficiencies in sub-Saharan Africa, micro-nutrient deficiencies in Asia where N and P fertilizers are widely used). SAT agriculture is inherently risky, due to limited water availability and seasonal variation and unreliability of rainfall.

Output 9.1 - An Activities Exemplar and Impact Pathway have been added.

Output 9.2 - The description of ICRISAT's research and current climate risk projects has been updated.

Output 9.3 - An example Impact Pathway for fertilizer micro dosing in Africa has been added.

Output 9.4 - An example Impact Pathway for Asia has been added.

Output 9.5 - An example Impact Pathway has been added.

Output 1: **New tools and methods for management of multiple use landscapes with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**

Description:

Priority 4A, Specific goal 1: Develop analytical methods and tools for the management of multiple use landscapes with a focus on sustainable productivity enhancement

This research will involve the following areas in Africa and Asia.

Africa: Development of predictive, spatially distributed models for tradeoffs analysis and decision support. Monitoring and evaluation protocols for ecosystem services. Studies on land use and land cover, baseline and changes.

Stemming from ICRISAT and partners involvement in the Soil Management CRSP (completed 2008), research on prototyping carbon sequestration services for smallholder communities in West Africa will continue throughout the 2009-2011 period. Field activities will focus on *Burkina Faso, Ghana, Mali, Nigeria* and *Senegal*.

Two new projects are funded in 2009 by the World Bank under the TerrAfrica initiative to provide guidance to the World Bank and to African government on climate change and sustainable land management (SLM) in Africa, including diagnostic tools to scale up selected SLM practices. 16 case studies are underway in *Kenya, Mali, Niger, Nigeria* and *Uganda*.

Asia: The research will involve application of geographical information system (GIS), simulation modeling of crop growth and field water balances for assessing the system productivity identification and of major constraints for increasing crop yields, sustainable of natural resources and their spatial distribution in the target regions in the SAT India, Thailand and Vietnam. This research will also address the issues of identification of adaptation, coping strategy for building resilience of the SAT systems through community watershed management. New tools like remote sensing coupled with GIS will be assessed and used for effectively selecting strategies and also to assess the impacts of different interventions for sustainable crop production.

Activities Exemplar

We have declared output 9.1.1 Stochastic data assimilation techniques introduced in field-to-landscape research/modeling for 2009

Activities:
9.1.1.1: Develop and calibrate simplified models of landscape C pools and cycling in annual, perennial plants and soils for West African smallholder conditions
9.1.1.2: Develop remote sensing methods for quantifying landscape C stocks and associated uncertainties for West African smallholder conditions
9.1.1.3: Develop and apply Ensemble Kalman Filters combining models, remote sensing and

in-situ observations for optimal estimates of smallholder C dynamics
9.1.1.4: Develop R and D linkages between West African scientist networks, selected communities, and the Chicago Climate Exchange

Milestones:
9.1.1.a: Simple soil carbon model developed and published (2008)
9.1.1.b: Datasets on tree age, metrics, and underlying soils generated for intensive study sites in Burkina Faso, Ghana, Mali, Senegal (Mar. 2009)
9.1.1.c: Remote sensing method for estimating landscape C stocks and associated uncertainty developed and published (Feb. 2009)
9.1.1.d: Allometry models for dominant local tree species developed for intensive study sites in Burkina Faso, Ghana, Mali, Senegal (Mar. 2009)
9.1.1.e: Logistic growth curve models fitted for dominant local tree species of Mali (Apr. 2009)
9.1.1.f: Crop, soil and tree carbon pools assembled in simple landscape C model (May 2009)
9.1.1.g: Ensemble Kalman Filter tested against long-term trial data in Burkina Faso (May 2009)
9.1.1.h: Ensemble Kalman Filter applied to smallholder farmer conditions in Mali, results published (Sep 2009)
9.1.1.i: Mid-size (USD 3M) proposal identified for community carbon contracts through Chicago Climate Exchange
9.1.1.j: Ensemble Kalman Filter applied to smallholder farmer conditions in Ghana (Dec 2009)

Activities exemplar

We have declared output target 9.1.3 National partners have effective tools, methods and necessary capacity building for assessing the carbon sequestration capacity of dry lands for 2010

Activities:
9.1.3.1: Assemply of soil C data sets along with necessary weather data from benchmark site
9.1.3.2: Needs assessment of the NARSs, Stakeholders for capacity development in the area of simulation modeling
9.1.3.3: Preparation of needed training material for conducting simulation modeling course
9.1.3.4: Training of PG students in the area of C Sequestration
9.1.3.5: Training of NARSs partners in use of century, APSIM and DSSAT crop models to manage C sequestration in the tropics.

Milestones:
1. Compilation and archiving of data sets from the benchmark locations (2009)
2. International workshop on C Sequestration (2009)
3. Three PG students in the area of C sequestration guided (2010)
4. NARSs Scientists sensitized and trained to use simulation modeling for C sequestration (2010)

Alignment to CGIAR Priorities : 4A: Promoting integrated land, water and forest management at landscape level;

Output 2: **New tools and methods for management of climatic variability with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**

Description:

Priority 4D, Specific goal 8: Identify social, economic, policy and institutional factors that determine decision-making about managing natural resources in intensive production systems and target interventions accordingly

This research will involve the following areas:

This is a rapidly growing area which ICRISAT is playing a leading role in promulgating. Between 2005-2007, ICRISAT partnered with meteorological services, CGIAR Centers and leading climate science researchers worldwide in the development and initiation of 8 specially funded Proof of Concept projects centered on climate risk management in SSA. The projects have received support from a range of donors, namely (i) The World Bank, (ii) ACIAR, (iii) African Development Bank, (iv) IDRC and (v) EU. Activities of these projects are currently underway in *Mozambique, South Africa, Kenya, Madagascar, Ethiopia, Malawi, Zambia, Zimbabwe, Uganda, Sudan, Kenya Ghana, Mali and Niger*. In 2008, 3 more such projects have been funded. Two , funded by IDRC-Research in Tobacco Control (RITC) and BMZ are active in Malawi and West Africa (Niger, Burkina Faso, Mali and Ghana) respectively, and a third, of particular importance, is the project funded by the Asian Development Bank which has expanded this work to *India, Peoples' Republic of China (PRC), Sri Lanka, Bangladesh, and Pakistan*. ICRISAT also projects that it will play a major role in the development of the forthcoming challenge program on climate change.

Activities Exemplar

We have declared output target 2010 9.2.1 At least one decision aide that support strategic and tactical decision making in selecting appropriate responses to manage climate induced risks and capitalize on opportunities created by variable climate, developed and availed to stakeholders.

Activities and internal milestones for this output target have been fully developed and are presented in the following box:

Activities:
(1.1) Hold Stakeholder Survey Workshop (March 2007) with NPP networks and projects to further specify their demands for climate risk information and conduct a gap analyses
(1.2) Undertake a literature review of information and results relevant to climate variability and change in ECA and where relevant, globally
(1.3) Hold a Stakeholder Review Workshop in December 2007 to discuss, prioritize and summarize usable outputs of the literature review
(1.4) Synthesize conclusions from activities 1.2 and 1.3
(1.5) Circulate synthesis report widely as an ASARECA publication with corresponding funding from ASARECA

Milestones:
(1) November 2007. Stakeholder Survey Workshop held
(2) March 2008. NPP priorities and gap analyses produced
(3) August 2009. Literature review completed
(4) August 2008. Stakeholder Review Workshop held
(5) March 2009. Information synthesis and publication completed(6) June 2009. Final report widely circulated to stakeholders by ASARECA

Activities:
(2.1) Organize and harmonize long-term daily climatic data for principal NMS stations together with data from surrounding stations and those stations with longest available data sets in collaborating countries
(2.2) Jointly train NMS and NARS in climate risk-based applications of the above data through e-learning and face-to-face workshops
(2.3) Work with leaders and decision makers in NMS and NARS to develop Good Practice guidelines that recognize and exploit the increased collaborative capacity of NMS and NARS at both central and decentralized locations

Milestones:
(1) December 2007. ToRs for activity 2.1 developed
(2) June 2008. E-learning and face-to-face training workshops completed
(3) September 2009. Meta climate data available on collaborating NMS websites

(4) May 2010. Good Practice guidelines documented and distributed to stakeholders of innovation system

Activities:
(3.1) Develop the criteria to guide prioritization and selection of Proof of Concept (PoC) studies. (e.g. data and expertise availability, gender, environmental gains expected, analytical complexity and innovation, regional relevance, etc.)
(3.2) Draw upon the outputs of activity 1.1 to identify and prioritize climate risk management NPP issues to be addressed in PoC studies according to criteria established in 3.1, and design and schedule PoCs with collaborating countries
(3.3) Initiate and backstop, through e-mail and visits, 8 PoCs in selected countries
(3.4) Hold two PoC review and analyses workshops in April 2008 and December 2008
(3.5) Synthesize PoC outputs and lessons learned based on an end of PoC reporting workshop in June 2009

Milestones:
(1) November 2007. Criteria for PoCs developed
(2) February 2008. Priority NPP climate risk management concerns identified.
(3) May 2008. Design and scheduling of PoCs completed
(4) June 2008. PoCs initiated
(5) December 2008. First mid-PoC review workshop held
(6) August 2009. Second mid-PoC review held
(7) February 2010. PoC Reporting and Synthesis Workshop held
(8) August 2010. PoC Synthesis Report available for distribution by ASARECA

Output 2009 9.2.2: A report on opportunities for Adapting Agriculture to climate variability and change in ECA published:

This publication will synthesize and present the opportunities for adapting agriculture to climate variability and change based on the reviews carried out by the Ethiopia, Kenya, Sudan and Tanzania country teams in 2008. The report will summarize the important lessons from the past research, identifies the gaps in our understanding and proposes intervention options that make agricultural systems in ECA more resilient to impacts of climate variability and change.

Output 2009 9.2.3: A synthesis report on “Tools and methodologies to assess climate vulnerabilities and support informed decision making for improved management of agricultural systems in ECA” published

The complex nature of the interactions between climate and agricultural systems calls for better use of available tools. However, lack of awareness about the available tools and their potential applications is limiting their widespread use by researchers from national systems to conduct required analysis to understand, monitor and manage climate induced crises on the soil-plant-climate systems. This publication is aimed at providing an overview of the available tools and demonstrate the usefulness of these tools with clear and easily understandable examples. The three important areas that this publication will deal with are:

a. characterizing and understanding the variability in the climate and possibly climate change
b. assessing the impacts of the variable climate on productivity, profitability and sustainability of various agricultural systems in semi-Arid tropics
c. enhancing and promoting informed decision making while selecting soil, water and crop management practices with due consideration to the risks and opportunities associated with them

Output 2011 9.2.2: A web based knowledge base on impacts of climate change and variability and associated physical and economic vulnerabilities in ECA created

ICRISAT and its partners are currently engaged in the implementation of a number of projects aimed at managing climate induced crises. This research is resulting in the generation of valuable data and information, which need to be carefully compiled and systematically organized for wider use by the target stakeholders. The proposed knowledge base acts as a single window source for all the relevant information on managing the impacts of climate variability as required by the various stakeholders ranging from farmers to policy makers. The knowledge base will also be made available on a CD.

Alignment to CGIAR Priorities : 4A: Promoting integrated land, water and forest management at landscape level; 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas;

Output 3: **Affordable and sustainable crop management options (nutrients and water management) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**

Description:

Priority 4C, Specific goal 1: Improved management practices that enhance the productivity of water

Priority 4D, Specific goal 1: Improve understanding of degradation thresholds and irreversibility, and the conditions necessary for success in low productivity areas

Priority 4D, Specific goal 3: Identify domains of potential adoption and improvement of technologies for improving soil productivity, preventing degradation and for rehabilitating degraded lands

Priority 4D, Specific goal 5: Improve soil quality to sustain increases in productivity, stability and environmental services through greater understanding of processes that govern soil quality and trends in soil quality in intensive systems

This research will involve the following areas:

- Land degradation
- Simulation modeling
- Improving productivity
- Enhancing soil nutrients

In the latter case our research in micro-dosing has evolved from simple fertilizer application research to the complex area of finding ways in which it is possible to scale-up these recommendations to regional level and to overcome the present constraints to farmer adoption that are currently articulated. ICRISAT's collaboration with Project Intrants (FAO) and the Warrantage schemes are developing important IPGs in this area which are showing their transferability across national boundaries.

Activity exemplar

3.1. In partnership with NARES, NGOs and extension units, scale out and up the microdose technique and inventory credit system (warrantage) to reach thousands of farmers in West Africa (Burkina Faso, Mali, and Niger)

Alignment to CGIAR Priorities : 4C: Improving water productivity; 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas;

Output 4: **Affordable and sustainable crop management options (IPM and IDM) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**

Description:

Priority 4D, Specific goal 6: Design methods to manage and enhance biodiversity to increase income, reduce risk and vulnerability through IPM, crop diversification and rotations, and genetic diversity within crop species

This research will involve the following areas:

- Simulation modeling
- Improving productivity
- Pests and diseases through IPM

In the latter case our research will focus on further development and promotion of IDM for ICRISAT's mandate legume crops in Asia, and the development and testing of early warning systems for Aflotoxin risk in West Africa. These activities are delivering important IPGs, which are showing their transferability across national boundaries.

Alignment to CGIAR Priorities : 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas;

Output 5: **Affordable and crop-livestock management options developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**

Description:

Priority 4C, Specific goal 1: Improved management practices that enhance the productivity of water

Priority 4D, Specific goal 2: Protect the livelihoods of rural livestock keepers in low potential areas

This research will involve the following areas:

- Availability and access to feed resources
- Assessment of drivers for change in water use at the landscape scale and an assessment of their effectiveness for integrated water management in crop livestock systems

2011 9.5.1: Dual purpose crop varieties for food and fodder production evaluated and promoted with farmers participation in the watersheds of India and Africa

Activity exemplar:

Dual purpose sweet sorghum varieties are tested on-farm and on-station to select varieties suitable for food and feed production while taking in consideration water use efficiency and suitability as supplementary feeding during the dry season. Varieties selected will be further tested and made available especially to livestock keepers experiencing severe dry season feed shortages.

Impact statement:

Livestock quality and production is severely affected by poor nutritional status of livestock – developing markets to improve income growth on small scale farms in the SAT in the absence of efficient feed systems is counter productive. The livestock market development work done by ICRISAT and ILRI in southern Africa will provide the incentive for farmers to invest in improved feed systems. This dual approach will ensure that farmers have access to both functional markets and improved feed systems which will ensure the rapid development of improved mixed systems with long term positive impact on human livelihoods and the environment as fewer livestock will be dependant on natural resources during the dry season.

Alignment to CGIAR Priorities : 4C: Improving water productivity; 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas;

Impact Pathways by Output

Output 1: New tools and methods for management of multiple use landscapes with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Increasing awareness of different stakeholders such as scientists, policy makers and students is a critical step for achieving the desired impact. Most of the stakeholders from the NARSs and NGO's are not trained in use of simulation models for estimating C sequestration due to different sustainable interventions. Key activities to overcome such constraints include:

- Workshops, training of students and researchers and the sensitization of the policy maker on the impacts of climate change on livelihoods of poor in the SAT who are more vulnerable
- Be able to simplify smallholder carbon accounting protocols to make them operational and adaptable by interested NARS, NGOs and monitoring agencies
- Showcase examples of existing agricultural carbon trade contracts to raise awareness about opportunities among local stakeholders
- Develop linkages with effective funding mechanisms and brokers such as the Chicago Climate Exchange
- Increase publication rate about carbon sequestration potential in smallholder settings to increase partner awareness
- Work towards inclusion of soil carbon sequestration as a CER option in the CDM and other regulating mechanisms

Output 2: New tools and methods for management of climatic variability with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Increasingly a wide range of reliable and proven tools and approaches are becoming available for the assessment and management of both current and projected future climate-induced risk associated with rain-fed agricultural production in the SAT of Africa and Asia.

- The first imperative for impact is that such tools and their products become more widely used by our NARS partners who seek to promote agricultural innovations for adoption by risk averse small-scale farmers. To this end, building their capacity to use and apply such tools is a high priority

In addition, many of these tools rely upon the availability and usability of long-term daily climatic data that has been collected by the National Meteorological Services (NMS) for many decades. Currently, in most countries in Africa and Asia, NMS are largely sidelined from agricultural development and are not properly aware of the central role that they could and should assume in assisting both researchers and the farming communities cope better with current and future climate risk.

- The second imperative for impact is that, through a combination of advocacy and capacity building, the NMS must be helped to "move centre stage" in agricultural development

Through the use of such tools and approaches, ICRISAT and her partners have built a body of evidence over the last 4 years that strongly points to the fact that helping vulnerable farming communities cope better with the current climate risk associated with season-to-season variability in rainfall is an absolute prerequisite for their eventual adaptation to projected climate change. In other words, the successful promotion and adoption of already proven agricultural innovations is essential in building livelihood resilience and the adaptive capacity of farmers and will do much to mitigate the negative impacts of projected climate change.

- The third imperative for impact is therefore advocacy based and targeted towards Policy Makers at a range of scales. They must be presented with persuasive evidence that convinces them that the global concern about adaptation to climate change should not and cannot be divorced from addressing their current development priorities

Output 3: Affordable and sustainable crop management options (nutrients and water management) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

The fertilizer microdosing technology has been promoted in Burkina Faso, Mali and Niger along with the warrantage or inventory credit system with increasing adoption rate but there is a still a need for a wider scaling up and out to reach millions of farmers across national boundaries for a greater impact on the livelihoods of rural communities.

- The first imperative for impact is to ensure that extension agents, NGOs, and farmers are fully involved in the establishment of large field demonstrations and farmers field schools via a participatory approach; Exchange visits between farmers across and within the national boundaries are crucial in exposing the technology to the end users as well as in enabling the sharing of experiences
- The second imperative for impact is that farmers organizations are strengthened through capacity building, thereby ensuring sustainability
- The third imperative for impact is to enhance farmers access to inputs and output markets by developing, training and strengthening agro-dealers in collaboration with other on-going initiatives such as the West African Seed Alliance (WASA), the Alliance for a Green Revolution in Africa (AGRA) Agro-dealer Development Program, etc.
- The fourth imperative for impact is that sound policy guidelines are developed and implemented to provide a conducive environment for the use of the technology by rural communities

Output 4: Affordable and sustainable crop management options (IPM and IDM) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Increasingly a wide range of reliable and proven components of Integrated Disease Management (IDM) Technologies are becoming available for the assessment and management of both current and projected future climate-induced fungal, viral and bacterial diseases caused yield losses to rain-fed food legumes crops in the SAT of Asia.

- The first imperative for impact of IDM components (for example disease resistant varieties, seed treatment, minimal uses of user friendly fungicides) either alone or in combination become more widely used by our NARS partners who seek to promote IDM innovations to minimize risk to the small small-scale Chickpea, Pigeonpea and Groundnut farmers. To this end, building their capacity following farmer's participatory IDM research and development to use and apply IDM components is a high priority

In addition, many of IDM components are location specific and rely upon the availability and usability of long-term farmer's centric, and scientist lead approach. Currently, in most SAT environments in Asia, Farmers Participatory Research and Development on IDM and its integration with Integrated Crop Management (ICM) is sidelined from agricultural development and are not properly aware of the central role that IDM/ICM could and should assume in assisting both researchers and the farming communities cope better with current and future climate change and present day diseases and their changing scenario, and new emerging diseases induced by moisture stress and variable durations of droughts.

- The second imperative for impact is that, through a combination of farmers orientation, advocacy and capacity building, the IDM as an integral part of ICM or improved crop management practices must be helped to "move centre stage" in agricultural development

Through the use of farmers participatory IDM and approaches, ICRISAT and her partners in Asia have built a body of evidence over the last 4 years that strongly points to the fact that helping vulnerable farming communities cope better with diseases of legumes such as wilt and sterility mosaic diseases of pigeonpea; wilt, Ascochyta blight and Botrytis Gray Mold diseases of chickpea and foliar Diseases of groundnut.

Further the currently climate risk associated with season-to-season variability in rainfall is an absolute prerequisite for the outbreak of new diseases or minor diseases becoming potential threat to food legumes production in the SAT environment. This needs preparedness to cope up with such a situation.

Output 5: Affordable and crop-livestock management options developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

The increasing demand for livestock products offers small-scale farmers in the SAT opportunities for increased market participation. However, existing production systems are poorly developed with limited integration with crops. In addition, livestock markets are largely informal with weakly developed inputs and services. Transaction costs are high, resulting in low prices. Farmers are therefore unable to exploit the full potential of their herds. Improved markets and management systems, specifically feed systems and health support will improve production, market participation and ultimately income growth. We hypothesize that improved market access will provide farmers with the incentive to invest in management technologies to enhance off take and increase the quality of their livestock.

First imperative: Markets which are functional, efficient and available to farmers. Market places should exist with appropriate infrastructure, and related institutions, and must conduct regular sales. Transaction costs should be reasonable with clear and transparent processes and information systems. The returns from such markets should provide opportunities for sales at competitive prices.

Second imperative: There should be a direct link between technologies employed and the market-based incentives. In order for the markets to function as incentives for greater technology adoption, there should be clear tangible returns on those investments at the market place. For instance, improved animal product quality as a result of increased investments in animal health and feed systems should have direct financial rewards in price per unit of higher quality products.

Third imperative: Increased information flow and integration between value chain players. Increased information exchange between value chain players will bring about improved coordination of transactions based on the requirements of players along the value chain. This could include consumers' requirements of products and synchronization of production with

demand. All of this should focus on increasing the efficiency of the value chain, thus reducing the transaction costs and allowing more profits to filter through to producers.

To achieve this: Innovation Platforms, forums that facilitate communication between farmers, market players, input and service suppliers in local production and marketing systems, are established 'around' specific livestock markets in southern Africa. The stakeholders (i.e. value chain participants) meet to identify challenges and opportunities with regards to both production and marketing and collectively identify and evaluate improvements in management technologies and markets. This new approach places technology and market development in a local context based on common interests and strong partnerships between the private and public sectors. It builds local capacity, aligns production with market demands, and improves the overall efficiency of the system, thereby increasing food security and income growth and supporting the development of sustainable impact pathways.

International Public Goods

Tools, methods for research and other IPGs that have applicability beyond one nations borders:

- Simulation models
- Climate information products
- Participatory approaches for crop and natural resource management
- Decision support systems
- Ways to link farmer-participatory research with biophysical simulation and predictive models
- Participatory approaches and decision support systems
- Ways to improve public-private sector linkages
- An exemplar model for watersheds consortium development
- Alternative feed and forage strategies
- Promotion of better practices in using macro and micro nutrients, low-input precision agriculture (micro-dosing), genetic resources, particularly legumes, and IPM/IDM strategies (Striga management) in sustaining productivity in rainfed and irrigated areas
- Improved strategies of crop rotation involving legumes to ensure system diversification
- Improved strategies that minimize risk and maximize returns
- Enhanced capacity of the NARES to conduct more comprehensive and in-depth research through application of new science tools and methods
- Scaling up methods used by NARES partners, NGOs and development agencies to widely disseminate improved soil fertility and water management technologies e.g. conservation agriculture

Elaboration of Partners Roles

The governments and NARES in Bangladesh, Botswana, Burkina Faso, Ethiopia, Ghana, India, Kenya, Malawi, Madagascar, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Tanzania, Thailand, Uganda, Vietnam and Zimbabwe are our principal research partners in the development of sustainable land, water and crop management interventions (FAO, the Alliance Centers, CSI, OASIS, DMP and INRM SWEPs), and will continue to benefit from active participation in this project. Graduate students will continue to be a focus area for capacity building. Research benefits that accrue and the skill of the project members will help develop the future IGNRM agricultural research strategies of sub-regional organizations such as ASARECA, SADC, INSAH, CORAF, FARA and APAARI.

In recent years, with the increased focus on climate issues, national meteorological departments are emerging as a important partners especially in our research aimed at better understanding of climate vulnerabilities and at developing strategies the mitigate the adverse impacts of variable climate.

The national program partners participate in project planning and implementation as well as in training and capacity building. The evolving network of IGNRM scientists adapt methods promulgated by ICRISAT while policy makers use alternative development pathways particularly for pro-poor policies and risk management strategies. We assume that research benefits also accrue to universities, NGOs, the private sector and many farmer organizations. For example, collaboration with research managers, scientists and development specialists on improved priority setting, will improve research efficiency, resource allocation, the effectiveness of development interventions, and our understanding of policy and institutional constraints. Related capacity building under Project 1 should help to ensure the achievement of this assumption. The SLP SWEP (ILRI et al.) and The Water and Food CP consortia provide a range of additional partners and it is expected that the African CP will do likewise in 2008.

Key Strategic Alliances: FAO/Warrantage Project Partners (for expertise in warehousing and micro-credit), Water and Food CP Consortia (Limpopo and Volta basins) for expertise in improving water use efficiency in dryland environments, CRIDA (India) for watershed management expertise and AREX (Zimbabwe) for local support in fertilizer trials as part of disaster relief processes. National Meteorological departments in ESA.

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**New tools and methods for management of multiple use landscapes with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**	NARES agronomists and breeders, Alliance and CSI partners Universities, NGOs, Africa and Water CP, climatologists and policy makers	New tools, approaches and technology options for sustainable development and improved livelihoods incorporated into the policy and implementation guidelines used by NARES partners New spatial tools and products on plant adaptation allow seed sector stakeholders, policy makers to deploy tactical and strategic mechanisms for food security	New strategies that exploit climate niches, through the use of tools that match commercial opportunities have brought improved livelihoods for the SAT poor
Target 2009: Materials	9.1.1 Stochastic data assimilation techniques introduced in field-to-landscape research/modeling	NARES, NGOs and policy makers, Alliance SWEP and CP partners, the input and output private sector	NARES research capabilities enhanced through collaborative activities, use of new tools (simulation models and GIS) and training	Income and food production of smallholders has increased without further degradation of natural resource base
Target 2010: Materials	9.1.1 Cultivar adaptation maps available to seed sector stakeholders, policy makers under current and projected climate conditions in West Africa			
Target 2010: Materials	9.1.2 Cost effective and statistically acceptable GIS-based interpretation method for mapping, soil deficiencies at micro-watershed and district levels			

	Outputs	Intended Users	Outcome	Impact
Target 2010: Capacity	9.1.3 National partners have effective tools, methods and necessary capacity building for assessing the carbon sequestration capacity of dry lands			
Target 2010: Capacity	9.1.4 Assessed and documented carbon stocks in major production systems in Indian SAT			
Target 2011: Capacity	9.1.1 Partners and watershed implementing agencies have an effective hydrological model for proper planning of water resource development at watershed scale			
Output 2	**New tools and methods for management of climatic variability with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**		End users (farmers and their support agents) are better able to adapt to climate variability and change, with improved management of seasonal and annual climate risks Decision makers identify and promote new strategies that exploit climate niches, through the use of tools that match commercial opportunities Capacity of national and regional institutions to understand the risks	In rainfed areas, greater resilience to climate variability through integrated land and watershed management. Agricultural productivity and incomes has been increased in target countries Communities have experienced reduced vulnerability to climate variability and are more resilient and better prepared through the implementation of the improved risk management strategies

	Outputs	Intended Users	Outcome	Impact
			associated with climatic variability enhanced	
Target 2009: Capacity	9.2.1 Greater application of climate predictions and cropping practices by NARS, extension agencies and farmers to manage climate risks in Africa and Asia			
Target 2009: Capacity	9.2.2 A report on opportunities for Adapting Agriculture to climate variability and change in ECA published 2009			
Target 2009: Capacity	9.2.3 A synthesis report on "Tools and methodologies to assess climate vulnerabilities and support informed decision making for improved management of agricultural systems in ECA" published			
Target 2009: Capacity	9.2.3 Ex-ante assessment of climate change impacts on SAT agriculture			
Target 2010: Practices	9.2.1 At least one decision aide that support strategic and tactical decision making in selecting appropriate responses to manage risks and capitalize on opportunities created by variable climate, developed and availed to stakeholders			
Target 2010: Other kinds of	9.2.2			

	Outputs	Intended Users	Outcome	Impact
knowledge	Impacts of global climate change projections on SAT agriculture evaluated in at least two countries in ECA			
Target 2010: Practices	9.2.3 An institutional innovation system for managing climate variability and change will established in ECA which will greatly enhance the awareness, competency and collaborative ability of key institutions including NARS, NMS, ASARECA Networks and other key change agents to jointly address climate risk concerns			
Target 2010: Capacity	9.2.4 Regional capacities in linking simulation models, participatory on-farm research and climatic forecasting to increase the competencies of smallholder farmers in coping with current climatic variability and adapting to potential climatic change strengthened in East and Southern Africa			
Target 2011: Capacity	9.2.1 Characterized and documented production zones for ICRISAT mandate crops in the context of climate change			
Target 2011: Capacity	9.2.2 A web based knowledgebase on impacts of climate change			

	Outputs	Intended Users	Outcome	Impact
	and variability and associated physical and economic vulnerabilities in ECA created			
Target 2012: Capacity	9.2.3 Documented the effect of climate change on ICRIST mandate crops and developed strategies for adoption against climate change			
Output 3	**Affordable and sustainable crop management options (nutrients and water management) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**	NARES, Universities NGOs and policy makers, Alliance, SWEP and Water CP partners NARES, NGOs, CBOs, private sector, Alliance and development partners	SWMnet and WFCP partners improve research efficiency, adopt improved practices/policies for enhancing water productivity and actively scale these out across the SAT	Pressure on the supply of water for irrigated land is reduced as rainfed agriculture has increased its contribution to food/feed production. NARES research capacity this area has been enhanced
Target 2009: Capacity	9.3.1a Capacity building of NARES partners to implement improved NRM approaches, including use of simulation models, for intensifying and diversifying cropping systems in low and high potential environments undertaken			
Target 2009: Other kinds of knowledge	9.3.2a The water productivity of at least three strategic crops, under improved water management systems quantified, for intensifying and improving the economic use of water in low and high potential environments, and			

	Outputs	Intended Users	Outcome	Impact
	widely disseminated in WCA and ESA regions			
Target 2009: Practices	9.3.2b At least six water management technologies/practices for strategic crops, adoptable by smallholder farmers in ESA are identified and their returns to investment quantified			
Target 2009: Other kinds of knowledge	9.3.1b At least two technical options (Nutrients and water management) provided for intensifying and diversifying production systems in low and high potential environments			
Target 2010: Policy strategies	9.3.1 Enabling policies for promotion and use of both macro and micronutrients in the semi-arid rainfed areas of Africa and Asia			
Target 2011: Policy strategies	9.3.1 Appropriate policy and strategies that would contribute to sustainability of land and water resources and encourages the use of conservation effective interventions developed and promoted in SAT Asia			
Target 2011: Practices	9.3.2 More efficient allocation and use of water resources in SAT by farmers to minimize			

	Outputs	Intended Users	Outcome	Impact
	adverse effects of climate variability			
Target 2012: Other kinds of knowledge	9.3.1 Microdosing technique and inventory credit system (warrantage) validated and adopted widely in Burkina Faso, Mali and Niger			
Output 4	**Affordable and sustainable crop management options (IPM and IDM) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia**	NARES, Universities NGOs, CBOs and policy makers, Alliance and CP partners, private sector	Partners (NARES, CBOs, private sector) promote better IDM/IPM strategies in rainfed and irrigated areas, particularly for legumes, fully exploiting available genetic resources	Larger and better targeted investment in rainfed agriculture by a range of stakeholders (district policy makers, private sector, micro-finance institutions, extension services, meteorological departments, NGOs) has occurred
Target 2011: Practices	9.4.1 At least two IDM approaches for groundnuts pigeon pea and chickpeas promoted in at least three regions of Asia			
Target 2011: Other kinds of knowledge	9.4.2 Aflatoxin advisories and mitigation evaluated by farmers, development actors			
Output 5	**Affordable and crop-livestock management options developed and promoted with associated capacity building in collaboration with NARES**	NARES, NGOs, CBOs and policy makers Local and regional planners, local and global researchers and investment decision	Partners have access to a new, custom early warning (EW) products in Mali and Ghana An understanding of the	Nutrition, health and income of smallholder groundnut producers improved through enhanced, targeted EW Improved natural resource

	Outputs	Intended Users	Outcome	Impact
	partners in Africa and Asia	makers Development planners and implementation agents, water management authorities, dissemination networks	dynamics of land degradation as influenced by water use aid in improved decision making with regard to water management by local and regional authorities A gap analysis of institutions involved in water management will allow for improvements to be made with water management Improved livelihood of SAT; farmers thru diversified livelihood options;	management, reduced environmental impact Strengthened institutional framework for more effective water management Sustainable livestock-based income enhancing systems developed for improving farmers incomes
Target 2010: Practices	9.5.1 Assessment of drivers for change in water use at the landscape scale including Water Governance profiles in study sites (Ethiopia and Zimbabwe) and an assessment of their effectiveness for integrated water management in crop livestock systems			
Target 2011: Materials	9.5.1 Dual purpose crop varieties for food and fodder production evaluated and promoted with farmers participation in the watersheds of India			

ICRISAT-10: Virtual Academy for the Semi Arid Tropics (VASAT) in Asia and West and Central Africa

Project Overview and Rationale

To improve agriculture and to mitigate the effects of drought, desertification and the other major constraints of SAT environments, there is an urgent need for a sustained information, communication, capacity building and social mobilization effort to link strategic sectors, especially most vulnerable rural communities, researchers, extension workers and policy-makers. The dictum information is the backbone of drought preparedness advocated by the UN accurately captures this need. Likewise, the UN Convention to Combat Desertification and Drought (UNCCD) has laid high importance on implementing a communication strategy, a blend of both top-down as well as bottom-up approaches, to support initiatives in combating drought and desertification. This project uses ICT-mediated methods to build the research and human resources capacity of our partners and helps ICRISAT to scale-out and scale-up its research results and technologies. We are harnessing recent advances in ICT and open-distance learning, as an innovative and cost-effective medium to inform, educate, and mobilize a critical mass of our partners and clients spread across big geographical areas in Asia. We are building partner power in West and Central Africa through a variety of participatory knowledge management methods to understand information needs and requirements and meet these with information IPGs and value-added products derived from them. We seek to enhance organizational information flows (internal as well as external) and make agricultural knowledge more accessible in the semi-arid tropics. This will eventually empower vulnerable rural communities to collectively identify problems, articulate their needs and take up informed action especially in times of drought and emergencies. This project will make a contribution to the achievement of MDG 8 on building global partnerships.

Genetic Outputs Description

The target ecoregion, the beneficiaries and end users
The target ecoregion for this project is the SAT of Asia and West and Central Africa. The immediate beneficiaries of this research are our diverse and varied partners in these regions: the NARES communicators, educators, extensionists, NGOs, CBOs and the Open Learning agencies. The end users are the rural communities, especially the women and youth, who would benefit from improved levels of preparedness to drought and desertification events. The results are immediately IPGs as they will be available and applicable to any web enabled scientist, agricultural professional or farmer throughout the SAT.

Is the center a primary or secondary research provider?
The Center started as a primary research provider in this project. An example is the design of a pilot repository of learning objects. However, as partners build capacities in association with the Center, the task of building such repositories will be moved to them. There will be a change in focus, on making available more and newer IPGs to the partners from Centers research, using ICT-mediated methods.

Is it a catalyser, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact
The Center will play all these roles in this research project, but its primary role is to catalyse the development of new technology blends and to enable partners to access information IPGs. The Center will not be a core-technology developer, but will develop strategies for appropriate blend of technologies that the partners need to enhance preparedness levels among the end users. An example is the blended use of community radio with the digital satellite radio in Niger in the Kahe community. A large quantity of ICRISAT-generated IPGs are partially in digital format, and this project will design novel methods to render them fully in digital format consistent with global specifications. This will enable significantly improved access to IPGs by the partners, and will contribute to easy value addition by partners for delivery to the end

users. Advocacy is needed on occasions to enable national policy makers to extend support to the NARES partners for inclusion of new technology blends in capacity strengthening and in extension.

Comparative and complementary advantages of the project activities
ICRISAT is in an advantageous position to develop new prototypes in information and knowledge sharing with partners and end users. A number of software tools have been developed during 2004-05 which were peer reviewed for cost-effectiveness and suitability, and can now be used to develop novel content repositories. ICRISAT is also well placed in terms of human resources and capacity to adopt new methods (such as Web 2.0) to augment internal knowledge flows such that external partners can access internally generated information products. The Center also has considerable expertise in the use of participatory appraisal methods. Over the last three years, we have also developed capability to sustain a coalition of partners using online methods. Our biggest comparative advantage is our internationality and global presence, which permits viable partnerships with partners from varied disciplines and countries to work together in sharing knowledge.

Playing a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs
During the last three years, the Center activities in capacity strengthening were cast in multiple roles, with its research focused on building a generic repository of learning materials. The catalyst role was and will be needed in the future to bring together core-technology development partners to build more flexible software tools that will be NARES-oriented. There is also a need to make core-software developments conform to global specifications. This will allow ICRISAT IPGs to be accessible in novel ways to an even wider, larger audience of NARES, NGO and CBO partners. Thus, the online system for accessing validated agricultural knowledge will itself be an IPG built on global specifications. The strategy for ICT-mediated information dissemination will be generic, combining participation with technology mediation, and thus will be an IPG in the area of extension communication. An example: over the year 2005, ICRISAT catalysed the offering of mass instruction (30000 learners) in India on drought-coping. The partner used a technology for one-way video and two-way audio with success. To expand it to other regions, even in India, a strategy for technology blending is needed and that will be generated on this project.

Alignment to CGIAR Priorities

Multiple (Priorities 2, 3, 4 and 5) but deemed presently to be Blue Skies research. Yet, as an example, this project will assist Projects 3, 4, 5 and 6 align closely with Systems priority Framework Plan 2C which has the following relevant objective:

Contribute importantly to the application and uptake of agricultural innovations within households, communities, regions, and nations

The development of more effective ways of transferring scientific knowledge to farmers and agricultural intermediaries is now a rapidly advancing science using ICT methods. This project works with FAO and many other universities and public and private sector partners to translate communication opportunities and scientific knowledge into beneficial actions for the disadvantaged farming communities of the SAT.

Outputs Description

Changes from Previous MTP
None.

Output 1: ICT-mediated knowledge sharing strategy developed and implemented with partners and online, web-based repository of learning materials designed and developed in the public domain with appropriate capacity building

Description:

Under this group of activities, we will focus on identification of partner information needs (including end user needs, through the partners), technology assessment, local capacities and resources, in order to develop a comprehensive knowledge sharing strategy that is tech-mediated (NOT tech-driven). This would be a contribution to the ongoing global search for novel knowledge sharing models that take research results to mass audience. Specific variants of this generic strategy will be tested with partners in two locations, one in Asia and another in WCA.

An integral component of activities on this group will be the design and development of a comprehensive repository of learning granules and objects derived from ICRISAT IPGs (instructional modules). There are no global procedures and protocols available for conversion of generic agricultural information and instruction into locally viable information materials. We will use this repository to develop a protocol for conversion of globally generated learning granules into local materials by partners. This will be anchored in a distributed grid of learning materials and in a training grid for partners.

Activities in 2011 will take forward the outputs and outcome of activities carried out during 2009-10. The repository designed and tested in the earlier years would be deployed for large-scale access to create a portal. This as is standard in industry would combine a wide range of SAT agricultural information from ICRISAT's research and training programs and ARI-generated open access research literature and readily available online services in mapping and meteorology to create opportunities for highly customized decision making at local levels by a host of partners allied with the NARES. Besides the ICT-KM program of CGIAR, the ICRISAT-FAO collaboration will play a major role in creating an ontological basis for highly effective classification and auto-tagging of web-based research and learning materials (already transformed into granular format in the preceding years) using its AGROVOC in English. The portal that is fully deployed will be a global first in agricultural sciences combining advanced content organization built on global specifications and standards (such as the FAO AGROVOC) with a spectrum of information services that can yield highly focused results in local-level decision making in the SAT region. The technological challenge of engineering rapid transformation of online IPGs into locally useful decision-support tools would have been fully demonstrated with NARES partners.

Activities exemplar

An information services portal for SAT agriculture with focus on mandate crops deployed for real time use, built on semantic web technologies (especially topic maps and semantic tools in Wikis) and using FAOs English AGROVOC as ontological basis.

Output target milestones for 2009-2011:
- Five component crop-based web sites involving topic maps (2009: 2 components available)
- 10000 information objects per standard definition (2009: 1000 information objects tested)
- 26000 AGROVOC terms fully revised to provide an ontology (2009 completed)
- Portal delivered also in off-line mode in high capacity discs to 50 NARES partners (2011)
- Services tested in four NARES partner locations for the year (2009-2010)
- Design, user testing and engineering acceptance documents published (2010)
- NARES users comments accessible directly on the portal blogs and Wikis (2010)

Alignment to CGIAR Priorities : 6A: New research; 6C: Development Activities;

Output 2: **New approaches for enhanced access to ICRISAT IPG's developed, tested and shared with partners**

Description: Learning and instructional module IPGs need to be supplemented with the availability of a host of other information IPGs from the center. There is a need to develop systems, software and online tools to facilitate validation and rapid publication of information IPGs for easy access by partners and for co-creation where necessary. A blend of tools and methods from the emerging paradigm of Web 2.0, Open Access/e-prints and online communities of practice will be developed for use by ICRISAT staff and partners. A detailed report on their development, deployment and use by partners will be prepared.

Alignment to CGIAR Priorities : 6A: New research; 6C: Development Activities;

Impact Pathways by Output

Output 1: ICT-mediated knowledge sharing strategy developed and implemented with partners and online, web-based repository of learning materials designed and developed in the public domain with appropriate capacity building

We assume that to improve SAT agriculture and to mitigate the effects of drought, there is a need to develop an integrated knowledge sharing process that links the vulnerable rural families with researchers, policy makers and extension workers (linked to Projects 3,5,6,7,8 and 9 + CSI (removed Oasis). The institutional strategy is to blend the recent developments in open and distance learning sector, (namely the granulation of learning and information materials and their re-combination to suit pedagogic and information management standards), and the hub-and-spokes model of ICT for development (combining the use of mobile phones, satellite and community radio and PC-based platforms) to launch and sustain this process with multiple partners in SAT Asia and WCA. This effort is linked to the AGROCURI Consortium (11 CG centers and 12 ARI+ NARES partners) and supports graduate student research at local universities. A supporting strategic activity and capacity development will be to facilitate production and validation research information using highly accessible Web 2.0 methods that, we assume will enable NARES partners to collaborate in content generation and we offer capacity development to help ensure this.

An Impact Pathway Problem Tree and Network Map were developed for this project and are shown in the 2008-2010 MTP document.

Regional:

In SAT Asia, the KMS along with GT-AE, GT-CI and GT-IMPI will design an online repository of learning granules and objects that conform to global specifications and standards. In one rural cluster, ICRISAT and partners will test the process of knowledge sharing on a large scale with the repository-derived information and will use internet-connected rural access centers.

In WCA, the online repository will be used while the KMS (removed DMP) will conduct tests on mass dissemination using a blend of satellite digital radio and community radio.

Output 2: New approaches for enhanced access to ICRISAT IPG's developed, tested and shared with partners

Remains same and consistent with previous MTP.

International Public Goods

- Baseline information needs in one location in SAT Asia and another in WCA assessed using ethnographic action research (UNESCO) and the FAOs Participatory Rural Communication Appraisal methods will be gathered
- Number of learning modules created in the LO repository in granular, re-useable form will be assessed
- Number of granules used or localized by the partners as evident in their web sites or radio scripts will be measured
- Number of learners passing through the partners channels will be quantified
- Number of Blogs, Wiki articles and entries in E-print server of ICRISAT will be monitored
- Crop knowledge Models for all 5 Mandate Crops

Elaboration of Partners Roles

Identification of Partner Roles:

- LO repository
    - Platform design and management: ICRISAT KMS
    - Nuclear content and validation: ICRISAT GTs AE and CI
    - Assessment of sample LOs for suitability in pedagogy: the University of Florida (changed from the Commonwealth of Learning, which is not a partner- MOU expired and not renewed)
    - Ontology design: ICRISAT KMS with FAO
    - Rural users localization and assessment: ICRISAT KMS (changed from GT-IMPI) with CSO partners (AMS in India)

- Strengthening Knowledge Flows and capacity building
    - User tests on the platform: One OU (YCMOU) and one SAU (GBPUAT- which shares resources from NAIP with us, and not ANGRAU) in SAT Asia and RANET in WCA
    - Collaborative content creation on the platform with one NARES partner in SAT Asia (ICAR-DRR, CRIDA and UAS-R). (removed the DMP) See also the network map below

Key Strategic Partners: VASAT Consortium (expertise in on-line educational techniques), FAO (expertise in ontological study issues).

Logical Framework

	Outputs	Intended Users	Outcome	Impact
Output 1	**ICT-mediated knowledge sharing strategy developed and implemented with partners and online, web-based repository of learning materials designed and developed in the public domain with appropriate capacity building**	NARES, University and extension organizations, CBOs and NGOs, ICT/KM IARC partners, private sector	New tools, approaches and technology options for sustainable development and improved livelihoods incorporated into the policy and implementation guidelines used by NARES partners New spatial tools and products on plant adaptation allow seed sector stakeholders, policy makers to deploy tactical and strategic mechanisms for food security	NARES capacity to foster drought preparedness has been enhanced in Asia; and partner capacity has been augmented in WCA to combat desertification and drought-induced stresses.
Target 2009: Practices	10.1.1 Platform installed in 3 partner organizations			
Target 2010: Other kinds of knowledge	10.1.1 Joint evaluation with partners completed and document on effectiveness of new delivery service developed and shared with all partners			
Target 2011: Practices	10.1.1 Deployment of a web-based information and learning services portal for SAT agro-eco region with focus on 5 mandate crops completed using semantic web technologies			

	Outputs	Intended Users	Outcome	Impact
Output 2	**New approaches for enhanced access to ICRISAT IPG's developed, tested and shared with partners**	NARES and global technology partners, ICT/KM, SWEP and Alliance members	Augmented access to IPG's by NARES and CBO partners brings enhanced capacity to add value to IPG's for more localized use	Improved adoption of ICRISAT materials and technologies by partners has led to better conservation, and more sustainable and integrated use of genetic and natural resources
Target 2009: Other kinds of knowledge	10.2.1 New approach based on web services tested for localization with two partners			
Target 2010: Other kinds of knowledge	10.2.1 Document on the new LO approach and effectiveness developed and published			
Target 2011: Practices	10.2.1 Advanced online repository for sharing higher-education level learning materials fully designed and deployed			

Annexes

Implementation of EPMR/CPER Recommendations

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
R1. The Panel recommends that ICRISAT continue to enhance investments in personnel and infrastructure in the SSA and use the potential for spillover to SSA as one of the explicit criteria used in prioritization of strategic investments in research conducted at the Patancheru headquarters.	Accepted. We will continue enhancing and expanding our investments in sub-Saharan Africa (SSA). We will use potential spillovers to SSA, and vice versa, as an explicit criterion for prioritization of research conducted in Asia through strategic planning and priority setting.	R1.1. Management will plan target investments in SSA keeping in view the external funding environment and regional research requirements.	Strategies for resource mobilization in line with the set targets developed.	In progress	Dec 2009
		R1.2. While conducting the priority setting exercise, as advised by the Panel; an analysis of spillover to SSA and vice versa will be conducted.	Results used as an input in deciding the strategic investments for research for both Asia and SSA.		Mar 2010
R2. The Panel recommends that ICRISAT take ownership of and celebrate the strategic planning and research prioritization process based on: (i) proactive engagement of staff, Board, stakeholders, partners, and donors; (ii) analysis and understanding of recent crop yield and production trends, and projected growth in production	Accepted. Through a redesigned and revitalized strategic planning and priority setting process, the Governing Board and ICRISAT will effectively respond to the priorities of stakeholders for the sustainable development of semi-arid agriculture. Towards this, we will develop and implement a knowledge-based process that is inclusive, seeking	R2.1. Assemble background information, e.g., existing Strategic Plan to 2015, Global Theme strategies, updated information on SAT agricultural trends, regional priorities, ICRISAT's successes and challenges in SSA and South Asia and the new CGIAR Consortium SRF and Mega-Programs.	Background information required for strategic planning identified and assemble.	Internal website established with initial set of documents available.	May 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
and demand for its mandate crops, (iii) scenario analyses that utilizes geospatial analysis, ecosystem and crop modelling, and an appropriate socioeconomic framework.	inputs from key partners and stakeholders, more systematic and more explicit. This will build on our achievements, partnerships and comparative advantages in improving agricultural systems in the semi-arid tropics.				
		R2.2. Evaluate and update all information required for strategic planning. Develop any additional documents.	All required background information required for strategic planning updated and available.	Meeting planned in mid-July to discuss what further documents are required.	Aug 2009
		R2.3 Develop an overview of background strategic planning documents and discuss during the Fall 2009 Governing Board Program Committee meeting.	Governing Board consensus and background information to be used for strategic planning.	Meeting planned in mid-July to draft overview.	Sep 2009
		R2.4. Conduct regional planning meetings (Asia, ESA and WCA) that include key partners and stakeholders to discuss priorities for the region.	Regional priorities and ICRISAT's comparative advantage identified.		Mar 2010
		R2.5. Discuss outcomes of regional meetings with Governing Board.	Overall strategy identified.		Mar 2010
		R2.6. Conduct a global in-house review and planning meeting to discuss and finalize the overall Strategic Plan to 2020.	Regional strategic plans updated.		Jul 2010

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		R2.7. Finalize new Strategic Plan to 2020, seeking final inputs from key stakeholders and partners, and present to Governing Board for discussion and approval.	New Strategic Plan to 2020.		Sep 2010
		R2.8. Develop MTP projects and Business Plan.	MTP projects and business plans.		Mar 2011
R3. The Panel recommends a thorough analysis of past and likely future research spillovers between Africa and Asia to guide ICRISAT resource allocations between those two regions.	Accepted. We will expand our work on studying research spillovers to guide strategic planning and resource allocation across regions and programs with special focus on identifying common biophysical and socioeconomic conditions that enable the adaptation and sharing of innovations.	R3.1. Identification of specific ICRISAT technologies for systematic analysis of the technology spillover benefits across Africa and Asia, taking a sample for different crops, varieties and natural resource management innovations.	A short documentation for each of the identified ICRISAT technologies for systematic analysis of research spillovers.	In progress	Sep 2009
		R3.2. Collect information and key parameters from biophysical scientists and partners in the different countries for estimating spillovers between Africa and Asia.	Database on key parameters essential for estimating the past and likely future research spillovers between Africa and Asia.		Dec 2010
		R3.3. Conduct socioeconomic survey on target technologies across regions.	Database on key parameters essential for estimating the past and likely future research spillovers between Africa and Asia.		May 2011
		R3.4. Conduct geospatial analysis using GIS tools and crop models to determine common impact target	GIS maps showing high potential spillover domains for technologies selected in step 1.		Sep 2011

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		domains across Asia and Africa for technologies identified in 3.1.			
		R3.5. Estimate the extent of spillover benefits from technologies developed in a particular target region to another non-target region.	Technical report on spillover benefits of selected technologies across regions.		Sep 2012
		R3.6. Synthesize the key findings across crops and management technologies and draw lessons and implications for research organization, planning and priority setting in the semi-arid areas	Synthesis report on lessons and implications for resource allocation, for use in Recommendation # 1.		Mar 2013
R4. The Panel recommends that ICRISAT capitalize on its core social science strengths to enhance activities in three areas and their interactions: • research prioritization and project planning (at all levels within the Center); • technology development and adaptation; and • impact assessment	Accepted. We will continue harnessing our strengths in social science to improve research targeting, development, delivery and impacts. This will be institutionalized further as an integral part of our strategic research and planning process whereby insights gained from technology development and adaptation and impact assessment will be used as a guide.	R4.1. Documentation of the current state of research priority setting and project planning process at ICRISAT (at all levels within the Center).	A report describing the current state of priority setting and planning at ICRISAT (project level, regional level, and theme/global level).	In progress	Sep 2009
		R4.2. Analyze trends in crop	Situation and outlook		Mar 2010

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		yield and production for ICRISAT mandate crops for ESA, WCA and Asia.	reports.		
		R4.3. Conduct scenario analysis for ESA, WCA and Asia using an appropriate socio-economic framework, complemented by geospatial analysis, ecosystem and crop modeling.	Regional SAT Futures report for ESA, WCA and Asia.		Dec 2010
		R4.4. Conduct stakeholder and expert consultations involving staff, GB, donors and partners.	Regional reports on priority agricultural research for the SAT of ESA, WCA and Asia based on consultations.		Mar 2011
		R4.5. Perform priority setting using economic framework with required minimum dataset, and outputs from R4.2, R4.3, R4.4 .	Document on regional priorities.		Dec 2011
		R4.6. Prioritize research at the global level (based on comprehensive priority setting in step 2 a, b, c and d and assessment of emerging global issues).	ICRISAT Medium Term Plan reflecting the global and regional priorities.		Sep 2012
		R4.7. Conduct a meta-analysis of all past impact assessments.	Synthesis report of lessons learned on adoption pathways, constraints and impacts documented for ESA, WCA and Asia.		Dec 2012
R5. The Panel recommends that GT-IMPI work on the development of hypotheses	Accepted. Using impact assessment and other tools, ICRISAT will identify	R5.1. Develop an inventory of ICRISAT's downstream work on technology	Report on inventory of ICRISAT's downstream work on technology development,	In progress	Sep 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
that determine the IPG potential of ICRISAT's downstream work on technology development, testing and adaptation.	lessons and testable hypotheses that offer new insights to facilitate scaling up of technologies. We will implement this through wider dialogues among scientists across research themes and locations and with partners, including donors to demonstrate that our impact-oriented downstream work leads to IPGs.	development, testing and adaptation in the last 5-10 years.	testing and adaptation.		
		R5.2. Identify and process documentation for one comprehensive case study for each region, for developing a set of hypothesis to determine the IPG potential of ICRISAT's downstream work on technology development, testing and adaptation.	Selected case studies with indicators to determine the IPG potential of ICRISAT's downstream work.		Apr 2010
		R5.3. Formulate hypothesis and process for up-scaling the technology for one comprehensive case study for each region, for developing a set of hypothesis to determine the IPG potential of ICRISAT's downstream work on technology development, testing and adaptation.	Hypotheses and scaling up processes for the selected case studies.		Jul 2010
		R5.4. Assess using relevant indicators the IPG potential	Report on the selected case studies with indicators to		Dec 2010

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		of ICRISAT's downstream work on technology development, testing and adaptation for one case study for each region	determine the IPG potential of ICRISAT's downstream work.		
		R5.5. Synthesize lessons learned from the inventory and set of case studies selected to determine the IPG potential of ICRISAT's downstream work.	A synthesis on IPG characteristics of down stream technologies including key findings related to the theory of change and associated indicators.		Sep 2011
R6. The Panel recommends that ICRISAT expand expertise and research capacity in advanced biometrics for analysis of germplasm performance across multi-location environments using data generated across the network of multi-environment trials conducted by the Center and its partners across the Asian and African SAT.	Accepted. In collaboration with strategic partners in both regions and with ARIs, we will enhance our biometrics capacity to capture the special opportunity available for ICRISAT to use multi-environment data, including genetic studies, in drawing lessons for future crop improvement research strategies.	R6.1. Identify and prioritize multi-environment data sets for analysis.	Available multi-location datasets identified, and one priority case study per region identified.	Case studies being collated for prioritization for each of the three regions	Sep 2009
		R6.2. Discuss with CGIAR Centers and ARI partners methods for analysis of multi-location datasets.	Negotiations with ARI partners completed for methods of data analysis agreed.		Mar 2010
		R6.3. Develop agreements with the concerned NARS for utilizing their data for multi-environment analysis.	Agreements with NARS partners for data sharing and analysis completed.		Sep 2010

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		R6.4. Share results of GxE and multi-environment studies.	Papers from joint studies published and results shared with partners.		Dec 2011
		R6.5. Internalize and institutionalize the process of obtaining and using multi-location trial data.	Process of GxE studies internalized and institutionalized.		Jan 2012
R7. The Panel recommends that ICRISAT scale up its activities in marker development through strategic partnerships and resource targeting to accelerate the generation of high density reference maps that facilitate gene tagging for MAS in the mandate crops.	Accepted. We will further enhance our efforts to produce genomic tools for our mandate crops by tapping available markers from our partners and developing new marker systems that are genome-wide and cost effective.	R7.1. Compile a table of crop x marker type x markers available. This is currently underway with input from the scientists concerned. The table will be used to identify opportunity for additional resource development	Dynamic inventory of genomic resources and tool available. Priority list for additional marker development.	List of markers (SSR, SNP and DArT) currently available per mandate crop compiled	May 2009
		R7.2. Compile a table of crop x mapping population x target trait. This is currently underway with input from the scientists concerned.	Inventory of existing mapping populations and status of marker genotyping in these.	Inventory of mapping populations nearly complete	Jun 2009
		R7.3. Once priorities have been identified (under 7.1), potential partners with resources or technologies will be identified and contacted.	List of strategic partners for each crop where strategic collaboration can enhance our resources – Strategy established for new marker types.		Dec 2009
		R7.4. In consultation with GT-CI, target traits for improvement using molecular tools will be identified for priority crops.	Inventory of target for MAS in the next 5 years.		Mar 2010

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
R8. The Panel recommends that ICRISAT establish minimal biotechnology facilities in Bamako or Niamey to allow DNA extraction, low throughput PCR-based genotyping and direct access to the bioinformatics platform at headquarters.	Accepted. We will establish minimum facilities for DNA extraction in WCA and provide access by a critical mass of scientists in the region to genotyping services, bioinformatics platform, and training on how to use molecular data in crop breeding.	R8.1. Conduct a feasibility and potential benefit analysis for establishing basic molecular marker facilities at Niamey and Bamako, taking into account existing infra-structure and potential linkages (Universities etc). Dr Waliyar has identified Niamey as the most suitable location for the facility.	Choice of either Niamey or Bamako as the new center for basic DNA analysis facilities.	Niamey has been selected as preferred location	Apr 2009
		R8.2. A list of equipment needed will be compiled, and a budget drafted, taking into account equipment that may be able to be sourced from Patancheru.	An inventory of existing equipment that could be transferred to WCA, and budget of equipment needed to be purchased.	Initial inventory list drafted for further discussion	Jun 2009
		R8.3. Train one ICRISAT scientist based in Niamey in DNA extraction, low throughput PCR who will later train appropriate scientific officers in the region. Regional Director WCA to identify appropriate individual for training.	Trained personnel in WCA.		Dec 2009
		R8.4. In consultation with ISU and Regional Director, assess connectivity and ICRIS/iMAS access from WCA. Plan a training course – to	Scientists from ICRISAT and NARS from WCA trained to use marker technology – adequate connectivity to bioinformatics platform secured.		Mar 2010

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		be held either at Niamey, BecA or Patancheru – for scientists and partners			
R9. The Panel recommends that ICRISAT build a core team with expertise in systems analysis, crop modelling, climate analysis, geo-spatial analysis, and economics located in Africa as a center-wide resource for research, strategic planning and impact assessment, and to concentrate the efforts now dispersed across regions.	Accepted. In implementing this recommendation, ICRISAT will weigh the benefits of deploying such a core team at a single location in SSA against the need of retaining expertise in some of the recommended disciplines in various locations in the regions, and assemble the core team based on ICRISAT's current expertise and prioritized research issues.	R9.1. Define the general Terms of Reference of the proposed Core GIS/Modelling Team based upon (i) considerations of ICRISAT's comparative advantage both now and in the future, (ii) other related EPMR recommendations and (iii) the optimal composition of such a Team that is required to address those ToRs.	ToR and composition of core team defined.	In progress	Sep 2009
		R9.2. Decide to what extent the recommended GIS/Modelling core team should be based, in its entirety, at a single location in Africa and balance this decision against the need to retain some staff with the required disciplines at their current location to support on-going regionally-based initiatives.	Location of entire team defined.	In progress	Sep 2009
		R9.3 Decide at which possible location in Africa for the core GIS/Modelling team based on (i) access to office space and research support facilities and (ii) travel and electronic	Location of core team in Africa.	In progress	Jun 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		connectivity.			
		R9.4 More precisely define the priority research issues identified in the ToRs in 9.1 that the core GIS/Modelling team will need to address in the fields of (i) climate risk management and change, (ii) strategic planning and (iii) and impact assessment. This will be guided by internal considerations as well as external factors, particularly the anticipated definitions of the Mega Programmes and current and future funding support opportunities.	Priority research issues identified.	In progress	Dec 2009
		R9.5. Develop an order of priority for the recruitment of new core GIS/Modelling team members based upon the outcome of steps 9.1-9.4 and taking into consideration the expertise already on board within ICRISAT and that of the new GTL-AES.	Priority for recruitment of core team.		Mar 2010
R10. The Panel recommends that ICRISAT move rapidly to de-emphasise current mature lines of work, particularly in GT-AE (e.g. watershed management in Asia, microdosing, Africa market gardens, dryland eco-farms), and work that can be	Accepted. ICRISAT will adopt a nuanced approach in implementing this recommendation, guided by: (1) the availability and strengths of NARS and development-oriented partners, (2) need to provide technical support	R10.1. Determine which current AES activities in all 3 regions will be de-emphasized and the time frame for such devolution, guided by: (1) the extent and duration of on-going (or pipeline) specially funded projects which	Activities to de-emphasize defined	In progress	Sep 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
performed by the NARS (e.g. jatropha, pongamia, chickpea in rice fallow systems) to free up resources needed for new initiatives.	for such devolution, and (3) extent of remaining research issues for which ICRISAT has a comparative advantage.	support lines of work that are recommended for devolution by the EPMR; (2) the availability and strengths of NARS and development-oriented partners; (3) The need to provide technical support for such devolution; and (4) the extent of remaining strategic research issues for which ICRISAT has a comparative advantage.			
		R10.2. Identify research opportunities that are likely to result from the pro-active devolution of identified lines of AES research to development partners.	Research opportunities for devolution identified.		Mar 2010
		R10.3. Identify new priority areas of AES research for the staff time that will be freed up by the process of devolution.	New priority areas for future research identified.		Mar 2010
R11. The Panel recommends that ICRISAT reorganize the structure and oversight of training and capacity building, and develop output quality criteria, as well as explicit expectations for mentoring and supervising research scholars, research fellows, and interns by ICRISAT scientists.	Accepted. We will restructure and enhance the quality of our training and capacity building initiatives by developing performance and output indicators, fortifying consistency in selecting, mentoring and overseeing scholars and training participants and improving the mentoring capacity of	R11.1. Standardize indicators for performance outputs and quality of training. The Senior Management will set up an appropriate task group for this purpose**.** The LSU Manual of Procedures will be revised to reflect institute-wide standards for research performance assessment in respect of	Document containing revised and new procedures, and online/offline software to capture data.	In progress	Aug 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
	our scientists. ICRISAT sees a particular need for an emphasis on SSA, and believes this should be a system-wide CGIAR priority.	individuals; models from the ARI's and advanced NARES will be considered. Revised procedures and criteria for classification of research scholars, fellows and interns, and processes for trainee data gathering and reporting will be re-engineered and developed. Such data will include trainee-authored publications.			
		R11.2. Standardize institute-wide processes for selection, identification and oversight of scholars and trainees. Existing norms and procedures will be substantially revised to reflect our commitment to grooming future scientists and research managers and to build a global network of alumni of merit and distinction. The task group of Senior Management (in 11.1) will complete this task as well.	Document containing the standardized procedures with guidelines for process data monitoring.	In progress	Dec 2009
		R11.3. Enhance mentoring capabilities of ICRISAT scientists. Through organization of special engagement sessions with reputed peers from ARIs and advanced NARES, and through making available documents on good	Online documents in the Institute Intranet with DVDs being made available to all scientists.		Dec 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		practices online or offline in all the locations. The existing system of seminars by leading academics will be made use of. Senior Management will task the relevant offices and units to complete this step and will follow up.			
R12. The Panel recommends that the Board bring greater rigor to the assessment of its own performance, and emphasize, in the orientation for new members, the responsibility of the Board to sustain its independence and its effectiveness.	Accepted. Building on the present system, the Board is reassessing its current performance evaluation scheme to incorporate more rigor. The orientation of new members will underscore the critical importance of the Governing Board in effective governance and independence. In addition, the Board will continue to improve the rigor of its assessment of ICRISAT.	R12.1. GB will continue to review its evaluation and self-assessment system and strengthen it further.	Refined GB evaluation and self-assessment system	In progress - GB will discuss a more rigorous self-assessment at the Sep 09 meeting	Mar 2010
R13. The panel recommends that ICRISAT create succinct documents that synthesize 5-year trends in financial performance, priority setting and performance to give the Board more efficient and transparent access to information critical to oversight.	Accepted. We will synthesize trends in ICRISAT's institutional performance and prepare relevant succinct documents to assist the Board's critical oversight.	R13.1.Prepare documents relating to financial performance, project development (core unrestricted and restricted project funding; project proposals submitted; grants awarded; challenge program funding; non-traditional funding; and indirect cost recovery), priority setting and performance (PMI indicators) synthesizing 5-	5-year institute trends in key performance areas. Strengthened GB oversight.	In progress	Sep 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		year trends. R13.2. Present and discuss at Spring GB meetings.			
R14. The Panel recommends that the Board adopt a multi-source evaluation process for the Director General that is rigorous and balanced and that provides the Board with more inflected and diverse inputs to the process. In addition to senior staff, the Board and DG should annually agree on a list of partners, donors and peers to be asked to participate in the evaluation.	Accepted. To further strengthen the annual quantified and performance-based assessment of the Director General, the Board is adopting a more rigorous, balanced and multi-source evaluation scheme involving key partners, donors and peers.	R14.1.Develop 360-degree feedback process to be used as a multi source evaluation of DG. R14.2.GB and DG to agree on the list of partners, donors and peers who will participate in the multi source evaluation.	Performance based assessment of DG using the 360-degree process. List of partners, donors and peers as agreed by GB and DG.	In progress and will be implemented at the next scheduled evaluation of the DG	Jul 2009 Sep 2009
R15. The Panel recommends that training be provided to senior scientific and administrative staff about how to develop and manage large projects, and how to balance research and project management.	Accepted. Harnessing appropriate external and internal expertise and best practices, we will enhance the capacity of our senior scientific and administrative staff in developing and managing large projects.	R15.1. Provide training to key project staff in the management of large projects and provide other support to PI's as may be appropriate; for example, through technical support positions (such as postdoctoral fellows) and/or administrative support positions	Trained staff in management of large projects	In progress	Sep 2010
R16. The Panel recommends that ICRISAT's leadership clarify the role of PDMO in priority setting and send a clear signal about the drivers and determinants for establishing priorities for	Accepted. We will further clarify PDMO's role as recommended. Priority setting at ICRISAT will continue to be performed by its Research Committee (RC) vetted by Management and finally approved by the	R16.1. Establish a Resource Planning and Marketing office in place of the PDMO. R16.2. Appoint new Director-RPM.	New RPM Office and Director Revised TORs for RPM operations	Action taken and completed	Sep 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
resource development.	Governing Board. The PDMO plays a catalytic role in mobilizing resources.	R16.3Revise TOR for RPM to clearly indicate that RPM activities are determined by institutional priorities as determined by the Governing Board and Management of the Centre. RPM has a proactive role to play in ensuring that the research profile of the Centre is highlighted in appropriate fora and that opportunities for funding are brought to the attention of and followed up with Management and staff. RPM also has prime responsibility for ensuring that ICRISAT submits timely, quality reports to donors and investors and that, as such, the Centre is seen to be a preferred research provider/partner.			
R17. The Panel recommends that ICRISAT must present ASP's mission, structure and relationship to research in a more transparent fashion and re-assess ASP, either to narrow the ventures it pursues, or, in the interests of minimizing risks to the Center's reputation, create a different structure with clearer boundaries between it and the Center.	Accepted. We will carefully assess ASP's mission, structure and function to further enhance its complementarity with ICRISAT's research and resource development, and to minimize risk.	R17.1. Analyze mission of ASP in relation to ICRISAT's mission.	Synchronized mission and function of ASP with ICRISAT's research agenda.	In progress	Sep 2009
		R17.2. Reassess ASP's	Streamlined scope of	In progress	Sep 2009

EPMR Recommendation	Institutional Response	Action Steps	Milestones	Progress Achieved	Target Date
		scope, restructure organizational set up and enhance transparency.	operations of ASP Revised O and M structure of ASP clearly delineated vis a vis that of ICRISAT Detailed and distinct financial reports on ASP.		
		R17.3. Clarify locus of approving and monitoring authority in ASP.	Identified lines of authority in ASP.	In progress	Sep 2009

Financing plan

ICRISAT-Table 1: Allocation of Project Costs by Priority Area and Priorities, 2010

in $millions

	Priority Area 1		Priority Area 2				Priority Area 3			Priority Area 4			Priority Area 5				Non-Priority Area			
Project	1A	1B	2A	2B	2C	2D	3A	3B	3D	4A	4C	4D	5A	5B	5C	5D	Development Activities	New Research Areas	Stand-alone Training	Total
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT													2.068	1.628	0.571	3.616				7.883
10. The Virtual Academy for the African and Asian SAT																		1.672		1.672
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)																	0.815	0.753	0.821	2.389
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations	2.242	1.074	0.750	1.015																5.081
3. Producing more and better food at lower cost of the staple cereals and legumes of the WCA SAT (Sorghum, Pearl Millet and Groundnut) through genetic imp.			3.816	2.903	1.639	0.168														8.526
4. Producing more and better food at lower cost of the staple cereals and legumes of the ESA SAT (Sorghum, Millets, Groundnut, Pigeonpea and Chickpea) through genetic improvement			2.431	2.037	0.763															5.231

	Priority Area 1		Priority Area 2				Priority Area 3			Priority Area 4			Priority Area 5				Non-Priority Area			
Project	**1A**	**1B**	**2A**	**2B**	**2C**	**2D**	**3A**	**3B**	**3D**	**4A**	**4C**	**4D**	**5A**	**5B**	**5C**	**5D**	**Development Activities**	**New Research Areas**	**Stand-alone Training**	**Total**
5. Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (Sorghum, Pearl Millet and Pigeonpea) through genetic improvement.			1.413	0.680	0.811	1.248														4.152
6. Producing more and better food at lower cost of staple open-pollinated cereals and legumes in the Asian SAT (Sorghum, Millets, Pigeonpea, Chickpea and Groundnut through genetic improvement			3.726	2.534	0.839	0.009														7.108
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products							2.235	0.831	0.310											3.376
8. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources, particularly at the Desert Margins of the Sahel and the drylands of ESA																				
9. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources through sustainable agro-ecological intensification in low- and high-potential environments										2.171	0.649	2.409								5.229
Total	**2.242**	**1.074**	**12.136**	**9.169**	**4.052**	**1.425**	**2.235**	**0.831**	**0.310**	**2.171**	**0.649**	**2.409**	**2.068**	**1.628**	**0.571**	**3.616**	**0.815**	**2.425**	**0.821**	**50.647**

ICRISAT-Table 2: Allocation of Project Costs to CGIAR Priorities, 2008-2012

in $millions

Projects / Priorities	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT					
5A	3.165	2.330	2.068	2.111	2.160
5B	1.742	1.569	1.628	1.661	1.700
5C	0.517	0.565	0.571	0.580	0.592
5D	0.975	2.091	3.616	3.703	3.796
Total Project	**6.399**	**6.555**	**7.883**	**8.055**	**8.248**
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations					
1A	3.325	2.742	2.242	2.281	2.331
1B	1.372	2.016	1.074	1.096	1.122
2A	0.283	0.433	0.750	0.770	0.791
2B	0.566	0.704	1.015	1.042	1.070
Total Project	**5.546**	**5.895**	**5.081**	**5.189**	**5.314**
3. Producing more and better food at lower cost of the staple cereals and legumes of the WCA SAT (Sorghum, Pearl Millet and Groundnut) through genetic imp.					
2A	4.189	3.599	3.816	3.907	4.005
2B	2.271	2.351	2.903	2.973	3.046
2C	0.969	1.367	1.639	1.675	1.716
2D	0.031	0.091	0.168	0.173	0.177
Total Project	**7.460**	**7.408**	**8.526**	**8.728**	**8.944**
4. Producing more and better food at lower cost of the staple cereals and legumes of the ESA SAT (Sorghum, Millets, Groundnut, Pigeonpea and Chickpea) through genetic improvement					
2A	2.280	2.143	2.431	2.485	2.545
2B	1.964	1.769	2.037	2.083	2.133
2C	0.820	0.823	0.763	0.776	0.792
Total Project	**5.064**	**4.735**	**5.231**	**5.344**	**5.470**
5. Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (Sorghum, Pearl Millet and Pigeonpea) through genetic improvement.					

Projects / Priorities	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
2A	1.204	1.225	1.413	1.439	1.472
2B	0.610	0.650	0.680	0.690	0.703
2C	0.509	0.778	0.811	0.825	0.843
2D	0.875	0.872	1.248	1.282	1.315
Total Project	**3.198**	**3.525**	**4.152**	**4.236**	**4.333**
6. Producing more and better food at lower cost of staple open-pollinated cereals and legumes in the Asian SAT (Sorghum, Millets, Pigeonpea, Chickpea and Groundnut through genetic improvement					
2A	2.809	2.985	3.726	3.815	3.910
2B	2.047	2.073	2.534	2.594	2.657
2C	0.556	1.024	0.839	0.854	0.872
2D	0.063	0.009	0.009	0.009	0.009
Total Project	**5.475**	**6.091**	**7.108**	**7.272**	**7.448**
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products					
3A	2.425	2.874	2.235	2.246	2.283
3B	1.025	0.760	0.831	0.853	0.876
3D	0.392	0.341	0.310	0.319	0.327
Total Project	**3.842**	**3.975**	**3.376**	**3.418**	**3.486**
8. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources, particularly at the Desert Margins of the Sahel and the drylands of ESA					
4A	0.864	0.000	0.000	0.000	0.000
Total Project	**0.864**	**0.000**	**0.000**	**0.000**	**0.000**
9. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources through sustainable agro-ecological intensification in low- and high-potential environments					
4A	1.673	2.251	2.171	2.231	2.289
4C	1.425	1.611	0.649	0.667	0.684
4D	2.957	2.903	2.409	2.426	2.468
Total Project	**6.055**	**6.765**	**5.229**	**5.324**	**5.441**
10. The Virtual Academy for the African and Asian SAT					

Projects / Priorities	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
Stand-alone Training	0.000	0.000	0.000	0.000	0.000
New Research Areas	1.646	1.781	1.672	1.680	1.707
Total Project	**1.646**	**1.781**	**1.672**	**1.680**	**1.707**
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)					
Development Activities	0.861	0.743	0.815	0.825	0.842
Stand-alone Training	0.673	0.895	0.821	0.822	0.784
New Research Areas	0.464	0.649	0.753	0.766	0.835
Total Project	**1.998**	**2.287**	**2.389**	**2.413**	**2.461**
Total	**47.547**	**49.017**	**50.647**	**51.659**	**52.852**

ICRISAT-Table 3: Summary of Project Costs, 2008-2012

in $millions

Project	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	6.399	6.555	7.883	8.055	8.248
10. The Virtual Academy for the African and Asian SAT	1.646	1.781	1.672	1.680	1.707
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)	1.998	2.287	2.389	2.413	2.461
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations	5.546	5.895	5.081	5.189	5.314
3. Producing more and better food at lower cost of the staple cereals and legumes of the WCA SAT (Sorghum, Pearl Millet and Groundnut) through genetic imp.	7.460	7.408	8.526	8.728	8.944
4. Producing more and better food at lower cost of the staple cereals and legumes of the ESA SAT (Sorghum, Millets, Groundnut, Pigeonpea and Chickpea) through genetic improvement	5.064	4.735	5.231	5.344	5.470
5. Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (Sorghum, Pearl Millet and Pigeonpea) through genetic improvement.	3.198	3.525	4.152	4.236	4.333
6. Producing more and better food at lower cost of staple open-pollinated cereals and legumes in the Asian SAT (Sorghum, Millets, Pigeonpea, Chickpea and Groundnut through genetic improvement	5.475	6.091	7.108	7.272	7.448
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products	3.842	3.975	3.376	3.418	3.486
8. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources, particularly at the Desert Margins of the Sahel and the drylands of ESA	0.864	0.000	0.000	0.000	0.000
9. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources through sustainable agro-ecological intensification in low- and high-potential environments	6.055	6.765	5.229	5.324	5.441
Total	47.547	49.017	50.647	51.659	52.852

ICRISAT-Table 4: Summary of Priority Costs, 2008-2012

in $millions

Priorities	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
1A	3.325	2.742	2.242	2.281	2.331
1B	1.372	2.016	1.074	1.096	1.122
2A	10.765	10.385	12.136	12.416	12.723
2B	7.458	7.547	9.169	9.382	9.609
2C	2.854	3.992	4.052	4.130	4.223
2D	0.969	0.972	1.425	1.464	1.501
3A	2.425	2.874	2.235	2.246	2.283
3B	1.025	0.760	0.831	0.853	0.876
3D	0.392	0.341	0.310	0.319	0.327
4A	2.537	2.251	2.171	2.231	2.289
4C	1.425	1.611	0.649	0.667	0.684
4D	2.957	2.903	2.409	2.426	2.468
5A	3.165	2.330	2.068	2.111	2.160
5B	1.742	1.569	1.628	1.661	1.700
5C	0.517	0.565	0.571	0.580	0.592
5D	0.975	2.091	3.616	3.703	3.796
Development Activities	0.861	0.743	0.815	0.825	0.842
Stand-alone Training	0.673	0.895	0.821	0.822	0.784
New Research Areas	2.110	2.430	2.425	2.446	2.542
Total	47.547	49.017	50.647	51.659	52.852

ICRISAT-Table 5: Investments by Undertaking, Activity and Sector, 2008-2012

in $millions

	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
Increasing Productivity	23.147	23.732	24.171	24.648	25.214
Germplasm Enhancement & Breeding	14.247	14.309	14.902	15.200	15.551
Production Systems Development & Management	8.900	9.423	9.269	9.448	9.663
Cropping systems	8.010	8.481	8.341	8.503	8.697
Livestock systems	0.623	0.660	0.649	0.662	0.676
Tree systems	0.267	0.282	0.279	0.283	0.290
Fish systems	0.000	0.000	0.000	0.000	0.000
Protecting the Environment	6.807	7.207	7.087	7.224	7.389
Saving Biodiversity	3.949	4.126	4.202	4.286	4.384
Improving Policies	6.788	6.789	8.031	8.206	8.402
Strengthening NARS	6.856	7.163	7.156	7.295	7.463
Training and Professional Development	3.799	3.972	3.957	4.033	4.126
Documentation, Publications, Info. Dissemination	2.452	2.556	2.569	2.619	2.679
Organization & Management Couselling	0.000	0.000	0.000	0.000	0.000
Networks	0.605	0.635	0.630	0.643	0.658
Total	**47.547**	**49.017**	**50.647**	**51.659**	**52.852**

ICRISAT-Table 6: Project Investments by Developing Region, 2008-2012

in $millions

Project	Region	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	Asia	2.752	2.622	3.153	3.222	3.299
	SSA	3.647	3.933	4.730	4.833	4.949
	Total Project	**6.399**	**6.555**	**7.883**	**8.055**	**8.248**
10. The Virtual Academy for the African and Asian SAT	Asia	0.708	0.712	0.669	0.672	0.683
	SSA	0.938	1.069	1.003	1.008	1.024
	Total Project	**1.646**	**1.781**	**1.672**	**1.680**	**1.707**
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)	Asia	0.859	0.915	0.956	0.965	0.984
	SSA	1.139	1.372	1.433	1.448	1.477
	Total Project	**1.998**	**2.287**	**2.389**	**2.413**	**2.461**
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations	Asia	2.385	2.358	2.032	2.076	2.126
	SSA	3.161	3.537	3.049	3.113	3.188
	Total Project	**5.546**	**5.895**	**5.081**	**5.189**	**5.314**
3. Producing more and better food at lower cost of the staple cereals and legumes of the WCA SAT (Sorghum, Pearl Millet and Groundnut) through genetic imp.	Asia	3.208	2.963	3.410	3.491	3.578
	SSA	4.252	4.445	5.116	5.237	5.366
	Total Project	**7.460**	**7.408**	**8.526**	**8.728**	**8.944**
4. Producing more and better food at lower cost of the staple cereals and legumes of the ESA SAT (Sorghum, Millets, Groundnut, Pigeonpea and Chickpea) through genetic improvement	Asia	2.178	1.894	2.092	2.138	2.188
	SSA	2.886	2.841	3.139	3.206	3.282
	Total Project	**5.064**	**4.735**	**5.231**	**5.344**	**5.470**
5. Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (Sorghum, Pearl Millet and Pigeonpea) through genetic improvement.	Asia	1.375	1.410	1.661	1.694	1.733
	SSA	1.823	2.115	2.491	2.542	2.600
	Total Project	**3.198**	**3.525**	**4.152**	**4.236**	**4.333**

Project	Region	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
6. Producing more and better food at lower cost of staple open- pollinated cereals and legumes in the Asian SAT (Sorghum, Millets, Pigeonpea, Chickpea and Groundnut through genetic improvement	Asia	2.354	2.436	2.843	2.909	2.979
	SSA	3.121	3.655	4.265	4.363	4.469
	Total Project	**5.475**	**6.091**	**7.108**	**7.272**	**7.448**
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products	Asia	1.652	1.590	1.350	1.367	1.394
	SSA	2.190	2.385	2.026	2.051	2.092
	Total Project	**3.842**	**3.975**	**3.376**	**3.418**	**3.486**
8. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources, particularly at the Desert Margins of the Sahel and the drylands of ESA	Asia	0.372	0.000	0.000	0.000	0.000
	SSA	0.492	0.000	0.000	0.000	0.000
	Total Project	**0.864**	**0.000**	**0.000**	**0.000**	**0.000**
9. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources through sustainable agro- ecological intensification in low- and high-potential environments	Asia	2.604	2.706	2.092	2.130	2.176
	SSA	3.451	4.059	3.137	3.194	3.265
	Total Project	**6.055**	**6.765**	**5.229**	**5.324**	**5.441**
	Total	**47.547**	**49.017**	**50.647**	**51.659**	**52.852**

ICRISAT-Table 7: Summary of Investments by Developing Region, 2008-2012 in $millions					
Region	**Actual 2008**	**Estimated 2009**	**Proposal 2010**	**Plan 1 2011**	**Plan 2 2012**
SSA	27.100	29.411	30.389	30.995	31.712
Asia	20.447	19.606	20.258	20.664	21.140
Total	**47.547**	**49.017**	**50.647**	**51.659**	**52.852**

ICRISAT-Table 8: Expenditure by Object, 2008-2012

in $millions

Object of Expenditure	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
Personnel	21.377	25.781	27.597	28.419	29.247
Supplies and services	13.537	9.831	9.195	8.806	8.564
Collaboration/ Partnerships	6.792	7.132	7.488	7.863	8.256
Operational Travel	3.699	3.884	4.078	4.282	4.496
Depreciation	2.142	2.389	2.289	2.289	2.289
Total	**47.547**	**49.017**	**50.647**	**51.659**	**52.852**

ICRISAT-Table 9: Member and Non-Member Unrestricted Grants, 2008-2010

in $millions NC = National Currency

Member	Type NC	Actual 2008 (US$)	Actual 2008 (NC)	Estimated 2009 (US$)	Estimated 2009 (NC)	Proposal 2010 (US$)	Proposal 2010 (NC)
Unrestricted Grants							
Member							
Australia		0.442	0.500	0.490	0.500	0.490	0.500
Belgium		0.511	0.400	0.209	0.160	0.209	0.160
Canada		1.109	1.109	0.848	0.848	0.848	0.848
China		0.120	0.120	0.060	0.060	0.060	0.060
France		0.103	0.075	0.098	0.075	0.098	0.075
Germany		0.517	0.366	0.366	0.366	0.366	0.366
India		0.150	0.150	0.150	0.150	0.150	0.150
Ireland		0.510	0.340	0.444	0.340	0.444	0.340
Israel		0.185	0.185	0.185	0.185	0.185	0.185
Japan		0.025	0.025	0.025	0.025	0.025	0.025
Korea, Republic of		0.050	0.050	0.050	0.050	0.050	0.050
Morocco		0.000	0.000	0.000	0.000	0.000	0.000
Netherlands		0.000	0.000	0.000	0.000	0.000	0.000
Norway		1.528	8.000	1.057	8.000	1.057	8.000
Philippines		0.034	1.561	0.033	1.561	0.033	1.561
South Africa		0.220	0.220	0.080	0.080	0.080	0.080
Sweden		0.534	3.800	0.476	3.800	0.476	3.800
Switzerland		0.873	0.900	0.778	0.900	0.778	0.900
Thailand		0.020	0.020	0.020	0.020	0.020	0.020
Turkey		0.010	0.010	0.010	0.010	0.010	0.010
United Kingdom		2.201	1.260	1.881	1.260	1.881	1.260
United States		1.288	1.288	1.288	1.288	1.288	1.288
World Bank		2.080	2.080	1.700	1.700	1.700	1.700
	Subtotal	**12.510**		**10.248**		**10.248**	
	Total Unrestricted	**12.510**		**10.248**		**10.248**	

ICRISAT-Table 9a: Member and Non-Member Unrestricted and Restricted Grants, 2008-2010

in $millions

Member / Non-Member	Actual 2008	Estimated 2009	Proposal 2010
Unrestricted Grants			
Member			
Australia	0.442	0.490	0.490
Belgium	0.511	0.209	0.209
Canada	1.109	0.848	0.848
China	0.120	0.060	0.060
France	0.103	0.098	0.098
Germany	0.517	0.366	0.366
India	0.150	0.150	0.150
Ireland	0.510	0.444	0.444
Israel	0.185	0.185	0.185
Japan	0.025	0.025	0.025
Korea, Republic of	0.050	0.050	0.050
Morocco	0.000	0.000	0.000
Netherlands	0.000	0.000	0.000
Norway	1.528	1.057	1.057
Philippines	0.034	0.033	0.033
South Africa	0.220	0.080	0.080
Sweden	0.534	0.476	0.476
Switzerland	0.873	0.778	0.778
Thailand	0.020	0.020	0.020
Turkey	0.010	0.010	0.010
United Kingdom	2.201	1.881	1.881
United States	1.288	1.288	1.288
World Bank	2.080	1.700	1.700
Subtotal	**12.510**	**10.248**	**10.248**

Member / Non-Member	Actual 2008	Estimated 2009	Proposal 2010
Total Unrestricted	**12.510**	**10.248**	**10.248**
Member			
ADB	0.094	0.380	0.533
Australia	0.579	0.384	0.461
Belgium	0.019	0.000	0.000
Canada	0.793	0.769	0.726
CGIAR	0.080	0.000	0.000
China	0.000	0.018	0.022
Denmark	0.000	0.022	0.025
European Commission	2.194	2.257	2.532
FAO	0.177	0.055	0.000
Finland	0.006	0.000	0.000
France	0.024	0.012	0.014
Germany	1.438	1.307	1.524
IDB	0.000	0.000	0.000
IFAD	1.939	1.631	1.907
India	4.496	4.825	6.538
Iran	0.018	0.026	0.020
Ireland	0.014	0.223	0.272
Italy	0.156	0.131	0.131
Japan	0.255	0.262	0.238
Netherlands	0.639	0.626	0.816
Norway	0.649	0.571	0.274
OPEC Fund	0.100	0.038	0.000
Philippines	0.016	0.104	0.106
Rockefeller Foundation	0.090	0.026	0.006
South Africa	0.000	0.000	0.000
Switzerland	0.011	0.000	0.000

Member / Non-Member	Actual 2008	Estimated 2009	Proposal 2010
Syngenta Foundation	0.119	0.062	0.003
UNEP	1.318	1.870	0.104
United Kingdom	0.631	0.452	0.855
United States	5.347	3.741	4.157
World Bank	0.508	0.486	0.237
Subtotal	**21.710**	**20.278**	**21.501**
Non-member			
AGRHYMET, Niger	0.000	0.000	0.000
ASARECA	0.000	0.000	0.000
Bill and Melinda Gates Foundation	6.767	7.462	10.565
Bioversity International	0.005	0.022	0.017
Catholic Relief Services	0.000	0.000	0.000
CIMMYT	0.000	0.020	0.000
Common Fund for Commodities - CFC	0.252	0.132	0.000
CORAF/WECARD	0.025	0.000	0.000
Generation/CP	2.472	1.479	1.335
Global Crop Diversity Trust (GCDT)	0.315	0.313	0.423
HarvestPlus/CP	0.196	0.603	0.460
ICARDA	0.019	0.033	0.000
IFPRI	0.150	0.401	0.412
IITA	0.000	0.000	0.000
ILRI	0.029	0.079	0.058
International Fund for Agricultural Research (IFAR)	0.000	0.000	0.000
IRRI	0.011	0.059	0.028
IWMI	0.088	0.063	0.066
McKnight Foundation	0.437	0.377	0.191
Mozambique	0.060	0.078	0.000
Others	0.074	0.154	0.138
Plan International	0.103	0.123	0.162
Seed Companies	0.880	0.693	0.803

Member / Non-Member	Actual 2008	Estimated 2009	Proposal 2010
Sehgal Family Foundation	0.361	0.170	0.084
Sir Dorabji Tata Trust	0.504	0.676	0.826
SSA/CP	0.054	0.081	0.000
Tanzania	0.000	0.000	0.000
Water & Food/CP	0.628	0.773	0.000
World Agroforestry	0.000	0.000	0.000
World Wildlife Fund	0.000	0.000	0.000
Subtotal	**13.430**	**13.791**	**15.568**
Total Restricted	**35.140**	**34.069**	**37.069**
Total Grants	**47.650**	**44.317**	**47.317**

Summary and Statement of Activities	Actual 2008	Estimated 2009	Proposal 2010
Total Grants	**47.650**	**44.317**	**47.317**
Center Income	**2.635**	**3.300**	**3.650**
Revenue	**50.285**	**47.617**	**50.967**
Total Investment	**47.547**	**49.017**	**50.647**
Surplus (Deficit)	**2.738**	**-1.400**	**0.320**

ICRISAT-Table 10: Allocation of Member, Non-Member Grants and Other Sources to Projects, 2008-2010

in $millions

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	Member	ADB	0.094	0.380	0.533
		Australia	0.000	0.000	0.000
		Canada	0.070	0.221	0.301
		European Commission	0.423	0.386	0.387
		FAO	0.052	0.000	0.000
		Germany	0.000	0.000	0.000
		IFAD	0.377	0.398	0.587
		India	0.142	0.046	0.072
		Ireland	0.014	0.223	0.272
		Netherlands	0.189	0.184	0.245
		Norway	0.000	0.000	0.000
		OPEC Fund	0.000	0.000	0.000
		Philippines	0.008	0.000	0.000
		Rockefeller Foundation	0.000	0.000	0.000
		United Kingdom	0.000	0.000	0.000
	Non Member	United States	3.144	1.302	0.883
		World Bank	0.148	0.022	0.000
		Bill and Melinda Gates Foundation	0.126	1.258	2.684
		Bioversity International	0.000	0.000	0.000
		Catholic Relief Services	0.000	0.000	0.000
		Common Fund for Commodities - CFC	0.000	0.000	0.000
		ICARDA	0.000	0.005	0.000
		IFPRI	0.025	0.226	0.234
		IITA	0.000	0.000	0.000
		ILRI	0.000	0.017	0.000

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
		IRRI	0.011	0.000	0.000
		McKnight Foundation	0.000	0.000	0.000
		Mozambique	0.060	0.078	0.000
		Others	0.022	0.007	0.000
		Plan International	0.103	0.123	0.162
	Unrestricted + Other sources		1.391	1.679	1.523
		Project Total	**6.399**	**6.555**	**7.883**
10. The Virtual Academy for the African and Asian SAT	Member	Canada	0.008	0.000	0.000
		FAO	0.050	0.000	0.000
		Germany	0.000	0.000	0.000
		India	0.190	0.195	0.225
		Philippines	0.000	0.052	0.053
	Non Member	World Bank	0.000	0.000	0.000
		ICARDA	0.000	0.000	0.000
		IFPRI	0.125	0.000	0.000
		ILRI	0.000	0.000	0.000
	Unrestricted + Other sources		1.273	1.534	1.394
		Project Total	**1.646**	**1.781**	**1.672**
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)	Member	China	0.000	0.018	0.022
		FAO	0.000	0.000	0.000
		Germany	0.014	0.025	0.021
		India	0.507	0.355	0.437
		Italy	0.000	0.000	0.000
		Netherlands	0.000	0.000	0.000
		UNEP	0.000	0.000	0.052
		United Kingdom	0.000	0.000	0.000
		United States	0.000	0.099	0.201
		World Bank	0.050	0.002	0.000

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
	Non Member	Bioversity International	0.003	0.000	0.000
		Mozambique	0.000	0.000	0.000
		Others	0.000	0.038	0.000
		Sir Dorabji Tata Trust	0.150	0.217	0.261
	Unrestricted + Other sources		1.274	1.533	1.395
		Project Total	**1.998**	**2.287**	**2.389**
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations	Member	Australia	0.032	0.021	0.037
		European Commission	0.422	0.386	0.386
		FAO	0.030	0.000	0.000
		France	0.000	0.000	0.000
		Germany	0.390	0.348	0.358
		India	1.039	0.872	1.015
		Iran	0.000	0.000	0.000
		Japan	0.055	0.055	0.047
		Netherlands	0.000	0.000	0.000
		Rockefeller Foundation	0.000	0.000	0.000
		South Africa	0.000	0.000	0.000
		Switzerland	0.006	0.000	0.000
		Syngenta Foundation	0.000	0.000	0.000
		UNEP	0.659	0.935	0.052
		United Kingdom	0.041	0.034	0.065
		United States	0.094	0.005	0.005
		World Bank	0.245	0.438	0.237
	Non Member	Bioversity International	0.002	0.022	0.017
		CIMMYT	0.000	0.020	0.000
		Generation/CP	1.131	0.599	0.491
		Global Crop Diversity Trust (GCDT)	0.315	0.313	0.423
		HarvestPlus/CP	0.007	0.061	0.028

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
		ICARDA	0.019	0.026	0.000
		ILRI	0.000	0.028	0.029
		IRRI	0.000	0.059	0.028
		Others	0.000	0.012	0.000
		Seed Companies	0.000	0.012	0.000
		Sehgal Family Foundation	0.017	0.028	0.014
	Unrestricted + Other sources		1.042	1.621	1.849
		Project Total	**5.546**	**5.895**	**5.081**
3. Producing more and better food at lower cost of the staple cereals and legumes of the WCA SAT (Sorghum, Pearl Millet and Groundnut) through genetic imp.	Member	Australia	0.011	0.000	0.000
		Canada	0.047	0.066	0.000
		European Commission	0.020	0.113	0.146
		FAO	0.000	0.000	0.000
		France	0.000	0.012	0.014
		Germany	0.604	0.589	0.714
		IFAD	0.712	0.294	0.050
		India	0.041	0.186	0.422
		Italy	0.078	0.066	0.065
		Japan	0.048	0.047	0.046
		Netherlands	0.126	0.123	0.162
		Rockefeller Foundation	0.090	0.026	0.006
		Switzerland	0.005	0.000	0.000
		Syngenta Foundation	0.056	0.026	0.001
		United Kingdom	0.013	0.011	0.016
		United States	1.605	2.056	2.850
	Non Member	Bill and Melinda Gates Foundation	2.102	2.002	2.557
		Bioversity International	0.000	0.000	0.000
		Catholic Relief Services	0.000	0.000	0.000
		Common Fund for Commodities - CFC	0.000	0.000	0.000

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
		Generation/CP	0.565	0.445	0.337
		HarvestPlus/CP	0.028	0.039	0.012
		IFPRI	0.000	0.112	0.178
		ILRI	0.000	0.006	0.000
		McKnight Foundation	0.265	0.198	0.066
		Others	0.000	0.000	0.000
		Sehgal Family Foundation	0.017	0.028	0.014
		World Agroforestry	0.000	0.000	0.000
	Unrestricted + Other sources		1.027	0.963	0.870
		Project Total	**7.460**	**7.408**	**8.526**
4. Producing more and better food at lower cost of the staple cereals and legumes of the ESA SAT (Sorghum, Millets, Groundnut, Pigeonpea and Chickpea) through genetic improvement	Member	Canada	0.023	0.023	0.023
		Denmark	0.000	0.000	0.000
		European Commission	0.501	0.534	0.543
		FAO	0.000	0.000	0.000
		France	0.024	0.000	0.000
		Germany	0.035	0.000	0.000
		IFAD	0.000	0.000	0.000
		India	0.000	0.169	0.403
		Japan	0.028	0.029	0.029
		Netherlands	0.063	0.062	0.081
		Rockefeller Foundation	0.000	0.000	0.000
		Syngenta Foundation	0.063	0.036	0.002
		United Kingdom	0.000	0.000	0.000
		United States	0.093	0.000	0.000
		World Bank	0.000	0.000	0.000
	Non Member	ASARECA	0.000	0.000	0.000
		Bill and Melinda Gates Foundation	2.406	2.200	2.767

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
		Generation/CP	0.652	0.268	0.330
		HarvestPlus/CP	0.000	0.000	0.000
		ILRI	0.000	0.028	0.029
		McKnight Foundation	0.158	0.161	0.109
		Others	0.000	0.013	0.000
		Water & Food/CP	0.000	0.000	0.000
	Unrestricted + Other sources		1.018	1.212	0.915
		Project Total	**5.064**	**4.735**	**5.231**
5. Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (Sorghum, Pearl Millet and Pigeonpea) through genetic improvement.	Member	European Commission	0.000	0.085	0.113
		IFAD	0.383	0.425	0.692
		India	0.525	0.802	1.330
		Japan	0.035	0.033	0.029
		OPEC Fund	0.000	0.038	0.000
		United Kingdom	0.017	0.010	0.017
	Non Member	Generation/CP	0.062	0.079	0.084
		HarvestPlus/CP	0.072	0.238	0.210
		ICARDA	0.000	0.000	0.000
		Others	0.008	0.015	0.032
		Seed Companies	0.763	0.560	0.732
		Sehgal Family Foundation	0.327	0.114	0.056
	Unrestricted + Other sources		1.006	1.126	0.857
		Project Total	**3.198**	**3.525**	**4.152**
6. Producing more and better food at lower cost of staple open-pollinated cereals and legumes in the Asian SAT (Sorghum, Millets, Pigeonpea, Chickpea and Groundnut through genetic improvement	Member	Australia	0.412	0.337	0.424
		European Commission	0.000	0.000	0.000
		FAO	0.000	0.005	0.000
		Germany	0.133	0.221	0.352

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
	Non Member	IFAD	0.467	0.307	0.441
		India	0.784	1.222	1.812
		Iran	0.018	0.026	0.020
		Japan	0.031	0.029	0.029
		Netherlands	0.010	0.012	0.000
		Norway	0.000	0.000	0.000
		OPEC Fund	0.100	0.000	0.000
		Philippines	0.008	0.052	0.053
		United Kingdom	0.017	0.011	0.017
		United States	0.007	0.015	0.016
		World Bank	0.000	0.000	0.000
		Bill and Melinda Gates Foundation	2.103	2.002	2.557
		Common Fund for Commodities - CFC	0.126	0.066	0.000
		Generation/CP	0.062	0.088	0.093
		HarvestPlus/CP	0.089	0.265	0.210
		ICARDA	0.000	0.000	0.000
		ILRI	0.000	0.000	0.000
		International Fund for Agricultural Research	0.000	0.000	0.000
		IRRI	0.000	0.000	0.000
		IWMI	0.000	0.000	0.000
		Others	0.000	0.000	0.000
		Water & Food/CP	0.106	0.225	0.000
	Unrestricted + Other sources		1.002	1.208	1.084
		Project Total	**5.475**	**6.091**	**7.108**
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products	Member	Australia	0.124	0.026	0.000
		Canada	0.092	0.000	0.000
		Denmark	0.000	0.022	0.025

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
		European Commission	0.582	0.602	0.765
		FAO	0.000	0.000	0.000
		Finland	0.006	0.000	0.000
		Germany	0.236	0.071	0.076
		IDB	0.000	0.000	0.000
		IFAD	0.000	0.000	0.000
		India	0.607	0.391	0.400
		Iran	0.000	0.000	0.000
		Japan	0.029	0.029	0.029
		Netherlands	0.063	0.061	0.082
		UNEP	0.000	0.535	0.000
		United Kingdom	0.000	0.000	0.000
		United States	0.153	0.021	0.020
	Non Member	AGRHYMET, Niger	0.000	0.000	0.000
		Common Fund for Commodities - CFC	0.126	0.066	0.000
		ILRI	0.029	0.000	0.000
		IWMI	0.088	0.063	0.066
		McKnight Foundation	0.000	0.000	0.000
		Others	0.000	0.000	0.000
		Seed Companies	0.019	0.055	0.066
		Sir Dorabji Tata Trust	0.000	0.000	0.000
		Water & Food/CP	0.000	0.000	0.000
		World Wildlife Fund	0.000	0.000	0.000
	Unrestricted + Other sources		1.688	2.033	1.847
		Project Total	**3.842**	**3.975**	**3.376**
8. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources, particularly at the Desert Margins of the Sahel and the drylands of ESA	Member	Canada	0.047	0.000	0.000
		CGIAR	0.080	0.000	0.000
		IDB	0.000	0.000	0.000

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
	Non Member	IFAD	0.000	0.000	0.000
		Italy	0.078	0.000	0.000
		UNEP	0.659	0.000	0.000
		United States	0.000	0.000	0.000
		World Bank	0.000	0.000	0.000
		AGRHYMET, Niger	0.000	0.000	0.000
		ICARDA	0.000	0.000	0.000
		Others	0.000	0.000	0.000
	Unrestricted + Other sources		0.000	0.000	0.000
		Project Total	**0.864**	**0.000**	**0.000**
9. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources through sustainable agro-ecological intensification in low- and high-potential environments	Member	ADB	0.000	0.000	0.000
		Australia	0.000	0.000	0.000
		Belgium	0.019	0.000	0.000
		Canada	0.506	0.459	0.402
		Denmark	0.000	0.000	0.000
		European Commission	0.246	0.151	0.192
		FAO	0.045	0.050	0.000
		Germany	0.026	0.053	0.003
		IFAD	0.000	0.207	0.137
		India	0.661	0.587	0.422
		Italy	0.000	0.065	0.066
		Japan	0.029	0.040	0.029
		Netherlands	0.188	0.184	0.246
		Norway	0.649	0.571	0.274
		UNEP	0.000	0.400	0.000
		United Kingdom	0.543	0.386	0.740
		United States	0.251	0.243	0.182

Project	Member		Actual 2008	Estimated 2009	Proposal 2010
		World Bank	0.065	0.024	0.000
	Non Member	AGRHYMET, Niger	0.000	0.000	0.000
		ASARECA	0.000	0.000	0.000
		Bill and Melinda Gates Foundation	0.030	0.000	0.000
		Bioversity International	0.000	0.000	0.000
		CIMMYT	0.000	0.000	0.000
		CORAF/WECARD	0.025	0.000	0.000
		ICARDA	0.000	0.002	0.000
		IFPRI	0.000	0.063	0.000
		IWMI	0.000	0.000	0.000
		McKnight Foundation	0.014	0.018	0.016
		Others	0.044	0.069	0.106
		Seed Companies	0.098	0.066	0.005
		Sir Dorabji Tata Trust	0.354	0.459	0.565
		SSA/CP	0.054	0.081	0.000
		Tanzania	0.000	0.000	0.000
		Water & Food/CP	0.522	0.548	0.000
		World Wildlife Fund	0.000	0.000	0.000
	Unrestricted + Other sources		1.686	2.039	1.844
		Project Total	**6.055**	**6.765**	**5.229**
		Total Restricted	**35.140**	**34.069**	**37.069**
		Total Unrestricted + Other sources	**12.407**	**14.948**	**13.578**
		Total	**47.547**	**49.017**	**50.647**

ICRISAT-Table 11: Internationally and Nationally Recruited Staff, 2008-2012

in $millions

	Actual 2008	Estimated 2009	Proposal 2010	Plan 1 2011	Plan 2 2012
NRS	1099	1100	1102	1104	1106
IRS	64	68	71	73	77
Total	**1163**	**1168**	**1173**	**1177**	**1183**

ICRISAT-Table 12: Currency Structure of Expenditure, 2008-2010

in millions of units and percent

	Actual 2008			Estimated 2009			Proposal 2010		
Currency	**Amount**	**$ Value**	**% Share**	**Amount**	**$ Value**	**% Share**	**Amount**	**$ Value**	**% Share**
EUR	0.340	0.470	1	0.260	0.460	1	0.260	0.480	1
INR	657.300	18.270	38	710.000	17.750	36	770.000	18.340	36
KES	40.400	0.600	1	39.000	0.580	1	46.000	0.600	1
Others	1883.100	5.730	12	7649.000	5.560	11	9442.830	5.740	11
USD	22.477	22.477	47	24.667	24.667	50	25.487	25.487	50
XOF	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
ZWD	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
Total		**47.547**	**100 %**		**49.017**	**100 %**		**50.647**	**100 %**

ICRISAT - Table 13: Statement of Financial Position (SFP), 2008-2010

in $millions

Assets, Liabilities and Net Assets	2008	2009	2010
Current Assets			
Cash and Cash Equivalents	5.378	7.000	7.500
Investments	7.582	7.800	8.000
Accounts Receivable			
- Donor	4.860	4.000	3.500
- Employees	0.478	0.350	0.300
- Other CGIAR Centers	0.906	1.000	1.800
- Others	4.018	4.200	4.500
Inventories	0.881	0.800	0.900
Pre-paid Expenses	0.277	0.250	0.200
Total Current Assets	24.38	25.40	26.70
Non-Current Assets			
Net Property, Plan and Equipment	5.460	5.550	5.600
Investments	27.62	29.00	29.00
Other Assets	1.203	1.400	1.400
Total Non-Current Assets	34.28	35.95	36.00
Total Assets	58.66	61.35	62.70
Current Liabilities			
Overdraft/Short Term Borrowings	0.000	0.000	0.000
Accounts Payable			
- Donor	12.73	14.00	14.50
- Employees	1.399	1.500	1.600
- Other CGIAR Centers	0.461	0.500	0.400
- Others	8.109	8.300	8.400
Accruals and Provisions	1.353	1.200	1.100
Total Current Liabilities	24.05	25.50	26.00
Non-Current Liabilities			
Accounts Payable			
- Employees	11.17	11.80	12.00
- Deferred Grant Revenue	0.000	0.000	0.000
- Others	0.000	0.000	0.000
Total Non-Current Liabilities	11.17	11.80	12.00
Total Liabilities	35.22	37.30	38.00
Net Assets			
Unrestricted			
- Fixed Assets	8.294	8.518	8.744
- Unrestricted Net Assets Excluding Fixed Assets	12.99	13.31	13.67
Total Unrestricted Net Assets	21.28	21.83	22.415
Restricted	2.154	2.219	2.285
Total Net Assets	23.441	24.050	24.700
Total Liabilities and Net Assets	58.669	61.350	62.700

ICRISAT-Table 14: Statement of Activities (SOA), 2008-2010

in $millions

		Unrestricted	Restricted		Total		
			Temporary	Challenge Programs	2008	2009	2010
Revenue and Gains	Grant Revenue	12.510	31.790	3.350	47.650	44.317	47.317
	Other revenue and gains	2.635	0.000	0.000	2.635	3.300	3.650
	Total revenue and gains	15.145	31.790	3.350	50.285	47.617	50.967
Expenses and Losses	Program related expenses	7.347	31.790	3.350	42.487	42.305	44.719
	Management and general expenses	7.973	0.000	0.000	7.973	9.912	10.478
	Other losses expenses	0.000	0.000	0.000	0.000	0.000	0.000
	Sub Total expenses and losses	15.320	31.790	3.350	50.460	52.217	55.197
	Indirect cost recovery	-2.913	0.000	0.000	-2.913	-3.200	-4.550
	Total expenses and losses	12.407	31.790	3.350	47.547	49.017	50.647
	Net Operating Surplus / (Deficit)	2.738	0.000	0.000	2.738	-1.400	0.320
	Extraordinary Items	0.000	0.000	0.000	0.000	0.000	0.000
	NET SURPLUS / (DEFICIT)	2.738	0.000	0.000	2.738	-1.400	0.320
Object of Expenditure	Personnel	11.615	8.875	0.887	21.377	25.781	27.597
	Supplies and services	-0.823	12.912	1.448	13.537	9.831	9.195
	Collaboration/ Partnerships	0.005	6.163	0.624	6.792	7.132	7.488
	Operational Travel	0.857	2.528	0.314	3.699	3.884	4.078
	Depreciation	0.753	1.312	0.077	2.142	2.389	2.289
	Total	12.407	31.790	3.350	47.547	49.017	50.647

About ICRISAT

ICRISAT
Science with a human face

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT is supported by the Consultative Group on International Agricultural Research (CGIAR).

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