International Crops Research Institute for the Semi-Arid Tropics

ICRISAT
Vision and Strategy to 2015
(Asia)

ICRISAT's Asian Vision and Strategy to 2015

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Chapter 1: Context

Overview

A Green Revolution for the Asian SAT following the International Year of Deserts and Desertification (2006)

Since the advent of the Green Revolution, favorable agricultural environments in the developing world have achieved impressive gains in food production, food security and rural poverty reduction. Heightened intensification of agriculture through the use of irrigation, fertilizers and pesticides combined with high yielding varieties and, in some countries, continued price support for key cereals like rice and wheat, and direct or indirect subsidization of electrical power, water costs and other infrastructural investment continue to be the major driving forces for this success. However, many regions in less-favored, rainfed areas such as the semi-arid tropics (SAT) have not benefited equitably from these developmental drivers. There is an emerging pessimism among the world community that the Millennium Development Goals (MDGs) may not be achieved by 2015. ICRISAT seeks to redress this situation.

Beneficial changes resulting from agricultural research in the village economies of the more favored regions of Asia and Latin America in the last few decades now justify a reassessment of research and development (R&D) priorities in regions that have been bypassed, especially those in the SAT. The low productivity of SAT agriculture coupled with widespread poverty, water scarcity, continuing degradation of natural productive resources (land and biodiversity), disease morbidity (particularly HIV/AIDS and malaria) and a changing global environment are further marginalizing agriculture and livelihoods in the SAT. The forces associated with continued water scarcity, land degradation and desertification remain strong and unabated in the face of rapidly increasing populations and drought-induced reductions in effective human and animal land carrying capacity. Many of the promises associated with the United Nations Convention to Combat Desertification (UNCCD) remain unimplemented, and ICRISAT needs to continue to be at the forefront of such efforts in SSA and Asia. This can be assured with the DG of ICRISAT being Chair of the Committee of Science and Technology for the UNCCD in 2007-9. The emerging evidence of higher impacts on poverty as well as higher marginal productivity gains from public investments, particularly in roads, markets, information technology and research in the less-favored regions suggests the need to prioritize these hitherto overlooked areas in terms of technology, institutions and policy. These observations accord closely with the analysis of the new CGIAR Systemwide priorities in which reducing the erosion of biodiversity, developing pro-poor traits in crops, livestock and trees, overcoming abiotic stresses and providing appropriate policy and marketing environments for traditional and new sources of agricultural development are recurrent major themes.

However, many old and new problems in SAT areas globally remain unresolved. Rural poverty, intensity and frequency of droughts, biotic constraints to agriculture and rural-to-urban migration continue to increase, while the natural resource base is becoming more and more degraded. Similarly, human labor resources have the potential to be seriously compromised by AIDS in the coming decades, particularly in sub-Saharan Africa, India and China. Meanwhile, the balance between higher farm productivity and incomes on the one hand, and ecological sustainability in the face of emerging climatic change on the other remains critical. It is now widely accepted that whatever happens to future greenhouse gas emissions, we are now locked into global warming and inevitable changes to climatic patterns which are likely to exacerbate existing rainfall variability in the SAT and further increase the frequency of climatic extremes. It thus seems certain that global warming and associated climate changes are likely to impact on the nature of climate variability, often negatively, and hence the nature of risk associated with investment. Farmers and agricultural stakeholders will need to adapt their tactical and strategic planning to these evolving risks, but given the magnitude of the current challenges faced in the SAT, adaptation to climate change should not and cannot be divorced from current development priorities. Furthermore, agriculture in the SAT also faces new challenges relating to the lack of technological change and the unfinished transformation of subsistence-oriented agriculture. In terms of equity, efficiency and sustainability, the need to improve productivity and profitability in rainfed regions, using Integrated Genetic and Natural Resource Management (IGNRM) technologies is becoming more compelling. IGNRM is a powerful integrative philosophy of research that seeks to maximize the synergies between the disciplines of plant breeding , using conventional and biotechnological approaches, agronomy and the social sciences. Given the complexity and dynamism of semi-arid systems, one of the prime objectives of ICRISAT's IGNRM approach is to improve the adaptive capacity of the system, i.e. its ability to sustain a flow of diverse products and services that poor people depend upon, and to do so under constantly changing conditions. Research will need to strengthen the farmer's ability to manage a broad range of production factors, thus increasing his/her flexibility and ability to respond to exogenous influences. Considerable focus will be on managers themselves, helping them to achieve skills and acquire the technologies that will enhance control over their own destinies. Thus, many interactions have to be addressed. These include: direct interventions to improve the status of the natural resource base, strengthening farmer knowledge and skills, improving organizational linkages that promote better learning and sharing of ideas between the R&D community and the end-user/beneficiaries, support to micro-finance and formal credit schemes, and improving access to input and output markets. However, ICRISAT cannot and must not attempt to address all these issues as an Institute on its own. ICRISAT scientists must continue to foster and broker partnerships that provide synergies to our core mandate, thus leading to greater global impacts.

A vision and strategy for ICRISAT-Asia to 2015

ICRISAT, as the apex dryland agricultural research organization for the global SAT areas in the Alliance of Future Harvest Centers, seeks in this document to refine its strategic thinking towards 2015 from 2010. More so, ICRISAT wishes to exemplify the importance and growing vulnerability of its mandated area – the SAT which is home to a substantial majority of the world's truly poor people (mostly in sub-Saharan Africa and south Asia) where population growth rates remain very high and the vulnerability of agriculture to the vagaries of weather and the potential of further climate change is high. Additionally, it wishes to articulate more clearly its alignment with the MDGs, CGIAR strategic directions and the new CGIAR System priorities. These are seen to be the necessary basis for future medium term planning (following the Governing Board's advice in September 2005). These are viewed presently as suitable frameworks on which a robust research strategy can be formulated to account for changes in the likely external environment for the foreseeable future.

Likewise, some refinement in earlier thinking is appropriate and timely in response to increasing globalization of markets, greater environmental insecurity, lower prices for agricultural commodities and higher fuel prices, new intellectual property right regimes, the growing importance of new research partnerships in the environment, health, ICT/KM and private sectors and finally the emergence of the Future Harvest Alliance (including associated centers such as AVRDC, IFDC) as a major driver in concerted research actions.

As an offshoot of the 2003 External Program Review recommendations, ICRISAT's administrative and executive structure was re-organized to give greater emphasis and devolution of authority to regional programs while still retaining four global themes to ensure, and more fully exploit, the international public goods nature of the Center's research output. Hence, ICRISAT's work is now planned and executed in three principal regions – West and Central Africa (WCA), Eastern and Southern Africa (ESA) and Asia and integrated by global research themes. The regions and the themes seek to maximize the synergies which can be found between their activities. This is coordinated through the office of the DDG Research via the Global Research Committee and is clearly evident in the attendance of all the Research Committee members at all regional and global annual in-house reviews and planning meetings. In addition, synergy is also facilitated by the membership of all global theme leaders (wherever based) on the respective regional research coordination committees.

In refining its new strategic thinking, ICRISAT has adopted a fully participatory solicitation of partner opinion that is reflected in the diversity of regional and disciplinary emphases. These are expressed in seven supplementary documents that include separate strategic papers for the three ICRISAT regions – WCA, ESA and Asia (this document) and for the four global themes – Institutions, Markets, Policy and Impacts (IMPI), Biotechnology (Biotech), Crop Improvement (CI) and Agroecosystems (AE). ICRISAT seeks to derive additional positive synergies from its new structural arrangements which give it the ability to act regionally and yet produce IPGs that have global impact. This type of regional/global matrix structure allows the institution to derive maximum benefit from its research investment from local-national-regional-global levels. ICRISAT seeks positively to maximize the spillovers of research knowledge from Asia to Africa and from Africa to Asia and at the same time to link its disciplinary efforts at both regional and global levels. Not only does ICRISAT wish to operate effectively at all geographic scales within its mandate area but it also intends to position itself broadly throughout the research for development spectrum. This implies both the production of upstream science and the conduct of more downstream research activities which can more directly facilitate development impact. For ICRISAT, the advantage of being broadly positioned on the research for development spectrum means that potential bottlenecks to the emergence, or application, of research outputs can be directly forestalled by ICRISAT, thereby preventing such constraints from jeopardizing fruitful outcomes from our research with our key partners.

In addition in 2001, ICRISAT completed a major, long-view research report on the "Future Challenges and Opportunities for Agricultural Research and Development in the Semi-arid Tropics" (Ryan and Spencer 2001) that details the dimensions of poverty and the dynamics of agriculture throughout the SAT. The findings of this study, along with the CGIAR's Seven Planks mission statement, guided ICRISAT's deliberations as it charted a new vision and research strategy for the next ten years (ICRISAT 2002).

Agriculture in SAT Asia

The semi-arid tropics (SAT) covers parts of 55 developing countries where the 75-180 day growing period has a mean daily temperature of more than 20 degrees Celsius. Based on 1996 statistics, the SAT is home to about 1.4 billion people, of which 560 million (40%) are classified as poor, and 70% of the poor reside in rural areas (Ryan and Spencer 2002). *To clarify in layman's terminology*: The semi-arid tropics have very short growing seasons, separated by very hot and dry periods in which growth without irrigation or stored soil moisture is impossible. Natural soil fertility is often low and pest and disease pressure can be intense. Farmers face further substantive risks, even within the growing season, as there are irregular periods of drought and high evaporative demand which can seriously compromise crop productivity. Though the environments of the SAT across continents have many similarities which are the *raison d'etre* of ICRISAT's existence, the differences among regions are also of great importance for planning purposes and thus ICRISAT has deemed that research planning is most appropriate starting from a regional level that is coalesced at the global level. As such, a discussion of the research context at the regional level follows in this document in order to encapsulate the logic for ICRISAT's current regional organizational structure.

Human well-being in the rural areas of SAT Asia remains highly dependent on agriculture and related employment possibilities. Access to productive assets (e.g., land) and new technologies is very crucial for equitable growth and sustainable food security. Under the influence of population growth and stagnation of the non-agricultural sector, land-person ratios have been declining progressively. Intensification of crop production and transformation of subsistence-oriented agriculture into more viable family farms through the adoption of green revolution technologies has counteracted this process of land scarcity in many more-favored regions. In the SAT and many less-favored regions, such transformation of subsistence agriculture has not occurred. This means that the rate of productivity growth in rainfed agriculture has been much lower than in irrigated regions.

Sorghum and millet are important grain crops of SAT Asia. Over the last three decades, the area planted to both crops has fallen by nearly one third. The area under rainy-season sorghum fell by nearly one half, while that under postrainy-season sorghum remains essentially the same. But there were productivity gains so that the production of these grains reduced less sharply. The area under other important SAT crops like pigeonpea, chickpea and groundnut has remained consistent during this period. Except for chickpea, the yield increases have been less sharp in these crops. New crops like maize, soybean and cotton have become popular in the SAT areas mainly because of their rising market demand.

The area under irrigation has increased even in the SAT areas and the irrigation coverage of traditional SAT crops has increased considerably. Crops like wheat, rice and vegetables have gained in area because of expansion of irrigation. Livestock enterprises have become more important contributors to the incomes of farm families. Besides the diversification of agriculture, the livelihood opportunities have also become more diversified due to opportunities thrown open in the non-farm sector. However, land degradation and ground water depletion have eroded the asset base of farmers considerably. They face rising costs of water exploration even to maintain the areas under irrigation.

On the whole, Asia has achieved impressive gains in food production, food security, and rural poverty reduction since the 1960s. Heightened intensification of agriculture through use of irrigation, fertilizers, and pesticides combined with high-yielding varieties and, in some countries, continued price support for the key cereals – rice and wheat – and subsidization of electrical power costs in more-favored, high-potential zones were, and continue to be, the major driving forces for this success.

However, many regions in less-favored, rainfed areas such as much of the SAT have not benefited enough from this process, and there is emerging pessimism among the world community that the MDGs may not be achieved by 2015. Evidence from literature suggests there have been sweeping changes in the village economies of the more favored regions of Asia in the last few decades, justifying a reassessment of R&D priorities in regions that have been bypassed. Although poor net food buyers in SAT Asia have also benefited from low food prices resulting from increased surplus in more-favored regions, small farmers in the less-favored regions with low crop yields and high costs of production have been adversely affected.

Contemporary issues, challenges and opportunities

Low productivity and rural poverty

Low productivity of SAT agriculture coupled with widespread poverty, water scarcity, degradation of natural productive resources (land and biodiversity), and a changing global environment are marginalizing agriculture and livelihoods in the Asian SAT. The emerging evidence of higher impacts on poverty as well as higher marginal productivity gains from public investments, particularly in roads, markets, information technology and research in the less-favored regions, suggests the need to prioritize these overlooked areas in terms of technology, institutions, and policy.

Food insecurity and malnutrition

Despite the surplus reserve of grains, food insecurity and child malnutrition in SAT Asia remain at unacceptably high levels, both in favored and less-favored areas. Owing to the high levels of population growth and unequal access to productive assets, the gains from productivity growth in agriculture were not sufficient to bring down the levels of poverty. In 1999, South Asia alone accounted for over one half of the 1.1 billion poor people living in the developing world. India alone contributes over 70% of the absolute poor in South Asia and about one-third of the absolute poor in the developing countries. The incidence of poverty in the region ranges from 35% in India and Pakistan to 42% in Nepal. About three-fourths of the poor in the South Asian region are concentrated in rural areas. There is a paucity of data on spatial distribution of poverty based on the potential of agricultural land. More detailed poverty mapping needs to be carried out for a complete understanding of the concentration of poverty, its spatial distribution and the associated socioeconomic and biophysical factors that may explain the distribution.

South Asia alone accounted for almost all (236 of the 237 million) of the rural poor in SAT Asia and about 63% of the rural poor in the SAT worldwide. This also indicates that about 50% of the abject poverty in South Asia is concentrated in the SAT. There is shortage of data on the relative incidence of poverty within the rural populations in more-favored and less-favored regions. We may hypothesize that the relative incidence and depth of poverty is higher in marginal areas where the productivity of land is low, market access is limited and opportunities for non-farm employment are scarce.

Asia is the most populous and diverse continent in the world. Semi-arid tropical areas in Asia are largely concentrated in India, with some small areas distributed in Pakistan, Myanmar, Thailand, Yemen and Indonesia. South Asia, which has most of the SAT area, had a per capita availability of only 163 kg of cereals, 22 kg of roots and tubers, 27 kg of sugar, 11 kg of pulses, 8 kg of vegetable oils, 5 kg of meat and 68 kg of milk per year during the triennium 1997-99. East Asia scored better with a per capita availability of 199 kg of cereals, 66 kg of roots and tubers, 12 kg of sugar, 2 kg of pulses, 10 kg of edible oils, 38 kg of meat and 10 kg of milk. In terms of per capita daily consumption, South Asia consumes only 2403 calories as against 2921 in East Asia, 2681 in the developing countries and 2803 in the world. India's SAT areas have the highest poverty incidence of 24% when compared to other agro-climatic regions. South Asia accounts for the highest number of people earning less than $1 a day among all the regions of the world.

Water scarcity and resource degradation

Agriculture and livelihoods in the SAT have 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 fertility of soils (largely related at present to micronutrient deficiencies as N and P fertilizers are widely used). The limited fresh water availability and seasonal variation and unreliability of rainfall make agriculture in the semi-arid regions inherently risky. In rainfed systems of the SAT, the constant risk of drought increases the vulnerability of livelihoods and decreases human security. Since water is vital for crop growth, the low and unreliable rainfall in the SAT for rainfed agriculture makes drought management a key strategy for agricultural development in these regions. Apart from the tightening water scarcity constraint, degradation of soil resources (due to salinization, waterlogging, soil erosion and nutrient depletion) threatens livelihoods and sustainability of food production across the SAT region.

Globalization and marginalization

With increasing strides towards globalization of markets through domestic market reforms that encourage integration and liberalization of import and export markets, production efficiency and competitiveness of agricultural products within the domestic market and international markets is becoming an important policy issue in the agricultural sector. In the past, macroeconomic policies and R&D investments in many developing countries targeted food security and self-sufficiency in major food products. With increasing openness in the global economy, national self-sufficiency may not be a viable development strategy, as certain food products may be cheaper to import than to produce domestically. However, considering agriculture's role as a means of livelihood for millions of poor people, enhancing its competitiveness by cutting average costs of production is critical for the survival of many smallholder farmers.

Accessing domestic and global markets requires investment in new cost-reducing or yield-enhancing technologies as well as basic marketing infrastructure. Investments in irrigation to boost yields and reduce production risk, extension services, supply of credit facilities, and required inputs at the right time to supply the desired high quality and competitive products is essential for competitiveness of production. Identifying niche markets and comparative competitive advantages and harnessing such niches are challenges to many poor nations lacking the requisite human, organizational and technological skills. For countries lagging behind in terms of technological advances and development of efficient market structures, there is a risk that globalization may lead to further marginalization and poverty. Similarly, without adequate investment in productivity-enhancing technologies and basic infrastructure and human resources, less-favored areas poorly serviced in the past in terms of these investments, may lose out even further as agricultural markets become more liberalized and competitive. This means that globalization and increased market liberalization could further marginalize these areas, potentially leading to worsening poverty and environmental degradation.

Chapter 2: ICRISAT's Task Environment

As ICRISAT maps out its vision and strategy to 2015, there are a number of significant developments that must be reckoned with in its rapidly changing task environment. Foremost among these are the attainment of the Millennium Development Goals and the Systemwide research priorities to 2015. As a proactive organization, ICRISAT recognizes the influence of these developments and has considered them in charting its research direction.

The Millennium Development Goals

Background

In September 2000, member states of the United Nations (UN) unanimously adopted the Millennium Declaration - a common commitment to end global poverty and suffering. Following consultations among international agencies, including the World Bank, IMF, OECD and specialized UN agencies, the UN General Assembly recognized the Millennium Development Goals (MDGs) as part of the road map for implementing the Millennium Declaration. Endorsed by 189 nations, the MDGs represent broad international consensus. They have also galvanized unprecedented global efforts to meet the needs of the world's poorest.

In general, the MDGs commit the international community to an expanded vision of development which promotes human development as the key to sustaining social and economic progress throughout the world. Recognizing the importance of creating global partnerships for development, MDGs have been commonly accepted as a framework for measuring development progress in the 21st century.

More specifically, the MDGs establish yardsticks for measuring results, not just for developing countries but also for rich countries that help to fund development programs and for the multilateral institutions that help countries implement them. The first seven goals are mutually reinforcing and are directed at reducing poverty in all its forms. The last goal -- global partnership for development -- is about the means to achieve the first seven.

Summary of the MDGs

The MDGs set 8 goals, 18 targets and 48 performance indicators on poverty reduction, including income and other measures of human well-being. The goals and corresponding targets are indicated below.

1. Eradicate extreme poverty and hunger:
    - Reduce by half the proportion of people living on less than a dollar a day
    - Reduce by half the proportion of people who suffer from hunger
2. Achieve universal primary education:
    - Ensure that all boys and girls complete a full course of primary schooling
3. Promote gender equality and empower women:
    - Eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015
4. Reduce child mortality:
    - Reduce by two thirds the mortality rate among children under five

5. Improve maternal health:
   - Reduce by three quarters the maternal mortality ratio

6. Combat HIV/AIDS, malaria and other diseases:
   - Halt and begin to reverse the spread of HIV/AIDS
   - Halt and begin to reverse the incidence of malaria and other major diseases

7. Ensure environmental sustainability:
   - Integrate the principles of sustainable development into country policies and programs; reverse loss of environmental resources
   - Reduce by half the proportion of people without sustainable access to safe drinking water
   - Achieve significant improvement in lives of at least 100 million slum dwellers, by 2020

8. Develop a global partnership for development:
   - Develop further an open trading and financial system that is rule-based, predictable and non-discriminatory, includes a commitment to good governance, development and poverty reduction— nationally and internationally
   - Address the least developed countries' special needs. This includes tariff- and quota-free access for their exports; enhanced debt relief for heavily indebted poor countries; cancellation of official bilateral debt; and more generous official development assistance for countries committed to poverty reduction
   - Address the special needs of landlocked and small island developing states
   - Deal comprehensively with developing countries' debt problems through national and international measures to make debt sustainable in the long term
   - In cooperation with the developing countries, develop decent and productive work for youth
   - In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries
   - In cooperation with the private sector, make available the benefits of new technologies—especially information and communications technologies.

New CGIAR Systemwide Priorities to 2015

Background

At the CGIAR Annual General Meeting in 2005, the CGIAR adopted a new set of research priorities for the System. Spearheaded by the Science Council, priority setting resulted in a set of 20 research themes, bundled within five priority areas. On the whole, the priorities provide a set of specific goals for research activities around which the Centers will organize their scientific and related capacities.

The new priorities were selected on the basis of: (1) expected impact on poverty alleviation, food security and nutrition, and sustainable management of natural resources, taking into account the expected probability of success and expected impact if successful; (2) degree to which the research provides international public goods; and (3) existence of alternative sources of supply of the research and the CGIAR's comparative advantage in undertaking the research.

Part II of this document shows in detail how ICRISAT has aligned its research strategy to 2015 with the new CGIAR Systemwide priorities as shown below.

The new CGIAR Systemwide priorities

Priority area 1: Sustaining biodiversity for current and future generations:

a. Promoting conservation and characterization of staple crops
b. Promoting conservation and characterization of underutilized plant genetic resources
c. Promoting conservation of indigenous livestock
d. Promoting conservation of aquatic animal genetic resources

Priority area 2: Producing more and better food at lower cost through genetic improvements:

a. Maintaining and enhancing yields and yield potential of food staples
b. Improving tolerance to selected biotic stresses
c. Enhancing nutritional quality and safety
d. Genetically enhancing selected high-value species

Priority area 3: Reducing rural poverty through agricultural diversification and emerging opportunities for high-value commodities and products:

a. Increasing income from fruit and vegetables
b. Increasing income from livestock
c. Enhancing income through increased productivity of fisheries and aquaculture
d. Promoting sustainable income generation from forests and trees

Priority area 4: Promoting poverty alleviation and sustainable management of water, land, and forest resources:

a. Promoting integrated land, water and forest management at landscape level
b. Sustaining and managing aquatic ecosystems for food and livelihoods
c. Improving water productivity
d. Promoting sustainable agro-ecological intensification in low- and high-potential areas

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

a. Improving science and technology policies and institutions
b. Making international and domestic markets work for the poor
c. Improving rural institutions and their governance
d. Improving research and development options to reduce rural poverty and vulnerability.

Implications for ICRISAT's strategy and resource allocation

As the foregoing discussion implies, the task environment in which ICRISAT operates has significantly changed over the past several years. The MDGs have tremendously broadened the agricultural research agenda from increasing food supply to embrace poverty and hunger reduction, environmental sustainability and social issues such as gender equality, health and nutrition.

Likewise, the CGIAR vision and strategy indicate a strong imperative for ICRISAT to adopt a people and poverty focus, mobilizing new science tools, addressing sub-Saharan Africa, follow a regional approach to research planning, establish strategic partnerships and assume a catalytic role in technology exchange. In the same manner, the new CGIAR research priorities require that ICRISAT thematic and regional strategies be aligned with sustaining biodiversity, producing more, better and cheaper food, feed and fuel, reducing rural poverty, sustainable natural resource management, improving policies and facilitating institutional innovation.

With the recognition that ICRISAT's research strategy can contribute substantially to MDGs 1 and 8 and more indirectly to the remaining goals, it is appropriate that ICRISAT's vision and mission are in accordance with the mainstream of those of other research and development agencies though it is clear that our principal contribution would be in the area of assisting in the insurance of food and nutritional security. It is also appropriate that the attainment of ICRISAT's goal would be a substantial contribution to the attainment of the CGIAR System's overall goal. This assumes that the research carried out by the CGIAR and its partners continues to improve the livelihood of low-income people in developing countries through reduced poverty, food insecurity, eradicating malnutrition, gender inequality and child mortality, to help cope with HIV/AIDS and to foster better institutions, policies, and sustainable management of natural resources of particular importance to agriculture and poor people.

During the past decade, publicly funded agricultural research has declined by over 50%. The private sector has assumed an increasing share of agricultural research and ownership of new technologies, leading to a gradual convergence of the public sector's pro-poor development goals and private sector commercial interests. The emergence of global markets, biotechnology and information and communication technologies (ICTs) have a strong influence in changing the strategic direction of ICRISAT's research.

These changes are happening at a time when international agricultural research is seeing the emergence of a new set of institutional arrangements where public-private partnerships are mainstreamed towards a new vision of agriculture and rural development. Similarly, new patterns of accountability and governance are changing the role of agricultural research institutions and their relationships with civil society. Now that the solid foundations of the Future Harvest Alliance are established, ICRISAT will pursue its new vision and strategy within the collective action framework of the 15 Centers in the CGIAR. Moreover, it will undertake its research efforts, where possible, in as participatory a manner as possible. It will seek to build new strategic partnerships or alliances and generate as much community support for its research agenda as it can. ICRISAT believes that this type of people- and partner-based approach can lead to the rapid and effective attainment of its development-oriented goals.

Starting in 2006, ICRISAT seeks annually to effectively allocate $10 million for its new Asian strategy and by 2015, this may be approaching $17 million. Since this is a large annual investment, ICRISAT recognizes the importance of rigorous research prioritization. This is clearly indicated in its series of rolling medium term plans (MTPs), of which the ones for 2007-2009, 2008-2010 and 2009-2011 has been prepared to help pursue this strategic plan. Currently (2007-2008), about 46% of resources are invested in biotechnology and crop improvement, 32% in agro-ecosystems,15% in institutions, markets, policy and impacts and 7% in knowledge management and sharing etc. This level of investment based on themes will, more or less, continue for the next three years and depending on institutional priorities and new global developments, may change over time.

ICRISAT Long Term Visioning Initiative

The development of ICRISAT's long term vision and strategy to 2015 generated contributions from all global themes and regions, whereby a total of seven regional and global research strategies evolved to reflect regional needs and global priorities. This was simultaneously complemented by an assessment of the Institute's overall strengths, challenges, opportunities and threats (SCOT) through a participatory visioning exercise designed to encompass the wide-ranging perspectives of ICRISAT stakeholders and pressing issues both in research and research management. An open-ended questionnaire was developed for the SCOT survey to elicit responses from scientists and stakeholders across all locations. The exercise provided an avenue to "think out of the box" in identifying priorities and new innovations within the context of the environmental and socio-economic-political concerns especially affecting the semi-arid tropics.

Chapter 3: Vision, Mission, Goal and Strategy

ICRISAT's regional vision, mission and goal

Vision

Improved well-being of the poor of the semi-arid tropics in Asia.

Mission

To reduce poverty, enhance food and nutritional security and protect the environment of the Asian semi-arid tropics by helping empower the poor through science with a human face.

Goal

To mobilize cutting edge science and institutional innovations for poverty alleviation, food security, human development and environmental protection for poor rural families in the semi-arid farming systems of Asia.

ICRISAT will pursue the foregoing goal by enhancing the livelihoods of the poor in semi-arid farming systems through integrated genetic and natural resource management strategies**.** ICRISAT will make major food crops more productive, nutritious, safe and affordable to the poor; diversify utilization options for staple food crops; develop tools and techniques to manage risk and more sustainably utilize the natural resource base of semi-arid tropics systems; identify opportunities to diversify income sources and strengthen delivery systems. Partnership-based research for impact, gender sensitivity, capacity building and enhanced knowledge and technology flows are integral to this goal. ICRISAT will provide custodianship to six mandate crops and improve germplasm and options for the diversification of SAT farming systems that will contribute to the development policies of national, sub-regional and regional institutions and donors aimed at meeting the MDGs.

ICRISAT's intermediary goals or global impact target areas (GITAs) have been repositioned along the new discipline-based Systemwide priorities. ICRISAT's GITAs are based on more generic cross-disciplinary research for development concepts as stated below:

1. *Generating profits and reducing risk:* Reducing poverty through improvement and diversification of crop-livestock systems and enhancement of income generation opportunities from trade and commercialization (incorporated under System Priorities 2, 3 and 5);
2. *Nourishing families and agro-enterprises:* Food and nutritional security and human and livestock health improved through increased agricultural productivity, gender-sensitive interventions and better food/feed quality (incorporated under System Priorities 1, 2, 3 and 5);
3. *Enhancing livelihood and ecosystem resilience:* Impact of acute and chronic crises from conflict, drought, desertification, degraded environments, and pests mitigated in smallholder agriculture with a view to facilitate long term recovery and enhance self-reliance (partially incorporated under System Priorities 2, 4 and 5);
4. *Building partner power:* R&D partners empowered through enhanced and relevant skills that include the ability to prioritize and implement interventions and predict trends (partially incorporated under all five System Priorities).

Overall strategy

ICRISAT adopts integrated genetic and natural resource management (IGNRM) as its overarching research strategy to attain scientific excellence in agriculture in the semi-arid tropics, focusing on key livelihood and income opportunities to improve the well-being of the poor with equity, multidisciplinarity, sustainability and community participation as core principles.

ICRISAT's vision and strategy is guided by the MDGs, seven planks of the CGIAR vision and strategy; new Systemwide priorities; its core competencies and thematic comparative advantages; strategic analysis of opportunities in the SAT regions; and the new setting for international agricultural research and its impact on the livelihoods of the poor.

ICRISAT's strategic focus is to attain impact through scientific excellence in agriculture in the semi-arid tropics. This vision and strategy targets key opportunities for improving the well-being of the poor, with food security being fundamental. Above all, it recognizes the need for greater thematic integration and diversification of partnerships as a core principle for engaging in science and technology for development. This ensures that its deliverables improve the lives of poor people.

As an innovation-driven organization, ICRISAT will facilitate institutional linkages among research, extension, farmers and markets that will enhance its impact in reducing food insecurity and poverty. Along with this, we will further intensify our linkages with a wide range of strategic partners which include the Future Harvest Alliance, advanced research institutes, regional and sub-regional organizations, NARES, the private sector and civil society organizations. Priority setting, impact assessment and the conservation and strategic use of biodiversity will also be put into the mainstream. In addition, ICRISAT will integrate its research with other fields of development such as education, human health, nutrition, energy and water quality.

ICRISAT recognizes that by 2015, a very significant percentage of the world's poor will be living in urban environments. Even today, urban agriculture is a significant activity that enables many impoverished urban dwellers to improve their livelihoods through the production and sale of commodities such as vegetables, fruits, meat and milk. ICRISAT's mandate crops *per se* do not, however, have a major place and comparative advantage in urban agriculture. Whilst the CGIAR as a whole is addressing this issue through its Urban Harvest system wide initiative, we will maintain our focus on rural agriculture. There will, however, be instances where there are substantive interactions between rural and urban agriculture and where opportunities for rural income generation exist within such interactions. One important example is the rural production and sale of fodder for urban livestock enterprises. In such examples, ICRISAT will undertake the studies necessary to fully exploit such opportunities.

ICRISAT recognizes that its vision and strategy must be anchored on demonstrable action. This will be achieved through the adoption of the five new CGIAR Systemwide priorities as the 'ribs' around which the 'flesh' of our global research and regional strategies will be attached. Consistent with the position of the Future Harvest Alliance, ICRISAT's vision and strategy straddles the research to development continuum, generating IPGs globally and doing downstream research as a bridge, broker and catalyst to attain more impacts. Moreover, ICRISAT is confident that its adoption of IGNRM as an overarching principle to its strategy is an effective and necessary approach if our science is to have the global impact on development which it merits within the context of current global complexity.

The four global research themes and three regional strategies have been integrated to help ICRISAT refocus its efforts to the needs of smallholder farmers and development partners in SSA and Asia and help achieve the MDGs (Table 1). Global action which will pursue ICRISAT's research strategy anchored on the new CGIAR Systemwide priorities is further detailed in this document.

Table 1. Achieving the Millennium Development Goals through ICRISAT's research.	
MDGs	ICRISAT's research thrust
1. Eradicate extreme poverty and hunger.	The semi-arid tropics (SAT) is home to more than 800 million poor. ICRISAT contributes to improved food security, livelihood resilience and poverty reduction in this agro-ecological zone through its Integrated Genetic and Natural Resource Management and people-oriented, partnership-based research. ICRISAT's research outputs empower the poor to mitigate market and non-market generated shocks, inequalities and risks.
2. Achieve universal primary education.	ICRISAT's impact-oriented research endows farmers with innovations that facilitate risk reduction, income diversification, ensure better quality of marketable products and commercialization strategies. These lead to higher incomes and consequently greater investment in children's education. With more efficient technologies at their disposal, stakeholders have the time to acquire primary education.
3. Promote gender equality and empower women.	With the feminization of agriculture and poverty in the SAT, ICRISAT acknowledges the contribution of men and women in decision making. With its gender-sensitive innovations, skills and knowledge, ICRISAT makes SAT farming systems more efficient, thereby empowering women to pursue profitable on-farm and off-farm activities.
4. Reduce child mortality.	Child mortality can be reduced considerably with nutritious crops. ICRISAT's improved cultivars and integrated crop management technologies produce more nutritious crops. Eating nutritious and safe cereal grains and legumes protect the most vulnerable, especially children, from hidden hunger and malnutrition.
5. Improve maternal health.	Nutritious cereals (sorghum and millet) and legumes (pigeonpea, chickpea and groundnut) and mycotoxin-free foods contribute to enhanced maternal health, ensuring that poor pregnant and lactating women get the right quality of food. ICRISAT's research on women's social networks identifies entry points for better access to markets and health services.
6. Combat HIV/AIDS, malaria and other diseases.	ICRISAT's village-level studies identify intervention points at which agricultural innovations, policy and practice help prevent and mitigate shocks at the village level such as HIV-AIDS. Likewise, ICRISAT's research on controlling aflatoxin contamination leads to safer and more nutritious food through genetic enhancement and helps people challenged by HIV-AIDS.
7. Ensure environmental sustainability.	ICRISAT promotes integrated pest and disease management methods that improve the soil and are environment-friendly and affordable to poor farmers. Research on carbon sequestration contributes directly to fertility replenishment in depleted soils. Moreover, *in situ* conservation of locally relevant biodiversity improves adaptation in stressed environments of the SAT.
8. Develop a global partnership for development.	ICRISAT works through strategic partnerships with diverse sectors, like the Future Harvest Alliance, advanced research institutes, regional and sub-regional organizations, NARS, international and national civil society organizations and the private sector through its Agri-Science Park.

Thematic goals and strategies

Institutions, markets, policy and impacts

In keeping with recent recommendations of our external reviews, ICRISAT focused research programs through four global research themes, one of them being Institutions, Markets, Policy and Impacts (earlier known as SAT Futures and Development Pathways). The theme's objective is to inform and provide strategic direction and prioritization of research issues within an IGNRM context and to provide appropriate capacity building. It scrutinizes the key driving factors influencing farmer to market linkages, optimal input and output options (including seed systems) and on more effective policy and impact generation. The poor face a wide range of social and economic constraints, so we maintain constant communication with them to understand their needs and seek solutions. In addition, following subsequent Governing Board advice in September 2005, ICRISAT reviewed its priorities to ensure that they are closely aligned with the CGIAR Systemwide priorities.

Goal and purpose

The goal of the Global Theme on Institutions, Markets, Policy and Impacts is to help generate policies, tools, lessons, and investment guidelines that contribute to improved food security, livelihood resilience and poverty reduction while protecting the environment of the production systems in the semi-arid tropics.

Towards this, the theme aims to facilitate:

- Adoption and implementation of new tools, policy recommendations and best practices by researchers and policymakers in the SAT to make efficient choices in support of SAT agriculture;
- Adoption of alternative risk reducing, income diversification and commercialization strategies and innovations for improved livelihoods by SAT farmers; and
- Utilization of innovation systems (institutional arrangements, alliances, and monitoring and evaluation) by researchers in the NARS, IARCs and other actors in the research for development continuum to promote learning and impact.

Strategy

The Global Theme on Institutions, Markets, Policy and Impacts will generate and share vital information and analytical tools that will provide a rational foundation for decisions that affect the welfare of farmers and consumers in the semi-arid tropics. It will widen and expand the scope of village level studies in Asia to contribute to research relevance and policy formulation

It will continue to build from ICRISAT's strong socio-economics and policy research experience rooted in a long tradition of working at the farm level through Village Level Studies and Impact surveys. It will further strengthen participatory and multi-disciplinary approaches to ensure that ICRISAT addresses the urgent concerns in SAT agriculture and the changing external environment both at the micro and macro levels. It will complement the micro-level analysis of village level databases with the analysis of macro-level data for policy formulation and development of research priorities.

Likewise, it will further intensify innovative partnerships with the NARS and other stakeholders to effectively contribute to the global research agenda by complementing national programs to improve the well-being of SAT populations in Asia.

Biotechnology

ICRISAT believes in the potential of biotechnology to enhance the speed, precision, efficiency and value addition in many aspects of its crop improvement and IGNRM efforts. This is especially true in addressing the complex traits that have remained intransigent to conventional breeding approaches. In addition, many of the crops under ICRISAT's mandate have had little attention paid to them, especially in the biotechnology arena, and thus it is critical that ICRISAT continues to focus efforts on these so that our clients and partners can reap the benefits of modern scientific solutions to their problems.

ICRISAT's Global Theme, "Harnessing Biotechnology for the Poor'' was established in 2001 to provide a concerted effort in the application of modern science for its mandated crops. A multidisciplinary team of scientists assigned to the theme provide expertise in both the laboratory and field aspects of biotechnology applications to crop improvement.

A major challenge for the theme is to maintain a critical mass of scientists across the various areas of biotechnology, to coordinate ICRISAT's activities between its regional laboratories in Asia and Africa, and to evaluate the rapidly changing technologies in genomics, adopting those that will enhance the effectiveness of ICRISAT's research projects. Capacity development is therefore an important dimension of GT Biotechnology's efforts.

Goal and purpose

The overall goal of the Global Theme on Biotechnology is to reduce poverty, hunger, malnutrition and environmental degradation in the SAT by applying promising genomic, genetic engineering, wide-hybridization, diagnostic and bio-informatics tools and approaches to the improvement of ICRISAT's mandate crops.

In our efforts to reach the above goal, we will focus our strategic direction to:

- Improve the efficiency, effectiveness, speed and precision of plant breeding for abiotic stress tolerance, pest and disease resistance, better agronomic traits, and improved food, feed and fodder quality; and
- Develop diagnostic tools for the detection of viral infections, toxic contaminants in crops and crop-based products, presence of transgenes, and purity of seed production systems.

Strategy

ICRISAT's scientific team has made great progress in the adoption and application of various tools and techniques of biotechnology. To ensure that the above objectives are met during the next strategic period, scientists in ICRISAT's Global Theme on Biotechnology will continue to evaluate advances in modern science and acquire, adapt and apply the most relevant of these in their research programs.

Biotechnology is a broad field, and ICRISAT employs techniques in many areas. These include the more traditional technologies such as the use of tissue culture for embryo rescue of wide-cross hybrids and immunological methods for antibody production; modern genomic technologies such as structural and functional genomics to identify, isolate and manipulate genes for traits of interest; and genetic engineering to introduce novel genetic variability for traits lacking sufficient inheritable diversity. In addition to these technologies, ICRISAT employs a bioinformatics platform to provide the necessary links, databases and analysis tools to ICRISAT's researchers and partners.

As being done at present, specific target traits and crops will be determined in collaboration with the Global Theme on Crop Improvement and with ICRISAT's various partners. These close interactions will ensure that the highest priority traits are being addressed in each crop, as well as the most appropriate technologies are being used in each case.

Towards 2015, the Global Theme will pursue strategies to ensure that the necessary tools and techniques are available for ICRISAT and its partners to use in their efforts to develop improved crop varieties for the SAT. These strategies will be used to provide the required biotechnology-based inputs to meet the outputs outlined under the CGIAR Systemwide priorities 1 and 2. Further details on the specific goals, outputs, outcomes and impact pathways can be found later in this document.

Crop improvement and management

The world's earliest crop improvement pioneers were the farmers who domesticated and improved yield and quality traits in crop plants. From then on plant breeders have continued their efforts to enhance productivity, improve quality, and diversify the uses of crop plantsIn order to address ICRISAT's vision and strategy to 2015 and to significantly contribute to the MDGs, particularly those addressing poverty, hunger, health, gender and environmental sustainability, there is a need to further enhance not only crop productivity and production, but also the quality of food, feed and fodder and where possible, reduce the cost of production.

The Global Theme on Crop Improvement and Management encompasses genetic resources and crop improvement to develop improved cultivars; provide eco-friendly pest and disease management options; and technologies to promote alternative uses of crops to encourage value-addition and commercialization. Improved crop cultivars (seed-based technologies) within an IGNRM context are the cheapest and easiest of technology interventions that can be easily adapted and adopted by farmers anywhere in the world.

Research is conducted in the three ICRISAT mandate regions [(Asia, Eastern and Southern Africa (ESA), and West and Central Africa (WCA)], catering to the needs of the national programs in the regions. A global project addresses collection, conservation, exchange and utilization of genetic resources in all the three regions. Therefore, each region has aA Regional Project each in ESA and WCA addressing the priority needs of the regions., Thus there are three regional projects – one each in Eastern and Southern Africa, West and Central Africa and Asia dealing with genetic improvement and diversification, pest and disease management, and where required, post-harvest utilization. In Asia there is a regional project to develop improved open-pollinated varieties of cereals and legumes, and another project to develop improved hybrid parents in sorghum, pearl millet and pigeonpea. Capacity development is an important consideration in all regional projects.

Goal and purpose

To contribute to improved food security and livelihoods by enhanced crop production and environmental protection catalyzed by improved and diversified cultivars, eco-friendly and cost-effective pest and disease management practices, efficient seed systems, and diversified and alternative uses of crop produce.

To achieve the foregoing, our strategic focus will be to:

- Collect, conserve, characterize and share germplasm within the global R&D community;
- Undertake genetic diversification and enhancement of ICRISAT mandate crops for high and stable grain, fodder yield with improved quality and high bioethanol production potential (sorghum);
- Develop cost-effective and eco-friendly integrated pest management (IPM) technologies;

- Address alternative crop produce utilization strategies, including food and feed safety issues, and the prospects for commercialization;
- Increase adoption of improved varieties by farmers through farmer- participatory methods, and sustainable seed-supply systems; and
- Accelerate technology exchange and information sharing, using both conventional methods and information and communication technologies (ICT) for capacity building of partners to achieve on-farm impact, and improve food security and livelihoods of the poor in SAT regions.

Strategy

Towards 2015, genetic diversification and enhancement will be a major thrust of this Global Theme to address the new CGIAR research priorities on sustaining biodiversity and producing more and better food at lower cost. Moreover, it will focus on the development and testing of cutting edge methodologies to enhance effectiveness of breeding technologies with input from GT Biotechnology.

ICRISAT's crop improvement program will pursue a global approach with a regional focus. Since each region has to cater to many countries having varied agro-climatic zones, the emphasis will be on enhancing and strengthening partnerships with national programs where mandate crops are important for national food and nutritional security. Strengthening NARS crop improvement programs and capacity building of partners will be priority, especially in SSA, but also in some of the weaker NARS in Asia.

Research will be carried out by an inter-disciplinary research teams. Often, improved cultivars serve as catalysts for adoption of other technologies (agronomy, fertilizers, etc). Therefore, GT Crop Improvement will work closely with the GT on Agro-ecosystems (soil, water and biodiversity) and the GT on Institutions Markets, Policy and Impacts, to foster the Integrated Genetic and Natural resources Management (IGNRM) approach.

Most of the research activities will be undertaken in partnership with NARS, private sector, research and technology exchange networks, non-governmental organizations (NGOs), advanced research institutions, farmers' organizations, and farmers in the target areas. Technology exchange and capacity building (using both conventional and the emerging information and communication technologies) will be important components in all global and regional projects.

Agro-ecosystem development

ICRISAT has expanded the Integrated Natural Resource Management paradigm to acknowledge the role which crops and genetic improvement can play in enabling SAT agriculture to achieve its potential. There is a growing acceptance of the expanded version of this term to include both genetic and non-genetic solutions – Integrated Genetic and Natural Resource Management (IGNRM).

In response to the recommendations of the 5th External Program Reviews recommendations, core resources have been subsequently redeployed in a phased manner to better address the major challenges in SSA. However, given the availability of opportunities for special project funding in the area of natural resources management in Asia, it was agreed that ICRISAT would continue to pursue these simultaneously and create a self-supporting natural resource management (NRM) team in Asia. In this way, NRM scientists would continue to contribute to ICRISAT's IGNRM new science strategies and draw lessons from long-term development programs in Asia to help translate these for impact in SSA. In addition, they will make substantive contributions to capacity development amongst their partners. This position was strongly endorsed by the 2006 AE CCER.

Goal and purpose

Agro-ecosystem development aims to improve rural livelihoods, increase food security and sustainable natural resource management throughout the semi-arid tropics as a result of a greater impact of agricultural research for development. Moreover, it is committed to help achieve sustainable increases in food security and income growth in the semi-arid farming systems of Asia through the use of evolving research tools and approaches in the fields of soil, water, agro-biodiversity and climatic management (IGNRM). To pursue the foregoing, GTAE will:

- Develop and promote affordable and sustainable soil, water, crop and nutrient management options and integrated approaches to watershed management;
- Identify and promote options for systems diversification (high-value crops, trees and livestock) to improve rural livelihood security;
- Enhance capacity of research and development partners, and regional networks to formulate and implement research for impact;
- Develop and promote appropriate methodologies and approaches for agricultural rehabilitation following natural and/or civil disasters including HIV/ AIDS; and
- Forge strategic partnerships with government agencies, donors, non-governmental organizations, community-based organizations and the private sector to ensure options are tailored to fit farmers' diverse investment and risk management options.

Strategy

Towards 2015, GTAE will develop and promote sustainable IGNRM innovations relevant to the needs of smallholders in the SAT. To pursue this, GTAE will focus on the development of methodologies, approaches and resource conserving technologies and practices.

At national level, ICRISAT will play the role of enabler and facilitator in developing and evaluating IGNRM interventions that will help rural households to better cope with climate variability and alleviate food insecurity. In addition, ICRISATs rich information base and network with IARCs and ARI's will enable it to work closely with ILRI in developing alternative feed/fodder resources within crop-livestock systems.

Towards 2015, GTAE will also serve as a primary and secondary research provider. As a primary research provider, it will develop new science tools such as systems simulation, climate forecasting and farmer participatory approaches that integrate genetic and non-genetic solutions. As a secondary provider, it will support and coordinate the watersheds consortium in India, and the emerging consortium to evaluate the agricultural implications of current climatic variability and planning for future climate change.

ICRISAT, ILRI and IWMI will continue to facilitate the development of collaborative links between SSA and Asia to improve water productivity for food, feed and animal production under smallholder crop-livestock mixed systems (SCLIMS), in the face of water scarcity (including economic) by optimizing water use to sustainably alleviate poverty and enhance ecosystem health in rainfed SSA and India. Much effort has gone into providing livestock drinking water in SSA and South Asia, but this has not been true of water for feed production. Research by IWMI on water productivity, ICRISAT on dryland crops and ILRI on livestock feeds/fodders suggests that under rainfed systems, enhanced water productivity is possible through improvements in water and soil fertility management, agronomic practices such as conservation tillage, and use of improved genotypes of food-feed crops. In most of the semi-arid tropics of Africa and Asia, the nexus between water and feed limitation is the primary constraint to effective livestock production.

ICRISAT continues to work with an ever expanding range of partners from both the public and the private sectors to pursue more participatory strategies, linking on-farm trials with crop systems simulation in order to increase the impacts of soil fertility research. Farmer participation ensures that technology development and testing are based on farmers' needs and perspectives; simulation allows the testing of a wider array of options in different (simulated) seasons and environments. The results continue to be promising, with large yield gains, higher water-use efficiency, and increasing adoption by smallholder farmers when input supply constraints are addressed.

Goal and strategy for knowledge sharing

National agricultural research and extension systems (NARES) are characterized by variability among and within countries and regions with respect to their capabilities in undertaking agricultural RD&E. At present, there is a very strong and persistent need from the NARES for capacity building due to the continued lack of a critical mass and resources to implement strong IGNRM RD&E programs. Hence, increasing demands are being addressed to ICRISAT and other CGIAR Centers to assist in building and/or strengthening national RD&E capacity.

On the whole, ICRISAT has a strong capacity to set trends, organize and share knowledge, provide strategic direction, and enhance the quality of agricultural science and its utilization in the Asian SAT. Amidst the continued decline of core resources, this task is a big challenge which calls for the design, development and upscaling of innovative ways in capacity building. ICRISAT is committed to improve the human and institutional capacity of SAT NARES to conduct agricultural R&D by building partner power through:

- Assessing and addressing partners' training and education needs;
- Enhancing the capacity of partners to conduct joint research on cutting edge concepts, methodologies, and knowledge sharing; and
- Organizing and sharing information, knowledge and best practices on SAT agriculture.

Goal and purpose

ICRISAT envisions a world in which all stakeholders in the agricultural innovation process can easily access and share information, knowledge and skills they need - anywhere and anytime – to enhance the food security and livelihoods of the poor. Hence, ICRISAT is committed to harness innovative tools and concepts in learning, information and communication technologies and knowledge management to build partner power in the SAT.

Strategy

Towards 2015, ICRISAT's strategy for knowledge sharing will be fully aligned with the CGIAR's new research priority on facilitating institutional innovations to support sustainable reduction of poverty and hunger. This will be pursued by generating innovative approaches of linking policymakers, researchers, development workers, farmers, private support providers and other stakeholders of the agricultural innovation process.

The ICRISAT-led Virtual Academy for the Semi-Arid Tropics (VASAT) will be upscaled with partners to enable dynamic linkages among diverse, distributed human and information resources in the SAT. By doing this, ICRISAT will facilitate institutional learning and provide a platform for becoming a leading provider of relevant content through the interface of ICT and open-distance learning. Moreover, VASAT will accelerate pursuit of the CGIAR's ICT-KM strategy of incorporating new practices to preserve, produce and improve access to the agricultural global public goods needed by the poor in developing countries. Linkages will be established with partners such as the Global Open Food and Agriculture University (GOFAU) and national open universities to develop courses in distance mode and other innovative learning opportunities.

Towards 2015, ICRISAT will offer vast opportunities for value-added collaboration among CGIAR Centers as well as with other partners, and will deploy novel platforms for knowledge sharing. ICRISAT will work with partners to enable capacity building within the CGIAR in designing, maintaining and upgrading knowledge management systems. It will also develop expertise in assessing and deploying various connectivity technologies in sharing information and knowledge with remote regions in the SAT.

The future of ICRISAT's mandate crops

SAT agriculture has demonstrated appreciable dynamism, with the growth rate in agriculture production and total factor productivity moderate, if not high. A brief outlook of each ICRISAT mandate crop is presented below (details in ICRISAT, 2004). Cropping pattern shifts are taking place and coarse cereals are being replaced in more favored areas by pigeonpea, chickpea, lentil, sunflower, soybean, and in some places maize. In addition pearl millet hybrids are replacing rainy season sorghum as their grain is less damaged by grain molds and their shorter duration facilitates land preparation for more predictable and remunerative post-rainy season crops, permitting intensification of land use. Dietary changes are significant across all income brackets. Not withstanding this dynamism, production-related risk, poverty, natural resource degradation, and bio-diversity loss persist and are projected to worsen under the impact of globalization, climate change, modernization, and inadequate or ineffective public sector interventions in terms of investment, service and support system.

Increasing population and higher expectations of lifestyle has placed greater demand on increasing crop/animal production and for raising incomes. There is a need for greater attention from the public sector to SAT agriculture as the profits from the small, fragmented markets are often too low to attract attention from the private sector. Improving the efficiency of both the input as well as the output markets would substantially help emerging commercial and semi-commercial farmers in resource poor areas. Combining various enterprises, which can enhance profit-earning opportunities, will help SAT farmers to improve their income and employment levels. Formal and informal extension systems should develop further capacity to render advice to the farmers on new opportunities such as alternative land use and marketing systems, livestock enterprises, and better watershed management practices.

Sorghum:

Sorghum is the world's fifth most important cereal crop; and is traditionally a staple food crop for millions of poor in the semi-arid tropics (SAT) of Asia and Africa. It is the cheapest source of energy, protein, zinc and iron after pearl millet. Sorghum remains an important food crop in the major growing regions in Asia. Of late, sorghum is passing through a transition stage from being a food and fodder crop to an industrially valued raw material in Asia. However, considering the substantial increase in the demand for animal products (meat, milk and eggs) in developing countries by 2020 (Ryan and Spencer 2001) there would be a greater demand for sorghum grain in poultry feed industry and its stover and forage for dairy industry. In addition, sorghum grain has potential for use in producing potable alcohol, and stalks for bio-fuel production. The value-added product diversification of sorghum would, however require innovative institutional and industrial alliances.

Pearl Millet:

Pearl millet is a hardy cereal crop, grown mostly in marginal environments of the arid and semi-arid tropical regions, primarily for grain production. It is also valued for its fodder, the importance of which has been rising in the recent years. The crop residue/straw of dual-purpose pearl millet is an important source of fodder (particularly in low rainfall regions) accounting for 40-50% of the dry matter intake and is often the only source of feed in dry months. Owing to growing demand for milk and meat the demand for crop residues is increasing as reflected in the rising grain to straw price ratio for coarse cereals like sorghum and pearl millet.

Although food use of pearl millet is predicted to decline due to urbanization and income growth, the crop will continue to be an important staple for low-income consumers in the major growing regions in the foreseeable future. There are however, prospects for a rise in demand for processed pearl millet products as urban consumers become more nutrition-conscious. With the on-going livestock revolution, the demand for pearl millet grain in poultry feed, and its straw as well as green forage for dairy animals will continue to rise in the coming decades.

Pigeonpea:

Pigeonpea is grown in many countries, but there are only about a dozen countries where it is grown as a commercial crop. Pigeonpea is a major food legume of the global tropical and sub-tropical regions. It plays an important role in the sustainability of smallholder farming systems in many Asian, African, and Caribbean countries. Its high protein leaves are used as fodder and the dry crushed seeds as animal feed while the dry stems make quality fuel wood. Traditional varieties generally mature in 6-9 months, which restricts its adaptation but newly developed varieties have greater flexibility in maturity which has helped in crop diversification for increased sustainability and profits. Such improved lines are also finding new niches where pigeonpea was never grown in the past. The adoption of new hybrid technology in this crop will surely help in increasing the productivity and profitability of resource poor farmers. Thus, the future of pigeonpea seems bright and the next few years should see a substantial increase in the global pigeonpea production and utilization.

Chickpea:

Chickpea is the second most important food legume in Asia after dry beans in terms of area, production and consumption. Chickpea is an important source of protein, minerals, fiber and vitamins in the diets of millions of people in Asia. The global chickpea demand in 2010 is estimated to be 11.1 million t, an increase of 29% from its current production level of 8.6 million t during 2003-04. Approximately 90% of the additional demand will come from Asia. This likely increased demand is a major challenge to the chickpea scientific community, policy makers and extension agencies. A combination of productivity enhancement through varietal improvement and integrated crop management and expansion of area can help to achieve this target.

Groundnut:

Groundnut is one of the world's principal oilseed crops. Developing countries account for nearly 95 percent of world production, and Asia for about 68 percent. During the past two decades, groundnut area has expanded in Africa and Asia, increased marginally in developed countries, and declined sharply in Latin America and the Caribbean. Demand for groundnut products has been driven by several factors. In Africa, population growth has been the primary factor. In Asia, demand has grown due to a combination of population growth, growth in per capita income, and urbanization—higher incomes, higher opportunity cost of time, and therefore greater demand for convenience foods. Future work must therefore focus on increasing adoption rates of new varieties and to strengthen seed production and distribution systems and new crop management methods to substantially improve productivity especially in drier areas.

Regional goals and strategy

ICRISAT's wide ranging and continuing stakeholder analysis in Asia over the last five years, particularly the annual interaction with APAARI and the Crop and Livestock Network for Asia and the global problem analysis in the SAT done by Ryan and Spencer in 2001 and EPR report in 2003 suggest key drivers of research for development in the Asian SAT:

- The growing and dominant importance of water availability, management and use in agriculture and the need for more effective sources of drought-tolerant and water-use efficient crop germplasm.
- The vital importance of crop and crop-livestock systems diversification and commercialization and overcoming the effects of insufficient investment in labor saving measures, post-harvest value addition, market information and market outlets for SAT farming products.
- The consequences of weak social institutions and policy support, inadequate healthcare and health education, underdeveloped social infrastructure, socially excluded and often feminized agricultural landholdings and inadequate seed systems in the public sector.
- The decline in relative importance of sorghum and pearl millet caused by the imbalanced price support and research effort for rice and wheat. This is now increasingly offset by rising demand for livestock products, particularly milk and poultry which require greater feed availability and new opportunities for using cereal crops for industrial purposes.
- The continued significance of pulse crops in human and livestock diets, health maintenance regimes, improved environmental services and commercialization of agriculture.

Goal and purpose

ICRISAT-Asia seeks to align its goals with the strategic principles outlined in its global "ICRISAT Strategy to 2010: Reaping the Seeds of Success" approved by the Governing Board in September 2004 which were to:

- Reduce poverty, hunger and malnutrition in the SAT
- Enhance productivity, quality and use of SAT crops
- Manage the fragile risk-prone environments of the SAT effectively
- Diversify options for income generation and greater commercialization within SAT crop-livestock systems.

Strategy

ICRISAT–Asia will pursue its goal by fully exploiting the germplasm, soil, water and land resources at its headquarters in Patancheru, India, within an IGNRM approach. We will optimize the very large germplasm collection of our five major crops and five additional small millets to provide functional and widely diverse genetic material for our crop improvement activities. We will use the best mix of modern and traditional science tools to ensure that our parental and varietal materials will be of maximum value. We will continue to work as the world leader in understanding the genetics of our crops and use this knowledge in advancing the goals of ICRISAT and the Future Harvest Alliance.

We will harness improved varieties and improved water use efficiency as major entry points in our IGNRM efforts, especially at watershed/landscape levels, to enhance profitability, market-orientation and resilience of farming enterprises. This will include diversification of a wide range of potential crops, including those of higher value than staple cereals and legumes. We will identify alternative uses and value addition for our staple crops and maximize the effectiveness and sustainability of crop-livestock systems. We will ensure that our recommendations are pro-poor, allow equitable sharing of resources and promote gender equality.

Our efforts will specifically include the maintenance and safeguarding of human health through our biofortified mandate crops and the reduction of food and feed contamination by mycotoxins. We will also seriously consider the socioeconomic and policy implications of drought as an additional factor in the vulnerability of farming communities to HIV/AIDS.

Capacity building will continue to be one of ICRISAT's major thrusts in Asia, utilizing the most innovative methods of knowledge sharing. Irrespective of our major investments in this area to date, we see ICRISAT's role in capacity building to be as vital today and in the future as it was when ICRISAT was established in 1972. In addition, we see capacity building as a major mechanism of sharing our research efforts with our partners in sub-Saharan Africa, particularly in the context of South-South collaboration.

Chapter 4: System Priority 5

System Priority 5. Improving Policies and Facilitating Institutional Innovation to Support the Sustained Reduction of Poverty and Hunger Nationally and Regionally in the SAT Countries of Asia

5A. Science and technology policies and institutions

Introduction: Science and Technology are the most important drivers of productivity enhancement. The experience of the green revolution in several developing countries during the second half of twentieth century has shown that the total factor productivity grew at an impressive pace in these countries. It has also caused a decrease in the real costs of production per unit of output. Intensification of agriculture has also led to generation of additional employment and to increases in real wages. Increased real wages and reduced real prices of food together had a strong impact on the reduction of poverty. All these positive developments occurred as a result of technological innovations developed by the International Agricultural Research Centres, which were later fine tuned and adapted to the local conditions by the National Agricultural Research Systems. Several Governmental and Non-governmental agencies aided in taking the technologies to the farmers and several supporting institutions and policies facilitated the processes of development. The rates of returns on the R&D investments were estimated to be quite high. These processes need to be carried forward with renewed vigour to achieve the Millennium Development Goals and the CGIAR priorities.

Specific goal

Enhancing the structure, conduct and performance of knowledge-intensive institutions

Output (1) 2010:

- Participatory, pro-poor (to measure impacts on poor) Monitoring and Evaluation models developed and associated capacity building for each research area i.e., Agro-ecosystems, Biotechnology, Crop Improvement and Social Sciences and applied to research projects in ICRISAT and national systems in Asia

Outcomes (1) 2015:

- Refinement of models and their use by NARS in three Asian countries.
- Impacts of research on the incomes and employment of poor farmers and agricultural labor quantified by ICRISAT and NARES.

Output (2) 2015:

- Three models based on a coalition approach and applying the principles and methodologies of ILAC developed, documented and implemented in select Asian countries with global and national partners

Outcomes (2) 2015:

- Three alternate models of Institutional Learning And Change (ILAC) adapted and tested by the institutions in the NARES in selected Asian Countries
- Partner NARES institutions derive benefits from improved and participatory methods of technology development and adaptation

Output (3) 2010-2015:

- Novel decision support systems and required database on SAT agriculture developed for NARES and regional global organizations for prioritization, investment decisions, monitoring and evaluation and technology forecasting (for 2020) and associated capacity development developed and tested and further refinement and enrichment of the databases and support systems by 2015.

Outcomes (3) 2010-2015:
- NARS partners use databases on research resource allocation, prioritization, monitoring and evaluation at ICRISAT and in other NARS partner organizations
- NARS strengthened through enhanced ability to develop and maintain databases and decision support systems in selected Asian countries

Potential impact:
- The improved competence of NARS and other partners would be likely to have a major beneficial impact

Impact pathway:
- Monitor changes in the research environment at the global, regional, sub-regional and national levels for implications for strategies and priorities

Predominant capability:
- The interdisciplinary approaches and international character of ICRISAT gives it a clear advantage over other organizations in undertaking this work with IPG models and databases

Counterfactual:
- There is no likelihood of other organizations developing such IPG models for application in SAT Asia and therefore many project research activities would be diminished. The cessation of the VLS would deprive policy makers of a unique quantitative data set describing development in villages over the last 30 years.

5B. Making international and domestic markets work for the poor

Rising incomes, urbanization and change in tastes and preferences are spurring rapid growth in demand for high value commodities like milk, meat, fruits, vegetables and fishery, quality products for niche markets and processed food products. Due to the demand led livestock revolution the derived demand for feed grains, brans, oil, meals etc would increase both at the national and international level. Thus, trade liberalization and globalization (accompanied by removal of distortions in global trade) would open additional demand centers for developing countries for export of feed ingredients, besides high value commodities. Alternative uses or non-food uses for a number of coarse grains in the SAT countries are on the increase. For example, while food use for sorghum is declining in Asia its use in poultry feed, alcohol manufacturing etc is increasing and the trend is expected to continue in the foreseeable future. Niche markets for green and canned pigeonpeas, bold seeded and/or organically grown chickpeas, edible (HPS) groundnuts would be other opportunities for small farmers in the SAT.

There are however, apprehensions about the ability of smallholders to take advantage of the emerging opportunities. There are a number of reasons for low participation of small producers in the markets, like for example small marketed surplus, thin markets often far away from the production centers, exploitation by middle men, stringent food safety norms etc. These escalate transportation and associated transaction costs.

The agro-processing industry generally prefers to source its raw material in bulk and from near by-markets and production centers. Owing to small and scattered production and lack of adherence to quality standards small -scale producers may not be able to meet the requirements of the industry in a cost effective manner. Options to link smallholders with industry or consumers include formation of producers associating contract farming, group marketing etc. Economic reforms in Asian countries are paving the way for increasing participation by the private sector in procurement and markets (For example, the Model Marketing Act by the GOI). The markets are now transforming to a vertically coordinated structure. The vertical structures include linkages between cooperatives, producers' associations / clubs with processors and / or contract farming.

Under its institutional innovation research ICRISAT is experimenting with innovative institutional arrangement to link small-scale sorghum and pearl millet producers with poultry feed manufacturers in India, China and Thailand. The activities under this component include bulking, grading and storage of produce for sale directly to the feed manufacturers. The models would link not only producers and processors but also link input suppliers, credit agencies and transport providers and market agents. Based on experimentation at the field level appropriate models of market linkages will be identified. The models will be generic in nature i.e., applicable to many commodities in several regions with minor changes to meet local requirements.

World market prices of mandate crops 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.

ICRISAT seeks to increase adaptive capacity of small holders to exploit opportunities provided by international and domestic markets and to offset the negative impacts of global charges.

Outputs and Outcomes:

Output (1) 2010:

- Appropriate innovative / vertical integration / market linkage models identified, tried and adapted for selected commodities / SAT mandate crops and made available to NARES with associated capacity building measures in three countries in Asia by 2010

Outcome (1) 2015:

- Successful models implemented by NARES in three countries by 2010 and up-scaled in target countries and out-scaled in other selected Asian countries by 2015
- Small and marginal scale farmers in Asia begin producing the ICRISAT mandate crops for niche markets or alternative uses, i.e., non-food uses (feed, alcohol, ethanol etc) high value food products (bakery items, foods with medicinal value etc)
- Enhanced technical know-how, institutional linkages, bargaining power; reduced transaction costs, reduced market risk for small -scale producers evident in partner organizations.

Output (2) 2010:

- Development of forecasting models and data mining tools and associated capacity development in collaboration with other CG centers and partners for situational analysis and outlook in commodities including phyto-sanitary standards (SPS) and technical specifications for international trade

Outcomes (1) 2015:

- Model testing completed by 2010, refined and in use by partners between 2010 and 2015
- More informed decision making by Asian leaders for SAT regions and commodities
- Asian producers meet international quality standards in a cost effective manner

Potential impact by 2015:

- Supply and demand projections for SAT mandate crops is based on more scientific information that would lead to more informed research resource allocation and research priority setting by commodities and regions.
- ICRISAT mandate crops are tailored to meet international quality standards for the benefit of small scale farmers.

Impact pathway:

- Examination of the performance of institutions along the full market chain

Predominant capability:

- In house availability of multidisciplinary expertise for the mandate crops
- Availability of varieties suitable for alternative uses or expertise on tailoring varieties for end uses
- Hands on experiences in consortium approaches for 3-5 years
- Existing linkages with various partners across Asia
- International reach and political neutrality
- Expertise in all aspects related to mandate crops. Archived databases & lessons learnt from past work.

Counterfactual:

- Farmers not growing mandate crops for niche markets or alternative uses
- Increased price risk and lack of opportunities for growing mandate cereals
- Small producers may not realize the benefits of a consortium approach
- The area particularly under mandate cereals may go down further with detrimental consequences for the environment, human health and livestock feed.
- Resource allocation not based on scientific forecasting of trends in SAT agriculture

5D. Improving research and development options to reduce rural poverty and vulnerability

Background: Nearly 0.6 billion people in SAT Asia are still engaged in small-scale agriculture. But the ability of the agricultural sector to contribute to enhanced economic and social development is constrained by diminishing farm sizes, degrading soil and water resources, increased variability in climatic parameters, human disease burdens, unfavorable policies and practices and rapid urbanization. There are also tremendous changes occurring in consumption patterns, employment absorption, and livelihood strategies in response to changes in climate, markets, institutions and policies. Besides addressing technical issues relating to the entire value chain in agriculture from production to marketing, agricultural research and development should monitor the impacts of technologies on the economic, social and political aspects of rural life. 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.

What ICRISAT and its partners can hope to achieve by 2015?

ICRISAT and its partners can aim to maximize the impact of agricultural research by improving research and development options to reduce rural poverty and vulnerability in Asia. To achieve this, we will focus on mapping the complex development pathways and alternative livelihood options with 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 the 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, assess priorities and impacts, and target efforts more effectively at the poor.
- 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 resources management practices and participation in higher-value product markets; as well as identifying binding constraints for agricultural transformation in rural SAT with reference to the drivers of socio-economic, institutional and political change at the micro and macro level.
- Determine 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 nonfarm rural employment and enterprise, migration and remittances, market interventions and policy changes.
- Improve the quality of the context (markets and other infrastructure, institutions, public goods, policies and governance) where the poor use their assets and reduce the risks affecting livelihoods. This involves development of institutional innovations to improve the availability and effectiveness of credit, social networks, safety nets, asset and labor markets, common property access, and indigenous knowledge.
- 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.
- Analyze the effectiveness of public sector assistance programs and rural development strategies to improve livelihood resilience and reduce poverty; and design new strategies to achieve those goals combining agricultural and non-agricultural sources of incomes and employment.

The proposed work is highly innovative, since it will link vulnerability, distress and risk behavior to the stability/instability of sources of livelihoods including the 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, specially considering gender dimensions. More importantly, the links between farm-households' 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.

Outputs:

A set of outputs would be produced from this initiative including intensive capacity building through collaboration with Asian regional and international researchers. Policy dialogues with governments on improving rural livelihoods and social protection interventions will be catalyzed.

Output 1:

- 2010: Village Level Studies fully completed in the 10 original bench mark sites in India and methodologies/database plus associated capacity building shared with national and global partners in SAT Asia
- 2015: Village Level Studies expanded to new partners in two countries in SAT Asia to support the mapping of complex development pathways in the rural SAT economy

Output 2:

- 2010: 10 case studies fully documented on uptake pathways of SAT technologies in Asia developed and shared with national program partners in Asia (3 from genetic enhancement, 3 from biotechnology, 2 from NRM and 2 from social sciences)
- 2015: Meta analysis and lessons learned on the constraints and mediating factors facilitating adoption of SAT technologies shared with partners globally

Output 3:

- 2010: Policy package on risk management strategies (both ex-ante and ex-post) for mitigating the impact of risks inherent in rainfed agriculture developed and made available to partners
- 2015: Capacity building on risk management policy package for at least 200 policy makers in SAT Asia made available to NARES partners

Potential impact by 2015 and beyond:

- Capacity of NARS social scientists is enhanced

Policy makers are better informed on alternative development pathways for rural SAT economies

- Institutional learning and feedback process based on village level insights to research are enhanced through network involving biological and social scientists and policy makers
- Policy formulation is enhanced to benefit the poor and marginalized sectors of the SAT
- Better targeting of research products by ICRISAT and national program partners in SAT Asia

Impact Pathway:

- Examination of partners performances in being able to create and influence policy with a pro-poor orientation

ICRISAT's predominant capability:

- ICRISAT is a leader in this research area and in linking micro and macro-level analysis to inform policy development and is a center of excellence for developing technologies for SAT

Counterfactual:

- Lost opportunity to contribute significantly in understanding the dynamics of poverty in SAT rural economies in collaboration with partners
- A lost valuable contribution in enhancing the capacity of NARS in VLS and micro-level based policy formulation
- An important ICRISAT IPG lost
- Lack of targeted technology development
- Lack of reflection of lessons based on past successes and failures in ICRISAT and NARS research
- Technologies for welfare of SAT farmers may not be documented
- Pro-poor strategies strengthened by village level insights may not have evolved

Chapter 5: System Priority 1

System Priority 1. Sustaining Biodiversity of Sorghum, Pearl Millet, Minor Millets, Groundnut, Pigeonpea and Chickpea in the Asian SAT

1A. Conservation and characterization of staple crops

Introduction: The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT – one of the 15 CGIAR centers) has a Genetic Resources Unit for assembly, characterization, evaluation, maintenance, conservation, documentation and distribution of its five mandate crops (sorghum, pearl millet, chickpea, pigeonpea and groundnut) and their wild relatives. Currently, the genebank holds 104,677 germplasm accessions representing 130 countries of the world. Recently we have obtained new and unique accessions of chickpea (2122) and sorghum (1619).

Conservation/storage: The entire germplasm collection at ICRISAT-Patancheru is conserved in medium-term-storage (MTS) (4^0C, 30% RH). These collections will also be conserved in long-term-storage (MTS) (-20^0C) in a phased manner. By September 2005, a total of 85,217 accessions (81.4%) have been placed in LTS. To meet the FAO's germplasm agreement requirement, the entire germplasm also needs to be conserved in a safety-backup in a location or locations outside India. By September 2005, the germplasm of groundnut (2006 accessions) and pearl millet (5205) have been placed in safety-backup at the ICRISAT Regional Genebank at Niamey, Niger and for chickpea (2000 accessions) at ICARDA, Syria.

Characterization/evaluation: Agronomic and botanical characterization is necessary to facilitate the utilization of germplasm. Evaluation of germplasm accessions for traits of agronomic importance enhances its utility for greater use by research workers. Germplasm accessions of all the crops were sown in batches over the years and have been characterized for botanical and agronomic traits. Germplasm screening against insect-pests and diseases, and abiotic stresses were carried out in collaboration with entomologists, pathologists and physiologists. Grains were tested for nutritive value such as protein and oil content and cooking time. Germplasm sets were evaluated over locations jointly with NARS in India, Nepal, Thailand, and Indonesia. The considerable germplasm data gathered on chickpea and pigeonpea were summarized and published in the form of catalogs.

Supply: Supply of germplasm of ICRISAT mandate crops to the users is the mission that ICRISAT undertakes wholeheartedly. From the 1974 until 2004, a sum of 670,057 germplasm samples was supplied to scientists outside ICRISAT in 143 countries.

Utilization – core and mini-core sets: There has been insufficient use of germplasm in crop improvement programs. This is possibly because of the large size of collections and unavailability of data on traits of breeder's interest, which show large genotype x environment interactions and require replicated multilocational evaluations. Developing core collections (10% of the entire collection) representing the species diversity is a means to reduce the size for meaningful evaluation. At ICRISAT, we have studied the diversity of germplasm collections using the available characterization and evaluation and passport data, and developed core collections of all the five mandate crops and finger millet (2247 accessions of sorghum, 1600 of pearl millet, 1956 of chickpea, 1290 of pigeonpea and 1704 of groundnut). We have evaluated the groundnut and chickpea core collections and identified early-maturing diverse parents in groundnut and chickpea, and large-seeded diverse Kabuli types in chickpea.

When the size of the entire collection is large, even a core collection becomes unwieldy for evaluation by breeders. To overcome this, ICRISAT scientists developed a two-stage strategy to then develop a mini-core collection, which consists of 10% of the accessions of the core collection (only 1% of the entire collection). This mini-core subset still acts as a representative proxy for the diversity of the entire core collection. The first stage involves developing a representative core subset (about 10%) from the entire collection using all the available information on origin, geographical distribution, and characterization and evaluation data of accessions. The second stage involves evaluation of the core subset for various morphological, agronomic, and quality traits, and selecting a further subset of about 10% accessions from the core subset. At both stages standard clustering procedure is used to separate groups of similar accessions. At ICRISAT, we have already developed mini-core collections of chickpea (211 accessions) and groundnut (184 accessions). These collections are now being genotyped.

To gain benefits, the mini-core collections of chickpea and groundnut have been evaluated and diverse sources for useful traits have been identified. From the chickpea mini-core, 10 accessions having traits related to drought tolerance and five accessions tolerant to soil salinity have been identified. The evaluation of the groundnut mini-core resulted in the identification of 18 diverse accessions with high water use efficiency.

Development of a 'composite set' of germplasm in research has been conceptualized recently within the initiatives of the Generation Challenge Program. The composite set (about 3000 accessions) represents the entire collection by geographic origin, mini-core sets, main germplasm diversities, and other economic traits. At ICRISAT composite sets of sorghum, chickpea, groundnut and pigeonpea have been developed. The composite sets will be analyzed using molecular markers for drought tolerance and other economic traits that will enhance breeders' efficiency in utilizing genetically diverse germplasm in research.

Specific Goals to 2010 and 2015:

2010

A. *Conservation and safety duplication*
   Present status: a) Germplasm conserved: 65%
   b) Safety duplication: 9%

Output:

- 90% of germplasm transferred to long-term storage (LTS) and 25% safely duplicated and approximately 50% placed in the Svalbard seed vault in Norway.

Outcome:

- FAO acknowledges ICRISAT's responsibilities to its five mandate crops are largely achieved in terms of storage and substantive progress has been made in safety duplication.

Potential impacts:

- A very high percentage of germplasm conserved safely and available for repatriation and supply to R&D partners

Impact pathways:

- Germplasm regenerated, tested for seed health, and conserved in LTS and safely duplicated
- Germplasm annually available for repatriation and for R&D by partners

Predominant capability:

- The only organization with a global mandate from FAO for this activity

Counterfactual:

- Potential loss of priceless global germplasm collections

B. Characterization and evaluation

Present status: Newly acquired germplasm not characterized, and there are gaps in the available characterization data

Output:

- Morpho-agronomic characterization of newly acquired germplasm completed and gaps in data for existing germplasm filled and available in the Singer database
- Diversity in composite germplasm collections characterized and published
- Global reference collections and populations of five mandate crops developed, regenerated, conserved and made available to partners

Outcome:

- Partners have easy access to characterization data on entire germplasm collection
- Partners have access to newly established population structures of chickpea and sorghum
- Partners have access to new global reference populations of mandate crops

Potential impacts:

- Data easily available on the SINGER website leading to increased interest in using germplasm
- Genetically diverse germplasm as parents available for use by breeders and in the targeted collections
- Accessibility to reference population by R&D community improved

Impact pathways:

- Newly acquired germplasm and germplasm with incomplete data grown out and data recorded on morpho-agronomic characters
- Data transferred to SINGER website
- Composite collections of five mandate crops developed and genotyped using SSR markers.
- Population structure of chickpea and sorghum described
- Diversity of composite collections assessed and a reference collection (300 accessions) in each crop selected, regenerated, and conserved for future R&D
- Reference collections made available for research to the global community

Predominant capability:

- The only organization with a global mandate from FAO for this activity

Counterfactual:

- n/a

C. *Utilization*

Present status:
a) Core collection (10% of entire collection) of all mandate crops established
b) Mini-core collection (10% of core collection; 1% of entire collection) of chickpea and groundnut established
c) No trait-specific germplasm sets available

Output:

- Mini-core collection of sorghum, pearl millet and pigeonpea established
- Trait specific germplasm sets of all five crops identified

Outcome:

- Partners have access to full diversity of germplasm in a small, breeder-efficient subset of germplasm (core and mini core collections)
- Partners have access to new targeted-germplasm sources for two important traits

Potential impacts:

- Enhanced use of trait-specific germplasm by breeders to develop genetically enhanced broad-based cultivars

Impact pathways:

- Core collections of sorghum, pigeonpea, and pearl millet evaluated for morpho-agronomic traits, data analyzed and representative mini core collections developed
- Core and/or mini core collections evaluated for specific traits and trait specific diverse, and agronomicaly superior germplasm identified, regenerated and conserved

Predominant capability:

- The only organization with a global mandate from FAO for this activity

Counterfactual:

- n/a

2015

A. *Conservation and safety duplication*

Proposed Outputs:

- 100% of mandate crop in-trust germplasm collections transferred to Long Term Storage
- 40% of such germplasm safety duplicated and approximately 95% will be transferred to the Svalbard seed vault in Norway.

B. *Characterization and evaluation*

Proposed Outputs:

- Population structure of groundnut, pigeonpea and pearl millet established and published

C. *Utilization*

Proposed Outputs:

- Germplasm sources identified and made available to partners for an additional five important traits

1B. Promoting conservation and characterization of under-utilized plant genetic resources globally

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 (5949 finger millet, 1535 foxtail millet, 842 proso millet, 743 barnyard millet, 658 kodo millet, and 466 little millet) of these crops. We have recently obtained 61 new and unique foxtail millet germplasm samples (35 from China and 26 from Bangladesh).

The entire collection is conserved in medium-term-storage (MTS) (4^0C, 30% RH), will also be conserved in long-term-storage (LTS) (-20^0C) in a phased manner. By September 2005, a total of 7751 accessions (76%) have been placed in LTS. To meet the requirement of FAO's germplasm agreement, the entire germplasm of the under-utilized crops collection will need to be conserved in safety-backup at a location outside India. By September 2005, 4580 accessions of finger millet have been placed in a safety-backup at the ICRISAT Regional Genebank at Niamey, Niger.

Agronomic and botanical characterization is necessary to facilitate the utilization of germplasm of under-utilized crops. Evaluation of germplasm accessions for traits of agronomic importance enhances their utility to researchers.

In most cases, including under-utilized crops, use of basic germplasm in crop improvement is very sub-optimal. This is possibly because of the large size of collections and the lack of sufficient data on traits of breeder's interest, which show large genotype x environment interactions and require replicated multi-locational evaluation. Developing core collections (10% of the entire collection) representing species diversity is a means to reduce the size for meaningful evaluation. Germplasm collections will be studied using the available characterization/evaluation and passport data to develop core collections. We will also develop composite sets of accessions to characterize them using molecular markers. Using molecular marker data, a reference collection will be formed that will be evaluated extensively for drought tolerance and other agronomic traits and genotyped using additional molecular markers to enhance utilization by the breeders.

Under-utilized crops (Finger-, Foxtail-, Proso-, Barnyard-, Kodo- and Little millets)

Specific Goal:

2010

A. *Conservation and safety duplication*

Present status: a) Germplasm conserved: 65%
b) Safety duplication: 30%

Output:
- 90% of germplasm transferred to long-term storage and 50% safety duplicated

Outcome
- FAO acknowledges ICRISAT's responsibilities to its five mandate crops are largely achieved in terms of storage and substantive progress has been made in safety duplication.

Potential impacts:
- A very high percentage of germplasm conserved safely and available for repatriation and supply to R&D partners

Impact pathways:
- Germplasm regenerated, tested for seed health, and conserved in LTS and safely duplicated
- Germplasm annually available for repatriation and for R&D by partners

Predominant capability:
- The only organization with a global mandate from FAO for this activity

Counterfactual:
- Potential loss of priceless global germplasm collections

B. *Characterization and evaluation*

Present status: Newly acquired germplasm not characterized and gaps in present characterization data

Output:
- Morpho-agronomic characterization of newly acquired germplasm completed and gaps in data for existing germplasm filled and available in the Singer database

- Diversity in composite germplasm collections characterized and published
- Global reference collections and populations of finger and foxtail developed, regenerated, conserved and made available to partners

Outcome:
- Partners have easy access to characterization data on entire germplasm collection
- Partners have access to newly established population structures of finger and foxtail millets
- Partners have access to new global reference populations of finger and foxtail millets

Potential impacts:
- Data easily available on the SINGER website leading to increased interest in using germplasm
- Genetically diverse germplasm as parents available for use by breeders and in the targeted collections

Impact pathways:
- Newly acquired germplasm and germplasm with incomplete data grown out and data recorded on morpho-agronomic characters
- Data transferred to SINGER website
- Composite collections of finger and foxtail millets developed and genotyped using SSR markers.
- Population structure of finger and foxtail millets described
- Diversity of composite collections assessed and a reference collection (300 accessions) in each crop selected, regenerated, and conserved for future R&D
- Reference collections made available for research to the global community

Predominant capability:
- The only organization with a global mandate from FAO for this activity

Counterfactual:
- n/a

C. *Utilization*

Output:
- Core collections of finger and foxtail millet established and made available to partners
- Mini-core collection of finger millet established and made available to partners
- Trait-specific germplasm of all six small millets identified and made available to partners

Outcome:
- Partners have access to full diversity of germplasm in core collections
- Partners have access to new germplasm sources available for two important traits

Potential impact:
- Enhanced use of trait-specific germplasm by breeders to develop genetically enhanced broad-based cultivars

Impact pathways:
- Core collections of finger millet evaluated for morpho-agronomic traits, data analyzed and representative mini core collections developed
- Core collection of foxtail millet and core/mini core collection of finger millet evaluated for specific traits and trait specific diverse, and agronomicaly superior germplasm identified, regenerated and conserved

- Selected germplasm of proso, barnyard, kodo, and little millets evaluated for specific traits and trait specific diverse, and agronomicaly superior germplasm identified, regenerated and conserved

Predominant capability:
- The only organization with a global mandate from FAO for this activity

Counterfactual:
- n/a

2015

A. Conservation and safety duplication

Potential Outputs:
- 100% of germplasm collections transferred to Long Term Storage
- 70% of germplasm safely duplicated

B. Characterization and evaluation

Potential Output:
- Population structure of foxtail millet established and published

C. *Utilization*

Potential Output:
- Germplasm sources identified and made available to partners for an additional five important traits

Chapter 6: System Priority 2

System Priority 2. Producing More and Better Food at Lower Cost through Genetic Improvements, particularly for Tolerance to Abiotic Stress and Improvement of Nutritional Quality of Sorghum, Pearl Millet, Minor Millets, Groundnut, Pigeonpea and Chickpea in Asia

2A. Maintaining and enhancing yield potential of staples

To address ICRISAT's vision of "continued well-being of the poor in the SAT through agricultural research for impact", and to substantially contribute to the Millennium Development Goals (MDGs), particularly those addressing poverty, hunger, gender, health, and environmental sustainability, we need to enhance productivity and production of staple food crops. Poverty is still pervasive in many countries of Asia. Although many countries are reported to be self-sufficient in staple foods, poverty is still widespread in Asia, especially in South Asia.

Crops

All the five mandate crops – sorghum, pearl millet, chickpea, pigeonpea and groundnut – are important for food and nutrition security of the people of Asia. Sorghum is cultivated in 11.2 m ha, accounting for 26% of world area. Pearl millet at 12.1 m ha accounts for 35% of the world pearl millet area. Nearly 91% of chickpea (10.2 m ha) and 90% of pigeonpea (3.9 m ha) is in Asia. Groundnut area (13.3 m ha) in Asia accounts for 54% of the world area. These statistics clearly indicate the magnitude of dependence of people on these staple crops, and the need for R&D institutions such as ICRISAT, and its partners, to increase the crop productivity by developing high yielding cultivars (varieties and hybrids).

Constraints to production

The five mandate crops are grown under varied agroclimates (from 54^{o} E to 120^{o} E longitude, and 15^{o}S to 35^{o}N latitude, and elevations from 0 to 2000 masl). Consequently, the crops are subject to numerous pests, diseases, and other abiotic stresses (drought, cold, salinity, acid soils, etc.). Some constraints are regional, while many others are widespread cutting across the national boundaries of many countries. Obviously, ICRISAT cannot address all the constraints. Based on the importance (yield losses caused due to the constraint) and the likely ability to address the problem through research (resistant sources and technology/methods available to manage the pest/disease), the following is a list of major constraints in Asia:

Crop	Constraint	Priority*
Sorghum	Grain mold	1
	Anthracnose	2
	Shoot fly	1
	Stem borer	2
	Midge	2
	Drought	1
	Salinity	2
	Low sugar content	1
Pearl millet	Downy mildew	1
	Drought	1
	Salinity	2

Chickpea	Fusarium wilt Ascochyta blight Botrytis mold Pod borer Drought Cold tolerance Salinity	1 2 2 1 1 2 2
Groundnut	Aflatoxin Foliar diseases Bud necrosis Bacterial wilt Spodoptera Leaf miner Red Hairy Caterpillar Drought Salinity	1 2 1 3 2 2 3 1 2
Pigeonpea	Fusarium wilt Sterility mosaic Pod borer Pod fly Maruca Drought	1 1 1 2 2 1
*Priority rating: 1 = Low, 2 = Medium and 3 = High		

Phosphorus deficiency
Low P is often tacitly thought to be only the problem of ICRISAT's African locations, whereas more than 60% of fields in India are P deficient, according to a recent nation-wide workshop held on P deficiency in India.

Phosphorus is after nitrogen the most limiting nutrient limiting crop production. In fact, drought interacts with various nutrient deficiencies and it is known, for instance, that the conductance of root to water is decreased under low P. The problem of phosphorus is doubly damaging: (i) it can be a simple lack in the soil, in which case only management options are possible; (ii) the phosphorus is present in the soil but not available in a form (soluble) that roots can absorb. The first case exists and only amendments programs would render these soils suitable for agricultural production. The second case is by far the most common, in particular in the semi-arid tropic where the highly weathered soils have usually a high sorption capacity, i.e. the capacity to immobilize the soluble ions into insoluble complexed form, mostly hydroxides. There has been very little effort to date to breed for low P adapted crops. The challenge for ICRISAT will also be to harness the potential of its mandate legumes and cereals, in a systems approach to low P alleviation.

Challenges and opportunities for Crop Improvement
Asia, as a continent, offers a wide range of challenges for crop improvement due to the varied agroclimates, numerous biotic and abiotic constraints affecting crop production, and the degree of capacities for crop improvement research in the national programs.

- Varied NARS capacities (for example, China and India v/s Myanmar & Nepal) necessitates that we develop both early and advanced generation breeding materials for sharing with stronger NARS, and also develop near-finished varieties on request for supplying to NARS partners for local testing.
- Considering that hybrid cultivars are feasible in sorghum, pearl millet and pigeonpea, there will be dual emphasis on developing hybrid parents (for countries with a developed hybrid seed industry) and varieties for other countries.

- Because of the presence of a large number of private sector seed companies in Asia (mostly India), our partnership in research should involve both the public and private sectors, but research emphasis will be on producing IPGs, without exclusivity being granted to any of the partners.
- The food use (especially of sorghum and pearl millet in Asia) is reducing in comparison to the 1970s when ICRISAT started working on these crops. Currently, and more so in the future, grains will be increasingly used for animal feed, alcohol production, and in processed food industry. Demand for fodder is increasing, fuelled by the increasing demand from the fast growing dairy industry. A shift in emphasis from grain yield for food only to grain for feed and biomass for fodder is essential.
- With the developments in biotechnology, we need to integrate marker-assisted breeding (MAB) and transgenics in to mainstream crop improvement. MAB will be deployed for traits (especially resistance/tolerance) that are difficult to score/select phenotypically in the field, or for pyramiding QTL for enhancing levels of resistance. Transgenics will be employed for incorporating resistance genes from outside the species, wherever the levels of resistance within the species is either low or not available.
- Participatory breeding will be the general rule: meaning that we incorporate the inputs and feed back from stakeholders (farmers, traders, processors and consumers) and plan the breeding strategy to address the user-needs. Wherever needed, farmer-participatory varietal selection will be encouraged.
- One of the major reasons for lack of adoption of improved varieties is the non-availability and timely supply of quality seed of improved varieties to farmers. We will work with the NARS, private sector, NGO, CSO and Farmers' Organizations to develop seed multiplication and distribution strategies at the appropriate level.

Crop Improvement Strategies

Owing to the availability of cyto-plasmic male sterility (CMS) in sorghum, pearl millet and now in pigeonpea, primary emphasis in these crops will be to develop elite hybrid parents. Much of this research will be carried out under the "ICRISAT-Private Sector Hybrid Parents Research Consortia". However, the sorghum and pigeonpea program will also to develop varieties to serve the Asian national programs where hybrids are not yet feasible. The Asia-based crop improvement program will also to share early and advanced generation breeding material with ICRISAT programs in ESA, where the Patancheru-bred material have been found to be adapted. The chickpea and groundnut programs will develop early and advanced generation material for sharing with NARS, and will also provide near-finished varieties to NARS partners through international nurseries and trials, and also share the breeding material with ICRISAT programs in ESA and WCA.

a. Sorghum

In addition to grain yield for food and feed uses, future emphasis will also be placed on forage production and sweet-stalk sorghums. Currently the *caudatum* race has been used extensively to develop high-yielding male-sterile lines and restorers. Hence, there is need to diversify the genetic base using other sorghum races to further enhance the productivity per unit area. CMS-based seed parents and restorers need to be diversified by creating separate gene pools through crossing *guinea*-based B-lines and *durra*-based B lines; and between *caudatum*-based R lines and *bicolor/durra* based R lines. Of the several available non-milo CMS systems, A_2 offers an immediate option for diversifying the CMS base of hybrid parents. The hybrid parents need to be further diversified for *guinea*, *feterita* and *bicolor* races for grain yield, and *dochna* types that originated in Myanmar (and other high biomass types with sweet stalks and also brown-midrib lines) for multi-cut forage. Earlier attempts to breed for resistance to shoot fly, stem borer and grain mold have met with only partial success, owing to low-level of resistance in cultivated sorghum lines. Nevertheless, hybrids with moderate levels of resistance to these major constraints would be cost effective and eco-friendly. Such an approach will also significantly reduce the shoot fly and stem-borer populations, over time. Gene pyramiding, using marker assisted breeding, could be one of the approaches, along with possibilities of genetic transformation using appropriate resistance genes. Considering the high value of post rainy (*rabi*) sorghum grains, and the strategic importance of rabi sorghum in food security in certain regions, we will need to invest resources to develop *rabi*-adapted hybrids that should possess large, pearly white grains, with a good level of shoot fly resistance.

b. Pearl millet

There has been gradual increase in productivity of pearl millet, owing to increased area cultivated to hybrids [that have higher yield potential than OPVs and increased level of resistance of those hybrids to the downy mildew (DM) disease]. The diversified hybrid cultivars base has contributed to enhanced yield stability by preventing large-scale downy-mildew epidemics. More targeted breeding for DM resistance to multiple pathotypes, following both conventional pedigree breeding and marker-assisted breeding, will be required to continue the battle with the fast-mutating DM pathogen. An improved understanding of spatial and temporal patterns of virulence, pathotype-specific resistance, and effective green house screening for DM resistance will improve the breeding efficiency. Recent advances in pathotype-specific QTL have further enhanced marker-assisted breeding approaches.

The more marginal environments in Western Rajasthan, Gujarat and Haryana in India (the A1 zone) have been somewhat bypassed by the success of hybrid technologies. Combining genetic potential for high yield with DM resistance and drought tolerance holds promise for enhancing pearl millet productivity in this region, provided NARS partners can provide more test sites for adeqaute selection and evaluation of breeding lines.

The value of pearl millet as a fodder crop is increasing due to increased fodder needs by the dairy industry. Pearl millet has good potential as a fodder crop owing to its high biomass production, high water-use efficiency, tolerance to heat and drought, fewer pests and diseases, and low anti-nutritional factors. Availability of the new A_5 CMS system with high maintainer frequency provides opportunity to make faster progress in breeding high yielding forage hybrids.

c. Groundnut

The importance of groundnut in Asia is two-fold: (i) as a major oil seed crop and (ii) as a protein-supplement in diets. In Asia, a major portion of groundnut is used to extract oil and a small proportion is used for confectionery or table purposes. In recent years, the food-use of groundnut is increasing, but the export prospects are limited by strict norms of aflatoxin content (<5 ppb in most European countries). Being a drought tolerant crop, it has the ability to recover quickly from long drought periods and produce a reasonable yield when drought stress is released; and with ability to tolerate long mid-season droughts during the growing periods as rainfall is highly erratic in the SAT areas. As and when markers are identified for drought-conferring traits (for example, high water-use efficiency), MAB will be integrated in conventional breeding to speed-up the development of improved breeding lines and varieties. Since the probability for aflatoxin contamination is high when the crop is subjected to drought (which is very common in the Asian SAT) prior to harvest, efforts will be geared towards incorporating the necessary genes using MAB or using a transgenic approach.

Incorporating resistance to foliar diseases (early leaf spot, late leaf spot, and rust) is mandatory in both short and medium duration materials, as the crop is subjected to heavy disease pressure during the rainy season. Similarly, resistance/tolerance to defoliators (Spodoptera), leaf miner, and to some extent to jassids and thrips will be required for stability of performance.

c. Chickpea

In Asia both desi (small seeded with a dark colored seed coat) and kabuli (large seeded with beige seed coat) types are grown. Currently the desi types predominate in South Asia, and kabulis are common in West Asia. However, with the development of short-duration, large-seeded kabuli varieties, the area under kabuli types are increasing in South-Asia, especially in latitudes below 25°N. Therefore, future crop improvement efforts need to give equal importance to both desi and kabuli types. Chickpea has been displaced by high yielding wheat varieties in many countries. This has resulted in chickpea being grown in more marginal lands, leading to lower yields. Another reason for displacement of chickpea is due to damage caused by ascochyta blight and botrytis gray mold in favorable lands (i.e. good soil fertility and soil moisture). Therefore, if chickpea is to be rehabilitated, we need to develop input responsive varieties with resistance ascochyta and botrytis gray mold, plus resistance to *Helicoverpa* pod borer. Resistance to fusarium wilt is mandatory for all chickpea growing areas, and all breeding lines will have fusarium wilt resistance.

Since much of chickpea will continue to be grown under residual moisture conditions, drought (or limited soil moisture) will continue to be the major constraint. Emphasis will continue for developing short-duration varieties (that can escape terminal drought) with resistance to fusarium wilt, root rots, and pod borer. In addition, we will emphasize developing varieties that can respond to better soil moisture conditions. We will use MAB to incorporate root traits with the ability to extract available soil moisture, and sustain the crop for a longer duration so that total productivity can be enhanced.

Breeding for resistance to *Helicoverpa* pod borer has had limited success due to low-level resistance (tolerance) available in the cultivated chickpea germplasm. A higher level of resistance is available in *cicer* wild species, and needs to be introgressed in to chickpea. This will need embryo-rescue as some species are not crossable with chickpea. Another approach to resistance to pod borer is to incorporate Bt and SBTI genes to enhance level of resistance. Protocols for transformation and regeneration are available and can be used effectively.

Considering the low levels of resistance available in chickpea for ascochyta blight and botrytis gray mold, pyramiding of genes or QTL using markers is likely to be cost effective. Genetic transformation using anti-fungal genes (chitinase, glucanase and PGIP) also holds promise.

d. Pigeonpea

Significant progress has been made in incorporating resistance to fusarium wilt and sterility mosaic diseases, which has led to the stabilization of the hectarage, production and productivity in the major pigeonpea growing areas. Development of extra-short and short-duration cultivars has enabled pigeonpea to be grown as catch crop and as a rotation crop with wheat, in the rice-wheat areas of north-west India.

In view of the limited progress in increasing the productivity of varieties, concerted efforts were made to develop hybrid cultivars, initially with genetic male sterility systems and more recently with cytoplasmic male sterility (CMS) system. The floral biology of pigeonpea permits cross pollination (by insects), enabling large-scale commercial hybrid seed production. Currently four CMS systems are available: (i) A_1, derived from *Cajanus sericeus*, (ii) A_2 from C. *scarabaeoides*, (iii) A_3 from C. *volubilis*, and (iv) A_4 from C. *cajanifolius*. Among these the A_4 CMS system is considered to be the best source for commercial exploitation.

Research and development towards making hybrid pigeonpea cultivars available to farmers is being carried out under the Pigeonpea Hybrid Parents Research Consortium. The partnership research involves: (i) conversion of adapted parents of appropriate maturity duration (extra-short, short, medium and long duration) lines having resistance to wilt and sterility mosaic disease, (ii) identifying suitable restorers, (iii) finding heterotic combinations, (iv) technology for large-scale hybrid seed production, and (v) release of hybrids for farmers' cultivation. The first commercial hybrid is expected in 2007.

Breeding for resistance to wilt and sterility mosaic disease will continue, and all breeding materials will carry resistance to both diseases. Considering that these are different races in sterility mosaic disease, appropriate resistant sources will be used to incorporate resistances.

Breeding for resistance to pests (especially *Helicoverpa* pod borer) has been partially successful. Some varieties with moderate level of resistance have been released. Future research will involve incorporating Bt genes to enhance resistance levels. Protocols for transformation and regeneration are available. The first generation of Bt transformed pigeonpea are in contained field tests, but the level of resistance is not high. Further research is needed to develop transformed plants with higher level of resistance.

Outputs, outcomes 2A:

ICRISAT will offer capacity development opportunities associated with all its proposed outputs to its partners and these are not otherwise articulated other than in Chapter 9.

Enhancing grain yield and pro-poor traits in cereals and hybrid pigeonpea

ICRISAT's priorities for sorghum and pearl millet research in Asia focus on hybrid parents and cultivars that combine increased grain yield potential and traits of particular value to resource-poor small farmers. These so-called pro-poor traits include genetic resistance to major pest and disease problems, for which chemical control is generally not a viable option, good grain quality for human consumption, and straw productivity and quality for maintaining domestic animals. Because of a very efficient seed industry in place in much of Asia, hybrid seed of these two crops is available to most farmers, at competitive prices (hybrid coverage in India is estimated at 60% of total hecterage in the case of pearl millet and 80% in the case of rainy season sorghum). Because hybrid pigeonpea is now a reality, which should reach farmers by 2010, this part of the overall program on pigeonpea is also included in this section.

ICRISAT works in partnership with both the public and private sector parts of national research programs in Asia, which assures that the products of ICRISAT's breeding programs are efficiently delivered to farmers. The partnership with the private sector in India has been formalized in the Hybrid Parents Research Consortium, through which commercial seed producers provide partial funding to support all three of ICRISAT's hybrid parent breeding programs. ICRISAT supports this partnership in a continuum of strategic research on enhancing breeding effectiveness (Output 3, below), the production of breeding lines with new or essential traits (Output 2), and the production of finished hybrid parental lines (Output 1). An additional public/private partnership consortium has been added in 2007 to cover issues related to Biofuels.

ICRISAT has a unique combination of an integrated multi-disciplinary research team, informed access to the world germplasm of all three crops, outstanding conventional and biotech research facilities and above all, its mandate to produce International Public Goods (IPGs), which are freely available to all users who agree to allow them to remain in the public domain. This places ICRISAT in an ideal (and unchallenged) position to capitalize on the synergies of a partnership mode of research to produce and deliver improved cultivars to Asian farmers.

1. Finished products: hybrid parental lines

Output:

- High-yielding hybrid parents (80 to 100 across three crops by 2010) with pro-poor traits (particularly resistance/tolerance to major biotic stresses) in diverse and elite genetic backgrounds and made available to breeders in partnership with NARS and the private sector at their request and for their benefit.

Outcome:

- Commercially available seed of a range of new hybrids produced by partners based on ICRISAT-derived hybrid parents (40% of all hybrids in sorghum, 60% in pearl millet, and 30% in pigeonpea) across Asian production areas of these crops by 2015

Potential impact:

- Sustained annual growth rate in productivity of 1 – 2% in sorghum and pearl millet, with pigeonpea hybrids adopted on at least 100,000 ha, in Asia by 2015. As these crops are primarily grown and consumed by poorer farmers and consumers in Asia, they will be the major beneficiaries of increased production of their staple crops. Secondary benefits will accrue to the seed and feed producers and urban consumers

Impact pathways:

- Scientists' field days and consultation meetings are held to provide information on new materials available, documentation of seed supplied to partners, registration of named genetic material, obtaining annual information from seed companies on ICRISAT parents used in their newly released hybrids

Predominant capability:

- ICRISAT's unique combination of a well-integrated, multidisciplinary research team, informed access to crop genetic resources, strong linkages to national programs and the private seed sector (particularly the Hybrid Parents Research Consortium in India, which provide partial financial support to ICRISAT's hybrid parent breeding programs), and particularly its focus on producing IPGs has not been duplicated in national programs

Counterfactual:

- National programs will become solely responsible for hybrid parent development, resulting in lower rates of genetic gain in hybrid breeding programs, reduction in competitiveness of smaller seed companies (resulting in increased concentration of hybrid seed markets and likely higher seed costs), and likely increased genetic vulnerability to disease and pest epidemics due to a narrower genetic base of the hybrids available to farmers

2. Unfinished products: breeding materials with special traits

Output:

- 800 - 1000 elite, trait-specific breeding lines, populations, etc. developed in partnership with NARS and the private sector at their request and for their benefit for specific target markets, production environments and research applications, made available to partners by 2015. (e.g., sweet stalk sorghums for ethanol production *rabi*-adapted lines with good grain quality traits, improved sources of resistance to biotic stress problems, and near-isogenic lines in elite backgrounds)

Outcome:

- Public and private sector breeding programs show evidence of improved capacity and diversification of the genetic base used

Potential impact:

- Higher-yielding and more genetically diverse hybrids and varieties are bred and released by national programs/private seed companies, for specific target markets and production environments. Primary beneficiaries will be the national research programs in Asia and secondary beneficiaries will be farmers exploiting the new cultivars.

Impact pathways:

- Scientists' field days and consultation meetings are held, documented supply of seed of trait-specific nurseries and of individual lines is provided as requested, registration of improved genetic material, publication of research results in peer-reviewed journals, presentation of paper/posters in conferences, symposia and workshops, articles in ICRISAT/global theme annual reports.

Predominant capability:

- ICRISAT's unique combination of a well-integrated, multidisciplinary research team, informed access to crop genetic resources, excellent scientific facilities, strong linkages to both public and private sector breeding programs, and focus on IPGs has not yet been duplicated in national programs.

Counterfactual:

- The genetic base of national breeding programs for sorghum, pearl millet, and pigeonpea will be broadened more slowly, and the ability to target special niche opportunities with these crops will be reduced, without access to new ICRISAT breeding lines. This will result in missed opportunities for farmers growing these crops, the slowing of progress in developing host plant resistance for various disease and pest problems, and thus an increased risk of disease and pest epidemics

3. *Knowledge and capacity building from strategic research*

Output:

- Strategic information and capacity building (disseminated through publications, training, workshops, etc.) in areas with significant potential to enhance breeding efficiency (e.g., alternative CMS systems, effectiveness of molecular marker and genetic transformation technologies, molecular diversity assessment of breeding gene pools, pathogenic variability changes, mapping populations and QTLs for needed traits, screening/ selection systems for phosphorus acquisition ability, and transgenic resistance to stem borers and pod borers)

Outcome:

- Enhanced efficiency of hybrid parent breeding programs at a global level, through the increased use of new breeding technologies (e.g. marker-assisted breeding methods, gene deployment strategies that reduce cultivar vulnerability to changes in pest populations, more effective CMS systems)

Potential impact:

- Various impacts depending upon the technologies adopted and on individual crops: reduced research costs per unit genetic gain (e.g., time reduced by 1 season per breeding cycle by 2015), a minimum of 10% reduction in losses due to pests and/or reduction in pesticide use, improvement in phosphorous use efficiency/adaptation to low soil P soils, effective strategies to avoid serious disease and pest epidemics, etc. Main beneficiaries will be national and international research programs working on these crops.

Impact pathways:

- Publication of results in peer-reviewed journals, masters, PhD and visiting scientist level training programs, workshops and training courses, presentation of paper/posters in conferences, symposia and workshops, articles in ICRISAT/global theme annual reports

Predominant capability:

- ICRISAT's experienced multidisciplinary research and capacity development team, supplemented by doctoral students and post doctoral scientists, excellent conventional and biotechnological research facilities, rapidly developing ability to exploit crop genetic resources, linkages to the global research community, and focus on IPG has not been duplicated in international or national programs.

Counterfactual:

- Slowing of the global growth of the knowledge base of these crops, fewer opportunities to improve current rates of genetic gain in yield potential, missed opportunities to improve disease and pest management and to enhance economic returns to sustainable soil fertility management practices, and ultimately a greater dependency of plant breeding programs and agricultural producers on large commercial suppliers for pro-poor research products.

Enhancing grain yield and pro-poor traits in legumes including non-hybrid pigeonpea

Chickpea:

Output (1) 2010:

- One hundred and fifty *desi* and *kabuli* chickpea advanced/elite breeding lines with resistance to *Ascochyta* blight, *Botrytis* gray mold, *Fusarium* wilt and *Helicoverpa* in superior agronomic backgrounds with preferred seed traits developed in partnership with NARS at their request and for their benefit.

Outcome (1) 2015:

- The NARS chickpea-breeding program demonstrating increased strength through use of diversified trait specific and multiple resistant breeding materials developed in partnership with ICRISAT.
- Improved diseases and *Helicoverpa* resistant chickpea varieties released by NARS leading to increased productivity of the crop in major chickpea growing countries

Expected Impact:

- Expansion of area in new niches such as rainfed rice fallows
- 10-15% gain in productivity and reduced pesticide application by 25%

Pigeonpea

Output (2) 2010:

- Twenty-five short- and medium- duration wilt, sterility mosaic and *Helicoverpa* tolerant advanced/elite breeding lines developed in partnership with NARS at their request and for their benefit.

Outcome (2) 2015:

- Breeding lines with multiple resistance developed with ICRISAT are used by NARS to enhance the effectiveness of their crop improvement programs.
- Improved diseases and pest resistant pigeonpea varieties released by NARS leading to improved productivity of the crop in rainfed cropping systems

Expected Impact:

- Crop expansion in non-traditional areas and non-traditional cropping systems
- 10 % gain in productivity and reduced pesticide use by 30-35%

Groundnut

Output (3) 2010:

- Three hundred short- and medium-duration, foliar diseases and aflatoxin resistant advanced/elite breeding lines for oil and food use developed in partnership with NARS at their request and for their benefit.

Outcome (3) 2015:

- Trait and end-use specific and diversified multiple resistant breeding lines received from ICRISAT are used by NARS to enhance the effectiveness of their groundnut breeding programs.
- Improved groundnut varieties released by NARS and productivity and quality of groundnut produce (pod and haulm) improved leading to increased production of the crop in rainfed areas

Expected impact:

- 15% gain in productivity and better quality of the produce (pods and hualms)
- Evidence of increased food use of the crop expected in traditional groundnut growing areas in Asia

All three Legumes:

Output (4) 2010:

- Peanut bud necrosis virus (PBNV) and tobacco streak virus (TSV) in groundnut identified and tested in open contained field trials in partnership with NARS at their request and for their benefit.

Outcome (4) 2015:

- The enhanced levels of resistance to *Helicoverpa*, peanut bud necrosis disease, and tobacco streak virus provided by transgenics developed with ICRISAT greatly improve the efficiency of legume resistance breeding programs of NARS.

Expected Impact:

- *New sources of resistance to* Helicoverpa, *PBNV and TSV available for deployment and enhancing productivity of chickpea, pigeonpea and groundnut against the constraints.*
- NARS capacity to mitigate crop losses enhanced

Output (5) 2010:

- Novel techniques (screening methods, genetic maps, molecular markers and association mapping tools and bioinformatics tools) and capacity building for improving efficiency of crop improvement in NARS developed in partnership specifically at their request and for their benefit.

Outcome (5) 2015:

- Outputs, methods, knowledge and databases shared with NARS partners which have enabled them to improve their crop improvement efficiency

Expected Impact:

- NARS capacity enhanced and national productivity of legumes in Asia increased

Impact pathways:

- Scientists' field days and consultation meetings are held to provide information on new materials available, documentation of seed supplied to partners, registration of named genetic material, documented supply of seed of trait-specific nurseries and of individual lines is provided as requested, registration of improved genetic material, publication of research results in peer-reviewed journals, presentation of paper/posters in conferences, symposia and workshops, articles in ICRISAT/global theme annual reports.

Predominant capability:

- ICRISAT's experienced multidisciplinary research and capacity development team, supplemented by doctoral students and post doctoral scientists, excellent conventional and biotechnological research facilities, rapidly developing ability to exploit crop genetic resources, linkages to the global research community, and focus on IPG has not been duplicated in international or national programs.

Counterfactual:

- Legumes, in general, continue to receive lower priority in many national research agenda due to their focus on staple cereals for achieving self sufficiency in food. The private sector has also shown little interest in the improvement of legumes with the exception of pigeonpea. As a consequence, the productivity of legumes remains stagnant. Legume (chickpea, pigeonpea and groundnut) improvement and development in Asia continues to depend heavily on ICRISAT. With IPR coming into force, the exchange of germplasm and breeding materials among NARS has almost ceased. ICRISAT remains the only source for NARS for obtaining germplasm and breeding populations and products of biotechnology for use in breeding programs. If the legume research and development at ICRISAT is discontinued, the NARS and ultimately the poor farmers of the rainfed Asia would be the biggest loosers who would be denied the annual gains in productivity and access to new technologies.

2B. Tolerance to selected abiotic stresses

Abiotic stresses – What are the needs

Abiotic stresses severely limit agricultural production. In groundnut alone, drought is supposed to be responsible for about 500 Million USD losses in India alone. There is a clear consensus that drought, salinity and low phosphorus availability are among the most severe stresses, in Asia. They are also those that ICRISAT crops face repetitively. The different avenues that have to be considered to undertake abiotic stress tolerance research are presented:-

What scopes and challenges exist for MAS breeding?

For complex traits, conventional breeding has already permitted production of better-adapted crops. A good example of such success has been the breeding of early varieties, such as in chickpea and groundnut, able to escape drought. Conventional breeding has been successful in such cases because the major component trait of drought tolerance, earliness, is both clearly related to drought tolerance and is easy to record.

The advent of molecular genetics and molecular markers is providing a tool of choice to disentangle the complexity associated with drought as well as most related abiotic stresses. Recent research has identified the portion of the genome (QTL) being quantitatively associated with tolerance to various abiotic stresses, which can be used in marker-assisted breeding programs. More detailed studies of these portions can lead to the identification of genes involved in tolerance. One of the benefits of MAS is to back up physiological research in the understanding of mechanisms involved in stress tolerance. However, one initial challenge is to have a sufficient number of molecular markers available for QTL mapping. In 3 out of the 5 ICRISAT mandate crops such markers are severely, if not totally, lacking.

To get further quantum leaps in drought tolerance, a better understanding of the complexity associated with most abiotic stresses is needed. The difficulty of working to improve crop performance in drought conditions lies in the fact that drought varies substantially in duration, timing and intensity. This inhibits the environment for which the crop is targeted being well identified. Yet, most scientists still refer to drought tolerance as an entity whereas examining the component traits of drought tolerance (therefore linking to a particular environment, i.e. a particular "type" of drought) would be more effective. The challenge will be to understand the interaction of environment with genotype better. Also, the genetic tools now available to ease this process have meaning *only* if they correlate well with a phenotype. So that another challenge will be to combine a plant approach to a molecular approach effectively, in particular with relation to the different gene-base approaches.

Finally, once component traits and their molecular markers are located on a linkage map, the challenge will then be to realise products of marker-assisted breeding for complex traits. Recent research at ICRISAT using terminal drought tolerance QTL in pearl millet is probably one of the first such examples.

So the needs/challenges in the area of abiotic stress research is to:

- Target and characterize the environment
- Identify the major component traits of interest for a given environment
- Link those traits of interest with an efficient marker system
- Develop markers in those crops where they are not available
- Deliver products from marker assisted selection
- Use the MAS products to progress in understanding of tolerance mechanisms

How can genetic engineering help abiotic stress research?

The emerging disciplines of genomics, transcriptomics and metabolomics are generating large volumes of information on the role of key genes in their response to abiotic stresses. The genetic transformation approach has the technical potential now to insert genes of known action, in an attempt to improve a plant's ability to thrive under stress. One of the challenges for genetic engineering in the area of abiotic stress research is whether a single-gene approach can be helpful with complex traits, which undoubtedly involve a cascade of genes. Also, the challenge is to concretise/validate the success of lab-type and short-term evaluations of recent transgenics into a success in the field or field-like conditions to go beyond what has been done so far.

Certainly, the use of transgenic research can back up research on tolerance mechanisms in different kinds of stress. A good example is the current research on transpiration efficiency (TE) in groundnut, which is progressing toward MAS breeding using RIL populations and DREB1A transformed plants. The range of variation found in the transgenics, and the fact that these are isogenic to the wild type but for DREB1A provide materials of choice to explore the physiological mechanisms that lead to increased TE, and also to identify the genes involved in high TE.

Last, but far from least, if GM crops are to be successful, there is a whole scope of regulatory issues that need to be considered. This comes back to one of the essential questions to be asked in relation to transgenics: Can they bring anything better for abiotic stress research than what is already available in conventional germplasm?

So, the need/challenges in term of transgenics will be:

- Prove whether/what type of transgenic can contribute to improving abiotic stress tolerance
- Prove that stress tolerance is better than any already available source
- Use transgenics to unlock the mechanisms involved in stress tolerance
- Solve regulatory issues

Can ICRISAT's crops be used as a source of tolerance alleles for other crops?

The five mandate crops of ICRISAT are all fairly well adapted to arid conditions, although genetic variation is obviously present, and already have "built in" characteristics that make them suitable for dry areas (deep roots, short cycle, waxed leaves, resistance mechanisms, etc.). We have also strong evidence that pearl millet and sorghum have high levels of tolerance to salinity. Pearl millet accumulates large amount of Na in the shoot, to levels that probably require compartmentalization (vacuoles) or relocation to less vital parts. This requires mechanisms and genes controlling those mechanisms, which could be understood and then transferred to less tolerant crops. With the advent of synteny studies, whereby genome studies reveal large portions of the genome being conserved across related species, there is a whole field open to investigate the genomic areas of a given species in relation with what is known in other species. The challenge would be to:

- Identify those genome areas in ICRISAT crops involved in abiotic stress tolerance
- Identify where are those regions in more susceptible and economically important crops (eg, rice, maize)

The role of wide crosses in abiotic stress tolerance

The first attempts to use wide crosses were made historically and the concept is not new. Wide crosses have been used to confer biotic stress tolerance. Less has been used to introduce abiotic stress tolerance, although some attempts have been made in pigeonpea and salinity, although there seems to have been no clear follow up. Recent reviews on groundnut address the use of wild relative of groundnut. Although the last of these reviews separately surveys the existing sources of tolerance for groundnut diseases in wild and cultivated germplasm, it does not *compare* the wild and cultivated germplasm for the value of these sources. So that it remains unclear for which disease resistance alleles should be brought from the wild relatives, and for which disease sufficient resistance levels already exist in the cultivated pool.

This raises the issue of how to evaluate wild relatives, and their crosses with cultivated germplasm, for abiotic traits, where plant size matters considerably. Success involving beneficial alleles from the pool of wild relatives will require a quantum leap in the understanding and identification of those traits from the wild that we think are important for abiotic stress tolerance in cultivated crops. For instance, wild chickpea do not have larger roots than cultivated one, mostly because their stature is also smaller, but they generally have larger root/shoot ratios. Only if such traits turn out to be important components of drought tolerance in a given environment, and if they are available only in the wild germplasm, should wide crossing be considered.

Further scope for using wide crosses is also the possibility to increase genetic polymorphism. Progress in MAS is often hampered by a lack of genetic polymorphism between the parents of the RIL population. The consequence being that linkage maps that are generated are imprecise and the precision of the subsequent MAS is decreased. In addition, further expenses are necessarily incurred in the development of more markers. A project currently starting in groundnut aims at "re-creating" the event that originated groundnut, to increase the amount of polymorphism in cultivated groundnut.

The need/challenge to involve wide crosses are to:

- Identify those traits from the wild that could contribute to abiotic stress tolerance in a cultivated background
- List the wild relatives where such traits can be found
- Set up efficient ways to evaluate the wild species for certain traits of abiotic stress tolerance
- Compare those traits with what currently exist in the cultivated gene pool
- Introgression of the trait into a cultivated background
- Introduce genetic variation in the cultivated gene-pool

Tapping the pool of resources in collections for abiotic stress tolerance
ICRISAT holds large collections of germplasm. Yet, only a very tiny portion of that entire germplasm has been used for breeding new varieties even in the growing presence of core and mini-core collections. Yet, the question arises whether this will enable breeding for abiotic stress tolerance to use more of these resources. It raises the question whether the mini-core collection based on agronomic and morphological traits represent the whole range of variation in the collection for abiotic stresses. While very useful to "structure" the germplasm collection, the concept of core and mini-core collection still needs to be "validated" for abiotic stress research.

The use of large numbers of varied germplasm accessions may ease the choice of parents that will be crossed for the development of RIL populations and the further development of mapping populations. In some cases in the past, not using a large range of genotypes for identification of the range of variation for a given traits has led to the crossing of parents that had little contrast (the case of chickpea and salinity). Also, the recent advent of molecular markers has revealed the lack of genetic polymorphism between the parents involved in certain crosses. The use of a large number of accessions to screen for abiotic stress tolerance can certainly help overcome this problem by making sure that parents involved in crosses vary genetically.

Last but not least, the contribution of germplasm resources in abiotic stress tolerance might be possible through association studies, whereby RIL populations would no longer be needed. So the needs/challenges from the genetic resources are:

- Test/validate the usefulness/representativeness of the core and mini-core concept for abiotic stress research
- Identify contrasting genotypes for traits of interest with sufficient polymorphism
- Explore a large range of genotypes to ensure that a full range of variability is considered
- Phenotype a representative collection for abiotic stress tolerance to carry out association genetic studies

What is expected from ICRISAT from 2007-2015
This all depends on issues such as the availability of markers in the different crops. For instance, in the case of the ICRISAT cereals, the number of available markers is, although insufficient, better than for the ICRISAT legumes, and better in sorghum than in millet. In specific cases, the limiting factor may be lack of knowledge of the range of variation in tolerance to different abiotic stresses, such as in salinity tolerance in groundnut.

Drought
Water capture (roots) and water use efficiency are probably two of the components of yield architecture ($Y = T \times TE \times HI$) that are important for crops growing under terminal drought conditions, which is the case for most SAT crops. Drought avoidance (i.e. getting more water or using it more efficiently) will be likely to be the major trait of interest to expand the production to presently uncropped areas and post-rainy fallows in Asia.

For root traits, we need to progress in understanding in those crop where roots have already proved to be beneficial for yield under terminal drought (chickpea), and then explore in those crops where little information on roots has been acquired (the other mandate crops). Specifically, there is a need to understand the dynamics of roots, how roots contribute to the overall water budget, and in particular how they contribute at the time of grain filling. Fairly recent results gathered at ICRISAT indicate that deeper rooting correlates with a higher harvest index (HI) in chickpea in conditions of more severe drought. Recent results tend to lead to a similar conclusion in pearl millet, where deep rooting is involved in the QTL for high panicle harvest index (thereby a link between roots, i.e. the "T" component of the yield architecture and HI).

Regarding transpiration efficiency (TE), our current state of the art is observed in groundnuts, where TE is addressed both through a MAS and a GE approach which should increase the chances of reaching our goals.

The comparative advantage of ICRISAT in this area is the availability of cheap and abundant labor in India and the availability of genetic resources (in particular for roots). However, effective exploitation of this subject would probably require a quantum leap in our phenotyping capacities, as well as in the methods used to investigate root traits.

Salinity

Soil salinity is an important limiting factor for crop yield improvement, which affect 5-7% of arable lands, ie, approximately 77 million ha worldwide. Most crops are sensitive to salt stress at all stages of plant development, including seed germination, vegetative growth and reproductive growth. Legumes, in general, are sensitive to salinity, and within legumes, chickpea, faba bean and pea are more sensitive than other food legumes. The salinity problem is increasing, in particular in areas where irrigation is a common practice. Management options exist to alleviate salt effects. However, management options are often in contradiction with the immediate economic choices of the concerned farmers and crop improvement for salt tolerance appears to be the only alternative.

The problem of salinity is basically two-fold. Either soil is saturated with sodium (Na) and soil pH remains within an optimal range for crop growth. This type of salinity refers to coastal or dry land salinity (Munns et al., 2002). These are soils that get saturated with sodium because an existing saline ground water table is rising (proximity to the sea or salt that have accumulated down in the soil profile), bringing the salt at the surface. Either soil is both saturated with Na (exchangeable sodium percentage, ESP, > 6, Isbell, 1996) and pH has reached levels above 8.5-9.0. This type of salinity is also called transient salinity, and is thereafter referred to as *sodicity* or *sodic soils*. In this case, the sodium saturation brings about the same effect as *salinity*, but the high pH dramatically affects the availability of micro-nutrients (low availability/solubility of micro-nutrient salts at these pH levels), the soil structure and porosity (poor drainage, tendency for water logging, little oxygenation, because of saturation of the exchange complexes in the soil by sodium). Most studies have focused on *salinity*, and few only on *sodicity*.

Despite the importance of salinity on the crop production worldwide, and the abundance of knowledge gathered about the effect of salinity on plant growth and development, there has been surprisingly little effort to breed for improved salinity tolerance, except a few exceptions like wheat, rice, barley, alfalfa or claims of soybean. Breeding tolerant crop varieties is therefore urgently needed.

ICRISAT´s challenge with regard to salinity is probably two-fold: (i) fill the gap between the knowledge acquired on plant responses to salinity and the paucity of efforts made to breed salt tolerant crops; (ii) increase the effort in the field of sodicity (salinity + high pH), which accounts for more than half of the saline soil, in India in particular.

Outputs and Outcomes to 2015:

Output 1:

- Entries generated at NARS and private sector partners request of pearl millet and sorghum with enhanced terminal drought tolerance issued from MAS made available for multi-location trials.

Outcome:

- Improved terminal drought tolerance becomes a trait used by NARS and the private sector in their hybrid development programs.

Potential impact:

- The potential for improved productivity and food security in marginal areas is increased.

Counterfactual:

- Higher year-to-year variation in yield and overall about 10-20% lesser productivity might be expected.

Output 2:

- QTL with major effects on salinity tolerance in pearl millet, sorghum and chickpea, and for root traits in chickpea, detected from different populations.

Outcome:

- Research on breeding salinity tolerant crops is for the first time included in mainstream breeding programs through the use of modern and efficient molecular tools. Information is published and disseminated, and made available to breeding programs nationally and internationally.

Potential impact:

- ICRISAT takes the lead in breeding for salinity tolerance. Varieties with improved salinity tolerance “colonize” areas previously improper for agriculture.

Counterfactual:

- Options to increase cultivation in fallow/saline affected area is reduced. Dryland agriculture remains exposed to risks of crop failure.

Output 3:

- Additional genetically diverse sources (10 per crop) of tolerance to terminal drought and salinity identified from phenotyping of GCP composite germplasm subsets in chickpea, groundnut, pearl millet and sorghum and made available to partners.

Outcome:

- Partner breeders use additional sources of tolerance to drought and salinity increase the genetic base of breeding programs nationally and internationally.

Potential impact:

- Broader range of target environment reached by improved products because of a larger portfolio of “adaptability” in improved products.

Counterfactual:

- Slower progress made from earlier sources of tolerance identified. Less diversity in the sources of tolerance available creates a “genetic” bottleneck in tolerant materials bred, leading to increased risk of epidemic.

Output 4:

- High throughput molecular genetic and phenotyping platforms (QTLs, transgenics, etc…) developed, used in its breeding program, and used to improve capacity development in NARS and private sector breeding programs.

Outcome:

- Increased efficiency in breeding for drought tolerance in 4 mandate crops shown by NARS and the private sector resulting in better efficiency and cost-effectiveness of breeding.
- Genome portions related to drought and salinity tolerance are initially aligned with related species and thus have the potential to benefit less tolerant but more economically important crops in breeding programs worldwide.

Potential impact:

- Quicker and more cost effective release of tolerant varieties with particular use to harsh environments.

Counterfactual:

- Major legume staple and cash crops remain inaccessible to molecular breeding, leading to reduced and slower prospect to improve crops for abiotic stress. As a consequence, the interest of public-private partnership to develop improved varieties decreases. NARS suffer major crop losses in the future.

Impact pathway:

- Examination of partner breeding programs to determine if resistance to abiotic stresses is being adequately incorporated

Predominant capability:

- Availability of large germplasm bank, knowledge of the structure of collections, high throughput molecular lab and excellent field testing and controlled environment facilities in a regularly stressed environment provide a reasonably unique combination for exploitation in abiotic stress research. The private seed sector is not active in developing these products for economic reasons. Collaborating NARS have solicited ICRISAT to take the lead in developing these types of products.

2C. Enhancing nutritional quality and safety

The current world population, approximately 5.8 billion, is expected to double by the year 2050. The population increase in developing countries constitutes 97% of the global increase, and it is estimated that by 2050, 90% of the planet's population will reside in the developing countries of the southern hemisphere. The challenge for the future, therefore, lies in global food security that necessitates a doubling of food production in the next 50 years to meet the needs of the population. Besides, sufficient micronutrients in the daily diet are one of the prerequisites for human health. Estimates suggest that some 815 million households worldwide suffer from micronutrient deficiency. The ill effects on human health are further compounded by the quality and safety of foods that can often be contaminated by microbial toxins due to improper pre- and post-harvest conditions in the SAT. In view of the acute present malnutrition in SAT-Asia and to help developing countries attain food security and reduce poverty and malnutrition, it is important that ICRISAT focuses its research in developing technologies that improve the nutritional and vitamin status of its mandate crops and provides safety measures to decrease the risk of food and feed contamination by mycotoxins. ICRISAT strategy to tackle micronutrient malnutrition and constitutive mycotoxin-contamination in foods and feeds are given under SC Priority 2C Specific Goals 1 and 3, respectively.

Specific Goal 1: Increase the content of micronutrients in the edible parts of crop plants through improved biotechnologies and breeding

Micronutrient malnutrition, often called "Hidden Hunger", is primarily the result of diets poor in bio-available vitamins and minerals, results in clinical deficiency and associated diseases such as respiratory and immunodeficiency diseases, childhood diseases such as measles besides blindness and anemia (and even death). Today, micronutrient malnutrition may diminish the health, productivity, and well being of over half of the global community, with impact primarily on women, infants, and children from low-income families. The ramifications of micronutrient malnutrition to human health, livelihood, well being, fertility, and, ultimately, the sustainability of national development efforts in third world countries are many. This hidden hunger results in huge costs to society that greatly impair national development efforts, reducing labor productivity, lowering educational attainments in children, reducing school enrolments and attendance, increasing mortality and morbidity rates, and increasing health-care costs. 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. While most forms of hidden hunger have been overcome in industrialized countries, they still remain a major source of health problems in developing countries.

Three micronutrients, Fe, Zn and beta-carotene, are widely recognized as limiting by the World Health Organization (WHO). Deficiency of these micronutrients is highest in South and Southeast Asia and Sub-Saharan Africa. These are also the regions where ICRISAT mandate crops are cultivated and consumed as food by large numbers of people who have poor access to formal markets and health care systems. Past programs to combat micronutrients malnutrition have relied primarily upon food fortification and to some extent supply of vitamins and mineral pills as readymade source. Unfortunately, these approaches have not proven to be sustainable for various reasons including lack of funds and poor infrastructure and are not able to reach all the people at highest risk of malnutrition. The strategy for enhancing micronutrient levels in the edible parts of staple food crops has become the greatest priority to sustain nutritional security. In the past, breeding efforts in crop improvement have largely focused on genetic enhancement of yield potential and resistance to biotic and abiotic stresses. The emphasis on biofortification of staple food crops has now been initiated and is expected to be further enhanced in the coming years. The introduction of crop varieties selected and/or bred for increased, Fe and Zn, beta-carotene contents through genetic enhancement approach will complement existing approaches to combat micronutrient deficiency and can complement the ongoing benefits throughout the developing world by taking advantage of the consistent daily consumption of large quantities of sorghum, pearl millet, groundnut and pigeonpea-based diets by people at a fraction of the recurring cost of food fortification achieved during processing.

Outputs and Outcomes:

Outputs 2010:

- Stable high yielding biofortified hybrid parents/varieties/populations of sorghum and pearl millet (10 across two cereal crops with 50-70 ppm iron and 40-60 ppm zinc), and characterized biofortified transgenic events of groundnut and pigeonpea (2 to 3 across two legume crops with enhanced level of beta-carotene) are made available to NARS at their request.
- Proof of concept on the feasibility of conventional breeding and transgenic approaches of crop improvement for biofortification of mandate crops published.
- Information on breeding strategies, bioavailability, toxicity, stability, consumption patterns and public acceptance of biofortified foods published and used for capacity development at NARES and NGO request.

Outcomes 2010:

- NARS and private sector breeding programs are strengthened by the use of selected hybrids / varieties/ populations of sorghum and millet with enhanced level of iron and zinc and groundnut and pigeon pea with enhanced levels of beta-carotene. NGOs and GOs benefit from improved awareness, knowledge and capacity development

Potential impacts:

- Enhanced awareness, both in the public and private sectors nationally, crop improvement programs able to focus on breeding of micronutrient dense hybrids/ population/ varietiesforn eco-regionally adapted cultivars

Output 2015:

- High yielding and micronutrient dense hybrids/ improved population/ varieties (5-10 across two cereal crops) and promising transgenic events of biofortified groundnut and pigeonpea in national trials. Information on bioavailability of iron, zinc and pro-vitamin A in biofortified products available. Biofortified hybrid parents of sorghum and millet and promising transgenic events of groundnut and pigeonpea rich in beta-carotene made available to NARS for release and marketing. Associated capacity strengthening in NARES and the private sector.

Outcomes 2015:

- Increased numbers of micronutrients dense hybrids/ varieties produced and selection of hybrid parents with enhanced levels of iron and zinc in the sorghum and pearl millet turn used routinely in both private and public sector breeding programs. Biofortified transgenic varieties of groundnut and pigeonpea with enhanced level of beta-carotene used for introgression into locally adapted germplasm by NARS (public and private) partners. Biofortified cereal hybrids and legumes varieties developed by NARS are released / marketed for commercial cultivation

Potential impacts:

- Biofortified hybrids/ varieties released for consumption to rural poor and urban consumers. Awareness increase for the availability of biofortified staple food crops to rural and urban consumers. Food technology research takes up biofortified products to design new/ quality foodstuffs. Biofortified crops contribute to the value addition of the crop that is an important subsistence food crop in the semi-arid tropics. Such value-enhanced crops are expected to have a significant impact on the nourishment and nutrient interactions involving other micronutrients under multiple commodity diets by playing a major role in better bio-availability and metabolic efficiency.

Impact Pathways:

- Publications in peer-reviewed journals and presentations at workshops, symposia, and conferences both at national and international are the pathways for communication. Technology and products developed will be channeled through training and collaboration with NARS, NGOs and private sector. Biofortified grains available to both public and private sector plant breeder and seed producers globally, who will, in turn, use these to produce locally adapted varieties with improved nutritional quality traits for SAT farmer who depend upon our crops for their livelihoods.

Predominant capability:

- The NARS in Asia currently do no have capability or capacity for undertaking work on crop biofortification especially through transgenic approaches. The private seed sector has shown no interest in this area since it is not a high priority for their commercial interest. ICRISAT has a comparative advantage over the NARS as ICRISAT over the years has built in-house capacity to undertake such product development and training in terms of human resources and infrastructure, such as well-established analytical laboratories for Fe and Zn analysis comparable to international standards, well-equipped tissue culture and genetic transformation laboratories with optimized protocols for transgenic research, and access to the Consortium of sorghum and pearl millet hybrid parent research.

Counterfactual:

- Micronutrient enhancement in food grains is not a recognized priority in the national programs of Asia and Sub-Saharan Africa. The private seed sector has not shown any interest in this area since micronutrient dense hybrids/ varieties do not add any income due to lack of brand equity of such commodities. If ICRISAT does not carry out this research, it is likely that malnutrition risk groups in developing and undeveloped countries of SAT will be deprived of cheaper and sustainable source of micronutrients. Alternative sources such as pills or diversified food sources are not readily available for poor people. Diseases associated with vitamin A, iron and zinc deficiencies will continue to rise resulting in hidden hunger which accentuates the effects of malnutrition that include night blindness, diarrhea, child mortality, and diseases like AIDS. Augmenting pro-poor crops (sorghum, pearl millet, pigeonpea and groundnut) with these micronutrients will enhance these essential micronutrients in the daily dietary supplements resulting in better health especially of children and women.

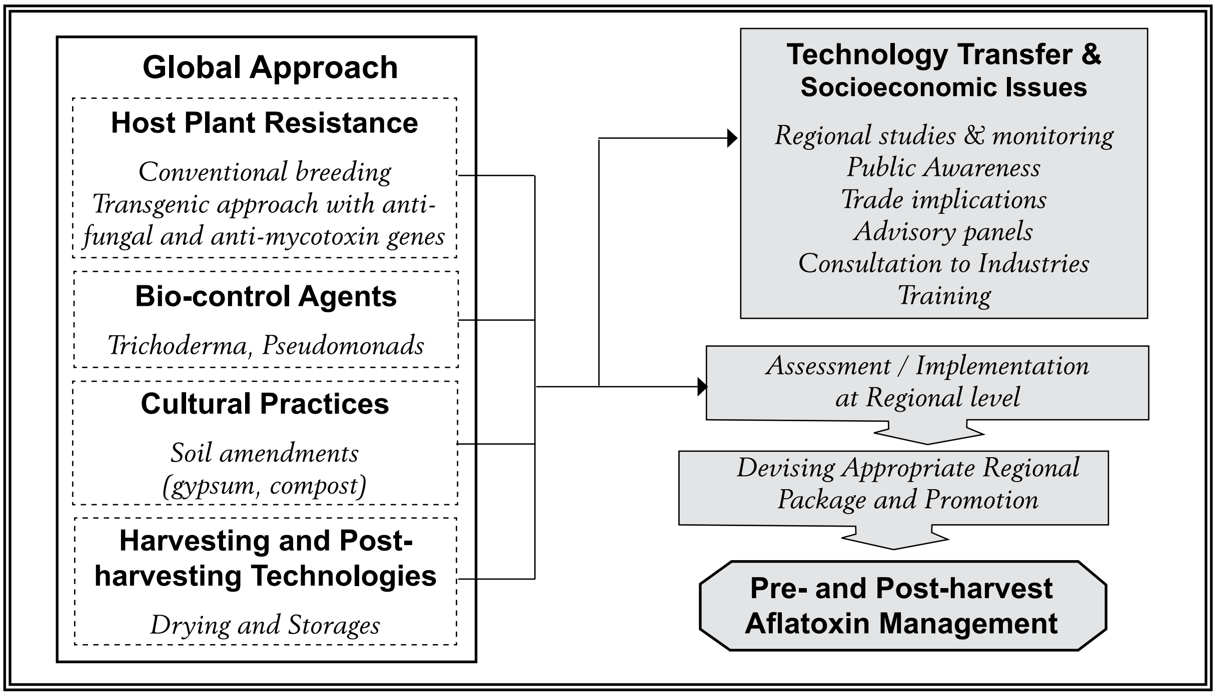
Specific goal 3: To reduce the content of constitutive or microbial toxins in selected staples that affects quality, food safety and human health

In addition to micronutrient malnutrition, several mycotoxins contaminate the food crops of the poor in the SAT. Among them, aflatoxins, which are toxic, carcinogenic, teratogenic and immuno-suppressive substances, are produced when toxigenic strains of the fungi *Aspergillus flavus* and *A. parasiticus* contaminate groundnut, maize, cotton, chillies, and many other agricultural commodities. About 4.5 billion people living in the developing countries are presently chronically exposed to largely uncontrolled amounts of these toxins. Blood tests have shown that a very high percentages of the populations are exposed to aflatoxins in several developing countries of Asia and Africa. Exposure to aflatoxins compromises immunity and interferes with metabolism of some proteins and micronutrients. They are highly toxic to livestock and are implicated in human diseases. Aflatoxins are well recognized as a cause of liver cancer. Chronic exposure to aflatoxin has major effects on the nutritional status of human beings and animals. It has been shown that humans, particularly children and animals that consume contaminated food/feed have reduced rates of growth. The interactions between vitamins and aflatoxin have also been studied and it has been reported that several vitamins including vitamin A levels decrease with increased level of aflatoxin in the livers of animals.

Management of mycotoxin has proven to be a difficult challenge in developing countries due to lack of awareness, lack of stringent food safety regulations, environmental conditions and farming practices that are conducive for the contamination and lack of diagnostic tools for monitoring mycotoxins. To attain significant health improvement of the poor in SAT, there is an urgent need to address these issues in ICRISAT mandate crops and also in other staple and high value crops such as chilies, spices, maize, tree nuts etc., that are very important in the diets of people in these regions.

To tackle mycotoxin contamination, ICRISAT emphasizes an IGNRM strategy by developing mycotoxin-tolerant cultivars of mandate crops, particularly groundnut, and appropriate pre- and post-harvest technologies that reduce the risk of food/feed contamination. These involve genetic enhancement through both conventional plant breeding and biotechnology applications; better pre- and post-harvest crop management technologies including agronomic practices, biological control and post harvest techniques, development of simple and low-cost mycotoxin diagnostic tools (see Figure on next page). This is possible to be achieved only with major collaborative efforts between different stakeholders.

Schematic representation of integrated management strategy for pre- and post-harvest management of mycotoxins



The role of ICRISAT will be to quantify the risk of mycotoxins contamination in food and feed in the region; to produce cultivars with higher levels of vitamins and micronutrients and tolerance to mycotoxins contamination; develop and disseminate technologies that reduce mycotoxins in food and feed; and in collaboration with other institutions and understand and provide new solutions for better management of health status of the disadvantaged populations in the region. There is also a need to profile the extent and intensity of mycotoxin contamination and related socioeconomic and health affects in different agro-eco systems of the SAT Asia, on different staple and high value crops, including ICRISAT mandate crops. To motivate the farmers to produce aflatoxin free crops it would be important to introduce, among other parameters, price determination based on aflatoxin contamination in the produce as is done in many developed countries. It is proposed that these activities will further enhance our efforts to improve the nutritional status and health of the poor in SAT by providing then with both a better quality and a better quantity of food.

Output (1) by 2010:

- High quality and low cost diagnostic tools for estimating the risk of human exposure to aflatoxins and quantitative estimation of mycotoxins (Aflatoxins, Fumonisins and Ochratoxin-A) in crops, processed foods, feeds and commodities, developed and widely disseminated for use by NARES, farmers, traders and processors in the developing countries of Asia

Outcome (1a) by 2010:

- Low cost diagnostic tools widely available and used by NARES, traders and processors for monitoring human exposure to aflatoxins, and mycotoxin contamination in foods, feeds, milk and blood thereby enhancing the food quality, food safety and human health in developing countries in Asia

Outcome (1b) by 2015:

- Mycotoxins better regulated in foods and feeds through continued and routine use of diagnostic tools in various production, processing, supply and distribution chains.

Potential impacts:

- The diagnosis of aflatoxicoses in high-risk zones is enabled
- Enhanced awareness and human capacity to exclude carcinogenic mycotoxins from food and feeds, thereby mitigating food-borne illnesses in humans and animals
- Enhanced trade by enabling quality certification of produce providing better market opportunities for farmers and traders
- Legislators enabled to reliably implement food safety regulations in developing countries in Asia
- Processors enabled to monitor food and feed quality in final products for different markets

Impact pathways:

- Technology and products developed are channeled through collaboration with NARES, NGOs and private sector, and training programs. There is high likelihood for rapid adoption of these technologies as there is high demand for low-cost technologies suitable for poor farmers in diverse cropping systems, as they are facing serious health risks and trade restrictions. Traders and processing industries and policy makers are in need of low cost mycotoxin monitoring tools and management packages.

Predominant capability:

- Commercially available technologies are expensive and need importation, which is prohibiting routine and wide application in developing nations in Asia.
- NARES are limited in capacity and skills and have indicated their desire for ICRISAT to take the lead in R&D in partnership mode to bring in the awareness and develop aflatoxin reducing technologies
- ICRISAT over the years has built in-house capacity and skills to produce diagnostic reagents and develop simple and sensitive serological assays for estimating mycotoxins, which are enabling us to mass-produce the diagnostic reagents, strengthen local capacity in monitoring mycotoxins and commercialize technologies through private enterprise through non-exclusive rights, reducing the competition and thereby reducing unit cost of mycotoxin analysis.

Counterfactual:

- Food safety cannot be ensured; reliable enforcement of food safety regulations is not possible; farmers, traders and processors continue to suffer from trade restrictions and rejections of exports; processors in supply chain continue to waste resources on cleaning products; increasing overhead costs due to greater dependency on high-cost diagnostic tools from commercial suppliers; traders exploitation of farmers continue through arbitrary quality estimation. R&D programs on mitigating mycotoxin contamination in food and feed suffer because of high cost of aflatoxin detection from large number of farmers' production and therefore marketing will remain difficult therefore we need cost-effective diagnostic tools.

Output (2) 2010:

- Food and feed quality enhanced through incorporation of six aflatoxin resistant groundnut varieties, and a refined integrated technology package combining agronomic and genetic options for reducing aflatoxin contamination in staple and high value crops (groundnut, Sorghum, maize, chilies, pistachio) developed and promoted in Asia

Outcome (2a) 2010:

- Wide adoption by NARES partners of low cost technologies for reducing aflatoxin contamination in groundnut and other staple and high value crops grown in diverse farming systems in Asia

Outcome (2b) 2015:

- NARS nutrition institutes report human and animal health improved, enhanced market opportunities through increases in production of high quality food and feed free of aflatoxin or with low aflatoxin content.

Potential impacts:

- Food and feed quality improved by reducing health risks due to aflatoxin-related illnesses in humans and animals
- Enhanced awareness and human capacity to reduce aflatoxin contamination in food and feed, thereby mitigating food-borne illnesses in humans and animals and enhanced market opportunities for produces from developing countries
- Awareness on aflatoxin or aflatoxin-reducing technologies increased among various stakeholders in developing countries of Asia
- Availability of low-cost technologies suitable for adoption for farmers from low-income groups, which will contribute in 5-10% income gains.
- Policy support to provide incentive mechanism in the market to encourage the production of aflatoxin-free produce
- Poor farmers in marginal farming systems in developing countries of Asia who will benefit from adoption of improved varieties and packages to reduce aflatoxin contamination in groundnut and other staple and high value crops (maize, sorghum, pistachio, chillies etc.).
- NARES who adopt and further promote and use the technologies, especially diagnostic tools, in there research and extension programs.
- Traders and processing industries that benefit from diagnostic tools in monitoring produce for national and international markets and benefit from clean product produced by farmers using improved packages through these interventions.
- Policy makers will benefit from supporting data produced by the project to align with state policies on food safety regulations and trade, and extend necessary support to farming communities.

Impact pathways:

- Technology and products developed are channeled through collaboration with NARES, NGOs and private sector, and training programs. There is high likelihood for rapid adoption of these technologies as there is high demand for low-cost technologies suitable for poor farmers in diverse cropping systems, as they are facing serious health risks and trade restrictions. Traders and processing industries and policy makers are in need of low cost mycotoxin monitoring tools and management packages.

Predominant capability:

- NARES outreach is limited to specific regions within the country. Whereas ICRISAT's mission is to produce IPGs. Moreover, ICRISAT has the in house diagnostics tools necessary to evaluate various technologies in mitigating aflatoxin contamination; access to global groundnut germplasm for developing resistant varieties through conventional breeding; capacity to exploit genetic engineering approaches by incorporating anti-fungal and anti-mycotoxin genes for enhancing genetic resistance (included under Priority 2A); and networks and partnerships with several organizations in several countries to promote technologies.
- Aflatoxin-management activities are not catered for by the private sector, whose interest lies in high-potential agriculture, but not on the marginal farming sectors - who are most vulnerable to mycotoxin contamination related illnesses.

Counterfactual:

- Aflatoxin contamination in crops and crop-based products continue to be high and unchecked; human and animal health in marginal farming systems continue to be affected due to aflatoxin-related illnesses; outbreaks of human and animal mycotoxicoses cannot be prevented; confidence among exporters and importers remains low due to risk of contamination; trade restrictions on import of crop-based products from developing countries remain unlocked; threat of liver cancer due to aflatoxin accumulation especially among Hepatitis-B and C virus-affected patients remains high; aflatoxin contamination continues to be a major negative influence on health of children, human and animal productivity and ability of HIV-affected patients to cope with the illnesses.

Priority 2D: Genetic Improvement of High Value Species

Improved forage and fodder cultivars

Background and justification

Demand for livestock products in South Asian countries has been growing, and it is unlikely to subside in the near future as the factors underlying the demand growth such as urbanization, income growth and change in tastes and preferences will continue to strengthen in the near future. Besides, the globalization of agricultural markets also offers significant opportunities to countries to augment their exports. For example, in south Asia the demand for milk and meat is expected to increase up to 2 times between 2000 and 2020 with a few exceptions. Despite this, per capita consumption of milk and meat would continue even then to be lower than global average consumption levels implying scope for further increases.

Diversification of the agricultural sector towards livestock production thus offers an opportunity to improve the economic welfare of the rural poor. More than one-third of the population in the region is poor, and poverty is concentrated mainly among rural landless and small landholders. Evidence shows that the distribution of livestock in the region is more egalitarian than that of land, and thus has the potential to contribute powerfully to poverty reduction. Smallholders and the landless together control 75 percent of Indian livestock resources, and have the capability to generate livestock products at low cost, because of sufficient labor endowments and low opportunity costs, and use of free common grazing resources. The market for livestock products offers an opportunity for augmenting their income, even for those who do not have access to land and capital resources. Products like milk and eggs are steady sources of cash income, and live animals can be easily liquidated for cash during emergencies.

Technology adoption and livestock productivity

An adequate supply of feed and fodder is crucial to improving livestock productivity. Crop-residues from food-feed cereals such as rice, wheat, coarse cereals, pulses and legumes constitute 45–60% (on dry matter basis) of the total feed fed to large ruminants in South Asian countries. The cultivation of green fodder crops is low and largely restricted to the irrigated tracts and peri-urban areas of Pakistan and India. The rest is made up from grazing in rangelands that include pastures, forest grazing, wastelands, and fallows. Small ruminants are mainly grazed. The use of agro-industrial by-products (grains, brans and oilcakes) is low and mainly restricted to milk animals and the commercial poultry sector. Compound feeds or pre-mixed feeds are limited and restricted to commercial poultry feed, with very small quantities used for ruminants. The use of grain for animal feed is less than 5% (except for maize) in most countries, and the lion's share of this goes for poultry feed. Most of the future demand for livestock products will have to be met by small-scale farmers in mixed crop-livestock systems. During the last two decades, mixed crop-livestock systems have responded to the growing demand as reflected in the impressive growth in the livestock sector compared to the growth in the crop sector. The growth however, was largely achieved by an increase in animal numbers, with only a minimal contribution through productivity gains. Future growth in livestock production will have to come from productivity increases and not from increases in livestock numbers as in the past.

The role of ICRISAT

Although crop residues are an important source of feed their nutritive value is low and farmers are unwilling to improve quality through chemical and biological treatment of straw owing to knowledge, land, labor and capital constraints. Breeding for improved varieties with superior grain and straw quality is an option that would have potential payoffs. ICRISAT along with its partners can play a very important role in augmenting fodder resources and thus contributing to animal production and the incomes of small holders. Fodder (stover, haulms) from ICRISAT mandate crops an important source of livestock feed in the semi-arid tropics. The derived demand for fodder is growing due to the increase in demand for livestock products. At the same time the demand for coarse grains as animal feed is also growing particularly in the poultry sector that is the fastest growing in the region. Poultry meat now accounts for nearly 50% of the total meat consumption in south Asia.

ICRISAT and its partners will contribute to augmenting income from livestock through breeding for dual-purpose cereals, legumes and oilseed that have higher fodder yields and superior fodder quality. Increase in the digestibility coefficient of fodder is directly related to higher milk yields and hence higher incomes for resource poor farmers. Recent studies at ICRISAT have shown that improvement in the yield of groundnut haulm quality has contributed to higher milk yield in the Deccan Plateau of India. The digestibility of ICRISAT- partner released improved sorghum cultivars were found to be superior. Among the cultivars analyzed S 35, PSV 16 (46%), CSV 15 (46%) and CSH 16 (43%) were the best. The digestibility of local sorghum is 40-41% only. It is also found that irrespective of the soil type the improved cultivars are found superior to local cultivars for their stover digestibility. Research on using the stillage/bagasse from sweet sorghum after juice extraction for ethanol as a basis for "feed blocks" is now in progress with our ILRI partners.

The dairy and poultry industry too are also demanding coarse grains that are free from molds and mycotoxins and specific traits suitable for ruminants, monogastrics etc. Breeding for these traits will augment the supplies of these grains for the livestock sector that would help in reducing per unit costs of production. Presently, the area under forage crops in the semi-arid regions is low. Availability of improved varieties of forage types for sorghum and pearl millet (ICRISAT mandate cereals) will help in augmenting the area under forage crops in the semi-arid tropics and would contribute to higher milk production and productivity. Since feed is such an important component determining livestock productivity ICRISAT in collaboration with its partners can contribute to higher productivity and thus enhance incomes from the livestock sector.

Outputs and Outcomes:

Output:

- High-yielding forage hybrid parents and varieties, and hybrid parents and varieties with improved stover quality (an estimated 25 across two cereal crops and pigeonpea by 2015) in elite, diverse genetic backgrounds resistant/tolerant to major biotic stresses made available for use by partners and associated capacity building measures completed

Outcome:

- Hybrids and varieties bred by private and public sector organizations with improved forage/fodder yield and ruminant nutritional quality under evaluation in national trials by 2010 -2015 and capacity of partner breeder organizations enhanced

Potential impact:

- Cropping system diversification and increased household incomes of poorer farmers, through better exploiting opportunities for increasing animal production using improved dual- purpose food-feed crops

Impact pathways:

- Scientists' field days and consultation meetings, documented supply of seed of trait-specific nurseries and of individual lines as requested, registration of the genetic material, publication in peer-reviewed journals, presentation of paper/posters in conferences, symposia and workshops, articles in ICRISAT/global theme annual reports.

Predominant capability:

- ICRISAT's joint programs with the International Livestock Research Institute focusing on improvement of fodder resources in Asia, with its unique access to crop genetic resources, excellent scientific facilities, linkages to private and public sector national programs, and focus on IPGs, can not be easily substituted for within the national programs in Asia.

Counterfactual:

- Reduced options for small, poor farmers to increase production and nutritional quality of dry fodder and of green forages, reducing opportunities for diversification of household income sources, especially through milk production

Chapter 7: System Priority 3

System Priority 3. Reducing Rural poverty through Agricultural Diversification and Emerging Opportunities for High-Value Commodities through increasing income from fruit, vegetables, medicinal crops, oil crops and livestock in the Asian SAT

3A. Increasing income from fruit, vegetables and plant products

The Asian SAT is the home for 18% of the World's population and of these a substantial number of poor people reside in rainfed areas. In all, about 42% of the Asian population reside in rainfed (SAT, sub-humid and arid) areas. This is unlikely to change as the cost of developing additional irrigated land ranges from US$2 000 to 10 000/ha. Growing environmental concerns, and long-standing social and equity issues demand that urgent and substantial investment in research and development takes place for the benefit of rainfed areas. It is imperative that alternative water-management and production systems be considered for at least a part of the anticipated increased demand for food to permit future sustainable food security and environmental protection. Soil- and water-management options for rainfed areas, such as integrated watershed management, conservation agriculture, runoff farming, and dry farming using fallow storage, can increase soil moisture and groundwater availability in dryland areas, increase yields and improve the livelihoods of rural people. Considering present market externalities and environmental concerns there is an urgent need to diversify systems using high-value and less water demanding crops and by using integrated crop, soil, nutrient and pest management options. For sustainable development, farmer incomes need to be raised while still protecting land, water, and environmental resources. ICRISAT-Asia is employing this type of strategy to increase income through diversification of systems with increased soil and water conservation at a catchment scale. By adopting an integrated genetic and natural resource management approach, ICRISAT is able to demonstrate the enhancement of livelihoods on sustainable basis in rainfed areas. Our capacity for such research has been substantively enhanced by the decision by the World Vegetable Center (AVRDC) to place their S. Asian office at ICRISAT, Patancheru and joint research has been much enhanced as a result. With the advent of the High Value Crops – Fruit and Vegetables Challenge Program from 2008, this interaction can be expected to be further developed with a broader range of R & D partners.

Development of sustainable and efficient farming systems

- **Diversification through vegetables and fruits**: Through rainwater harvesting initiatives a considerable increase in groundwater can enable farmers to undertake investments in cultivating high-value crops with supplemental irrigation. In Asia our efforts are to increase water use efficiency in terms of economic returns using vegetables and fruits that have good market demand. It also addresses the need for greater consumption of such nutritionally rich products and thus the adoption of more nutritionally-sound diets in the disadvantaged communities of the rainfed areas.
- **Diversification with medicinal and aromatic plants**: In rainfed areas low water-requiring aromatic grasses and medicinal plants can be successfully grown. Where groundwater is available supplemental irrigation allows cultivation of high-value medicinal plants such as *Coleus forskolii*, *Andrographis paniculata*, *Cassisa angustifolia*, and *Withinia sominifera*. Through capacity building these crops can be processed in a decentralized manner in villages and value added products can then be marketed. Marketing of diversified crops products is a major constraint, in addition to developing the management options, for such new systems. ICRISAT is harnessing the potential of partnerships with private entrepreneurs to provide farmers with assured markets for value added products.

- Earlier studies show that livestock contribute as important positive sources for livelihood improvement in watersheds. Hence our focus is on sustainable rural livelihoods that capitalise on the integration of agroforestry, livestock improvement, horticulture and silviculture as per land capability and the assets of specific communities.

- Equitable development within the community through diversification in the watersheds is a necessary target. Our efforts are on ensuring gender parity and poverty alleviation for all.
- Improved livelihoods through biodiesel plantations: Common property resources in the villages are degraded and are in urgent need of rehabilitation. These CPRs are not fulfilling their original purpose of providing fodder and fuel for the villagers particularly for the landless. With the increasing rise in the prices of fossil fuel and also the increasing concentration of global atmospheric CO_2 there is urgency to develop alternative energy sources. In Asian countries, an alternative source of biodiesel is non-edible oils. *Pongamia* a N_2-fixing tree and *Jatropha* are proving to be good candidates for use as biodiesel plants. Seeds of these plants contain 30-35% oil. They are not browsed by the animals, are drought tolerant and are already grown in the region thus making them excellent candidate for biodiesel production. Our watershed consortia have initiated work to rehabilitate the degraded CPRs and low-quality private lands through establishing biodiesel plantations. In this area, public-private partnerships (PPP) are emerging quite strongly. Decentralized extraction of oil, growing of nurseries, collection of seeds, and use of seed cake a by-product after extracting oil as a organic source of plant nutrition provides a good income to the rural poor as well as minimizing land degradation.

- Sweet sorghum for ethanol production: ICRISAT has identified high-yielding sweet sorghum lines and developed varieties and hybrids which can be successfully used for ethanol production. Recently, several countries in Asia have adopted a policy of blending petrol with ethanol up to 10% creating a demand for ethanol. Traditional sugarcane molasses-based ethanol production is not presently meeting market needs. The water requirement (4000 m^3 for sorghum against 36000 m^3 for sugarcane) and crop growth duration (4 months for sorghum against 12 months for sugarcane) of sweet sorghum is much lower than that of sugarcane and thus sweet sorghum can be grown in the dry lands with low-volume irrigation facilities. Several pilot studies have recently indicated the economic feasibility of ethanol production from sweet sorghum. Likewise, there are several additional advantages to cultivating sweet sorghum. Farmers can get higher income from sweet sorghum cultivation—both from the sale of stalks to distilleries and the sale of the grain after harvest of the stalks for food or feed use. ICRISAT's strategy is two-pronged. ICRISAT besides developing sweet sorghum hybrid parents and varieties suitable for ethanol production facilitates the private sector to incubate ethanol production technology from sweet sorghum. Several promising sweet stalk seed parents and varieties/male parents have been identified. The genetic enhancement strategy of ICRISAT is to improve seed parents further for stalk sugar content and to develop, test, and identify promising hybrids for various agro-ecosystems in collaboration with national programs. Further, strategic research on the relative performances of hybrids *vis-a-vis* varieties for maturity duration, response to photoperiod variation, adaptability and biomass producing ability in various agro-ecosystems will receive priority at ICRISAT. Feed blocks using bagasse/stillage of sweet sorghum are being researched presently with our ILRI partners and these should excellent economic promise.

Outputs and Outcomes

Output 1:

- New approaches and technological options to diversify SAT systems using available water resources efficiently to grow high-value commodities that increase incomes for disadvantaged households identified and promoted by consortium partners to Government agencies, donors, NGOs, and CBOs in Asia.

Outcome 1:

- *Approaches and technological options 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.*

Potential Impact :

- 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 are developed and promoted in the SAT areas of India, Thailand, Vietnam, southern China, and Philippines.
- Incomes of the farmers in target rainfed areas using available water to grow high-value commodities potentially increased by 50%.
- Potential proof of concept for use of environment-friendly alternative sources of energy using biodiesel and ethanol from sweet sorghum to use as energy source in the target countries (India, Thailand, and Philippines).

Output 2:

- Technological options and approaches to add value to high-value crops to increase farmers incomes through ensured high-quality marketable products developed and scaled up by partners.

Outcome 2:

- Technologies and approaches to add value through processing and improved quality standards adopted by target country institutions resulting in enhanced market opportunities and increased incomes. **(2010-2015)**

Potential Impact:

- Value addition and better quality (healthy) products from agriculture enhance marketability and incomes for the farmers.
- Stronger public-private partnerships and seamless integration of research and development initiatives promote development in the region.
- High-quality hygienic products benefit human and animal health and green fuel options protect environmental quality.

Impact pathways:

- PR&D approaches and sites of learning empower the primary stakeholders to refine and adopt improved technologies.
- Close partnerships with CBOs, NGOs, and government departments sensitize development workers and policymakers to put in place favorable policies and institutions to diversify the SAT systems using high-value crops.
- Involvement of industries through PPP in consortia create market opportunities and generate demand for sustaining systems diversification in tune with the market.

Predominant Capability:

- ICRISAT has a comparative advantage of working at watershed/catchment scale through consortium approach. It's international nature along with its multidisciplinary team of scientists enables it to act as a facilitator and honest broker which is trusted by partners to advocate strongly the introduction of necessary policy and institutional changes in the target countries.

Counterfactual:

- Farmers will continue to grow water inefficient crops using available water resources and farming will become a losing proposition resulting in increased poverty.
- CPRs will be further degraded and process of desertification will set in triggering distressed migration of unskilled people to cities.
- Over dependence on fossil fuel with increasing prices will push the developing countries on a downward spiral of development and also increase environmental pollution through release of greenhouse gases (GHGs).

Chapter 8: System Priority 4

System Priority 4. Poverty Alleviation and Sustainable Management of Water, Land and Forest Resources at Watershed Level throughout the Asian SAT

4A. Integrated land, water and forest management at landscape level

Introduction: Most of the world's poor and marginalized people living in rural South and Southeast Asia derive their livelihoods from land, water and forest resources. With an ever increasing population in the region, in countries like India, Thailand, Vietnam, and China more marginal lands are being brought under cultivation and land and water resources are being over exploited to meet food, feed and fuel needs. With increasing competition from other sectors of the economy for these natural resources, more food will have to be produced with less land, water, labor, and other resources. Currently the productivity of these natural resources is declining because of the lack of control over the negative externalities of prevailing practices and policies. The productivity of these resources must be increased in a sustainable manner to reduce poverty and enhance environmental quality. More effective systems of practices, policies, and institutions need to be developed urgently for appropriate management of natural resources in order to derive benefits on sustainable basis.

With increasing use of water in agriculture and other competing demands, water is becoming a scarce commodity. Water tables have gone down with increased groundwater use, which need to be replenished and more efficiently used. With increasing competition for water, suitable methods, policies and institutions need to be developed to optimize the use of water in an equitable and efficient manner amongst the various sectors of the economy.

Natural resources need to be developed and managed both at the local level (household or community) and at the watershed landscape level to provide multiple products and environmental services. There is an increasing need to address issues of equity and gender for improving the livelihoods of the rural poor and to meet the MDG goals. Also the degraded and common lands need to be brought under vegetation (grasses, shrubs, agro-forestry, and other high value trees) so that the landless can potentially derive benefits from their products.

Therefore, natural resources in the rainfed regions of the SAT need to be managed and used to provide livelihood security and social well-being through achieving increased overall resource productivity in an ecologically sustainable manner. The landscape level watershed improvement programs in Asia have shown good potential to contribute to the development of the SAT rainfed areas. Their alliance now with the development of the OASIS Consortium of partners with the emergence of the Degraded Lands Challenge Program in 2008 will help achieve greater levels of upscaling and impact in the driest regions of the world.

Outputs and Outcomes:

Output (1):

- New tools, approaches, technology and capacity building options to help cope with water scarcity and climate variability made available to appropriate researchers, development donors, government departments, NGOs and CBOs for efficient and sustainable management of soil, water and production systems at a watershed scale in the Asian SAT.

Outcome (1):

- New tools, approaches and technology options for sustainable development and improved livelihoods incorporated into the policy and implementation guidelines used by NARES partners in India, China, Thailand, Vietnam and Philippines for strengthening their integrated watershed research and development programs.

Output (2):

- Generic policies and institutional guidelines developed and delivered for suitable adaptation by public and private sector partners for sustainable development and up-scaling the benefits of integrated watershed management for increasing productivity and incomes of rural poor and enhancement of environmental quality in the Asian SAT.

Outcome (2):

- Enabling policies and budgetary allocation in place nationally and locally for the promotion of Integrated Watershed Management in selected regions in India, China, Thailand, Vietnam and Philippines.

Potential impact:

- In rainfed areas increased resilience to climate variability through Integrated Watershed Management. Agricultural productivity and incomes will be increased by 40% by farmer participants in India, Thailand, Vietnam and China by 2015. Land degradation is reduced and water availability increased
- Integrated watershed development will promote diversification of crops, income generating opportunities, better health for people and animals. Policy makers, government departments, NGOs and CBOs are better equipped to scale-up the benefits of watershed management independently.

Impact pathways:

- Through participatory research and development approach and partnerships with different stakeholders, suitable models enable capacity building, appropriate policies and institutions for scaling-up the benefits of improved watershed development. Knowledge sharing, reflections and shared learnings by consortium partners will further enhance the impact.
- Our approach of building partnerships with government officials and policy makers and advocacy will enable and facilitate suitable policies and institutions favoring development of SAT areas to be put into practice.

Predominant capability:

- Apolitical, multi-disciplinary dedicated institution, ability to act as facilitator and honest broker. ICRISAT has already gained a competitive edge in research and development initiatives through establishment of benchmark sites in different countries and already forged strong partnerships.

Counterfactual:

- If ICRISAT ceases its watershed and NRM work today, opportunities for the formation and maintenance of effective research and development consortia may be lost. NARES may continue their historic tendency towards location specific, disciplinary oriented NRM studies which makes scaling-up to wider agro-ecological zones in the SAT very difficult.

4D. Sustainable agro-ecological intensification in low and high potential environments

Introduction: The semi-arid tropics (SAT) of South and Southeast Asia have agro-ecological environments ranging from low to high potential. The intensification and diversification of production systems is thus determined by natural resources, especially the land, climate (especially rainfall and its distribution and temperature), and the socio-economic conditions of farmers. Production systems are principally governed by the length of the growing season, which in turn is a function of total rainfall and its distribution and temperature, which affect evaporation and evapotranspiration. Apart from water shortages, SAT soils in Asia are generally low in nutrient reserves. For production systems to be sustainable, even at moderate productivity levels, sufficient inputs of nutrients and organic matter from external sources are crucial. Production systems should be so designed such that they generate sufficient organic matter and replenish depleted soil nutrients both through biological and mineral sources.

Soil degradation takes place in the SAT regions of Asia due to water and wind erosion, which not only removes soil but also the best pool of organic matter and nutrients, and limits the soil capacity to store water and nutrients. Most of the organic matter and nutrient reserves reside in the topsoil layer, which is affected by erosion. In addition to loss of soil and fertility by erosion, land degradation also takes place due to the mining of nutrients so much so that the deficiencies of nutrients and nutrient imbalances are becoming key constraints to productive farming at all levels of intensification both in dry and irrigated areas.

Most of the poor live on degraded land resources in marginal environments thus cannot generate sufficient incomes to extricate themselves from poverty. Therefore, new research and development efforts must target resource poor farmers and this research should focus in developing production systems suitable for the farmer resource base and their socio-economic conditions. The goal should be to bring the farmers out of poverty with no further impoverishment of soils and other natural resources.

Diagnostic research is needed to identify the active constraints that limit productivity in low production areas and to develop management options to mitigate them. Adoption of a livelihoods approach that provides options to the community seems highly desirable in such complex situations. Obviously, mixed farming, crop diversification/cropping intensification, and integration of livestock in the production systems also play key roles in low potential areas to provide a buffer for the means of livelihood, human nutrition, recycling of nutrients, and insurance against risks. Enhancing the availability of feed and crop-livestock interactions will in part help to stabilize and sustain mixed farming systems in low potential areas. Development of simple low cost and low-risk, integrated crop management technologies will be helpful in facilitating crop diversification/ cropping intensity in low/medium potential areas.

Land degradation is inherently not confined to low potential environments. There is increasing evidence of progressive degradation of intensified systems in high potential areas. Nutrient mining and nutrient imbalances, salinity in irrigated systems, changes in soil quality at field level, scarcity of water, and incidence of pests and diseases are reflected in the current decline in total factor productivity of intensive cereal systems, which if unchecked will result in much reduced capacity to meet staple food demand.

System intensification and diversification is taking place where there is access to markets and availability of new crops, varieties, high value crops and new production technologies. These efforts need to be scaled up to allow adoption by large numbers of farmers. This needs to be supported with research on appropriate agro-ecological intensification of land use to meet the rising demand for increasing yields of food crops along with diversification with high value crops and other products.

Output (1):

- At least five technical options (nutrients, water management, crop-livestock, IPM, cultivar) and associated capacity building provided to NARES partners for intensifying and diversifying production systems for increased productivity and incomes of poor in low and high potential environments.

Outcome (1):

- Role of micro and secondary nutrients, genetic resources and IPM strategies in sustaining productivity in dryland and irrigated areas understood and promoted by government extension services, private sector, NGOs and CBOs in India, Bangladesh, Nepal, China, Thailand, and Vietnam.

Potential impact:

- Crop intensification increased by 30%, crop production by 25%, and household incomes by 50% in the target areas.
- Land degradation reduced and more fodder available for animals.
- Risks and vulnerability to adverse conditions reduced

Impact pathways (1):

- By adopting a holistic IGNRM approach, environment-friendly natural resource management options become the preferred ways for sustainable development. In partnership with NGOs & CBOs, other development agencies and government departments, scaling-up and -out will be facilitated through capacity building initiatives.

Output (2):

- Two community-based models developed and promoted to partners for rehabilitating degraded common lands for selected regions in India and China.

Outcome (2):

- Enabling policies and budgetary allocation in place and adopted by partners for the promotion of community-based models in selected regions in India and China.

Potential impact:

- Crop intensification increased by 30%, crop production by 25%, and household incomes by 50% in the target areas.
- Land degradation reduced and more fodder available for animals.
- Risks and vulnerability to adverse conditions reduced

Impact pathways (2):

- Potential geographic areas and production systems for intensification / diversification identified.
- Collaborative arrangements developed with appropriate NARES, NGOs, and farmers groups for transfer and evaluation of technologies.
- Promising IGNRM technologies (genetic, soil, water, nutrient management, and IPM) evaluated with the partners.
- Capacity building of all stakeholders in the selected areas.

Output (3):

- Capacity of stakeholders (farmers, women, NGOs, NARS scientists) strengthened and engendered in 200 watersheds in four countries for implementing improved IGNRM practices in watersheds for intensifying and diversifying systems in Asia.

Outcome (3):

- Effective implementation and scaling-up of watershed technologies undertaken by partner NARES in SAT Asia

Potential impact:

- Crop intensification increased by 30%, crop production by 25%, and household incomes by 50% in the target areas.

- Land degradation reduced and more fodder available for animals.
- Risks and vulnerability to adverse conditions reduced

Impact pathways (3):

- By linking with research and development projects in the countries, the capacity of various participating stakeholders will be strengthened.

Predominant capability:

- It is an apolitical, multi-disciplinary institution, with the necessary ability and technical capacity to act as key facilitator and honest broker.

Counterfactual:

- If ICRISAT ceases its watershed work today, there will be low and inefficient ways of utilizing natural resources, further degradation of natural resources, low productivity of SAT systems and poverty may continue.

Chapter 9: System Non-Priority. Knowledge management and sharing

Background

Knowledge Management, originally a collection of primarily information sharing processes in the corporate sector, has evolved in the last ten years to become a component of development action and research. The recent initiatives of well known development investors such as the DFID, the SDC or the IDRC/Bellanet to promote knowledge management in development-oriented organizations indicate its emergence as a lever in generating impact. (It is more appropriately termed "knowledge management and sharing" in this context). An earlier CG-wide (2001-02) initiative, the Organizational Change Program, emphasized the importance of knowledge sharing processes in enhancing organizational effectiveness. In line with the system-wide effort in ICT and knowledge management, ICRISAT has developed its own brand and has built up a core of network services, library support, partner-oriented training programs and well-organized communication systems over the last five years, ICRISAT has further developed a pilot initiative (called VASAT) for knowledge sharing with partners and stakeholders, with the overall aim of improving food security and drought preparedness at the level of a community. The KMS strategic action framework is meant to support the Institute's effort to build new partnerships for enhanced development impact, expressed in MDG 8.

Role of ICT as a mediator in knowledge management and sharing

While knowledge sharing as a process has always been an integral part of a development research organization, incorporation of contemporary ICT adds value to its effectiveness. A number of standard information sharing processes have been transformed through the use of ICT, through significant increases in speed and volume. New technology developments enable rapid communication of results. More importantly, new collaborative opportunities in knowledge creation and sharing, as exemplified by the global Wikipedia (www.wikipedia.org), have emerged. Web-based content distribution technologies such as "Blogs" have created unprecedented advantages for experts engaged knowledge creation. All these technologies now enable "capture" of both formal as well as tacit knowledge of an individual expert to make it available to a larger community that can take suitable advantage. Our goal is to make an expert's knowledge available to any needy partner or stakeholder anytime, anywhere through virtualising presence. ICT is thus an essential component of KMS.

New developments among NARS partners

Increased information intensity in agricultural production and distribution and marketing has created new challenges for NARES partners. Non-linear onset of climate change-related phenomena were evident throughout the year 2005, and floods have resulted in major damages in regions which had been in the grip of severe drought for almost half of a decade. The potential spread of new hybrids, even GMOs, and the increases in internationalization of commodity markets have also led to increasing pressure on NARES partners to develop rapid responses which are knowledge-intensive. The preparedness levels in relation to disasters have to be higher at the level of a community, which is an information and knowledge-intensive process. The need for revamping public sector extension has been voiced in many regions, while policy makers have started to emphasize the need to change the character of agricultural education to make it easy for practicing farmers to access instructional delivery systems. The NARES partners (including new ones such as the field-based NGO's or the minor corporate sector) are looking for a new paradigm in knowledge sharing with an increasingly large number of farmers and other rural inhabitants.

Global interest in ICT4D and open access systems

In recent years, the ICT4D movement has made significant advances in Asia and Latin America while a blend of satellite digital radio and the community radio is fast emerging as a choice for development communication in the Sub Saharan Africa. The two-part WSIS organized by the UN has generated new global partnerships who aim to utilize the power of digital technologies to achieve the MDG's. On a parallel track, the science community has taken the lead in making research results available to peers and to the informed public through a different distribution model called the Open Access, fortified by the practice of reserving only limited nights. Several of the Open Access journals (e.g. PLOS-Biology, www.plos.org) have reached extraordinary impact levels within three years, and major development investors and research promoters are increasingly seen preferring OA methods for peer review and dissemination.

ICRISAT's comparative advantage

The main asset is the accumulated knowledge from ICRISAT research. The people, the ICRISAT experts, with their tacit as well as formal knowledge constitute the key resource in the process of knowledge sharing. Over the last five years, ICRISAT has stabilized an advanced network management service, along side a library service that has gradually moved into an electronic mode. By 2004, every country office of ICRISAT has an "always-on" type of connectivity, and a compact, efficient group of human resources have been created for managing digital information services. Over the same period, the training programs have been moved to a new level, supporting about 250 graduate learners through the year on an average. An advanced learning and content management system is in place, and partners such as the Commonwealth of Learning (www.col.org) have assessed ICRISAT as highly capable in developing new instructional delivery systems. ICRISAT led the trial project across the CGIAR in the use of video conferencing, and has developed advanced capability in the use of this technology for peer-to-peer and for extension communication. A diverse range of new partners have been linked into our KMS programs, ranging from corporate organizations such as the Microsoft, Sun Micro to national organizations such as the Indian Space Research Organization. Joint technology development is under way with many of them. We will also seek out new partners that previously may have been presumed to be unlinked to agriculture such as the telecom industry (IITs, Microsoft, ISRO, Coca Cola etc.). We have also tested on a pilot scale mass training and awareness building programs on drought (MKCL, an Indian partner, has conducted field training programs using ICT mediation, involving about 30 000 learners over six months). We thus have assets in terms of people, knowledge (formal as well as tacit), technology and partnerships.

<u>**Outputs and outcomes to 2009-2015**</u>

Outputs by 2009:

- Development of an architecture and building an infrastructure for advanced research informatics which will include
    - o web-based information services to enable instant publishing (eg GT-BT-Bioinfo, LIMS; GT-CI-genebank, varietal information; GT-AE-GIS, soil and meteorological data, MPI-VLS).
    - o Mainstreaming support systems to take advantage of tacit knowledge (based on Media Wiki and Blogs).
    - o Comprehensive and secure network services delivered to staff (intranet) and partners (extranet) based on unique ID authentication anywhere in the world
- Building a pilot educational materials grid with five NARES university partners to support post-secondary extension learning:

- A learning objects repository on SAT production and livelihoods with about 150,000 objects developed and linked to CG-Wide OLR.
  - Developing a seamless delivery method combining the web, digital satellite radio, and community radio in 3 locations in SSA.
  - Develop video conferencing as a routine method of transaction between the three regional hubs and two SSA-based country offices.
  - Develop an arrangement whereby ICRISAT-based experts are able to interact with NARES partners seeking knowledge using satellite-based video conferencing (20 locations in South Asia).
- E-library becomes Virtual SAT library with about 100,000 entries, accessible anywhere, anytime and is linked to the CGIAR Virtual Library program:
  - An e-print repository and an OA-science publication access system developed with 5000 entries.
- Training and capacity building at functional literacy levels in NRM, trade and biotechnology for 5000 advanced rural trainers using a virtual mode, each one capable of teaching 100 people (At least a third would be rural women):
  - Along with one ARI and the GOFAU, mainstream an online learning and graduation program in one sector (AE) and three minor areas (GIS-related).
  - Increase the number of fully-funded training courses to twelve a year.

By 2015:

- ICRISAT emerges as a META-University supporting new agricultural learning/ instruction delivery processes on a mass-scale:
  - twenty university partners, covering 100 000 advanced rural learners
  - web-based as well as video-interactive learning
  - ICRISAT and the FAO provide the backbone services in terms of global standards in content design
  - ICRISAT web site turns into semantic web portal for highly customized information and instruction delivery, anchoring about 25 institutional sites relevant to SAT.
- Every ICRISAT faculty is a global knowledge entrepreneur with a readily available array of online tools and techniques, and can virtually be an institution herself.

Outcomes:

- NARES partners design new extension-engagement processes based on ICRISAT KMS approaches.
- Agricultural universities develop new paradigms in customizable mass education for enhanced food security and livelihoods using ICRISAT exemplars.
- Users of ICRISAT Knowledge in the public domain provide significant new contributions of viable revenue for ICRISAT.

Potential impact:

- The totality of ICRISAT's research has a large potential for good development impact. The rate and coverage by which this good knowledge is received by primary and secondary users is dependent upon the strength of supporting extension and communication agencies. The ICRISAT Knowledge Management and Sharing program has the potential to make this process, faster and more effective and is thus a vital tool in ensuring ICRISAT's IPG bring the development for which the research is intended.

Impact pathway:

- Examination of the effectivness of a broad range of communication media in their ability to transfer agricultural knowledge

Predominant capability:

- ICRISAT is internationally recognized as a leader in ICT4D innovations and new learning/ content management/approaches. With appropriate right ideas and basic resources, ICRISAT sees no evident competition in customizable agricultural information delivery on a mass scale that would undermine our predominant capability

Counterfactual:

- The NARES need for developing a new farmer-engagement and mass education paradigm is real as well as pressing. There is a risk presently of the efforts of the current actors addressing this issue to do so in a piece-meal fashion which is likely to be less effective than if a large-scale coordinated effort is allowed to function. ICRISAT has strengths in playing such a unifying role for a large-scale effort which would otherwise be lost.

About ICRISAT®

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, 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).

Contact Information

ICRISAT-Patancheru
(Headquarters)
Patancheru 502 324
Andhra Pradesh, India
Tel +91 40 30713071
Fax +91 40 30713074
icrisat@cgiar.org

Liaison Office
CG Centers Block
NASC Complex
Dev Prakash Shastri Marg
New Delhi 110 012, India
Tel +91 11 32472306 to 08
Fax +91 11 25841294

ICRISAT-Nairobi
(Regional hub ESA)
PO Box 39063, Nairobi, Kenya
Tel +254 20 7224550
Fax +254 20 7224001
icrisat-nairobi@cgiar.org

ICRISAT-Niamey
(Regional hub WCA)
BP 12404
Niamey, Niger (Via Paris)
Tel +227 20 722626, 20 722529
Fax +227 20 734329
icrisatsc@cgiar.org

ICRISAT-Bamako
BP 320
Bamako, Mali
Tel +223 2223375
Fax +223 2228683
icrisat-w-mali@cgiar.org

ICRISAT-Bulawayo
Matopos Research Station
PO Box 776,
Bulawayo, Zimbabwe
Tel +263 83 8311 to 15
Fax +263 83 8253/8307
icrisatzw@cgiar.org

ICRISAT-Lilongwe
Chitedze Agricultural Research Station
PO Box 1096
Lilongwe, Malawi
Tel +265 1 707297/071/067/057
Fax +265 1 707298
icrisat-malawi@cgiar.org

ICRISAT-Maputo
c/o IIAM, Av. das FPLM No 2698
Caixa Postal 1906
Maputo, Mozambique
Tel +258 21 461657
Fax +258 21 461581
icrisatmoz@panintra.com

Visit us at www.icrisat.org

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