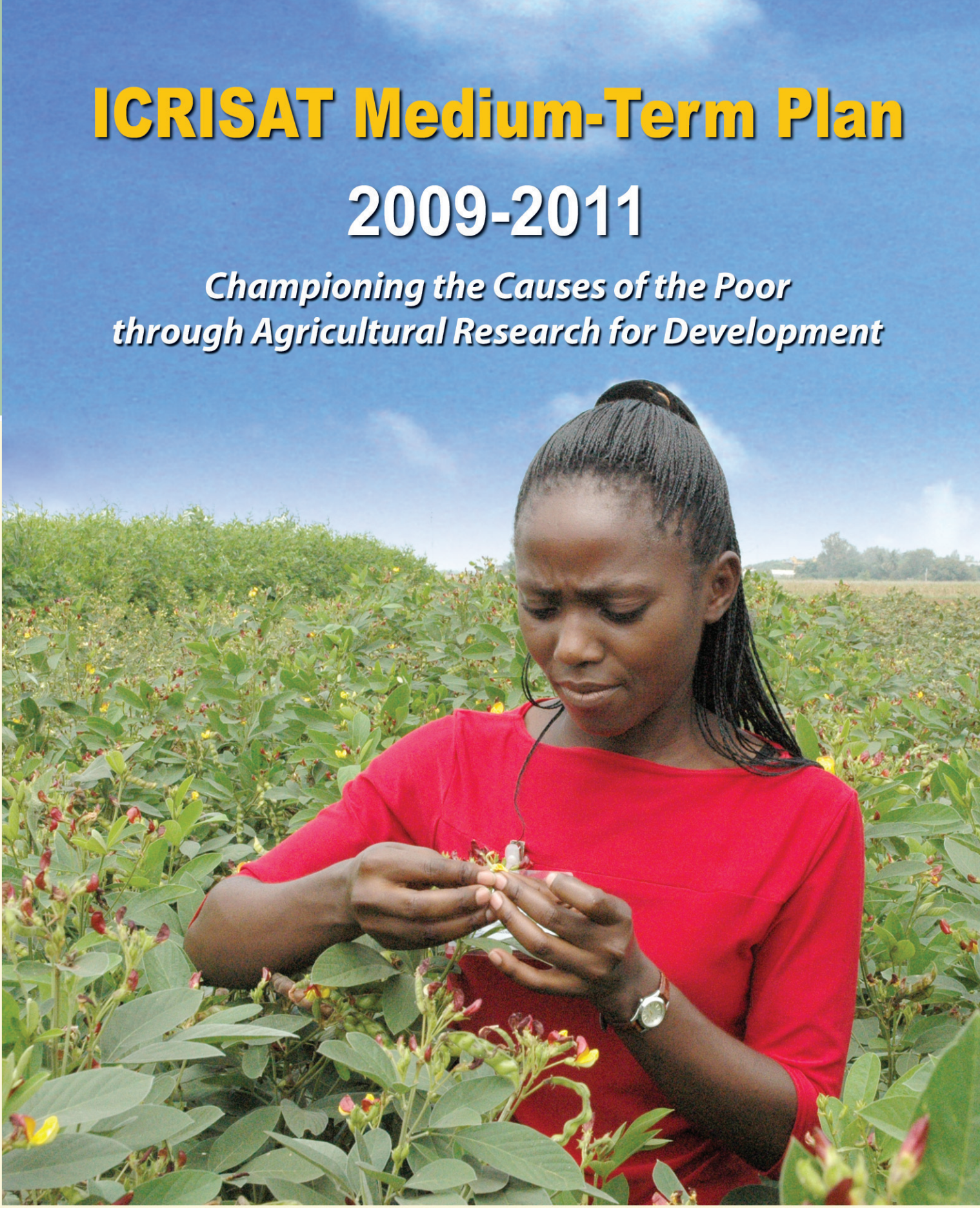
ICRISAT Medium-Term Plan

2009-2011

Championing the Causes of the Poor through Agricultural Research for Development



ICRISAT

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

Medium-Term Plan 2009-11

Submitted to the Science Council
of the
Consultative Group for Agricultural Research
(CGIAR)

June 15, 2008

International Crops Research Institute for the Semi-Arid Tropics
Medium-Term Plan 2009-11

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Adjustment to the Science Priorities and 2008-2010 MTP SC Commentary: The SC commentary for MTP 2008-2010 has acknowledged ICRISAT's current project portfolio is aligned with the SP goals. The CCERs performed in 2006 and 2007 have not recommended any change in ICRISAT's project structure which has thus remained unchanged in this MTP. The SC has requested more detail in the current MTP. In order to address this issue we have re-worked some projects and also included specific exemplars in each project of internal activities and milestones related to future output targets. Only exemplars can be provided as otherwise the volume of such information would far exceed the page length permitted in the MTP by the SC.

ICRISAT has concluded some special project research activities: Major concluded special project activities (>$500,000) which have no present likelihood of further support include Enhancing access to genetic diversity through scaling up participatory plant breeding: Roles of different types of farmer and development organizations in Mali funded by BMZ/GTZ (also responding to a CCER recommendation).

ICRISAT has introduced some new mainstream special projects: Several major new special projects have been won in 2007 and all are in mainstream accordance with ICRISAT's strategic plan. The biggest are Improving Tropical Legume Productivity for Marginal Environments in sub-Saharan Africa through CIMMYT and the GCP and Enhancing grain legumes productivity, and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia funded by the Bill and Melinda Gates Foundation in partnership with IITA and CIAT (This very large funding from these two projects has resulted in substantive increases in Projects 1, 3, 4 and 6 and in consequence Priorities 2A-C, and 5B --- See Tables 1 and 2). Similarly, the Implementation of the West African Seed Alliance funded by USAID has contributed to the large increase in proposed expenditure for project 3 (Tables 1).

ICRISAT has frozen the planning of Project 8: The expected funding of the Phase 3 of this activity which was expected to be forthcoming from the donor has been substantially delayed by changes in the donor's administrative protocols.

ICRISAT has recast the text and Logframe: For those projects singled out for extra-focus by the SC commentary on the MTP 2008-2010 namely: Projects 1, 7 and 9.

Major changes in existing collaborations including changes in participation in SWEPs & CPs: ICRISAT coordinates the new major project on Legume Improvement in SSA with CIAT and IITA. ICRISAT (through Oasis) is one of the principals in the current preparation of a CP proposal in the area of the mitigation of desertification.

Financial Indicators: All Center Financial Indicators are presently within CGIAR-accepted approved levels.

EPMR 2003 recommendations progress summary: Required action has been completed

in 2006. It is expecting its next EPMR to start at its Governing Board Meeting in August 2008.

Context

Retrospective: How the context in 2007/8 has changed plans for 2009

ICRISAT is now approaching its next EPMR (2008/9) and has completed its precursor CCER cycle in 2007. It had a most constructive and productive year in 2007 and was rated outstanding by the World Bank based on its 2006 Performance Indicators. The budget performance was strong and the scientific output was high. This MTP is in accordance with the Centers current strategic plan which in projected currently to 2015. The projected expenditure for 2008 has increased to $39.1 Million from $32.6 Million in 2007.

Highlights of Project Portfolio

ICRISAT for the purposes of sharpening the focus of its generic projects has recast the text and logframe of those projects singled out by the SC commentary on the MTP 2008-2010 namely: Projects 1, 7 and 9. Project 8 is an exception as it has been frozen.

The CCERs performed in 2006 and 2007 have not recommended any change in ICRISAT's project structure which has thus remained unchanged in this MTP. The SC has stated *The MTP still lacks the details on what actually is planned, i.e., the research activities that are to take place to generate the outputs. Project descriptions, therefore, could be more specific in this regard and more focused on specific issues under investigation. Concrete focused questions and approaches should be identified and the innovativeness more evident. At the level of generality provided in many of the Projects it is not possible to judge the quality of the research planning and monitoring.* In order to address this issue we have included specific exemplars for each project of internal activities and milestones related to future output targets. Only exemplars can be provided as otherwise the volume of such information would far exceed the page length permitted in the MTP by the SC. We expect that this will convince the SC that ICRISAT's research planning and monitoring is of a sufficient standard. Moreover, comprehensive supporting information of this type is already fully available on-line for 2006 and 2007: eg. www.icrisat.org/publications/ICRISAT_Archival_Report_2006.pdf

www.icrisat.org/publications/ICRISAT_Archival_Report_2007.pdf

New and Terminated Research

ICRISAT has concluded some special project research activities. Major concluded special project activities (>$500,000) which have no present likelihood of further support include Improved livelihoods in the Sahel through the development and implementation of household level bio-economic decision support systems funded by the Belgian Government, Provision of scientific partnership services for ECARSAM and SWMnet in the ASARECA region funded by the EU/ASARECA, Research into the development and effective use of ICT-enabled rural extension systems in Afghanistan, Enhancing access to genetic diversity through scaling up participatory plant breeding: Roles of different types of farmer and development organizations in Mali funded by BMZ/GTZ (also responding to a CCER recommendation).

ICRISAT has introduced some new mainstream special projects

Major new special projects won in 2007 but in mainstream accordance with ICRISAT's strategic plan include Increasing Food Security and Farmer Livelihoods through Enhanced legume Cultivation in the Central Dry Zone of Myanmar funded by ACIAR, Improving Tropical Legume Productivity for Marginal Environments in sub-Saharan Africa through CIMMYT and the GCP and Enhancing grain legumes productivity, and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia funded by the Bill and Melinda Gates Foundation in partnership with IITA and CIAT (This very large funding from these two projects has resulted in substantive increases in the Projects 1, 3, 4 and 6 and in consequence Priorities 2A-C and 5B --- See Tables 1 and 2), Sustainable Conservation and Utilization of Genetic Resources of two underutilized Crops Finger Millet and Foxtail Millet - to Enhance Productivity, Nutrition and Income in Africa and Asia funded by BMZ/GTZ, Providing for the Long-Term Funding of Ex Situ Collections of Germplasm held by ICRISAT funded by the Global Diversity Trust, Harnessing the True Potential of Legumes: Economic and Knowledge Empowerment of Poor Rainfed Farmers in Asia funded by IFAD, Programme for Integrated Innovations for Improving Legumes Productivity, Market Linkages and Risk Management in Eastern and Southern Africa funded by IFAD, Sweet sorghum ethanol value chain development project funded by the Government of India (NAIP), Producing More Food Grain with Less Water - Promoting Farm Based Methods to improve the Water Productivity funded by the Government of Norway, Implementation of the West African Seed Alliance funded by USAID (this last large project has contributed to the large increase in proposed expenditure for project 3 and Priority 2A-C, (See Tables 1 and 2).

Slower than Expected Progress in Previous MTP

ICRISAT has also been forced to freeze the activities and future planning of its Project 8 (Desert Margins Program SWEP)

The expected funding of the Phase 3 of this activity which was expected to be forthcoming from the donor has been substantially delayed by changes in the donors administrative protocols. This has meant that expenditure on Project 8 is restricted only to activities in support of the further development of the OASIS consortium and has resulted in a large fall in expenditure on priority 4A. This is expected to be only a temporary phenomenon but is dependent of whether funds for Phase III of the Desert Margins Program are, or are not, received in 2008/9.

Changes in Collaborative Arrangements

Major changes in existing collaborations including changes in participation in SWEPs & CPs

ICRISAT continues to participate broadly in all the current System Challenge Programs (particularly in Generation, Harvest Plus, Water and Food and FARA Africa). It coordinates the new major project on Legume Improvement in SSA with CIAT and IITA. ICRISAT continues to be the facilitator for the forthcoming CGIAR Centers Alliance --- Southern Sudan Consortium and OASIS jointly with ICARDA. ICRISAT (through Oasis) is one of the principals in the current preparation of a CP proposal in the area of the mitigation of

desertification.

Alignment with System Priorities

Adjustment to the Science Priorities and 2008-2010 MTP SC Commentary: The SC commentary for MTP 2008-2010 has acknowledged ICRISAT's current project portfolio is aligned with SP goals. The accordance of the work proposed with the respective priorities is described in the project narratives.

Non-System Priority Activities

Additional research and development which is not covered under CGIAR System Priorities.

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. Development activities include ICRISAT's facilitation of the UNEP Niger-Nigeria Trans-boundary Project and for contributions to the Agri-Science Park @ ICRISAT.

Center Financial Indicators

All Center Financial Indicators are presently within CGIAR-accepted approved levels.

ICRISAT's Project Structure

Table 1: **ICRISAT Projects 2009-2011**	**Expenditure Estimate $ 2007**	**Expenditure Estimate $ 2008**	**System Priority Area**
1. Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	$ 4.86M	$ 5.98M	5 (A-D)
2. Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets, Groundnut, Pigeonpea and Chickpea for current and future generations	$ 4.21M	$ 3.93M	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 imp.	$ 3.10M	$ 5.84M	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	$ 2.80M	$ 4.09M	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.	$ 1.95M	$ 2.90M	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	$ 2.87M	$ 4.65M	2 (A-C)
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities (HVCs) and products	$ 3.08M	$ 3.57M	3 (A, B, D)
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	$ 1.84M	$ 0.24M	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	$ 5.04M	$ 5.23M	4 (A, C, D)
10. The Virtual Academy for the African and Asian SAT	$ 1.35M	$ 1.03M	Blue Sky
Development activities	$ 1.29M	$ 1.35M	Development
Stand-alone training	$ 0.06M	$ 0.04M	Training
New research area	$ 0.18M	$ 0.20M	New research
	Total$ 32.6M	**Total$ 39.1M**	

Table 2

Cost Allocation of Resources by CGIAR System Priority

Amount in US $ Million

Priorities	Estimate 2007	Estimate 2008
	$M	**$M**
Priority 1A	2.875	2.695
Priority 1B	1.026	1.084
Priority 2A	4.956	6.489
Priority 2B	3.448	5.192
Priority 2C	2.577	5.537
Priority 2D	0.042	0.457
Priority 3A	2.120	2.498
Priority 3B	0.635	0.648
Priority 3D	0.329	0.426
Priority 4A	2.577	0.856
Priority 4C	1.521	1.642
Priority 4D	2.777	2.994
Priority 5A	2.139	1.927
Priority 5B	1.434	2.944
Priority 5C	0.573	0.523
Priority 5D	0.712	0.587
Development Activities	1.287	1.346
Stand-alone Training	0.057	0.036
New Research Areas	1.525	1.234
Total	**$32.6M**	**$39.1M**

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

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

This project provides the essential social science context for ICRISAT research. 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. This project will also focus on mapping the complex development pathways and alternative livelihood options to help make critical interventions to address poverty, vulnerability, marginalization and social exclusion. The project has the following four specific objectives which are in line with the mandate, goals and objectives of the Center as a whole:

a. Evaluate and develop innovative practices and policy options for expanding access and utilization of new technologies for smallholder producers, and enhance the conduct and performance of knowledge intensive institutions through impact studies for accountability and priority setting (links to Science Priority 5A)

b. Develop and promote strategies that enhance market access and competitiveness of dryland commodities for smallholder farmers and agro-enterprises and food safety for consumers (links to Science Priority 5B)

c. Examine, develop and promote strategies for strengthening rural institutions and pro-poor institutional change to reduce vulnerability of smallholder livelihoods (links to Science Priority 5C)

d. 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 (links to Science Priority 5D).

Generic Outputs Description

The target ecoregion, the beneficiaries and end users

The target ecoregion is the semi-arid tropics of sub-Saharan Africa and Asia. The remainder is unchanged from MTP 2007-2009 and MTP 2008-10.

Is the center the primary or secondary research provider?

The Center in this project is both a primary and secondary research provider.

Is it a catalyser, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact

ICRISAT 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.

Comparative and complementary advantage of the project activities

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. For more detail please see MTP 2007-2009.

Playing a catalytic, facilitating, enabling or advocacy role complementary to the centers research role and their contribution to IPGs

Ultimately ICRISAT and its partners hope to achieve enhanced policy and institutional arrangements for accelerated investment in SAT agriculture globally. This project addresses the complex challenges and emerging constraints facing agriculture in the semi-arid tropics which require a multi-faceted approach that encompasses innovations in policy, institutions and new technologies. Strategic assessments 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. Participatory, monitoring and evaluation models (to measure impact on the poor) will be developed and a coalition approach applying principles of innovation systems (including institutional arrangements) for better coordination and marketing will be documented and implemented as specific exemplars for IPG formulation.

Alignment to CGIAR Priorities

The research proposed in this project is in specific accordance with System Priority 5 --- Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT. It specifically covers priorities 5A, 5B, 5C and 5D. ICRISAT claims that 100% of this project's activities are encapsulated within the CGIAR System Priorities.

Outputs Description

Changes from previous MTP Outputs

In accordance with the MTP commentary, a new logframe for Project 1 was developed. Concrete and cohesive focal areas are distinguished with 10 outputs covering CGIAR Systems Priorities 5A, 5B, 5C, and 5D. Under each output, 3-5 output targets for the period 2008-2011 are identified. For example output 1.7 under Systems Priority 5B, i.e. 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, lists one output target for each year from 2008 to 2011.

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. [This output is shared regionally with projects 3 and 4]

Description: **Science Priority 5: Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger**

Priority 5A: Improving Science and Technology Policies and Institutions

Priority 5A, Specific goal 3: Improving incentives for technology generation,

access and use

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 registration, seed quality and certification procedures. 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 2008 and 2010:

2008 1.1.2: Best practices for harmonization of seed-related regulations and policies suitable for the specific conditions of the SADC (2008) region promoted

2010 1.1.1: Best practices for harmonization of seed-related regulations and policies suitable for the specific conditions of the ASARECA (2010) region 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.

List of Countries where Research is planned

Nigeria, Ghana, Niger, Mali, Burkina Faso, Senegal, Kenya, Sudan, Ethiopia, Uganda, all 14 countries of SADC

List of Potential beneficiary Countries

All countries in SSA

Alignment to CGIAR Priorities: 5A: Improving science and technology policies and institutions;
Countries of Planned Research: Angola; Botswana; Burkina Faso; Congo; Ethiopia; Ghana; Kenya; Lesotho; Malawi; Mali; Mauritius; Mozambique; Namibia; Niger; Nigeria; Senegal; Seychelles; South Africa; Sudan; Swaziland; Tanzania; Uganda; Zambia; Zimbabwe;

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: **Priority 5A, Specific goal 5: Enhancing the structure, conduct and performance of knowledge-intensive institutions**

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 1.4.1 Global economic outlooks for dryland agriculture including supply, demand, trade and prices for ICRISAT mandate crops;

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

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.

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 & 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.

List of Countries where Research is planned

Nigeria, Niger, Mali, Burkina Faso, Kenya, Ethiopia, Malawi, Zimbabwe, Mozambique, Zambia, India, Bangladesh and Sri Lanka

List of Potential beneficiary Countries

All countries in SSA, South Asia

Alignment to CGIAR Priorities: 5A: Improving science and technology policies and institutions;
Countries of Planned Research: Bangladesh; Burkina Faso; Ethiopia; India; Kenya; Malawi; Mali; Mozambique; Niger; Nigeria; Sri Lanka; Zambia; Zimbabwe;

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

Description: Description as per Output 2
Alignment to CGIAR Priorities: 5A: Improving science and technology policies and institutions;
Countries of Planned Research: Bangladesh; Burkina Faso; Ethiopia; India; Kenya; Malawi; Mali; Mozambique; Niger; Nigeria; Sri Lanka; Zambia; Zimbabwe;

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

Description: Description as per Output 2.
Alignment to CGIAR Priorities: 5A: Improving science and technology policies and institutions;
Countries of Planned Research: Bangladesh; Burkina Faso; Ethiopia; India; Kenya; Malawi; Mali; Mozambique; Niger; Nigeria; Sri Lanka; Zambia; Zimbabwe;

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

Description: Description as per Output 2.
Alignment to CGIAR Priorities: 5A: Improving science and technology policies and institutions;
Countries of Planned Research: Bangladesh; Burkina Faso; Ethiopia; India; Kenya; Malawi; Mali; Mozambique; Niger; Nigeria; Sri Lanka; Zambia; Zimbabwe;

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: **Priority 5B: Making international and domestic markets work for the poor**

Priority 5B, Specific goal 1: Enhanced livelihoods and competitiveness for smallholder producers and food safety for consumers influenced by changes in national and international markets

Priority 5B Specific goal 2: Improved marketing environment for smallholders by improving the efficiency of domestic markets

In the coming decade, whether smallholder producers in the SAT would be able to benefit from domestic and/or international markets would depend on their ability to access these markets, make the necessary adjustments to meet growing quality standards and improve 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 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:
- Institutional arrangements for better coordination of production and marketing
- Grading and quality control systems
- Profitable marketing channels and outlets in domestic and international markets
- Policies and strategies that enhance agricultural diversification and support industry competitiveness and intra-regional trade.

The research strategy focuses on the following output target for 2010:

2010 1.6.1: Policy options for establishing quality-based agricultural marketing systems for selected legumes, livestock and cereals identified and communicated to policy markers and partners

List of Countries where Research is planned

Ghana, Niger, Mali, Burkina Faso, Senegal, Kenya, Tanzania, Ethiopia, Malawi, Mozambique, Zimbabwe, India, Nepal and Bangladesh

List of Potential beneficiary Countries

Ghana, Niger, Mali, Burkina Faso, Senegal, Kenya, Tanzania, Rwanda, Ethiopia, Eritrea, Malawi, Mozambique, Zambia, Uganda, Zimbabwe, India, Nepal, Bangladesh, Philippines

Alignment to CGIAR Priorities: 5B: Making international and domestic markets work for the poor;
Countries of Planned Research: Bangladesh; Burkina Faso; Ethiopia; Ghana; India; Kenya; Malawi; Mali; Mozambique; Nepal; Niger; Senegal; Tanzania; Zimbabwe;

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: Description as per Output 6.
Alignment to CGIAR Priorities: 5B: Making international and domestic markets work for the poor;
Countries of Planned Research: Bangladesh; Burkina Faso; Ethiopia; Ghana; India; Kenya; Malawi; Mali; Mozambique; Nepal; Niger; Senegal; Tanzania; Zimbabwe;

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: Description as per Output 6.
Alignment to CGIAR Priorities: 5B: Making international and domestic markets work for the poor;
Countries of Planned Research: Bangladesh; Burkina Faso; Ethiopia; Ghana; India; Kenya; Malawi; Mali; Mozambique; Nepal; Niger; Senegal; Tanzania; Zimbabwe;

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

List of Countries where Research is planned

India

List of Potential beneficiary Countries

All countries in South Asia

Alignment to CGIAR Priorities: 5C: Improving rural institutions and their governance;
Countries of Planned Research: 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

Description: **Priority 5D. Improving research and development options to reduce rural poverty and vulnerability**

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&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.

Activities Exemplar
We have declared an output target summarizing this work for 2011 1.10.4: Policy package

elements on risk management strategies for mitigating the impact of risks inherent in rainfed agriculture developed and shared with partners in SAT. An exemplar activity and its internal milestones leading to this output target have been fully developed and are presented below. This activity is placed in the context of establishment of policy decision support system for rainfed agriculture in India and is based on a consistent high quality longitudinal database developed for two states of India, namely, Andhra Pradesh and Maharashtra.

The **activity** is Develop and evaluate social adaptation strategies or mechanisms to enhance coping to risks and shocks in rural SAT economies

Milestones:
2007: Baseline data on social networks and linkages documented and preliminary analysis to map the architecture of social networks in the SAT villages undertaken

2008: Qualitative and quantitative data and methods to understand key relationships of social and technological inter linkages with reference to drivers of change developed

2009: Comparative social analysis of longitudinal panel data documented (spatial and temporal analysis). Social architecture of two rural SAT villages mapped.

2010: Knowledge based on social networks established Policy recommendations based on village-level insights formulated, identifying the role of social institutions, social capital and social networks in adaptation processes and practices

2011: Social adaptation strategies and layers of resilience developed and documented. This will include:

- Enhanced linkages and facilitating layering new innovations through existing networks (eg. Self-Help groups, kinship networks)
- Greater access to resources through altered property rights regimes,
- New governance mechanisms based on participation and inclusion of community members.

2012: Government adaptation strategies & development plans formulated

The report for the 2007 internal milestone (See 2007 Archival Report) provides additional detail of the precise activities undertaken and includes a sociological analysis of the research undertaken during the period 1975-85 and 2005. The variables considered for the analysis include: membership in organization by type of organization, degree of participation, benefits from the groups; information networks and services. These are compared across caste and gender. Results from two villages - Aurepalle (Andhra Pradesh) and Kanzara (Maharashtra) - are compared in this analysis. The analysis of the intersection of gender and caste in the formation of diverse networks raises some issues a) to understand the factors that inhibit men and women from different social groups to become members of different groups and networks; b) are there cultural, social, economic or political reasons to form or not form diverse networks and be a part of them? A social networks analysis addresses these issues and may help us to identify these and such other reasons. The focus is on the SAT poor engaged in agriculture especially marginalized groups. Gender, caste and class considerations will be considered.

The **proposed work is highly innovative**, since it will link vulnerability, distress and risk behavior to the stability/instability of sources of livelihoods including financial, human and social capital, and the natural resource base and its management. In addition, the dynamics

of economic, social, and health issues underlying poverty will be addressed by adapting both economic and social lenses whereby the consequences of rural distress are discussed from the angle of sources of livelihoods including farm and non-farm income, off-farm options, migration and risky behavior, especially considering gender dimensions. More importantly, the links between farm-household initiatives to stabilize sources of livelihoods or reduce rural distress and their risk behavior will be established by scrutinizing evidence of individual household and collective action in the management of financial and human capital as well as the community's natural resource base. Ultimately, this work combines micro (VLS) and macro studies to best inform long-run priority setting at ICRISAT and design policy and technological interventions. Insights into the livelihood and coping strategies of the poor and vulnerable would support policy formulation in improving rural livelihoods. This improved understanding of sources of risk and vulnerability for the poor provides a basis for informing policy development. Innovative, long-term, durable multi-stakeholder partnerships will be established for fostering dialogue, enhancing the use of participatory methodologies and learning processes focusing on the actors and the sectors involved.

A linked pair of output targets summarizing this work for 2009 and 2011 are:

2009 1.10.1: Database and documentation of Changes in household economies on SAT Asia based on the panel data from 1975-2007.
2011 1.10.2: Policy package elements on risk management strategies for mitigating the impact of risks inherent in rainfed agriculture developed and shared with partners in Asia.
2012 1.10.1: A Ph.D. dissertation on options for mitigating susceptibility to HIV through agricultural technologies that increase food security in Malawi

List of Countries where Research is planned

Niger, Mali, Kenya, Malawi and India

List of Potential beneficiary Countries

All countries in the SAT in SSA and SA.

Alignment to CGIAR Priorities: 5D: Improving research and development options to reduce rural poverty and vulnerability;
Countries of Planned Research: India; Kenya; Malawi; Mali; Niger;

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. [This output is shared regionally with projects 3 and 4]**

Description of Impact Pathway: Project 1

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 1cycle. This impact pathway systematically outlines a hierarchy of outcomes that contributes to attaining Project 1s 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.

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
- Strategic assessments of future outlooks and development opportunities in SAT agriculture

- 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
- Identification of consumer preferences in intermediate and end user markets and implications for technology design
- Seed policy reform to facilitate sustained access to improved quality seed by farmers

Elaboration of Partners Roles

Elaboration of partner's roles and capacity development

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 promulgated 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 Mali, Burkina Faso, Niger, Senegal, Nigeria, Kenya, Ethiopia, Malawi, India, and Bangladesh are part of the evolving network of social scientists working on the SAT. They take decisions informed by studies on impacts, trade 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: IFPRI helps ICRISAT through its global expertise on marketing. 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 Priority 5A in Africa and NCAP (the Indian National Center for Agricultural Policy is the key partner in Asian and VLS activities owing to its extensive domestic reach in India and long experience of collaboration with ICRISAT (Priority 5D).

Logical Framework

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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. [This output is shared regionally with projects 3 and 4]**			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
	Output Target 2008: 1.1.1 Critical gaps in understanding safety standards and food safety regulations identified and new knowledge shared with partners for capacity development in ESA.	Capacity			
	Output Target 2008: 1.1.2	Policy strategies			

	Best practices for harmonization of seed-related regulations and policies suitable for SADC region documented and promoted				
	Output Target 2010: 1.1.1 Best practices for harmonization of seed-related regulations and policies suitable for ASARECA regions documented and promoted	Policy strategies			
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.
	Output Target 2008: 1.2.1 Ex-post impact studies conducted on selected dryland technologies:	Practices			

	Groundnut in Uganda; conservation farming and micro-dosing in Zimbabwe				
	Output Target 2009: 1.2.1 Ex-post impact studies on sorghum and pearl millet in Nigeria; sorghum and pearl millet for poultry feed in Asia	Materials			
	Output Target 2010: 1.2.1 Early adoption studies on chick pea, pigeon pea and groundnut in selected countries	Materials			
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.

	Output Target 2009: 1.3.1: Impact assessment master classes in Asia completed Documented	Capacity			
	Output Target 2010: 1.3.1: Impact pathways approach applied in ICRISAT planning and M&E process for enhancing relevance of R&D interventions in the SAT	Policy strategies			
	Output Target 2011: 1.3.1: Updated impact database shared in the website	Other kinds of knowledge			
	Output Target 2011: 1.3.2: New methodologies tackling impact on social processes (social capital and networks), capacity building and policy developed	Other kinds of knowledge			
	Output Target 2011: 1.3.3: Lessons learnt from analysis of impact pathways of representative ICRISAT NARS	Other kinds of knowledge			

	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.
	Output Target 2008: 1.4.1 Website for monitoring agricultural growth trends for southern Africa	Other kinds of knowledge			
	Output Target 2009: 1.4.1 Global economic outlook (supply, demand, trade, prices) report of ICRISAT mandate crops	Other kinds of knowledge			
	Output Target 2011: 1.4.1 Regional outlook	Other kinds of knowledge			standards for the benefit of

	(supply, demand, trade, prices) reports of ICRISAT mandate crops				small scale farmers
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
	Output Target 2008: 1.5.1 Agricultural input subsidies and contract farming policies to improve agricultural productivity in southern Africa	Policy strategies			
	Output Target 2009: 1.5.1 Development domains report for southern Africa	Practices			
	Output Target 2010: 1.5.1 Policy options for increasing agricultural productivity to	Policy strategies			

	mitigate HIV susceptibility				
	Output Target 2010: 1.5.2 Constraints, challenges and opportunities for regional cooperation in R&D and alternative regional research and development strategies in southern Africa report	Policy strategies			
	Output Target 2011: 1.5.1 Adaptation strategies and layers of resilience to climatic related shocks in Asia documented	Policy strategies			
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**			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 competitiveness, product quality and profitability of farmers, agro-enterprises, market agents and	The marketing industry harmonized at a regional level contributes greatly to the transformation of agricultural performance in SAT countries.

				processors and facilitate enhanced national, intra-regional and global trade	
	Output Target 2008: 1.6.1 The role of existing grading and quality control systems in selected legume, livestock and cereal marketing systems identified	Materials			
	Output Target 2009: 1.6.1 Preferred market traits identified for selected tradable legumes in three regions (ESA, WCA and Asia), livestock (in southern Africa) and dryland cereals in WCA region	Materials			
	Output Target 2010: 1.6.1 Policy options for establishing quality-based agricultural marketing systems for selected legumes, livestock and cereals identified and communicated to policy markers and partners	Policy strategies			
Output 7: Institutional innovations for			NARES partners, traders,	Partners show informed	The marketing industry

reducing transaction costs and improving coordination in input and output market chains for dryland commodities in domestic and international markets identified and promoted			processors, market agents, small-scale crop and livestock producers	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 niche markets, reduced transaction costs and reduced market risk.	harmonized at a regional level contributes greatly to the transformation of agricultural performance in SAT countries.
	Output Target 2008: 1.7.1 Performance of existing formal and informal markets for selected dryland commodities (legumes and ruminants) and inputs (seed, feed, fodder and services) understood and documented	Practices			
	Output Target 2009: 1.7.1 Innovative arrangements for better coordination of production,	Practices			

	access to inputs and services, and output marketing (for selected legumes (ESA), cereals (Asia) and ruminants in ESA) along the value chain for reducing transaction costs identified and communicated				
	Output Target 2010: 1.7.1 Policy recommendations for improving market access, linkages and coordination for selected commodities developed and shared with policy markers and partners	Policy strategies			
	Output Target 2011: 1.7.1 Synthesis of pilot market and institutional innovation studies in Asia using coalition approach (applying principles of ILAC) completed	Policy strategies			
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			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-	Agribusiness enterprises stimulated through high value products (e.g., legumes, livestock, biofuels, vegetables, etc);

agribusiness enterprises developed and promoted				scale producers of both crops and livestock to demonstrate enhanced technical know-how, reduced-risk production strategies, institutional linkages, bargaining power; access to niche markets, reduced transaction costs and reduced market risk	Emerging demand opportunities are met by smallholders
	Output Target 2009: 1.8.1 Research report on economic feasibility of diversification using legumes and livestock (ESA) completed	Policy strategies			
	Output Target 2010: 1.8.1 Research report on economic feasibility of diversification into high value products with emphasis on biofuels (ESA, Asia) and vegetables (WCA) completed	Policy strategies			
	Output Target 2011: 1.8.1 Policy options and recommendations for stimulating diversification of	Policy strategies			

	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	Development has occurred within a context in which rural institutions are newly strong and functional in the SAT resulting in improved rural livelihoods.
	Output Target 2011: 1.9.1 Policy report on the impact of rainfall insurance and recapitalization of cooperatives completed in India	Policy strategies			
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	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

				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	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
	Output Target 2008: 1.10.1 Panel dataset on village and household economies in West- Africa (2004-2006) fully documented	Practices			
	Output Target 2008: 1.10.2 Report on rural livelihoods in the context of relief programs in Zimbabwe completed	Practices			
	Output Target 2009: 1.10.1 Database and documentation of Changes in household economies on SAT Asia based on the panel data from 1975-2007 completed; VLS webpage	Practices			

	developed				
	Output Target 2009: 1.10.2 Report on rural livelihoods in West-Africa completed	Practices			
	Output Target 2010: 1.10.1 Report on Research and development options for West-African SAT Agriculture completed	Practices			
	Output Target 2010: 1.10.2 Uptake pathways of SAT technologies documented based on case studies and shared with national program partners in Asia	Capacity			
	Output Target 2011: 1.10.1 Policy brief on Investment options for the rural poor in West-African SAT published	Policy strategies			
	Output Target 2011: 1.10.2 Report on household economies in SAT Asia (2001-2009) completed	Policy strategies			
	Output Target 2011: 1.10.3 Analysis of alternate investment options and their trade-offs completed and accessible to rural poor in Asia	Policy strategies			

	Output Target 2011: 1.10.4 Policy package elements on risk management strategies 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	Policy strategies			
	Output Target 2012: 1.10.1 A Ph.D dissertation on options for mitigating susceptibility to HIV through agricultural technologies that increase food security in Malawi completed	Practices			

ICRISAT-2: Sustaining Biodiversity of Sorghum, Pearl Millet, Small Millets, Groundnut, Pigeonpea and Chickpea for Current and Future Generations

Project Overview and Rationale

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

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.

Generic Outputs Description

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 institutes 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&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 centers 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.

Alignment to CGIAR Priorities

Alignment to CGIAR Priorities and Framework Plan

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 Outputs

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.

Output 1: Germplasm of staple crops assembled and conserved and germplasm characterized and documented for utilization and knowledge shared with partners
Description: Germplasm of staple crops assembled and conserved and germplasm characterized and documented for utilization and knowledge shared with partners List of Countries where Research is planned Niger, Kenya, Zimbabwe, India List of Potential beneficiary Countries All countries growing ICRISAT mandate crops
Alignment to CGIAR Priorities:
Countries of Planned Research: India; Kenya; Niger; Zimbabwe;

Output 2: Germplasm of six small millets assembled and conserved germplasm characterized / evaluated and documented for utilization and knowledge shared with partners
Description: Germplasm of six small millets assembled and conserved germplasm characterized/ evaluated and documented for utilization and knowledge shared with partners List of Countries where Research is planned Niger, Kenya, Zimbabwe, India List of Potential beneficiary Countries All countries growing small millets (finger millet, foxtail millet, barnyard millet, little millet, kodo millet, and proso millet)
Alignment to CGIAR Priorities:
Countries of Planned Research: India; Kenya; Niger; Zimbabwe;

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 Centers 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 report for 2007 internal milestones provides 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 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.

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

List of Countries where Research is planned

Niger, Mali, Kenya, Tanzania, Malawi, Zimbabwe, India

List of Potential beneficiary Countries

All countries growing ICRISAT mandate crops

Alignment to CGIAR Priorities:
Countries of Planned Research: India; Kenya; Malawi; Mali; Niger; Tanzania; Zimbabwe;

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: **Systems Priority 1 A & B: Sustaining Biodiversity of Sorghum, Pearl millet, Small millets, Groundnut, Pigeonpea and Chickpea for current and future generations (all outputs are associated with the SGRP SWEP)**

Supporting exploration, exchange, and conservation of plant genetic resources (PGRs) is one of the main objectives of ICRISAT so that germplasm accessions are easily accessible to research workers, worldwide. Currently, the ICRISAT genebank holds 118,000+ germplasm accessions of its mandate crops and small millets representing contributions from 144 countries of the world.

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 as such 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. These small millets are characterized as underutilized crops and fall under Systems Priority 1B.

List of Countries where Research is planned

Niger, Mali, Uganda, Kenya, Tanzania, Malawi, Zimbabwe, India

List of Potential beneficiary Countries

All countries growing ICRISAT mandate crops

Alignment to CGIAR Priorities: 1A: Promoting conservation and characterization of staple crops; 1B: Promoting conservation and characterization of underutilized plant genetic resources;
Countries of Planned Research: India; Kenya; Malawi; Mali; Niger; Uganda; Zimbabwe;

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

Description of impact pathways and capacity development

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.

International Public Goods

Expected IPGs that have applicability beyond one nations borders in the MTP period

- Safely conserved germplasm and DNA collections of staple 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, Japan) and Africa (Kenya, Malawi) and universities for staple crops; and the MS Swaminathan Research Foundation (MSSRF) for small millets in India. 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 (Texas A & M University, USA) (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

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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.
	Output Target 2008: 2.1.1 Priorities areas identified for chickpea and pigeonpea for collection/assembly in collaboration with NARS	Other kinds of knowledge			

	Output Target 2008: 2.1.2 Sorghum germplasm from USDA (30 nos), pearl millet from Niger (400 accessions) and pigeonpea collections from Tanzania, Uganda and Mozambique (200 accessions) assembled [Output target can now only be partially achieved as germplasm from other countries was only available in reduced quantities]	Materials			
	Output Target 2008: 2.1.3 Sorghum germplasm from Niger (450 accessions), chickpea germplasm from ICARDA (500 accessions) and groundnut germplasm from Japan assembled and characterized for morpho-agronomic traits [Output target can now only be partially achieved as germplasm from other countries was only available in reduced quantities]	Materials			
	Output Target 2008: 2.1.4 Global databases of sorghum and	Other kinds of knowledge			

	groundnut compared to identify unique germplasm and to identify gaps for collection				
	Output Target 2009: 2.1.1 Priority areas for sorghum/groundnut for collection and assembly determined in collaboration with NARS and with associated capacity development	Other kinds of knowledge			
	Output Target 2009: 2.1.2 Staple crops germplasm databases updated and uploaded to SINGER database	Other kinds of knowledge			
	Output Target 2010: 2.1.1 Germplasm of staple crops assembled and conserved for utilization at regional genebanks in Africa (Bulawayo, Nairobi and Niamey)	Materials			
	Output Target 2010: 2.1.2 85% of germplasm characterized and documented for utilization	Materials			
	Output Target 2011: 2.1.1 Germplasm of staple crops regenerated (2000 accessions) for conservation and distribution	Materials			
Output 2:			Parties to	i)	i) Risks to

Germplasm of six small millets assembled and conserved germplasm characterized/ evaluated and documented for utilization and knowledge shared with partners			CBD and IT, Crop Diversity Trust, SGRP, Bioversity International, Generation CP partners, NARS, Universities, ARIs and the Svalbard Repository	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.	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
	Output Target 2008: 2.2.1 Global database of foxtail, little, kodo, proso and barnyard millet compared to identify unique germplasm	Other kinds of knowledge			
	Output Target	Other			

	2008: 2.2.2 Passport, characterization and evaluation data of small millets germplasm documented	kinds of knowledge			
	Output Target 2009: 2.2.1 Gaps in finger millet collection identified and potentially filled in at least two countries in ESA	Materials			
	Output Target 2009: 2.2.2 Germplasm databases of small millets updated to SINGER format	Other kinds of knowledge			
	Output Target 2009: 2.2.3 (2008 2.2.2)* Priority areas identified for foxtail, little, kodo, proso and barnyard millet for collection/assembly in collaboration with NARS [*Output target deferred to 2009]	Other kinds of knowledge			
	Output Target 2010: 2.2.1 Databases of small millets germplasm updated for utilization	Other kinds of knowledge			
	Output Target 2010: 2.2.2 Germplasm of six small millets assembled and conserved with 50% of germplasm characterized/ evaluated for desirable traits and	Materials			

	documented for utilization				
	Output Target 2011: 2.2.1 Germplasm of small millets supplied on request	Materials			
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
	Output Target 2008: 2.3.1 Mini-core collection of sorghum germplasm established for utilization (sorghum, finger millet)	Materials			
	Output Target 2008: 2.3.2 Diversity of groundnut and pigeonpea composite collections analyzed and reference sets (300 accessions each)	Practices			

	established				
	Output Target 2008: 2.3.3 Mini core collections of chickpea, groundnut, and pigeonpea evaluated in multilocations in Asia	Materials			
	Output Target 2008: 2.3.4 Core collection of foxtail millet germplasm established for utilization	Practices			
	Output Target 2009: 2.3.1 Mini-core collection of pigeonpea germplasm evaluated for resistance to wilt and sterility mosaic diseases under controlled environment and field conditions	Materials			
	Output Target 2010: 2.3.1 New reference sets of chickpea, groundnut, pigeonpea and sorghum germplasm (300 accessions each) established and evaluated for utilization	Practices			
	Output Target 2011: 2.3.1 Foxtail millet core collection evaluated for resistance to blast	Materials			
	Output Target 2011: 2.3.2	Practices			

	Diversity analyzed for molecular markers and markers associated with drought related (root traits) in chickpea identified				
	Output Target 2011: 2.3.3 Pearl millet mini core collection evaluated for resistance to downy mildew and rust	Materials			
	Output Target 2011: 2.3.4 Sorghum mini core or reference set screened for root traits	Materials			
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 ICRISAT mandate

					crops in the SAT
	Output Target 2008: 2.4.1 Genetic diversity and population structure of groundnut and pigeonpea composite collections assessed	Practices			
	Output Target 2008: 2.4.2 Data sets for chickpea and sorghum composite collections genotyping made available globally via internet	Other kinds of knowledge			
	Output Target 2008: 2.4.3 Trait specific mapping population/RILs of staple crops assembled	Materials			
	Output Target 2009: 2.4.1* Data sets of finger millet and foxtail millet composite collections genotyping made available globally via the internet [*Output target deferred to 2011]	Other kinds of knowledge			
	Output Target 2009: 2.4.2 Genetic diversity and population structure of finger millet composite collection assessed and reference set	Practices			

	(300 accessions) established				
	Output Target 2010: 2.4.1 DNA extracts of chickpea and groundnut mini-core collections of germplasm conserved for utilization	Materials			
	Output Target 2010: 2.4.2 Datasets for groundnut and pigeonpea, composite collections genotyping made available globally via the internet	Other kinds of knowledge			
	Output Target 2010: 2.4.3 Genetic diversity and population structure of foxtail millet composite collection assessed and reference set (200 accessions) established	Practices			
	Output Target 2010: 2.4.4 Agriculturally beneficial micro-organisms assembled for utilization with associated capacity development	Materials			
	Output Target 2011: 2.4.1 (2009 2.4.1*) Data sets of composite collections of finger millet and foxtail millet genotyping made available globally via the	Other kinds of knowledge			

	internet [*Output target deferred to 2011]				
	Output Target 2011: 2.4.2 Molecular genetic maps and consensus maps based on SSRs, DArTs and EST-based markers developed for chickpea, pigeonpea and groundnut	Practices			

ICRISAT-3: Producing more and better food of 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

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

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.

Generic Outputs Description

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. We are also trying to assist the few private sector marketing and seed enterprises. 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 crop 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 S*triga*, 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 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. 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 Outputs

The project structure for ICRISAT was re-worked newly in 2006 and has not changed in 2007 or 2008. The outputs have increased by one, with the creation of the West African Seed Alliance . Output targets have changed slightly as the output target 2009 3.3.2 Cereal processing tools characterized for improving bioavailability of iron and zinc in young children's diets has been re-scheduled as 2012 3.3.1 as ICRISAT now understands better the considerable difficulties associated with phytate analyses and bioavailability studies in the diets of young children. In addition, output target 2008 3.2.3 has been deleted through merger with output target 2008 3.3.1 for which the text has been somewhat modified to accommodate the change. Output targets for the newly created output 3.4 have been added.

Farmers and consumers in the semi-arid tropics of West and Central Africa, depending on sorghum and pearl millet as their staples 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.

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 three 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.

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 a 2010 output target of: 2010 3.1.1 New pearl millet and sorghum inbred lines with good combining ability and quantitative trait characterisation made available to partners for developing hybrid cultivars.

List of Countries where Research is planned

Niger, Mali, Senegal, Burkina Faso, Nigeria, Ghana

List of Potential beneficiary Countries

Senegal, Mali, Niger, Togo, Benin, Nigeria, Cameroon, Chad, Ghana, Sierra Leone, Southern Sudan, Mozambique, Tanzania

Alignment to CGIAR Priorities: 2A: Maintaining and enhancing yields and yield potential of food staples;
Countries of Planned Research: Burkina Faso; Ghana; Mali; Niger; Nigeria; Senegal;

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: **Activities Exemplar**

MTP Output target 2009 3.2.1

First availability of at least one allele-specific molecular marker for genes controlling photoperiod sensitivity of flowering time in pearl millet and sorghum

Activity 3.2.1: Searching for primer information, phenotyping, and genotyping sorghum and pearl millet lines and accessions

To precisely assess the photoperiodic reaction of diverse sets of materials (phenotyping), 200 pearl millet inbred lines (=S3 inbred generation) and 210 sorghum lines were grown in the rainy season 2007 at Sadore (Niger) and Samanko (Mali), respectively, using two planting dates and two replications per planting date. Special care was taken to determine days to first and 50% flag leaf appearance and days to first and 50% flowering. Data analysis is underway. Leaf samples were taken from all the phenotyped accessions and sent to the partner group at University of Hohenheim for DNA extraction. Simultaneously, the Hohenheim partners were able to sequence 10 candidate genes for sorghum and 5 candidate genes for pearl millet. Assessment of population structure and analysis of SNPs in the phenotyped materials is currently underway.

Milestones:

2007: Primer information available for candidate genes that could control the photoperiod response of pearl millet and sorghum (Hohenheim University)

2007: Paper published on effect of photoperiod on growth and development of West-African sorghum and pearl millet varieties.

2008: Phenotypic data for flowering response and SNP expression for contrasting pearl millet and sorghum materials available (Hohenheim University)

2009: Markers developed for photoperiod response in pearl millet and sorghum developed and article on markers for photoperiod response in sorghum and pearl millet published (Hohenheim University)

Activity 3.2.2: Study relationships between latitude and photoperiod-sensitivity in sorghum and pearl millet Milestones:

2008: Multi-latitudinal trials conducted from the equator to temperate latitudes with sorghum and pearl millet varieties characterized previously at one latitude only, data assembled

2009: Publication of results on relationship between latitude, and photoperiod sensitivity for flowering time

Activity 3.2.3:
Study root growth of sorghum and pearl millet and its relationships with above ground growth, and photoperiod sensitivity

Milestones:

2007 Trial conducted comparing root, above ground growth and development of sorghum, pearl millet and maize.

2008 Synthesis of data 2009 Publication on findings regarding comparative root growth of sorghum pearl millet and maize.

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

Priority 2B: Tolerance to abiotic stresses

The development and initial implementation of a regionally coordinated strategy for population improvement and participatory variety development for groundnut, pearl millet and sorghum will be based on improved understanding of the specific requirements for crop adaptation to production systems. Regional integration is expected to enhance breeding efficiency, since the target countries share the same 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. Marker-assisted selection (MAS) for appropriate photoperiod response in each adaptation zone may assure a more efficient exploitation of the full range of available pearl millet and sorghum genetic diversity in WCA for each adaptation zone.

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.

Research efforts towards these specific goals are encapsulated in the output targets for 2009 and 2010 namely:

2009 3.2.1 First availability of allele-specific molecular markers for genes controlling photoperiod sensitivity of flowering time in pearl millet and sorghum by 2009

2009 3.2.2 New Striga resistant genepool of pearl millet available for testing in WCA breeding programs by 2009

2010 3.2.2 Three NARS empowered to breed groundnut varieties with multiple attributes especially drought tolerance by 2010.

List of Countries where Research is planned

Niger, Mali, Burkina Faso, Senegal, Nigeria

List of Potential beneficiary Countries

Senegal, Mali, Niger, Togo, Benin, Nigeria, Cameroon, Chad, Ghana, Tanzania, Mozambique, Southern Sudan
Alignment to CGIAR Priorities: 2A: Maintaining and enhancing yields and yield potential of food staples; 2B: Improving tolerance to selected abiotic stresses;
Countries of Planned Research: Burkina Faso; Mali; Niger; Nigeria; Senegal;

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 also are an important source of micronutrients in this region, providing one third to one half of Fe

needs/person/day but 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. SC Commentary concern with reference to projects 3 and 4 Nowhere is the conflict between breeding for low nutrient status (soils?- ICRISAT addition) properly reconciled with the desire to biofortify crops was being addressed in specific trials at ICRISAT, Patancheru (Project 5) and no obvious correlation was found in replicated trials between low grain Zn and Fe content in sorghum with low soil nutrient status (ICRISAT Archival Report for 2005).

Research addressing these particular specific goals is summarized through two output targets for 2010 namely:
For groundnut, Effectiveness of seed bulking of new preferred varieties resistant to aflatoxin contamination through village seed banks assessed and knowledge shared with partners.
For sorghum and pearl millet we shall work towards the diffusion of knowledge and skills about cereal processing tools assessed for improving bioavailability of iron and zinc in young children

List of Countries where Research is planned

Niger, Mali

List of Potential beneficiary Countries

Senegal, Mali, Niger, Togo, Benin, Nigeria, Cameroon, Chad, Ghana

Alignment to CGIAR Priorities: 2C: Enhancing nutritional quality and safety;
Countries of Planned Research: Mali; Niger;

Output 4: Sustainable breeder, foundation and certified seed systems in partnership with NARES and private seed entrepreneurs developed through marketing of high quality seed of adapted released varieties of sorghum, millet groundnut , etc. accessible and affordable to resource poor farmers through network of agro-input dealers in an enabling agricultural environment

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

Priority 5B: Making international and domestic 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 West Africa Seed Alliance (WASA) will facilitate access by commercial seed companies, farmer associations, cooperatives and other interested parties to improved seed developed through public research investments. WASA will provide technical advice on seed production, business development services, and access to seed processing and storage technology to increase the supply of high-quality foundation and certified seed of improved varieties at an affordable price by these various entities. WASA will also support the development of an agro-dealer network for 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 that translate into a sustained increase in agricultural productivity.

Sorghum and millets are primary staples in much of West Africa, and these two crops are already being targeted by existing seed production programs in the region. WASA will add-value to these efforts and facilitate the production and marketing of hybrid millet and sorghum varieties that are already under development. The successful introduction of hybrid technology will require the development, introduction and implementation of quality control measures that are largely absent in the underdeveloped seed market to ensure that quality is maintained, and that farmers can benefit from hybrid technology that has proven successful elsewhere in Africa and the world.

The team will focus efforts on harmonizing seed legislation, variety release procedures, seed certification and seed import export 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 2010 are namely:

Output target 2010 3.4.1: Improved agricultural enabling environment established for marketing high quality seed of sorghum, millet groundnut and other crops between West African Countries

Output Target 2011 3.4.2: Enhanced businesses of foundation seed production to satisfy requests from certified seed producers/seed companies linked to product markets in Mali and Nigeria.

List of Countries where Research is planned

Niger, Mali, Nigeria

List of Potential beneficiary Countries

Senegal, Mali, Niger, Nigeria, Togo, Benin, Burkina Faso, Cameroon, Chad, Ghana, Ivory Coast, Gambia, Guinea, Mauretania

Alignment to CGIAR Priorities: 2A: Maintaining and enhancing yields and yield potential of food staples; 5B: Making international and domestic markets work for the poor; 5C: Improving rural institutions and their governance;
Countries of Planned Research: Mali; Niger; Nigeria;

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**

Description of impact pathways and capacity development

The key to achieving anticipated impact from the outputs 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.

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 as high. 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. 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.

The nutrition impacts, 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 described. 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.

All the outputs have important components of new knowledge sharing as targeted outputs. 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.

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.

International Public Goods

Expected IPGs that have applicability beyond one nations borders

- 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
- 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

Elaboration of Partners roles (see also Project 3 network map in MTP 2008-2010)

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 expect to work 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. The VASAT consortium (Project 10) is lead e-learning efforts. This project is also linked to the **SLP SWEP** through its work on forage quality in cereals.

Key Strategic Alliances: CIRAD (expertise in crop physiology), Hohenheim University (expertise to support breeding methods) and Wageningen University (expertise to support efforts on human nutrition).

Logical Framework

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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
	Output Target 2008: 3.1.1 Enhanced access and capacity development of NARS to new, characterised diversity of sorghum and millet germplasm in adapted backgrounds	Capacity			
	Output Target 2008: 3.1.2 Guinea race sorghum hybrid parents made available to NARS and PS breeders for developing hybrid cultivars	Materials			

	Output Target 2009: 3.1.1 Initial heterotic groupings for sorghum and pearl millet hybrid breeding for WCA established and published	Materials			
	Output Target 2010: 3.1.1 Ten new pearl millet and sorghum inbred lines with good combining ability and quantitative trait characterization made available to partners with associated capacity development for developing hybrid cultivars	Materials			
	Output Target 2011: 3.1.1 Two superior pearl millet topcross hybrids and 6 guinea hybrids for at least two countries in West Africa identified, release relevant information as well as parental seed made available to partners	Materials			
Output 2: **Improved methodologies developed for integrating breeding of groundnut, sorghum and pearl millet populations and varieties with crop management**			NARES and private sector breeders and NGO/CBOs, Alliance, PGRA, SLP, Generation CP, Africa CP partners and VASAT Consortium	NARES in WCA work together, involving farmer associations, private sector, and NGOs whenever appropriate to identify and release	Increasing and stabilized productivity of staple crops in a range of eco-systems, and production contexts has been

strategies to overcome key environmental and socio-economic constraints and making them available with new knowledge to partners			partners (project 10) in the WCA SAT	superior varieties using modern tools as appropriate	achieved through the availability of well-adapted, genetic diverse varieties and participatory methodologies which have helped farmers to identify their most promising options
	Output Target 2008: 3.2.1 At least two diversified dwarf Guinea-race sorghum populations and broad based pearl millet populations with farmer preferred traits made available with associated capacity development to partners for the first time for at least different SAT agro-ecologies in WCA (partly associated with SLP SWEP).	Materials			
	Output Target 2008: 3.2.2 Tools for effective integrated *Striga* management for different agro-ecologies made available to partners in at least two countries.	Other kinds of knowledge			
	Output Target	Other			

	2009: 3.2.1 First availability of allele-specific molecular markers for genes controlling photoperiod sensitivity of flowering time in pearl millet and sorghum	kinds of knowledge			
	Output Target 2009: 3.2.2 One new genepool of pearl millet with reduced *Striga* susceptibility available for testing in West African breeding programs	Materials			
	Output Target 2009: 3.2.3 Knowledge of adaptation and initial regional adaptation maps for 5 sorghum and pearl millet varieties each made available and disseminated with associated capacity development to WCA partners	Other kinds of knowledge			
	Output Target 2010: 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)	Other kinds of knowledge			
	Output Target 2010: 3.2.2	Capacity			

	Two NARS empowered to breed groundnut varieties with multiple attributes especially drought tolerance.				
	Output Target 2010: 3.2.3 Three high yielding, well adapted sorghum varieties with at least one trait adding value to the harvest (stover quality, brewing quality) identified for dissemination to farmers in two countries in WCA.	Materials			
	Output Target 2011: 3.2.1 At least two new breeding populations of groundnut with enhanced multiple attributes available for testing and selection by NARS	Materials			
	Output Target 2011: 3.2.2 At least 2 downy mildew resistant open pollinated varieties of pearl millet	Materials			
	Output Target 2011: 3.2.3 Refined adaptation maps for at least 10 sorghum and pearl millet varieties available for use by partners	Other kinds of knowledge			
	Output Target 2011: 3.2.4 Understanding of dry land cereal pest dynamics	Other kinds of knowledge			

	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 WCA**			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
	Output Target 2008: 3.3.1 Early adoption of crop management practices to reduce Aflatoxin contamination in Mali documented	Practices			
	Output Target 2009: 3.3.1 2-3 farmer-and market preferred groundnut varieties tolerant to aflatoxin contamination identified for	Materials			

	dissemination by at least three NARS in WCA				
	Output Target 2010: 3.3.1 Effectiveness of integrated management techniques , including new preferred varieties resistant to aflatoxin contamination, assessed and knowledge shared with associated capacity development with partners	Practices			
	Output Target 2010: 3.3.2 ELISA testing lab set up in at least 2 countries in WCA	Practices			
	Output Target 2011: 3.3.1 Crop management practices for reduced Aflatoxin contamination outscaled, and impact assessment initiated in at least two countries	Practices			
	Output Target 2011: 3.3.2 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	Materials			
	Output Target 2012: 3.3.1 Cereal processing	Practices			

	techniques characterized for improving bioavailability of iron and zinc in young childrens diets in Mali				
Output 4: **Sustainable breeder, foundation and certified seed systems in partnership with NARES and private seed entrepreneurs developed through marketing of high quality seed of adapted released varieties of sorghum, millet groundnut , etc. accessible and affordable to resource poor farmers through network of agro-input dealers in an enabling agricultural environment**			Breeders, seed technicians, seed lab analysts, seed producers, seed dealers and other private stakeholders	National variety release and seed certification process management manuals 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,	Registered private certified seed producers list established and improved seed uses and yield increases

				Ghana.	
	Output Target 2010: 3.4.1 Improved agricultural enabling environment established for marketing high quality seed of sorghum, millet groundnut, etc. between West African Countries	Capacity			
	Output Target 2011: 3.4.2 Enhanced businesses of foundation seed production to satisfy requests from certified seed producers/seed companies linked to product markets in Mali and Nigeria	Capacity			

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

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

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).

Generic Outputs Description

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. NARES crop improvement programs in ESA are becoming increasingly weak in terms of financial and human resource commitments with varying

strengths among the NARES to carry out breeding activities. The weaker NARES will therefore rely on the Center for semi-completed and finished breeding products while the stronger NARES may be able to develop the products independently. 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.

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 Outputs

ICRISAT's project structure was re-worked newly in 2006 and has not changed much in 2007 or 2008. The outputs have not changed and the output target 2009 4.4.2 has been postponed indefinitely as it has not been possible to transfer the appropriate nurseries from India to East Africa. Likewise, output targets 2009 4.2.2, and 2010 4.3.1 on multiple events for improved groundnut tolerance to drought have been deleted as special project funding has not been available to support the proposed activity. A new output target on sweet sorghum has been added under output 2. This is in anticipation of end users requests to be provided with sweet sorghum germplasm, as well as with information, tools and methods for evaluation.

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 are poorly staffed and under-funded in relation to the number of each countrys crop breeding challenges. 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 ICRISATESA 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 on Marker Assisted Selection (MAS). This approach will increase crop breeding efficiency through the use of novel tools and methods as well ass 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.

List of countries where research is planned

Ethiopia, Eritrea, Kenya, Uganda Tanzania, Malawi, Mozambique, Zambia and Zimbabwe

List of potential beneficiary countries

Ethiopia, Eritrea, Kenya, Uganda Tanzania, Malawi, Mozambique, South Africa and Zimbabwe

Alignment to CGIAR Priorities: 2A: Maintaining and enhancing yields and yield potential of food staples;
Countries of Planned Research: Eritrea; Ethiopia; Kenya; Malawi; Mozambique; Tanzania; Uganda; Zambia; Zimbabwe;

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 consumptiom, including traits prefered by the consumers and markets. Important biotic stresses and and pro poor traits that limit productivity have been identified for each crop. We will focus on developing geneticallly 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 pigeon peas. 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 ouptput 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 for potential scaling out and spillover.

Activity exemplar:

MTP Output target 2010 4.2.3:

Striga resistance transferred to farmer preferred sorghum varieties using MAS

Striga: The parasitic weed Striga hermonthica is a major biotic constraint to sorghum production particularly in semi-arid regions of Africa, where it can cause up to 100% yield losses. Genetic variation for resistance to Stiga though limited is available in sorghum germplasm, making host plant resistance a feasible control measure. The conventional approach to selection for resistance to Striga has involved evaluation of sorghum germplasm in Striga infested plots. This approach has not been very successful owing to the complexity of the biology of the hostparasite relationship and its interactions with other environmental factors. A mix of conventional and biotechnology approaches had to be pursued. Currently, molecular markers tightly linked to Striga resistance Quantitative Trait Loci (QTL) have been identified and are being used in Marker Assisted Backcrossing (MAB) integrated with farmer-participatory selection to move Striga resistance from resistant donor (N13) to susceptible Farmer Preferred Sorghum Varieties (FPSV) from Eritrea, Kenya and Sudan

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 & 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 unintentioanlly 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.

List of countries where research is planned

Eritrea, Sudan, Uganda, Kenya, Tanzania, Malawi, Zimbabwe, Mozambique, Zambia

List of Potential beneficiary Countries

Eritrea, Sudan, Uganda, Kenya, Tanzania, Malawi, Zimbabwe, Mozambique, Zambia,

Alignment to CGIAR Priorities: 2A: Maintaining and enhancing yields and yield potential of food staples;
Countries of Planned Research: Eritrea; Kenya; Malawi; Mozambique; Sudan; Tanzania; Uganda; Zambia; Zimbabwe;

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

List of countries where research is planned

Kenya, Tanzania, Malawi, Mozambique, Zambia

List of potential beneficiary countries

Eritrea, Sudan, Uganda, Kenya, Tanzania, Malawi, Zimbabwe, Mozambique, Zambia.

Alignment to CGIAR Priorities: 2B: Improving tolerance to selected abiotic stresses;
Countries of Planned Research: Kenya; Malawi; Mozambique; Tanzania; Zambia;

Output 4: Progress in knowledge and/or improved germplasm of nutritionally enhanced transgenic sorghum and biofortified transgenic events and non-transgenic germplasm with enhanced micronutrient levels available for evaluation and studies on risk assessment conducted

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

List of countries where Research is planned

Kenya and South Africa

List of potential beneficiary countries

Kenya, South Africa, Burkina Faso
Alignment to CGIAR Priorities: 2C: Enhancing nutritional quality and safety;
Countries of Planned Research: Kenya; South Africa;

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

List of countries where research is planned

Kenya, Tanzania, Malawi, Mozambique, Zambia

List of Potential beneficiary Countries

Uganda, Kenya, Tanzania, Malawi, Zimbabwe, Mozambique, Zambia

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 B&M 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.

List of countries were research is planned

South Africa, Eritrea, Sudan, Uganda, Kenya, Tanzania, Malawi, Zimbabwe, Mozambique, Zambia

List of potential beneficiary countries

South Africa, Eritrea, Sudan, Uganda, Kenya, Tanzania, Malawi, Zimbabwe, Mozambique, Zambia

Alignment to CGIAR Priorities: 2C: Enhancing nutritional quality and safety;
Countries of Planned Research: Eritrea; Kenya; Malawi; Mozambique; South Africa; Sudan; Tanzania; Uganda; Zambia; Zimbabwe;

Impact Pathways by Output

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

Description of impact pathways and capacity development:

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 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. 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 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 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) sorghum and pearl millet varieties 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.

International Public Goods

The IPGs that have applicability beyond one nations borders produced by the project include:

- 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

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 back-crossing 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

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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	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

				BECA facility is strengthened and is used by NARS scientists to build their capacity in modern breeding methods.	
	Output Target 2008: 4.1.1 A regional highland sorghum improvement program initiated with at least two NARS in ESA	Capacity			
	Output Target 2008: 4.1.2 Completion of regional field trial evaluation of 30 high yielding advanced chickpea lines for potential release in ESA	Materials			
	Output Target 2008: 4.1.3 At least 4 high-yielding long duration pigeonpea cultivars adapted to ESA cropping systems developed and available with associated capacity development to NARS partners	Materials			
	Output Target 2008: 4.1.4 At least 30 medium duration pigeonpea	Materials			

	evaluated in at least two ESA countries				
	Output Target 2008: 4.1.5 Groundnut variety adaptation trials including on farm variety tests conducted and monitored in ESA countries	Materials			
	Output Target 2008: 4.1.6 At least 5 t each of seed improved pigeonpea and chickpea cultivars produced for participatory variety evaluation and demonstration	Materials			
	Output Target 2009: 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	Materials			
	Output Target 2009: 4.1.2 Groundnut variety adaptation trials including on farm variety tests conducted and monitored in ESA	Materials			

	countries				
	Output Target 2009: 4.1.3 At least 3 high-yielding chickpea cultivars adapted to ESA cropping systems tested by NARS in Ethiopia, Kenya and Tanzania	Materials			
	Output Target 2009: 4.1.4 At least 2 sorghum and or millet varieties released in one country	Materials			
	Output Target 2010: 4.1.1 Three groups of task networks addressing the key constraints of drought and photoperiod response active in sharing improved germplasm regionally	Capacity			
	Output Target 2010: 4.1.2 At least 3 farmer/ market preferred groundnut varieties incorporating drought tolerance in short duration background released in 2 to 3 ESA countries	Materials			
	Output Target 2010: 4.1.3 At least one medium and one long duration pigeonpea variety	Materials			

	released in two countries of ESA				
	Output Target 2010: 4.1.4 At least 2 M.Sc students from ESA trained in pigeonpea and chickpea breeding and 2000 farmers trained in their production and management	Capacity			
	Output Target 2010: 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	Materials			
	Output Target 2010: 4.1.6 At least 200 kg of breeder seed of sorghum and or millet availed to two ESA countries	Materials			
	Output Target 2011: 4.1.1 Groundnut Varietal Adaptation Trials including On-farm variety tests conducted and monitored in ESA countries	Materials			
	Output Target 2011: 4.1.2 At least 500 kg of breeder seed and 10 t of seed of pigeonpea and	Materials			

	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 strengthene	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

				d and is used by NARS scientists to build their capacity in modern breeding methods	
	Output Target 2007: 4.2.1 SSR derived markers more tightly linked to *Striga* resistance in sorghum identified and mapped	Other kinds of knowledge			
	Output Target 2007: 4.2.2 Markers segregating with traits associated with resistance to sorghum midge identified and linkage map of the F2 population derived from AF28 and Seredo generated	Other kinds of knowledge			
	Output Target 2008: 4.2.1 Pigeonpea landraces from Tanzania and Mozambique fully screened for Fusarium wilt resistance	Other kinds of knowledge			
	Output Target 2008: 4.2.2 At least one improved sorghum	Materials			

	or pearl millet cultivar released in an ESA country				
	Output Target 2008: 4.2.3 Training of trainers for local seed production techniques for improved groundnuts completed	Capacity			
	Output Target 2008: 4.2.4 Infector row technique for screening of GRD resistance in groundnut operational in at least one ESA NARS	Practices			
	Output Target 2008: 4.2.5 GRAV CP transgenic groundnuts evaluated in a confined greenhouse trial for resistance to Groundnut Rosette Disease	Materials			
	Output Target 2008: 4.2.6 Locally adapted pigeon pea varieties evaluated for genetic transformation	Materials			

	using marker genes and different promoters and at least one scientist trained				
	Output Target 2008: 4.2.7 At least 5 locally adapted groundnut varieties evaluated in tissue culture for regeneration response and one scientist trained in the technique	Materials			
	Output Target 2008: 4.2.8 20 interspecific derivative lines of groundnut evaluated for Rosette and ELS disease in ESA and promising new sources of resistance comprising interspecific sources identified	Materials			
	Output Target 2008: 4.2.9 At least 5 kg groundnut nuclear seed of each of 15 varieties in Regional Trials produced annually from 2008 to 2011 as source for breeder seed and entries for collaborative trials with NARS in ESA	Materials			

	Output Target 2009: 4.2.1 Three elite farmer varieties of sorghum from three countries carrying 1 to 3 QTLs evaluated through a participatory approach	Materials			
	Output Target 2009: 4.2.2. At least two NARS availed with sweet sorghum germplasm and accompanying knowledge and tools for evaluation	Capacity			
	Output Target 2009: 4.2.3 6 newly improved pigeonpea cultivars disseminated through participatory methods in ESA	Materials			
	Output Target 2009: 4.2.4 Capacity building through training of local scientist on transformation protocols held at BecA	Capacity			
	Output Target 2009: 4.2.5 Groundnut Breeding activities (and associated phenotyping facilities) initiated in at least one research station in Malawi and	Capacity			

	Tanzania				
	Output Target 2009: 4.2.6 Locally adapted groundnut varieties evaluated for genetic transformation using marker genes and various promoters and at least one scientist trained in groundnut transformation	Materials			
	Output Target 2009: 4.2.7 At least 1 t 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	Materials			
	Output Target 2009: 4.2.8 Format for seed company business plan developed with training manual using the Malawi case study	Practices			
	Output Target 2010: 4.2.1 Performance and adaptability of bristled pearl millet ICMV221 evaluated for the first time in ESA to reduce chronic bird damage	Materials			

	Output Target 2010: 4.2.2 Fine mapping of sorghum midge resistance QTL completed	Other kinds of knowledge			
	Output Target 2010: 4.2.3 Striga resistance transferred to farmer-preferred sorghum varieties using MAS	Materials			
	Output Target 2010: 4.2.4 Best sources of groundnut rosette virus resistance and vector resistance introgressed in preferred varieties using molecular markers	Materials			
	Output Target 2010: 4.2.5 Segregating long duration pigeonpea populations with large grain and resistance to fusarium wilt developed	Materials			
	Output Target 2010: 4.2.6: Multi-locational trials of at least three farmer preferred sorghum varieties carrying one to three Striga resistance QTLs conducted	Other kinds of knowledge			
	Output Target 2010: 4.2.7 Segregating	Materials			

	medium duration pigeonpea populations with large round grains and traits associated with insect pest tolerance developed				
	Output Target 2010: 4.2.8 At least 5 kg nuclear seed of each of 15 varieties in Regional Trials produced annually from 2008 to 2011 as source for breeder seed and entries for collaborative trials with NARS in ESA	Materials			
	Output Target 2010: 4.2.9 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	Materials			
	Output Target 2010: 4.2.10 Format for seed company business plan developed with training manual using the Tanzania and Ethiopia case	Capacity			

	studies				
	Output Target 2011: 4.2.1 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	Materials			
	Output Target 2011: 4.2.2 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	Materials			
	Output Target 2011: 4.2.3 Best sources of groundnut rosette virus resistance and vector resistance introgressed in preferred varieties using molecular markers	Materials			
	Output Target 2011: 4.2.4 At least one farmer preferred sorghum variety carrying one to three Striga resistance QTLs is proposed for	Materials			

	release in at least one country and nucleus seed is available for production of subsequent seed classes				
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.
	Output Target 2007: 4.3.1 Drought tolerant varieties of sorghum for evaluation with water management technologies identified	Materials			

	Output Target 2008: 4.3.1 Efficiency and effectiveness of MAS for stay-green in sorghum determined	Other kinds of knowledge			
	Output Target 2008: 4.3.2 A groundnut working collection of at least 15 farmer- and market-preferred varieties, as the basis of a marker-assisted breeding program by 2008	Materials			
	Output Target 2009: 4.3.1 Segregating populations of sorghum for both photoperiod sensitivity and stay green evaluated using molecular markers	Materials			
	Output Target 2009: 4.3.2 Increased crop water productivity demonstrated with appropriate capacity development for sorghum and pearl millet lines	Other kinds of knowledge			

	Output Target 2009: 4.3.3 Field evaluations of drought tolerance of stay-green sorghum lines evaluated using a farmer-participatory approach in Kenya	Other kinds of knowledge			
	Output Target 2009: 4.3.4 At least one new breeding population each for GRD, ELS and rust resistance for ESA by 2009	Materials			
	Output Target 2010: 4.3.1 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	Materials			
Output 4: **Progress in knowledge and/or improved germplasm of nutritionally enhanced transgenic sorghum and biofortified transgenic events and non-transgenic germplasm with enhanced micronutrient**			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	Improved varieties and breeding materials that combine high yield potential with enhanced micronutrient contents and resistance to biotic and

levels available for evaluation and studies on risk assessment conducted				crops. NARS breeding programs incorporate improved nutritional standards as desirable goals	abiotic stresses as well as adaptation to environment have become available to farmers thus resulting in the improved health of malnourished SAT communities.
	Output Target 2007: 4.4.1 10 molecular markers identified for gene flow studies in sorghum identified	Other kinds of knowledge			
	Output Target 2008: 4.4.1 Farmers knowledge on wild and weedy sorghum and implications for cultivated sorghum documented with associated capacity development for at least 2 ESA countries	Capacity			
	Output Target 2008: 4.4.2 Outcrossing rates between sorghum and wild species determined	Other kinds of knowledge			

	Output Target 2009: 4.4.1 Heritability and correlations among important micronutrient traits determined in sorghum	Other kinds of knowledge			
	Output Target 2009: 4.4.2 Knowledge from geneflow studies of non-transgenic sorghum generated and provided with associated capacity development to national regulators	Other kinds of knowledge			
	Output Target 2010: 4.4.1 Documentation for risk/safety assessment for GM regulatory needs drafted	Other kinds of knowledge			
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.	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

				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	aflatoxin content.
	Output Target 2007: 4.5.1 Mycotoxin testing facilities and protocols developed in Kenya, Malawi and Mozambique	Capacity			
	Output Target 2008: 4.5.1 Protocol for isolation of atoxigenic strains of A. flavus developed in ESA	Practices			
	Output Target 2008: 4.5.2 IPG knowledge on	Capacity			

	the extent of mycotoxin contamination of groundnut in Malawi and Kenya with appropriate capacity development disseminated regionally				
	Output Target 2009: 4.5.1 Atoxigenic strains of A. flavus isolated from ESA soils	Other kinds of knowledge			
	Output Target 2009: 4.5.2 At least 3 trainers available in quality on-farm seed production and maintenance in at least 2 ESA NARS	Capacity			
	Output Target 2009: 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 practices in 2 ESA countries from 2009	Capacity			
	Output Target 2009: 4.5.4 Business plan developed for mycotoxin testing facility with	Capacity			

	associated training manuals				
	Output Target 2010: 4.5.1 Role of variety/genotype contribution to aflatoxin control documented in Sorghum and groundnut in ESA	Policy strategies			
	Output Target 2010: 4.5.2 Pre-harvest and post harvest aflatoxin control measures implemented in at least 2 countries in an annual basis by 2010	Practices			
	Output Target 2011: 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	Capacity			

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

Project Overview and Rationale

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

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.

Generic Outputs Description

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 of strategic 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 stage of its own and partner research. For instance, in pigeonpea hybrid research, it 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 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 transformation protocols, 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 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 will provide 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 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 policymakers to recognize the utility of agriculture and biotechnology in improving the health and well being of millions.

Outputs Description

Changes from previous MTP Outputs

Most of the outputs have not changed. Previous outputs 2009.5.1.3 PM, 2008.5.2.1 SOPM, 2008.5.2.2 SOPM, 2009 5.2.1 SOPM, and 2010 5.3.1 were dropped due to the lack of funding. Output target 2010 5.2.2 SOPM has been postponed by two years owing to the unpredictable weather during flowering, leading to unreliable screening in about 50% of the years and is re-numbered as 2012 5.2.1 SOPM. In addition a new output target has been indicated in response to new climate change, e.g., heat tolerance research namely 2010 5.2.2 SOPM and to provide an intermediary progress point for the postponed Output Target.

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

These are defined under each priority as below.

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. Transgenics offer the greatest promise for genetic improvement of pigeonpea pod borer and sorghum stem borer resistance, while marker-assisted selection (MAS) appears promising for the genetic improvement of shoot fly resistance in sorghum.

List of Countries where Research is planned

India, China, Philippines

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Nepal, Bhutan

Alignment to CGIAR Priorities: 2A: Maintaining and enhancing yields and yield potential of food staples;
Countries of Planned Research: China; India; Philippines;

Output 2: Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeon pea 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 appears to be implicated closely in drought tolerance issues. 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 degrees C. Most of the hybrids fail to set seed under such conditions and ways to circumvent this constraint are being examined.

List of Countries where Research is planned

India, China, Philippines

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Nepal, Bhutan

Alignment to CGIAR Priorities: 2B: Improving tolerance to selected abiotic stresses;
Countries of Planned Research: China; India; Philippines;

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 beta-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 iron and zinc 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 and 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 contentC1 (Fe), and the one produced from progenies selected for high zinc contentC1 (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 ($P < 0.01$) 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.

List of Countries where Research is planned

India

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Nepal

Alignment to CGIAR Priorities: 2C: Enhancing nutritional quality and safety;
Countries of Planned Research: India;

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 is emerging 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 the main and ratoon crops require about 8,000 cubic meters (m3) of water, whether from rainfall or irrigation. This is four times less than that required by one crop of sugarcane (12-16 months duration and 36,000 m3 of water per crop). Sweet sorghum can also be planted 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 cost 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 them 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 hybrids 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 were 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 plant 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.

List of Countries where Research is planned

India, Philippines

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Indonesia, Nepal

Alignment to CGIAR Priorities: 2D: Genetically enhancing selected high-value species;
Countries of Planned Research: India; Philippines;

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**

Description of impact pathways and capacity development

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 agro-ecologies, and (ii) NARS and the private sector have placed less emphasis, in terms of resource allocation, for hybrid development and testing. It is also assumed that world petroleum prices and/or interest of Governments in the SAT in ethanol as a petroleum substitute derived from sweet sorghum remain high enough for this technology to remain economically or politically viable.

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. Drought and salinity in sorghum and pearl millet; P-acquisition and high temperatures during flowering in pearl millet, and

micronutrient malnutrition in sorghum and pearl millet (grain iron and zinc).are being addressed in this project (NOTE: transgenics are in project 6). With the development of screening protocols and effective selection criteria, and increasing use of marker-assisted breeding in cereals, NARS and the private sector partners visualize clear benefits from drought, salinity and high temperatures tolerance and forage research, but they only play limited role in the current partnership. In other research areas, their interest, capacity and partnership have yet to develop. This provides the logic for ICRISAT to lead the way through technology development and dissemination, and capacity building in these new research areas. 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 the programs and enhanced skills), and increase in productivity of these crops and the associated livestock.

International Public Goods

Expected IPGs that have applicability beyond one nations borders

- 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 a single ICRISAT parent that the seed company will be creating a novel product and thus gaining their own IPRs. 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, 35 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.

Our 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

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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 pigeon pea hybrids are grown on at least 100,000 ha in Asia by 2015
	Output Target 2008: 5.1.1 SO Comparison of A_1, A_2, A_3 and A_4 CMS systems in hybrid combinations for key constraints in sorghum completed	Other kinds of knowledge			
	Output Target 2008: 5.1.1 PM QTL mapping of downy mildew	Other kinds of knowledge			

	(DM) resistance in five F6 RIL populations completed				
	Output Target 2008: 5.1.2 PM Additional hybrid parents (9 each of male-sterile and restorer lines) and more than 500 trait-specific and DM resistant improved breeding lines developed and disseminated with associated capacity development	Materials			
	Output Target 2008: 5.1.3 PM Knowledge on relative efficiency of 3 diverse CMS systems documented	Other kinds of knowledge			
	Output Target 2009: 5.1.1 SO Insect-host genotype-natural enemy interactions and mechanisms of resistance and inheritance clarified (associated with the SP-IPM SWEP)	Other kinds of knowledge			
	Output Target 2009: 5.1.2 SO Dual-purpose foliar disease resistant forage/sweet sorghum hybrid parents developed (associated with the SLP SWEP)	Materials			

	Output Target 2009: 5.1.3 SO More than 25 scientists and technicians trained in sorghum improvement through an international training course	Capacity			
	Output Target 2009: 5.1.4 SO Two major putative QTL for stem borer resistance identified	Other kinds of knowledge			
	Output Target 2009: 5.1.5 SO Techniques to screen for resistance to aphids and shoot bug standardized	Practices			
	Output Target 2009: 5.1.1 PM Two improved populations of pearl millet with high forage yield potential developed	Materials			
	Output Target 2009: 5.1.2 PM Virulence changes in Indian pearl millet downy mildew populations characterized	Other kinds of knowledge			
	Output Target	Capacity			

	2009: 5.1.3 PM More than 30 scientists develop pearl millet research and development skills through an international training course				
	Output Target 2009: 5.1.4 PM At least five each of blast and rust resistance sources identified	Materials			
	Output Target 2009: 5.1.5 PM Two PhD scholars complete their dissertation research	Capacity			
	Output Target 2009: 5.1.1 PP At least 15 high-yielding pigeonpea hybrids and a short-duration determinate male-sterile line made available to NARS partners	Materials			
	Output Target 2009: 5.1.2 PP Elite pigeonpea hybrid parents characterized for important agronomic traits and molecular diversity	Other kinds of knowledge			
	Output Target 2010: 5.1.1 SO At least six high-yielding and large-seeded male-sterile lines with	Materials			

	resistance to shoot fly and grain mold (3 each) developed				
	Output Target 2010: 5.1.3 SO Two F_6 RIL populations developed and QTL for traits associated with grain mold resistance identified	Other kinds of knowledge			
	Output Target 2010: 5.1.2 SO At least 30 scientists participate in Sorghum Field Day and select more than 300 breeding lines	Capacity			
	Output Target 2010: 5.1.1 PM At least 5 each of pearl millet seed and restorer parents adapted to arid conditions developed	Materials			
	Output Target 2010: 5.1.2 PM Genetics of four diverse CMS systems documented	Other kinds of knowledge			
	Output Target 2010: 5.1.3 PM More than 50 scientists participate in Pearl	Capacity			

	Millet Field Day and select more than 600 breeding lines				
	Output Target 2010: 5.1.4 PM Effect of putative QTLs identified for stover yield and quality on these traits in two genetic backgrounds assessed	Other kinds of knowledge			
	Output Target 2010: 5.1.1 PP Consensus molecular marker and genetic linkage maps developed and shared with partners	Other kinds of knowledge			
	Output Target 2010: 5.1.2 PP At least three short-duration determinate male-sterile lines and 10 hybrids made available to NARS partners	Materials			
	Output Target 2010: 5.1.3 PP Two Masters students and 50 scientists and technicians from NARS and private sector trained in pigeonpea breeding	Capacity			
	Output Target 2011: 5.1.1 SO At least four large-seeded postrainy season-adapted male-sterile lines	Materials			

	developed				
	Output Target 2011: 5.1.2 SO Relationship between grain and stover yield heterosis and genetic diversity of parental lines assessed	Other kinds of knowledge			
	Output Target 2011: 5.1.3 SO Two putative QTLs for traits associated with grain mold resistance identified from two mapping populations	Other kinds of knowledge			
	Output Target 2011: 5.1.1 PM At least 40 improved breeding lines with resistance to blast and rust (20 each) developed	Materials			
	Output Target 2011: 5.1.2 PM Recurrent selection response for stover quality assessed	Other kinds of knowledge			
	Output Target 2011: 5.1.3 PM Relationship between grain and stover yield heterosis and genetic diversity of parental lines	Other kinds of knowledge			

	documented				
	Output Target 2011: 5.1.1 PP Seven medium-duration male-sterile lines made available to NARS and private sector for use in hybrid development	Materials			
	Output Target 2011: 5.1.2 PP One PhD scholar and 35 scientists and technicians from NARS and seed sector trained in pigeonpea breeding	Capacity			
Output 2: Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeon pea 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
	Output Target 2008: 5.2.1 SOPM Physiological traits explaining terminal drought tolerance in pearl millet lines with drought tolerance QTL dissected	Other kinds of knowledge			

	Output Target 2009: 5.2.1 SOPM Physiological mechanisms explaining the stay-green trait dissected in sorghum near-isogenic lines with stay-green QTLs	Other kinds of knowledge			
	Output Target 2009: 5.2.2 SOPM Dual-purpose stay-green and foliar disease resistant forage/sweet sorghum hybrid parents developed (partly associated with the SLP SWEP)	Materials			
	Output Target 2010: 5.2.1 SOPM Relationship between yield under terminal drought stay-green and root-related traits established in sorghum	Other kinds of knowledge			
	Output Target 2010: 5.2.2 SOPM At least three pearl millet lines/parental lines with flowering-period heat tolerance at air temperatures exceeding 42C identified (new	Materials			

	output target)				
	Output Target 2010: 5.2.3 SOPM Mapping and introgression of stay-green QTLs into elite parental lines, and assessment of their effects on hybrid performance completed	Other kinds of knowledge			
	Output Target 2011: 5.2.1 SOPM Relationship between yield under terminal drought and root-related traits established in pearl millet	Other kinds of knowledge			
	Output Target 2011: 5.2.2 SOPM At least four parental lines of sorghum and six parental lines and populations of pearl millet with salinity tolerance developed/identifie d	Materials			
	Output Target 2012: 5.2.1 SOPM Relationship between pearl millet parental lines and their hybrids for flowering-period heat tolerance at air temperatures exceeding 42C assessed (output	Other kinds of knowledge			

	target postponed by two years, considering that 50% of the years field tests fail because of weather factors)				
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
	Output Target 2008: 5.3.1 SOPM Variability of Fe and Zn in commercial hybrids and core collection of the germplasm assessed in pearl millet	Other kinds of knowledge			
	Output Target 2009: 5.3.1 SOPM At least five sorghum germplasm hybrid parental lines with high Fe (>50 ppm) and Zn (>40 ppm) identified and made available to partners	Materials			

	Output Target 2010: 5.3.2 SOPM Comprehensive information on genetics of grain Fe and Zn content in sorghum and pearl millet generated	Other kinds of knowledge			
	Output Target 2011: 5.3.1 SOPM At least 10 germplasm accessions of sorghum from core collection with >60 ppm grain Fe and >40 ppm Zn content identified	Materials			
	Output Target 2011: 5.3.2 SOPM At least six improved breeding lines of pearl millet with >90 ppm grain iron and >60 ppm Zn developed	Materials			
	Output Target 2011: 5.3.3 SOPM At least two high-yielding hybrids of pearl millet with >70 ppm Fe and >50 ppm Zn developed	Materials			
	Output Target 2012: 5.3.1 SOPM Effectiveness of recurrent selection for grain iron and zinc content in a pearl millet population demonstrated	Other kinds of knowledge			
Output 4: **Sweet**			NARS	Highly	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			breeders, private sector partners, ARIs, and Alliance partners including ILRI and the SLP SWEP	sweet hybrid parental lines used by partners in breeding programs	sorghum has become an economicall y viable, pro-poor biofuel
	Output Target 2009: 5.4.1 SO More than 25 farmers training in sweet sorghum ethanol value chain	Capacity	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 economicall y viable, pro-poor biofuel
	Output Target 2010: 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)	Materials			
	Output Target 2011: 5.4.1 SO More than 25 scientists trained in sweet sorghum hybrid parents development through an international training course	Capacity			

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

Project Overview and Rationale

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

This project is extremely relevant and pro-poor for the semi-arid tropics (SAT) in Asia, where many farmers either cannot afford to buy hybrids/improved cultivar seed or have no access to them. 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 pearl millet, where commercial hybrids are available, nearly 30 to 40% area will continue to be under open-pollinated varieties as there may be no clear advantage of growing hybrids under harsh environmental conditions. Varieties will also continue to be popular with farmers because of their fodder value or specific adaptation requirements (nearly 4.5 million ha in pearl millet and 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 a major impact 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. There has been no changes in outputs in the past year. 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.

Generic Outputs Description

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 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 catalyser, facilitator, enabler and/or advocate to influence the impact pathway and thus to help ensure outcomes and impact?

ICRISAT plays all of these roles for sustaining the chain of developing technologies for crop improvement, high yielding pest and drought resistant cultivars, and seed production and distribution. 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, and 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 they 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 constraint 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.

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 legumes (self-pollinated varieties of 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. It is 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, 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 millions.

Outputs Description

Changes from previous MTP Outputs

The project structure for ICRISAT was re-worked newly in 2006 and has not changed in 2007 or 2008. The outputs have not changed.

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

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.

Pearl millet: There is a need to develop varieties with resistance to downy mildew and dual-purpose varieties for use as fodder and/or with enhanced levels of Fe and Zn, and adaptation to different agro-ecosystems. Introgression of genes from the cultivated germplasm through conventional breeding and marker-assisted selection are being employed to alleviate these stresses. It is also necessary to identify pearl millet 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-bold 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 and improved tolerance to drought.

Pigeonpea: Need to develop varieties with resistance to Fusarium wilt, sterility mosaic virus, 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.

List of Countries where Research is planned

India, Philippines, Myanmar, Pakistan, Nepal, Vietnam, Thailand, China,

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Indonesia, Nepal, Ethiopia, Kenya, Tanzania, Malawi, Zambia, Mozambique, Cambodia, Iran, Zimbabwe
Alignment to CGIAR Priorities: 2A: Maintaining and enhancing yields and yield potential of food staples;
Countries of Planned Research: China; India; Myanmar; Nepal; Pakistan; Philippines; Thailand; Viet Nam;

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. Drought and salinity are among the most severe abiotic stresses in Asia.

Drought: Drought avoidance 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 a transcription factor involved in drought response is showing promising results.

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 2010 Output Targets (2010 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 2007 (available at www.icrisat.org).

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

2007 Milestone: 50 transgenic events of chickpea with DREB1A and P5CSF genes developed and screened for drought tolerance in the contained greenhouse

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 (KKS/VV/PMG) 2009

2010 Milestone: One or two transgenic events of chickpea used for introgression into locally adapted genotypes with better adaptation and the progeny characterized and evaluated

2011 Milestone: 10-15 introgressed transgenic lines of chickpea with improved tolerance to water-limiting conditions evaluated and development of commercialization package initiated

The report for the 2007 internal milestone provides additional detail of the precise activities undertaken and was: Genetic engineering of chickpea for enhanced tolerance to water stress is being carried out using the osmoregulatory P5CSF129A gene and DREB1A transcription factor that acts as a major switch that triggers 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. Previously, 10 transgenic events each of rd29A:DREB1A and 35S: P5CSF129A in T5 generation were evaluated in drydown experiments, where the events exhibiting a diversity of stress response patterns, especially with respect to the normalized temperature ratio - fraction of transferable soil water (NTR-FTSW) relationship were selected from that ranking and comparative studies were carried out with these transgenics under optimized conditions for evaluating water use efficiency of the selected events. 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 for all events tested, as indicated by their lower FTSW threshold values. Besides, the physiological responses of the transgenic lines revealed a high photosynthetic activity (3.32-5.36) and stomatal conductance (0.0.29-0.71) under drought stress conditions as compared to the untransformed line (2.42; 0.037). These results indicated that although overexpression of osmolyte proline in the transgenic chickpeas resulted in a sort of osmotic adjustment by maintaining the cell turgor and physiological processes of these plants and resulting in postponement of dehydration as water deficits developed under the drydown conditions, however, there was no advantage in the TE values, which is one of the potential component traits of drought tolerance. The transpiration efficiency (TE) of only two transgenic events carrying 35S:P5CSF129A gene showed a modest increase in TE compared to the wild-type (WT) parent across experiments.

On the other hand, several events carrying the DREB1A transcription factors driven by a stress-responsive promoter rd29A showed significant increase in transpiration efficiency compared to the WT. Chickpea transgenics were assessed for over-expression of both P5CSF129A and DREB1A genes for water uptake and rooting pattern under water deficit in a lysimetric system, i.e., long PVC tubing mimicking a field-like soil profile. Here, a more realistic physiological response to progressive soil drying has been proposed to include a proper control of soil moisture depletion so as to ensure that plants are exposed to stress levels and kinetics of water-deficits approaching those occurring under field conditions. First experiment performed during the off-season did not show any particular advantage in the transgenics, and hence, will be repeated for the 2007-08 chickpea season under glasshouse conditions. Seed multiplication and maintenance of desirable transgenic events in T5 generation is being carried out and the plants are being characterized at molecular level to ascertain homozygosity. Additional events of chickpea carrying rd29A:DREB1A were being produced.

List of Countries where Research is planned

India, Myanmar, Vietnam, Brazil, Oman, Jordan, Syria, Uzbekistan, Kazakhstan

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Indonesia, Nepal, Ethiopia, Kenya, Tanzania, Malawi, Zambia, Mozambique

Alignment to CGIAR Priorities: 2B: Improving tolerance to selected abiotic stresses;
Countries of Planned Research: Brazil; India; Jordan; Kazakhstan; Myanmar; Oman; Syrian Arab Republic; Uzbekistan; Viet Nam;

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 pigeon pea 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 -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.

List of Countries where Research is planned

India, Myanmar

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Indonesia, Nepal, Kenya, Tanzania, Malawi, Zambia, Mozambique, Nigeria, Sudan, Senegal, Chad, Ghana, Congo, Niger, Burkina Faso, Mali, Brazil, Cameroon. Uganda

Alignment to CGIAR Priorities: 2C: Enhancing nutritional quality and safety;
Countries of Planned Research: India; Myanmar;

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**

Description of impact pathways and capacity development

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 the germplasm includes 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.

International Public Goods

Expected IPGs that have applicability beyond one nations borders

- 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 -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

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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.
	Output Target 2008: 6.1.1 GN 8-10 elite breeding lines evaluated and selected for resistance to stem necrosis and bud necrosis virus diseases	Materials			
	Output Target 2008: 6.1.1 GN 50 lines of advanced	Materials			

	generation interspecific derivatives of groundnut evaluated for LLS disease and promising lines identified				
	Output Target 2008: 6.1.2 CP Markers for Ascochyta Blight and Botrytis Grey mold resistance validated in a new population	Other kinds of knowledge			
	Output Target 2008: 6.1.3 CP Strategies to cross cultivated species with species of secondary and tertiary genepools developed	Practices			
	Output Target 2008: 6.1.1 PP New knowledge on vegetable pigeonpea production synthesized, published and disseminated to partners	Other kinds of knowledge			
	Output Target 2008: 6.1.1 SO Lines with large grain and high grain yield (5) with resistance to shoot	Materials			

	fly and adaptation to post-rainy season developed				
	Output Target 2009: 6.1.1 CP 10 Kabuli chickpea breeding lines with extra large seed (>50 g 100 seeds^{-1}) and high resistance to fusarium wilt developed	Materials			
	Output Target 2009: 6.1.1 PP Molecular characterization of wilt/sterility mosaic resistant and susceptible germplasm/breeding lines to identify diverse parents for developing mapping populations	Other kinds of knowledge			
	Output Target 2009: 6.1.1 PP 15 new sources of resistance to wilt and sterility mosaic virus identified and made available to partners	Materials			
	Output Target 2009: 6.1.1 PP At least 10 germplasm/ breeding lines with resistance to *Helicoverpa* identified and made available to	Materials			

	partners				
	Output Target 2009: 6.1.1 SO Two F6 sorghum RIL mapping populations (300 each) available for genotyping and assessment of yield, quality, and sugar content	Materials			
	Output Target 2010: 6.1.2 GN Two transgenic events with resistance to TSV used for introgression into locally adapted groundnut genotypes	Materials			
	Output Target 2010: 6.1.2 GN At least 10 transgenic events with resistance to PBNV characterized under greenhouse conditions	Materials			
	Output Target 2010: 6.1.4 CP 1-2 promising *Bt* transgenic events identified and characterized for insect resistance under contained field conditions	Other kinds of knowledge			
	Output Target 2010: 6.1.3 CP Interspecific	Materials			

	derivatives (10) with enhanced resistance to AB, BGM, and *Helicoverpa* identified and made available to partners				
	Output Target 2010: 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	Materials			
	Output Target 2010: 6.1.2 PP 1 2 promising *Bt* transgenic events of pigeonpea identified and used for introgression	Materials			
	Output Target 2010: 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	Materials			
	Output Target 2011: 6.1.1 GN Five stable interspecific derivatives of	Materials			

	groundnut with resistance to LLS tested on farmers fields				
	Output Target 2011: 6.1.2 GN Three mapping populations for LLS and two for confectionary traits developed	Materials			
	Output Target 2011: 6.1.1 CP Breeding lines (10) with combined resistance to Fusarium wilt and *Helicoverpa* identified	Materials			
	Output Target 2011: 6.1.1 CP Physico-chemical mechanisms of resistance to *Helicoverpa* identified and nature of inheritance studied	Other kinds of knowledge			
	Output Target 2011: 6.1.2 CP QTLs for *Helicoverpa* resistance identified from *Cicer arietinum* x *C. reticulatum* RIL population	Other kinds of knowledge			
	Output Target	Materials			

	2011: 6.1.3 PP 10-15 genetically diverse large-seeded vegetable type breeding populations and lines for further selection developed				
	Output Target 2011: 6.1.1 SO Ten sweet sorghum lines with high biomass and resistance to shoot pests and foliar diseases developed	Materials			
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 result of	Reduced risks to food insecurity through availability of drought tolerant cultivars in SAT Asia.

				availability of improved lines with drought tolerance, mapping populations, OTLs linked to drought, and transgenic plants with drought tolerance.	
	Output Target 2008: 6.2.1 GN New breeding strategies for drought tolerance in groundnut using surrogate traits developed	Other kinds of knowledge			
	Output Target 2008: 6.2.2 GN Molecular markers ready for validation in introgression studies for abiotic stresses	Other kinds of knowledge			
	Output Target 2008: 6.2.1 CP Phenotyping of ICCV 2 x JG 62 mapping population for salinity tolerance completed and marker data available for QTL mapping	Other kinds of knowledge			
	Output Target 2009: 6.2.1 GN 6-8 dual purpose	Materials			

	groundnut varieties with high biomass and improved haulm digestibility identified and promoted for drought prone areas in Asia (collaboration with ILRI)				
	Output Target 2009: 6.2.1 CP QTLs for drought avoidance and root traits validated	Other kinds of knowledge			
	Output Target 2009: 6.2.2 GN Three transgenic DREBIA events with drought resistance identified	Materials			
	Output Target 2009: 6.2.1 PP A set of pigeonpea genotypes suitable to breed for salinity tolerance identified	Materials			
	Output Target 2009: 6.2.1 SO Five sorghum varieties with salinity tolerance developed	Materials			
	Output Target 2010: 6.2.1 GN One to two farmer-	Materials			

	preferred drought tolerant varieties identified in partner countries				
	Output Target 2010: 6.2.1 CP MABC derived drought tolerant lines available from 2-3 locally adapted cultivars	Materials			
	Output Target 2010: 6.2.1 CP Transgenic DREB/P5CSF events transgenic events available for introgression into locally adapted genotypes	Materials			
	Output Target 2011: 6.2.1 GN QTLs for key root traits of drought tolerance identified	Other kinds of knowledge			
	Output Target 2011: 6.2.2 GN 15-20 introgressed transgenic lines of groundnut evaluated under water-limiting conditions	Materials			
	Output Target 2011: 6.2.1 CP QTLs for salinity tolerance in chickpea identified	Other kinds of knowledge			

	Output Target 2011: 6.2.1 PP At least two mapping populations developed to map QTLs for salinity tolerance	Materials			
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 pigeon pea crops and associated capacity building made available to partners internationally**			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 management, 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 OTLs linked	Risks of malnutrition, aflatoxin contamination, pesticide use, burden of pests and pathogens reduced substantially in Asia SAT through application of integrated crop production technologies.

				to pathogens, and transgenic plants with pest and pathogen 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.	
	Output Target 2008: 6.3.1 FORT At least 8 groundnut candidate *psy1* events with beta-carotene selected for contained field	Materials			

	trial				
	Output Target 2008: 6.3.5 CB Training course on chickpea production organized	Capacity			
	Output Target 2009: 6.3.1 FORT Pigeonpea *psy1* events with beta-carotene identified	Other kinds of knowledge			
	Output Target 2009: 6.3.4 DTOX 8-10 elite aflatoxin resistant lines identified and made available to NARS	Materials			
	Output Target 2009: 6.3.5 IPM Rural stakeholders trained in biopesticide production and utilization	Capacity			
	Output Target 2009: 6.3.5 CB NARS scientists field days organized for different crops	Capacity			
	Output Target 2010: 6.3.2 DTOX Five promising transgenic events of groundnut with *PNLOX13S* gene for *A. flavus* resistance identified	Materials			
	Output Target 2010: 6.3.5 CB	Capacity			

	At least 20 Ph.D. students, apprentices and technicians trained in various aspects of crop improvement, biotechnology				
	Output Target 2011: 6.3.1 FORT 1-2 transgenic events of groundnut/pigeonpea with high beta-carotene content available for introgression	Materials			
	Output Target 2011: 6.3.4 DTOX Ten interspecific derivatives of groundnut evaluated for *A. flavus* resistance and promising lines identified	Materials			
	Output Target 2011: 6.3.5 IPM Bio-safety of transgenic crops to nontarget organisms assessed	Policy strategies			
	Output Target 2011: 6.3.5 CB Training courses in mycotoxin detection technologies conducted for NARS staff	Capacity			

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

Project Overview and Rationale

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

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

Generic Outputs Description

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&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. 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 Outputs

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 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.

List of Countries where Research is planned

Senegal, Mali, Niger, Burkina Faso, Ghana

List of Potential beneficiary Countries

Senegal, Mali, Niger, Burkina Faso, Togo, Benin. Nigeria, Cameroon, Chad

Alignment to CGIAR Priorities: 3A: Increasing income from fruit and vegetables;
Countries of Planned Research: Burkina Faso; Ghana; Mali; Niger; Senegal;

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. 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

List of Countries where Research is planned

India, Philippines

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Indonesia, Nepal, Kenya, Tanzania, Malawi, Zambia, Mozambique

Alignment to CGIAR Priorities: 3A: Increasing income from fruit and vegetables;
Countries of Planned Research: India; Philippines;

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

List of Countries where Research is planned

Zimbabwe

List of Potential beneficiary Countries

Zimbabwe, Malawi, Zambia, Kenya, Tanzania, South Africa, Botswana

Alignment to CGIAR Priorities: 3B: Increasing income from livestock;
Countries of Planned Research: Zimbabwe;

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.

List of countries where research is planned

India, Mali and Niger

List of potential beneficiary countries

Thailand, Vietnam, China, Pakistan, Bangladesh, Kenya, Malawi, Ghana, Nigeria, Tanzania and Burkina Faso

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.

Activity sets
(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

Activity sets
(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

Activity sets
(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

Activity sets
(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

List of Countries where Research is planned

India, Philippines

List of Potential beneficiary Countries

India, Pakistan, Bangladesh, Myanmar, China, Vietnam, Philippines, Indonesia, Nepal

Alignment to CGIAR Priorities: 3D: Promoting sustainable income generation from forests and trees ;
Countries of Planned Research: India; Mali; Niger; Philippines;

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**

Description of impact pathways and capacity development

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.

International Public Goods

Expected IPGs that have applicability beyond one nations borders

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 scarce 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
- 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. 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 federal and state

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

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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.
	Output Target 2007: 7.1.1 African Market Garden: 1st proof of concept tested and validated in Sahelian countries and report drafted	Practices			
	Output Target 2009: 7.1.1 Authoritative AMG strategy published and advocacy campaign for policy amendment completed (associated with the DMP SWEP)	Policy strategies			
	Output Target 2009: 7.1.2 Single plant selections of Okra and hot pepper made and distributed to partners for testing	Materials			
	Output Target 2010: 7.1.1 F_2 heat tolerant population of sweet pepper advanced and material selected with partners	Materials			
	Output Target 2011: At least one tomato line with better fruit quality than ICRI-Xina identified and seed available for further rainy	Materials			

	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&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%.
	Output Target 2008: 7.2.1	Practices			

	Inventory of alternative watershed practices for 4 Asian countries documented and made available globally				
	Output Target 2009: 7.2.1 Capacity building for partners in crop diversification and the implementing of IGNRM practices	Capacity			
	Output Target 2009: 7.2.2 Balanced nutrient management options for vegetable cultivation evaluated	Practices			
	Output Target 2010: 7.2.1 Potential proof of concept for use of environment-friendly alternative sources of energy using biodiesel straight vegetable oil (SVO) to use as energy source	Other kinds of knowledge			
	Output Target 2011: 7.2.1 Monitoring and management of pesticide residues and impact of IPM established	Practices			
	Output Target 2011: 7.2.2 Impact of	Policy strategies			

	diversification with high-value crops assessed and documented in two countries				
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
	Output Target 2008: 7.3.1 Impact of livestock on natural resources described within different policy environments and agro-ecosystems, with reference to biodiversity and primary and secondary productivity.	Policy strategies			
	Output Target 2009: 7.3.1	Practices			

	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				
	Output Target 2009: 7.3.2 Improved land use strategies developed with all stakeholders to reduce risk and vulnerability, with recommendations on policy reform	Practices			
	Output Target 2010: 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	Capacity			
	Output Target 2011: 7.3.1 See Project 9 logframe	Capacity			
Output 4: **Opportunities for the market**			NGOs and government policy	Degraded wastelands are shown	The very poor have seen a

exploitation of biodiesel tree products by the poor promoted with associated capacity building			makers, ICRAF	to be an economic asset for the poor and government policy is amended accordingly	potential way out of poverty that is economicall y and politically highly desirable
	Output Target 2010: 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	Practices	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 economicall y and politically highly desirable
	Output Target 2011: 7.4.1 Recommendations for suitable agronomic practices for the block plantation of trees with potential for use as sources of biodiesel	Practices			
	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	Other kinds of knowledge			

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

Project frozen see below

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

The DMP is a collaborative initiative among nine African countries: Burkina Faso, Botswana, Mali, Namibia, Niger, Senegal, Kenya, South Africa, and Zimbabwe assisted by five CGIAR Centers (ICRAF, ICRISAT, IFDC, ILRI, TSBF-CIAT) and three Advanced Research Institutes (CEH, CIRAD, IRD). ICRISAT amongst other roles acts as the coordinating agency.

The proposed project, the Desert Margins Program SWEP (DMP), aims at arresting land degradation in sub-Saharan Africa's desert margins and at addressing issues of global environmental importance as well as issues of national economic and environmental importance; and in particular the loss of biological diversity, reduced sequestration of carbon, and increased soil erosion and sedimentation, associated with land degradation in these arid and semi-arid ecological zones. The overall objective of the DMP is to arrest land degradation in SSA's desert margins through demonstration and capacity building activities.

ICRISAT is the Executing Agency while the GEF Implementing Agency is the United Nations Environment Program (UNEP) with support by the United Nations Development Program (UNDP). This project fits within ICRISAT's mandate to enhance the livelihoods of the poor in semi-arid farming systems through integrated genetic and natural resource management strategies.

The Project is currently frozen due to a break between the Phase 2 and Phase 3 funding arrangements from UNEP. It is expected that Phase 3 funding will come on-stream in either late 2008 or 2009. However, as future activities will be decided by the DMP Steering Committee for Phase 3 only after funding is available, no forward planning is presently possible.

Alignment to CGIAR Priorities

The research proposed in this project has been in accordance with System Priority 1, goal 1b, promoting conservation and characterization of underutilized genetic resources to increase the income of the poor; under System Priority 4, goal 4b, integrated land, water and forest management at landscape level and goal 4d, sustainable agro-ecological intensification in low- and high-potential areas.

List of countries where research is planned

Burkina Faso, Botswana, Mali, Namibia, Niger, Senegal, Kenya, South Africa, and Zimbabwe

List of potential beneficiary countries

Burkina Faso, Botswana, Mali, Namibia, Niger, Senegal, Kenya, South Africa, and Zimbabwe

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

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

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.

Generic Outputs Description

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&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.

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 >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 recognises 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'etre* of ICRISAT's research being.

Outputs Description

Changes from previous MTP Outputs

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.

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

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:

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.
Management of climatic risk and uncertainty

This is a rapidly growing area which ICRISAT is playing a leading role in promulgating. New

Climate variability and change projects that ICRISAT staff in Africa and Asia are currently involved in, or have developed over the last 2 years and will be funded in 2007 the initiation of 6 pilot climate risk management/carbon sequestration projects in Africa which covered the countries, Cape Verde, Ethiopia, Gambia, Ghana, Kenya, Madagascar, Mali, Mozambique, Niger and Senegal. Furthermore, during 2006, ICRISAT and partners were successful with the submission of 5 competitive grant concept notes and have been invited to develop full proposals. One is to be funded by the African Development Bank through ASARECA and covers Sudan, Eritrea and Uganda with capacity building activities throughout East and Central Africa. Three are to be funded by IDRC / DFID through their Climate Change Adaptation in Africa (CCAA) grants scheme and cover Zimbabwe, Zambia, Ghana, Mali, Niger, Tanzania, Kenya, Ethiopia Eritrea and Sudan. The fifth will be funded by IDRC through their Research in Tobacco Control (RITC) Program and will focus on Malawi. In Asia over the same period six concept notes have been developed and two have move forward to full proposal development. 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 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:

Activity sets:
(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.

Activity sets:
(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.

Activity sets:
(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 & Synthesis Workshop held.
(8) August 2010. PoC Synthesis Report available for distribution by ASARECA.

List of countries where research is planned

Cape Verde, Ethiopia, Gambia, Ghana, Kenya, Madagascar, Mali, Mozambique, Niger, Senegal, Zimbabwe, Zambia,Tanzania, Eritrea, Sudan, Malawi, India

List of potential beneficiary countries

All SSA countries and Southern Asian Countries

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;
Countries of Planned Research: Cape Verde; Eritrea; Ethiopia; Gambia; Ghana; India; Kenya; Madagascar; Malawi; Mali; Mozambique; Niger; Senegal; Sudan; Tanzania; Zambia; Zimbabwe;

Output 2: New tools and methods for management of multiple use landscapes and 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: Description as per Output 1.
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;
Countries of Planned Research: Cape Verde; Eritrea; Ethiopia; Gambia; Ghana; India; Kenya; Madagascar; Malawi; Mali; Mozambique; Niger; Senegal; Sudan; Tanzania; Zambia; Zimbabwe;

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.

List of countries where research is planned

India, Nepal, Bangladesh, Thailand, Philippines, Vietnam, China, Zimbabwe , South Africa, Niger , Mali , Malawi , Mozambique , Ghana, Burkina Faso, Senegal

List of potential beneficiary countries

All countries in SSA and SA in the SAT

Alignment to CGIAR Priorities: 4C: Improving water productivity; 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas;
Countries of Planned Research: Bangladesh; Burkina Faso; China; Ghana; India; Malawi;

Mali; Mozambique; Nepal; Niger; Philippines; Senegal; South Africa; Thailand; Viet Nam; Zimbabwe;

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.

List of countries where research is planned

India, Nepal, Bangladesh, Ghana, Mal

List of potential beneficiary countries

All countries in SSA and SA in the SAT

Alignment to CGIAR Priorities: 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas;
Countries of Planned Research: Bangladesh; Ghana; India; Mali; Nepal;

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
List of countries where research is planned

Ethiopia, India, Zimbabwe

List of potential beneficiary countries

All countries in SSA and SA in the SAT

Alignment to CGIAR Priorities: 4C: Improving water productivity; 4D: Promoting sustainable agro-ecological intensification in low- and high-potential areas;
Countries of Planned Research: Ethiopia; India; Zimbabwe;

Impact Pathways by Output

Output 1: **New tools and methods for management of multiple use landscapes and 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 of impact pathways

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 not 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 itterative and participatory process that considers social and natural resource endowments and well-being,

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.

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
- 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

Elaboration of partners' roles and capacity building

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.

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.

Logical Framework

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
Output 1: **New tools and methods for management of multiple use landscapes and 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**			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
	Output Target 2009: 9.1.1 Stochastic data assimilation techniques introduced in field-to-landscape research/modeling	Materials	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

	Output Target 2010: 9.1.1 Cultivar adaptation maps available to seed sector stakeholders, policy makers under current and projected climate conditions in West Africa	Materials			
	Output Target 2010: 9.1.2: Cost effective and statistically acceptable GIS-based interpretation method for mapping, soil deficiencies at micro-watershed and district levels	Materials			
	Output Target 2010: 9.1.3 National partners have effective tools, methods and necessary capacity building for assessing the carbon sequestration capacity of dry lands	Capacity			
	Output Target 2011: 9.1.1 Partners and watershed implementing agencies have an effective hydrological model for proper planning of water resource development at	Capacity			

	watershed scale				
Output 2: New tools and methods for management of multiple use landscapes and 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 associated with climatic variability enhanced	In rainfed areas, greater resilience to climate variability through integrated land and watershed manageme nt. Agricultural productivity and incomes has been increased in target countries Communitie s have experienced reduced vulnerability to climate variability and are more resilient and better prepared through the implementa tion of the improved risk manageme nt strategies.
	Output Target 2008: 9.2.1 Ex ante impact assessment of climatic change impacts on SAT agriculture	Practices	NARES, NGOs and policy makers, Alliance, SWEP and Water CP partners	SWMnet and WFCP partners improve research efficiency, adopt improved practices/polici es for enhancing water	Pressure on the supply of water for irrigated land is reduced as rainfed agriculture has increased

				productivity and actively scale these out across the SAT	its contribution to food/feed production. NARES research capacity this area has been enhanced
	Output Target 2009: 9.2.1 Greater application of climate predictions and cropping practices by NARS, extension agencies and farmers to manage climate risks in Asia	Capacity			
	Output Target 2010: 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	Practices			
	Output Target 2010: 9.2.2 Impacts of global climate change projections on SAT agriculture evaluated in at least two countries	Other kinds of knowledge			

	in ECA				
	Output Target 2010: 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.	Practices			
	Output Target 2010: 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	Capacity			
Output 3: **Affordable and sustainable crop management**			NARES, NGOs, CBOs and policy	Partners (NARES, CBOs, private sector) promote better	Larger and better targeted investment

options (nutrients and water management) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia			makers, Alliance and CP partners, private sector NARES, Universities NGOs and policy makers, Alliance, SWEP and Water CP partners NARES, NGOs, CBOs, policy makers, private sector, Alliance and developmen t partners	practice in using macro and micro nutrients, fertilizer microdosing and genetic resources, particularly legumes in rainfed and irrigated areas. SWMnet and WFCP partners improve research efficiency, adopt improved practices/polici es for enhancing water productivity and actively scale these out across the SAT	in rainfed agriculture by a range of stakeholder s (district policy makers, private sector, micro-finance institutions, extension services, meteorologi cal department s, NGOs) has occurred 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
	Output Target 2008: 9.3.1 At least 2 technical options (nutrients and water management) provided for intensifying and diversifying production	Practices			

	systems in low and high potential environments				
	Output Target 2008: 9.3.2 At least six water management technologies/ practices for strategic crops, adaptable by smallholder farmers in ESA, are identified and their returns to investment quantified	Practices			
	Output Target 2009: 9.3.1 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	Capacity			
	Output Target 2009: 9.3.2 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	Other kinds of knowledge			

	environments, and widely disseminated in WCA and ESA regions				
	Output Target 2010: 9.3.1 Enabling policies for promotion and use of both macro and micronutrients in the semi-arid rainfed areas of Africa and Asia	Policy strategies			
	Output Target 2011: 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	Policy strategies			
	Output Target 2011: 9.3.2 More efficient allocation and use of water resources in SAT by farmers to minimize adverse effects of climate variability	Practices			
Output 4: **Affordable and sustainable crop management options (IPM and IDM) developed and promoted with**			NARES, Universities NGOs, CBOs and policy makers, Alliance and CP	Partners (NARES, CBOs, private sector) promote better IDM/IPM strategies in rainfed and irrigated areas,	Larger and better targeted investment in rainfed agriculture by a range of

associated capacity building in collaboration with NARES partners in Africa and Asia			partners, private sector NARES, NGOs, CBOs and policy makers	particularly for legumes, fully exploiting available genetic resources. Partners have access to a new, custom early warning (EW) products in Mali and Ghana	stakeholders (district policy makers, private sector, micro-finance institutions, extension services, meteorological departments, NGOs) has occurred Nutrition, health and income of smallholder groundnut producers improved through enhanced, targeted EW
	Output Target 2011: 9.4.1 At least two IDM approaches for groundnuts pigeon pea and chickpeas promoted in at least three regions of Asia	Practices			
	Output Target 2011: 9.4.2 Aflatoxin advisories and mitigation evaluated by farmers, development actors	Other kinds of knowledge			
Output 5: **Affordable and crop-livestock management**			Local and regional planners, local and	An understanding of the dynamics of	Improved natural resource manageme

options developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia			global researchers and investment decision makers Development planners and implementation agents, water management authorities, dissemination networks	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;	nt, reduced environmental impact Strengthened institutional framework for more effective water management Sustainable livestock-based income enhancing systems developed for improving farmers incomes;
	Output Target 2010: 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	Practices			
	Output Target 2011: 9.5.1 Dual purpose crop varieties for food	Materials			

	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

Rationale for the research within the context of the CGIAR SPs and the mandate, goals and objectives of the center

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 Outputs

The project structure for ICRISAT was re-worked newly in 2006 and has not changed in 2007 or 2008. The outputs have not changed.

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

Drought preparedness on a mass scale in SAT Asia and WCA is an unprecedented process. It can be achieved through a combination of emerging methods of open learning, participatory rural information appraisal, and ICT-enabled rural information dissemination. There is a need to develop a common strategy based on a blend of these technologies which can be adopted for partners in the specific regions. The Center has created well-regarded instructional materials that need to be transformed into granules and objects consistent with the open learning approach. These can be used by partners to design information modules of their own, based on a participatory assessment of local information needs.

In order to achieve this, there is a need to develop two groups of activities.

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: 1 component 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)

List of countries in which research is planned

India, Niger

List of potential beneficiary countries

All SAT countries

Alignment to CGIAR Priorities: 6A: New research; 6C: Development Activities;
Countries of Planned Research: India; Niger;

Output 2: New approaches for enhanced access to ICRISAT IPGs 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;
Countries of Planned Research: India; Niger;

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**

Description of impact pathways and 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 and 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 GO FA University Consortium 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 and the DMP will conduct tests on mass dissemination using a blend of satellite digital radio and community radio.

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.
- User surveys to assess changes in information demand and in use patterns will be conducted
- 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

Elaboration of Partners Roles

Identification of Partner Roles:

- LO repository:
  - o Platform design and management: ICRISAT KMS
  - o Nuclear content and validation: ICRISAT GTs AE and CI
  - o Assessment of sample LOs for suitability in pedagogy: the COL (Commonwealth of Learning)
  - o Ontology design: ICRISAT KMS with FAO
  - o Rural users localization and assessment: GT-IMPI with CSO partners (AMS in India

- Strengthening Knowledge Flows and capacity building:
  - o User tests on the platform: One OU (YCMOU) and one SAU (ANGRAU) in SAT Asia and RANET in WCA
  - o Collaborative content creation on the platform with one NARES partner in SAT Asia (CRIDA-ICAR) and 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

Output	Output targets	Output target types/Verification (optional)	Intended users	Outcomes	Impacts
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	Strengthening of both real-time as well as virtual partnerships in content creation, validation, delivery and impact assessment.	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.
	Output Target 2007: 10.1.1 Repository design with one group of objects completed and tested and report shared with partners	Other kinds of knowledge			
	Output Target 2008: 10.1.1 Prototype for delivery of learning objects for partner transformation tested with two partners	Other kinds of knowledge			
	Output Target 2008: 10.1.2 Repository design finalized (for large scale use) and documented for publication	Practices			
	Output Target	Practices			

	2009: 10.1.1 Platform installed in 3 partner organizations				
	Output Target 2010: 10.1.1 Joint evaluation with partners completed and document on effectiveness of new delivery service developed and shared with all partners	Other kinds of knowledge			
	Output Target 2011: 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	Practices			
Output 2: **New approaches for enhanced access to ICRISAT IPGs developed, tested and shared with partners**			NARES and global technology partners, ICT/KM, SWEP and Alliance members.	Augmented access to IPGs by NARES and CBO partners brings enhanced capacity to add value to IPGs 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.
	Output Target 2007: 10.2.1 Two capacity strengthening workshops on	Capacity			

	localization undertaken with two partners and reports published				
	Output Target 2008: 10.2.1 Editable web-based documentation on LO creation and localization developed and tested with three partners	Other kinds of knowledge			
	Output Target 2009: 10.2.1 New approach based on web services tested for localization with two partners	Other kinds of knowledge			
	Output Target 2010: 10.2.1 Document on the new LO approach and effectiveness developed and published	Other kinds of knowledge			
	Output Target 2011: 10.2.1 Advanced online repository for sharing higher-education level learning materials fully designed and deployed	Practices			

ANNEXES

Implementation of EPMR/CPER Recommendations

EPMR 2003 recommendations progress summary

EPMR Report Presentation and Discussion to:

- Science Council: EPR to Interim SC (ISC/TAC 85) 30 August 2003
- Executive Council: EPR and EMR to 5th ExCo September 19th 2003
- AGM: 28-31st October 2003 in Nairobi

Complete details of recommendations and responses were provided in Appendix 1 of MTP 2007-2009 and required action has been completed in 2006. ICRISAT has completed its cycle of four Center Commissioned External Reviews in 2007/8. It is expecting its next EPMR to start at its Governing Board Meeting in August 2008 with the report being available in 2009.

FINANCING PLAN

ICRISAT-Table 1: Allocation of Project Costs by Priority Area and Priorities, 2009 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													1.626	1.200	0.568	0.760				4.154
10. The Virtual Academy for the African and Asian SAT																		1.321		1.321
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)																	1.592	0.214	0.043	1.849
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations	2.714	1.499		0.868																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.			2.793	1.829	1.889															6.511
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			2.001	1.351	1.314															4.666
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.			1.504	0.812	0.798	0.183														3.297

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			3.904	1.925	1.742																7.571
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products							2.175	0.777	0.453												3.405
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										0.069											0.069
9. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources through sustainable agro-ecological intensification in low- and high-potential environments										0.832	0.838	2.611									4.281
Total	2.714	1.499	10.202	6.785	5.743	0.183	2.175	0.777	0.453	0.901	0.838	2.611	1.626	1.200	0.568	0.760	1.592	1.535	0.043	42.205

ICRISAT-Table 2: Allocation of Project Costs to CGIAR Priorities, 2008-2011

in $millions

Projects / Priorities	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT				
5A	1.926	1.626	1.705	1.792
5B	2.944	1.200	1.255	1.318
5C	0.523	0.568	0.591	0.616
5D	0.587	0.760	0.785	0.816
Project Total	**5.980**	**4.154**	**4.336**	**4.542**
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations				
1A	2.695	2.714	2.844	2.988
1B	1.085	1.499	1.584	1.675
2B	0.153	0.868	0.929	0.990
Project Total	**3.933**	**5.081**	**5.357**	**5.653**
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	2.295	2.793	2.958	3.128
2B	1.738	1.829	1.931	2.039
2C	1.806	1.889	1.998	2.112
Project Total	**5.839**	**6.511**	**6.887**	**7.279**
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	1.580	2.001	2.110	2.224
2B	1.271	1.351	1.419	1.493
2C	1.235	1.314	1.382	1.456

Project Total	**4.086**	**4.666**	**4.911**	**5.173**

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.

2A	0.905	1.504	1.567	1.634
2B	0.773	0.812	0.831	0.855
Projects / Priorities	**Estimated 2008**	**Proposal 2009**	**Plan 1 2010**	**Plan 2 2011**
2C	0.810	0.798	0.819	0.844
2D	0.457	0.183	0.191	0.199
Project Total	**2.945**	**3.297**	**3.408**	**3.532**

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	1.710	3.904	4.147	4.394
2B	1.254	1.925	2.034	2.148
2C	1.684	1.742	1.841	1.944
2D	0.000	0.000	0.000	0.000
Project Total	**4.648**	**7.571**	**8.022**	**8.486**

7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products

3A	2.497	2.175	2.189	2.235
3B	0.649	0.777	0.827	0.877
3D	0.427	0.453	0.480	0.507
Project Total	**3.573**	**3.405**	**3.496**	**3.619**

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	0.245	0.069	0.071	0.074
Project Total	**0.245**	**0.069**	**0.071**	**0.074**

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	0.612	0.832	0.888	0.944
4C	1.642	0.838	0.892	0.946
4D	2.993	2.611	2.656	2.732
Project Total	**5.247**	**4.281**	**4.436**	**4.622**

10. The Virtual Academy for the African and Asian SAT

New Research Areas	1.032	1.321	1.348	1.380
Project Total	**1.032**	**1.321**	**1.348**	**1.380**

Projects **Priorities**	**Estimated 2008**	**Proposal 2009**	**Plan 1 2010**	**Plan 2 2011**

11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)

Development Activities	1.346	1.592	1.668	1.757
Stand-alone Training	0.038	0.043	0.039	0.052
New Research Areas	0.202	0.214	0.208	0.231
Project Total	**1.586**	**1.849**	**1.915**	**2.040**
Total	**39.114**	**42.205**	**44.187**	**46.400**

ICRISAT-Table 3: Summary of Project Costs, 2008-2011

in $millions

Project	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	5.980	4.154	4.336	4.542
10. The Virtual Academy for the African and Asian SAT	1.032	1.321	1.348	1.380
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)	1.586	1.849	1.915	2.040
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations	3.933	5.081	5.357	5.653
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.	5.839	6.511	6.887	7.279
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	4.086	4.666	4.911	5.173
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.	2.945	3.297	3.408	3.532
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	4.648	7.571	8.022	8.486
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products	3.573	3.405	3.496	3.619
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	0.245	0.069	0.071	0.074
9. Poverty Alleviation and Sustainable Management of Water, Land, Livestock and Forest Resources through sustainable agro-ecological intensification in low- and high-potential environments	5.247	4.281	4.436	4.622
Total	**39.114**	**42.205**	**44.187**	**46.400**

ICRISAT-Table 4: Summary of Priority Costs, 2008-2012 in $millions

Priorities	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
1A	2.695	2.714	2.844	2.988
1B	1.085	1.499	1.584	1.675
2A	6.490	10.202	10.782	11.380
2B	5.189	6.785	7.144	7.525
2C	5.535	5.743	6.040	6.356
2D	0.457	0.183	0.191	0.199
3A	2.497	2.175	2.189	2.235
3B	0.649	0.777	0.827	0.877
3D	0.427	0.453	0.480	0.507
4A	0.857	0.901	0.959	1.018
4C	1.642	0.838	0.892	0.946
4D	2.993	2.611	2.656	2.732
5A	1.926	1.626	1.705	1.792
5B	2.944	1.200	1.255	1.318
5C	0.523	0.568	0.591	0.616
5D	0.587	0.760	0.785	0.816
Development Activities	1.346	1.592	1.668	1.757
Stand-alone Training	0.038	0.043	0.039	0.052
New Research Areas	1.234	1.535	1.556	1.611
Total	39.114	42.205	44.187	46.400

ICRISAT-Table 5: Investments by Undertaking, Activity and Sector, 2007-2011 in $millions

	Actual 2007	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
Increasing Productivity	18.276	17.990	20.894	21.876	22.971
Germplasm Enhancement & Breeding	10.985	10.685	13.516	14.176	14.905
Production Systems Development & Management	7.291	7.305	7.378	7.700	8.066
Cropping systems	6.562	6.575	6.639	6.930	7.259
Livestock systems	0.510	0.511	0.517	0.539	0.565
Tree systems	0.219	0.219	0.222	0.231	0.242
Fish systems	0.000	0.000	0.000	0.000	0.000
Protecting the Environment	5.564	5.585	5.629	5.873	6.155
Saving Biodiversity	3.044	3.275	3.308	3.458	3.627
Improving Policies	5.243	6.770	6.516	6.858	7.226
Strengthening NARS	5.472	5.494	5.858	6.122	6.421
Training and Professional Development	3.013	3.020	3.230	3.376	3.539
Documentation, Publications, Info. Dissemination	1.965	1.982	2.111	2.206	2.316
Organization & Management Couselling	0.000	0.000	0.000	0.000	0.000
Networks	0.494	0.492	0.517	0.540	0.566
Total	37.599	39.114	42.205	44.187	46.400

ICRISAT-Table 6: Project Investments by Developing Region, 2007-2011

in $millions

Project		Actual 2007	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	Asia	2.746	2.392	1.662	1.734	1.817
	SSA	3.496	3.588	2.492	2.602	2.725
	Total Project	**6.242**	**5.980**	**4.154**	**4.336**	**4.542**
10. The Virtual Academy for the African and Asian SAT	Asia	0.400	0.413	0.528	0.539	0.552
	SSA	0.509	0.619	0.793	0.809	0.828
	Total Project	**0.909**	**1.032**	**1.321**	**1.348**	**1.380**
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)	Asia	0.718	0.634	0.740	0.766	0.816
	SSA	0.913	0.952	1.109	1.149	1.224
	Total Project	**1.631**	**1.586**	**1.849**	**1.915**	**2.040**
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future gernerations	Asia	2.307	1.573	2.032	2.143	2.261
	SSA	2.937	2.360	3.049	3.214	3.392
	Total Project	**5.244**	**3.933**	**5.081**	**5.357**	**5.653**

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	1.580	2.336	2.604	2.755	2.912
	SSA	2.012	3.503	3.907	4.132	4.367
	Total Project	**3.592**	**5.839**	**6.511**	**6.887**	**7.279**
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	1.425	1.634	1.866	1.964	2.069
	SSA	1.813	2.452	2.800	2.947	3.104
	Total Project	**3.238**	**4.086**	**4.666**	**4.911**	**5.173**
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	1.306	1.178	1.319	1.363	1.413
	SSA	1.663	1.767	1.978	2.045	2.119
	Total Project	**2.969**	**2.945**	**3.297**	**3.408**	**3.532**
Project		**Actual 2007**	**Estimated 2008**	**Proposal 2009**	**Plan 1 2010**	**Plan 2 2011**
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	1.419	1.859	3.028	3.209	3.394
	SSA	1.807	2.789	4.543	4.813	5.092
	Total Project	**3.226**	**4.648**	**7.571**	**8.022**	**8.486**
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products	Asia	1.886	1.429	1.362	1.398	1.448

	SSA	2.401	2.144	2.043	2.098	2.171
	Total Project	**4.287**	**3.573**	**3.405**	**3.496**	**3.619**
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	0.192	0.098	0.028	0.028	0.030
	SSA	0.244	0.147	0.041	0.043	0.044
	Total Project	**0.436**	**0.245**	**0.069**	**0.071**	**0.074**
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	2.563	2.099	1.712	1.774	1.849
	SSA	3.262	3.148	2.569	2.662	2.773
	Total Project	**5.825**	**5.247**	**4.281**	**4.436**	**4.622**
	Total	**37.599**	**39.114**	**42.205**	**44.187**	**46.400**

ICRISAT-Table 7: Summary of Investments by Developing Region, 2007-2011

in $millions

Region	Actual 2007	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
SSA	21.057	23.469	25.324	26.514	27.839
Asia	16.542	15.645	16.881	17.673	18.561
Total	**37.599**	**39.114**	**42.205**	**44.187**	**46.400**

ICRISAT-Table 8: Expenditure by Object, 2007-2011

in $millions

Object of Expenditure	Actual 2007	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
Personnel	18.579	20.514	21.955	22.987	24.100
Supplies and services	11.972	11.133	12.345	12.900	13.590
Collaboration/ Partnerships	2.104	2.209	2.330	2.447	2.569
Operational Travel	3.243	3.405	3.575	3.753	3.941
Depreciation	1.701	1.853	2.000	2.100	2.200
Total	**37.599**	**39.114**	**42.205**	**44.187**	**46.400**

ICRISAT-Table 9: Member and Non-Member Unrestricted Grants, 2007-2009

in $millions NC = National Currency

Member	Type NC	Actual 2007 (US$)	Actual 2007 (NC)	Estimated 2008 (US$)	Estimated 2008 (NC)	Proposal 2009 (US$)	Proposal 2009 (NC)
Unrestricted Grants							
Member							
Australia	AUD	0.377	0.500	0.442	0.500	0.442	0.500
Belgium	Euro	0.441	0.306	0.447	0.306	0.447	0.306
Canada	USD	0.860	0.860	0.860	0.860	0.860	0.860
China	USD	0.000	0.000	0.000	0.000	0.000	0.000
Germany	Euro	0.358	0.260	0.380	0.260	0.380	0.260
India	USD	0.150	0.150	0.150	0.150	0.150	0.150
Ireland	Euro	0.463	0.340	0.496	0.340	0.496	0.340
Israel	USD	0.000	0.000	0.185	0.185	0.185	0.185
Japan	Yen	0.015	0.015	0.015	0.015	0.015	0.015
Korea, Republic of	USD	0.050	0.050	0.050	0.050	0.050	0.050
Morocco	USD	0.000	0.000	0.000	0.000	0.000	0.000
Netherlands	USD	0.000	0.000	0.000	0.000	0.000	0.000
Norway	NOK	1.231	7.500	1.288	7.500	1.288	7.500
Philippines	USD	0.039	0.039	0.038	0.038	0.038	0.038
Sweden	SEK	0.569	3.800	0.591	3.800	0.591	3.800
Switzerland	CHF	0.797	0.900	0.794	0.900	0.794	0.900
Thailand	USD	0.010	0.010	0.010	0.010	0.010	0.010
United Kingdom	GBP	1.921	1.260	2.500	1.260	2.500	1.260
United States	USD	1.749	1.749	1.478	1.478	1.478	1.478
World Bank	USD	2.400	2.400	1.700	1.700	1.700	1.700
Subtotal		**11.430**		**11.424**		**11.424**	
Total Unrestricted		**11.430**		**11.424**		**11.424**	

ICRISAT-Table 9a: Member and Non-Member Unrestricted and Restricted Grants, 2007-2009

in $millions

Member / Non-Member	Actual 2007	Estimated 2008	Proposal 2009
Unrestricted Grants			
Member			
Australia	0.377	0.442	0.442
Belgium	0.441	0.447	0.447
Canada	0.860	0.860	0.860
China	0.000	0.000	0.000
Germany	0.358	0.380	0.380
India	0.150	0.150	0.150
Ireland	0.463	0.496	0.496
Israel	0.000	0.185	0.185
Japan	0.015	0.015	0.015
Korea, Republic of	0.050	0.050	0.050
Morocco	0.000	0.000	0.000
Netherlands	0.000	0.000	0.000
Norway	1.231	1.288	1.288
Philippines	0.039	0.038	0.038
Sweden	0.569	0.591	0.591
Switzerland	0.797	0.794	0.794
Thailand	0.010	0.010	0.010
United Kingdom	1.921	2.500	2.500
United States	1.749	1.478	1.478
World Bank	2.400	1.700	1.700
Subtotal	**11.430**	**11.424**	**11.424**

Total Unrestricted	**11.430**	**11.424**	**11.424**

Restricted Grants

Member

Member / Non-Member	Actual 2007	Estimated 2008	Proposal 2009
ADB	0.000	0.000	0.292
Australia	0.629	0.214	0.306
Belgium	0.545	0.112	0.000
Canada	0.966	0.579	0.397
CGIAR	0.000	0.062	0.000
Denmark	0.000	0.000	0.000
European Commission	3.714	1.888	2.211
FAO	0.182	0.091	0.000
Finland	0.334	0.077	0.000
France	0.125	0.122	0.110
Germany	1.307	0.400	1.386
IDB	0.029	0.000	0.000
IFAD	1.044	1.582	1.408
India	3.368	3.172	4.997
Iran	0.040	0.036	0.036
Italy	0.068	0.068	0.068
Japan	0.233	0.228	0.222
Netherlands	0.531	0.719	0.401
Norway	0.077	0.697	0.239
OPEC Fund	0.100	0.077	0.080
Philippines	0.000	0.000	0.000
Rockefeller Foundation	0.227	0.104	0.008

South Africa	0.000	0.000	0.000
Switzerland	0.042	0.000	0.000
Syngenta Foundation	0.174	0.092	0.108
UNEP	1.793	1.060	1.450
United Kingdom	0.411	0.123	0.100
United States	3.794	5.122	3.376
World Bank	0.420	0.293	0.362
Subtotal	**20.153**	**16.918**	**17.557**

Member / Non-Member	Actual 2007	Estimated 2008	Proposal 2009
Non-member			
AGRHYMET, Niger	0.000	0.000	0.000
ASARECA	0.000	0.000	0.000
Bill and Melinda Gates Foundation	0.720	4.734	5.379
Bioversity International	0.041	0.000	0.000
Catholic Relief Services	0.012	0.000	0.000
CIMMYT	0.000	0.000	0.000
Common Fund for Commodities - CFC	0.610	0.282	0.106
CORAF/WECARD	0.046	0.024	0.000
Generation/CP	0.542	1.223	2.454
HarvestPlus/CP	0.560	0.366	0.382
ICARDA	0.006	0.000	0.000
IFPRI	0.073	0.000	0.000
IITA	0.000	0.008	0.000
ILRI	0.076	0.026	0.002
International Fund for Agricultural Research (IFAR)	0.011	0.000	0.000
IRRI	0.023	0.012	0.000
IWMI	0.141	0.057	0.059

McKnight Foundation	0.279	0.169	0.169
Mozambique	0.272	0.028	0.000
Others	0.228	0.080	0.115
Plan International	0.005	0.133	0.137
Seed Companies	0.909	0.709	0.572
Sehgal Family Foundation	0.191	0.044	0.465
Sir Dorabji Tata Trust	0.149	0.000	0.433
Tanzania	0.000	0.000	0.000
Water & Food/CP	0.753	0.652	0.635
World Agroforestry	0.000	0.000	0.000
World Wildlife Fund	0.000	0.000	0.000
Subtotal	**5.647**	**8.547**	**10.908**
Member / Non-Member	**Actual 2007**	**Estimated 2008**	**Proposal 2009**
Total Restricted	**25.800**	**25.465**	**28.465**
Total Grants	**37.230**	**36.889**	**39.889**

Summary and Statement of Activities	Actual 2007	Estimated 2008	Proposal 2009
Total Grants	37.230	36.889	39.889
Center Income	4.917	2.300	2.400
Revenue	42.147	39.189	42.289
Total Investment	37.599	39.114	42.205
Surplus (Deficit)	4.548	0.075	0.084

ICRISAT-Table 10: Allocation of Member Grants and Center Income to Projects, 2007-2009

in $millions

Project			Actual 2007	Estimated 2008	Proposal 2009
1. Improving Policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	Member	ADB	0.000	0.000	0.292
		Australia	0.016	0.000	0.000
		Canada	0.000	0.000	0.030
		European Commission	1.002	0.501	0.501
		FAO	0.115	0.030	0.000
		Germany	0.007	0.000	0.000
		IFAD	0.040	0.545	0.443
		India	0.249	0.269	0.123
		Netherlands	0.153	0.193	0.080
		Norway	0.000	0.000	0.000
		OPEC Fund	0.000	0.000	0.000
		Philippines	0.000	0.000	0.000
		Rockefeller Foundation	0.000	0.000	0.000
		United Kingdom	0.000	0.000	0.000
		United States	2.572	2.717	1.005
		World Bank	0.226	0.000	0.000
	Non Member	Bioversity International	0.000	0.000	0.000
		Catholic Relief Services	0.006	0.000	0.000
		Common Fund for Commodities - CFC	0.124	0.000	0.000
		ICARDA	0.006	0.000	0.000
		IFPRI	0.073	0.000	0.000

		IITA	0.000	0.008	0.000
		ILRI	0.056	0.018	0.000
		IRRI	0.004	0.006	0.000
		McKnight Foundation	0.000	0.000	0.000
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**
		Mozambique	0.187	0.028	0.000
		Others	0.078	0.000	0.000
		Plan International	0.005	0.133	0.137
	Unrestricted + Center Income		1.323	1.532	1.543
		Project Total	**6.242**	**5.980**	**4.154**
10. The Virtual Academy for the African and Asian SAT	Member	Canada	0.135	0.000	0.000
		FAO	0.000	0.038	0.000
		Germany	0.000	0.000	0.017
		India	0.004	0.098	0.405
		World Bank	0.000	0.000	0.000
	Non Member	ICARDA	0.000	0.000	0.000
		IFPRI	0.000	0.000	0.000
		ILRI	0.000	0.000	0.000
	Unrestricted + Center Income		0.770	0.896	0.899
		Project Total	**0.909**	**1.032**	**1.321**
11. Others (Development Oriented Activities, Science Park Activities, Generic Training etc.)	Member	FAO	0.000	0.000	0.000
		India	0.460	0.347	0.394
		Italy	0.000	0.000	0.000
		Netherlands	0.000	0.000	0.000
		UNEP	0.568	0.530	0.725
		United Kingdom	0.000	0.000	0.000

		World Bank	0.060	0.000	0.000
	Non Member	Mozambique	0.085	0.000	0.000
	Unrestricted + Center Income		0.458	0.709	0.730
		Project Total	**1.631**	**1.586**	**1.849**
2.Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets,Groundnut,Pigeonpea and Chickpea for current and future generations	Member	Australia	0.012	0.000	0.000
		European Commission	1.002	0.501	0.501
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**
		FAO	0.000	0.023	0.000
		France	0.055	0.055	0.055
		Germany	0.437	0.103	0.633
		India	0.987	0.878	0.504
		Iran	0.000	0.000	0.000
		Japan	0.057	0.047	0.046
		Netherlands	0.000	0.000	0.000
		Rockefeller Foundation	0.051	0.045	0.000
		South Africa	0.000	0.000	0.000
		Switzerland	0.021	0.000	0.000
		Syngenta Foundation	0.000	0.000	0.000
		UNEP	0.896	0.530	0.725
		United Kingdom	0.000	0.028	0.029
		United States	0.198	0.115	0.000
		World Bank	0.088	0.293	0.362
	Non Member	Bioversity International	0.041	0.000	0.000
		Generation/CP	0.409	0.166	1.068
		HarvestPlus/CP	0.000	0.000	0.000

		Others	0.000	0.000	0.000
		Sehgal Family Foundation	0.015	0.022	0.023
	Unrestricted + Center Income		0.975	1.127	1.135
		Project Total	**5.244**	**3.933**	**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	0.012	0.000	0.000
		Canada	0.016	0.037	0.000
		FAO	0.003	0.000	0.000
		France	0.000	0.000	0.000
		Germany	0.570	0.103	0.539
		IFAD	0.407	0.197	0.249
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**
		India	0.027	0.013	0.025
		Italy	0.034	0.034	0.034
		Japan	0.044	0.046	0.046
		Netherlands	0.143	0.138	0.062
		Rockefeller Foundation	0.068	0.059	0.008
		Switzerland	0.021	0.000	0.000
		Syngenta Foundation	0.059	0.046	0.054
		United Kingdom	0.000	0.000	0.021
		United States	0.319	1.804	1.813
	Non Member	Bill and Melinda Gates Foundation	0.240	1.578	1.793
		Bioversity International	0.000	0.000	0.000
		Catholic Relief Services	0.006	0.000	0.000
		Common Fund for Commodities - CFC	0.124	0.000	0.000
		Generation/CP	0.000	0.357	0.462

		HarvestPlus/CP	0.194	0.078	0.053
		ILRI	0.003	0.000	0.000
		McKnight Foundation	0.271	0.157	0.154
		Others	0.000	0.000	0.000
		Sehgal Family Foundation	0.015	0.022	0.023
		World Agroforestry	0.000	0.000	0.000
	Unrestricted + Center Income		1.016	1.170	1.175
		Project Total	**3.592**	**5.839**	**6.511**
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	0.000	0.000	0.030
		Denmark	0.000	0.000	0.000
		European Commission	1.219	0.521	0.501
		FAO	0.003	0.000	0.000
		France	0.070	0.067	0.055
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**
		Germany	0.124	0.000	0.000
		IFAD	0.032	0.000	0.000
		India	0.000	0.000	0.000
		Japan	0.024	0.026	0.026
		Netherlands	0.077	0.077	0.075
		Rockefeller Foundation	0.108	0.000	0.000
		Syngenta Foundation	0.115	0.046	0.054
		United Kingdom	0.000	0.000	0.021
		United States	0.000	0.152	0.381
		World Bank	0.000	0.000	0.000

	Non Member	ASARECA	0.000	0.000	0.000
		Bill and Melinda Gates Foundation	0.240	1.578	1.793
		Generation/CP	0.069	0.378	0.462
		HarvestPlus/CP	0.138	0.070	0.091
		ILRI	0.000	0.000	0.000
		McKnight Foundation	0.000	0.000	0.000
		Water & Food/CP	0.000	0.000	0.000
	Unrestricted + Center Income		1.019	1.171	1.177
		Project Total	**3.238**	**4.086**	**4.666**
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	IFAD	0.000	0.184	0.000
		India	0.194	0.205	0.436
		Japan	0.025	0.030	0.026
		OPEC Fund	0.000	0.000	0.000
		United Kingdom	0.005	0.000	0.000
	Non Member	Generation/CP	0.000	0.000	0.000
		HarvestPlus/CP	0.079	0.078	0.053
		ICARDA	0.000	0.000	0.000
		Others	0.018	0.000	0.056
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**
		Seed Companies	0.898	0.709	0.560
		Sehgal Family Foundation	0.161	0.000	0.419
	Unrestricted + Center Income		1.589	1.739	1.747
		Project Total	**2.969**	**2.945**	**3.297**

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	0.374	0.164	0.275
		European Commission	0.002	0.000	0.000
		FAO	0.003	0.000	0.000
		Germany	0.000	0.000	0.197
		IFAD	0.000	0.309	0.575
		India	0.673	0.456	2.483
		Iran	0.040	0.036	0.036
		Japan	0.025	0.027	0.026
		Netherlands	0.007	0.010	0.009
		Norway	0.077	0.000	0.000
		OPEC Fund	0.100	0.077	0.080
		Philippines	0.000	0.000	0.000
		United Kingdom	0.007	0.028	0.029
		United States	0.021	0.000	0.015
		World Bank	0.023	0.000	0.000
	Non Member	Bill and Melinda Gates Foundation	0.240	1.578	1.793
		Common Fund for Commodities - CFC	0.181	0.141	0.053
		Generation/CP	0.064	0.322	0.462
		HarvestPlus/CP	0.149	0.140	0.185
		ICARDA	0.000	0.000	0.000
		ILRI	0.000	0.000	0.000
		International Fund for Agricultural Research (IFAR)	0.011	0.000	0.000
		IRRI	0.019	0.006	0.000
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**

		IWMI	0.000	0.000	0.000
		Others	0.000	0.026	0.000
		Water & Food/CP	0.193	0.157	0.175
	Unrestricted + Center Income		1.017	1.171	1.178
		Project Total	**3.226**	**4.648**	**7.571**
7. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities and products	Member	Australia	0.104	0.050	0.031
		Canada	0.329	0.116	0.000
		European Commission	0.231	0.271	0.493
		FAO	0.000	0.000	0.000
		Finland	0.334	0.077	0.000
		Germany	0.169	0.194	0.000
		IDB	0.029	0.000	0.000
		IFAD	0.000	0.000	0.072
		India	0.480	0.473	0.419
		Iran	0.000	0.000	0.000
		Japan	0.024	0.026	0.026
		Netherlands	0.071	0.061	0.000
		UNEP	0.000	0.000	0.000
		United Kingdom	0.000	0.000	0.000
		United States	0.347	0.032	0.000
	Non Member	AGRHYMET, Niger	0.000	0.000	0.000
		Common Fund for Commodities - CFC	0.181	0.141	0.053
		ILRI	0.017	0.008	0.002
		IWMI	0.005	0.057	0.059
		McKnight Foundation	0.000	0.000	0.000
		Others	0.000	0.000	0.000
		Sir Dorabji Tata Trust	0.149	0.000	0.173

		Water & Food/CP	0.000	0.000	0.000
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**
		World Wildlife Fund	0.000	0.000	0.000
	Unrestricted + Center Income		1.817	2.067	2.077
		Project Total	**4.287**	**3.573**	**3.405**
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	0.016	0.037	0.000
		CGIAR	0.000	0.062	0.000
		IDB	0.000	0.000	0.000
		IFAD	0.000	0.000	0.000
		Italy	0.034	0.034	0.034
		UNEP	0.328	0.000	0.000
		United States	0.000	0.077	0.000
		World Bank	0.023	0.000	0.000
	Non Member	AGRHYMET, Niger	0.000	0.000	0.000
		ICARDA	0.000	0.000	0.000
	Unrestricted + Center Income		0.035	0.035	0.035
		Project Total	**0.436**	**0.245**	**0.069**
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	0.111	0.000	0.000
		Belgium	0.545	0.112	0.000
		Canada	0.470	0.389	0.337
		Denmark	0.000	0.000	0.000
		European Commission	0.258	0.094	0.215

		FAO	0.058	0.000	0.000
		IFAD	0.565	0.347	0.069
		India	0.294	0.433	0.208
		Italy	0.000	0.000	0.000
		Japan	0.034	0.026	0.026
Project			**Actual 2007**	**Estimated 2008**	**Proposal 2009**
		Netherlands	0.080	0.240	0.175
		Norway	0.000	0.697	0.239
		UNEP	0.001	0.000	0.000
		United Kingdom	0.399	0.067	0.000
		United States	0.337	0.225	0.162
	Non Member	AGRHYMET, Niger	0.000	0.000	0.000
		ASARECA	0.000	0.000	0.000
		Bioversity International	0.000	0.000	0.000
		CIMMYT	0.000	0.000	0.000
		CORAF/WECARD	0.046	0.024	0.000
		IFPRI	0.000	0.000	0.000
		IWMI	0.136	0.000	0.000
		McKnight Foundation	0.008	0.012	0.015
		Others	0.132	0.054	0.059
		Seed Companies	0.011	0.000	0.012
		Sir Dorabji Tata Trust	0.000	0.000	0.260
		Tanzania	0.000	0.000	0.000
		Water & Food/CP	0.560	0.495	0.460
		World Wildlife Fund	0.000	0.000	0.000
	Unrestricted + Center Income		1.780	2.032	2.044

Project Total	**5.825**	**5.247**	**4.281**
Total Restricted	**25.800**	**25.465**	**28.465**
Total Unrestricted + Center Income	**11.799**	**13.649**	**13.740**
Total	**37.599**	**39.114**	**42.205**

ICRISAT-Table 11: Internationally and Nationally Recruited Staff, 2007-2011

in $millions

	Actual 2007	Estimated 2008	Proposal 2009	Plan 1 2010	Plan 2 2011
NRS	974	1041	1041	1041	1041
IRS	68	72	72	72	72
Total	**1042**	**1113**	**1113**	**1113**	**1113**

ICRISAT-Table 12: Currency Structure of Expenditure, 2007-2009

in millions of units and percent

Currency	Actual 2007			Estimated 2008			Proposal 2009		
	Amount	$ Value	% Share	Amount	$ Value	% Share	Amount	$ Value	% Share
EUR	0.000	0.541	1	0.000	0.536	1	0.000	0.578	1
INR	515.000	10.322	27	409.000	10.223	26	430.000	11.031	26
KES	50.000	0.753	2	50.000	0.746	2	58.000	0.805	2
Others	0.000	0.770	2	0.000	0.763	2	0.000	0.825	2
USD	0.000	21.248	57	0.000	22.919	59	0.000	24.729	59
XOF	2397.000	3.965	11	1712.000	3.927	10	2157.000	4.237	10
ZWD	0.000	0.000	0	0.000	0.000	0	0.000	0.000	0
Total		**37.599**	**100 %**		**39.114**	**100 %**		**42.205**	**100 %**

ICRISAT - Table 13: Statement of Financial Position (SFP), 2007-2009
in $millions

Assets, Liabilities and Net Assets	2007	2008	2009
Current Assets			
Cash and Cash Equivalents	10.737	11.000	11.000
Investments	7.052	7.200	7.250
Accounts Receivable			
- Donor	2.810	3.000	3.000
- Employees	0.444	0.348	0.400
- Other CGIAR Centers	3.704	2.000	2.000
- Others	4.647	4.500	4.500
Inventories	0.647	0.600	0.620
Pre-paid Expenses	0.319	0.250	0.320
Total Current Assets	30.360	28.898	29.090
Non-Current Assets			
Net Property, Plan and Equipment	5.241	5.500	5.700
Investments	26.603	29.000	28.000
Other Assets	1.239	1.400	1.300
Total Non-Current Assets	33.083	35.900	35.000
Total Assets	63.443	64.798	64.090
Current Liabilities			
Overdraft/Short Term Borrowings	0.000	0.000	0.000
Accounts Payable			
- Donor	17.562	18.000	17.500
- Employees	1.348	1.700	1.400
- Other CGIAR Centers	0.379	0.500	0.400
- Others	8.369	8.500	8.400
Accruals and Provisions	0.634	0.700	0.500
Total Current Liabilities	28.292	29.400	28.200
Non-Current Liabilities			
Accounts Payable			
- Employees	12.972	13.100	13.300
- Deferred Grant Revenue	0.000	0.000	0.000
- Others	0.000	0.000	0.000
Total Non-Current Liabilities	12.972	13.100	13.300
Total Liabilities	41.264	42.500	41.500
Net Assets			
Unrestricted			
- Fixed Assets	10.255	10.326	10.465

- Unrestricted Net Assets Excluding Fixed Assets	9.522	9.422	9.500
Total Unrestricted Net Assets	19.777	19.748	19.965
Restricted	2.402	2.550	2.625
Total Net Assets	22.179	22.298	22.590
Total Liabilities and Net Assets	63.443	64.798	64.090

ICRISAT-Table 14: Statement of Activities (SOA), 2007-2009

in $millions

		Unrestricted	Restricted		Total		
			Temporary	Challenge Programs	2007	2008	2009
Revenue and Gains	Grant Revenue	11.430	23.968	1.816	37.214	36.876	39.876
	Other revenue and gains	4.917	0.000	0.000	4.917	2.300	2.400
	Total revenue and gains	16.347	23.968	1.816	42.131	39.176	42.276
Expenses and Losses	Program related expenses	5.386	23.968	1.816	31.170	33.631	36.487
	Management and general expenses	8.321	0.000	0.000	8.321	7.483	8.118
	Other losses expenses	0.000	0.000	0.000	0.000	0.000	0.000
	Sub Total expenses and losses	13.707	23.968	1.816	39.491	41.114	44.605
	Indirect cost recovery	-1.892	0.000	0.000	-1.892	-2.000	-2.400
	Total expenses and losses	11.815	23.968	1.816	37.599	39.114	42.205
	Net Operating Surplus / (Deficit)	4.532	0.000	0.000	4.532	0.062	0.071
	Extraordinary Items	0.000	0.000	0.000	0.000	0.000	0.000
	NET SURPLUS / (DEFICIT)	4.532	0.000	0.000	4.532	0.062	0.071
Object of Expenditure	Personnel	9.366	8.621	0.592	18.579	20.514	21.955
	Supplies and services	0.942	10.277	0.753	11.972	11.133	12.345
	Collaboration/ Partnerships	0.003	1.787	0.314	2.104	2.209	2.330
	Operational Travel	0.769	2.330	0.144	3.243	3.405	3.575
	Depreciation	0.735	0.953	0.013	1.701	1.853	2.000
	Total	11.815	23.968	1.816	37.599	39.114	42.205

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 belongs to the Alliance of Centers of the Consultative Group on International Agricultural Research (CGIAR).

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