



International Crops Research Institute for the Semi-Arid Tropics



ICRISAT

Vision and Strategy to 2015

Improved well-being of the poor of the semi-arid tropics



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ICRISAT Vision and Strategy to 2015



August 2006

International Crops Research Institute for the Semi-Arid Tropics



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Radha Singh

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Foreword

In spite of the tremendous impact of agricultural innovations which spurred the Green Revolution in favorable areas, about half a billion people in less-favored, rainfed areas such as the semi-arid tropics (SAT) have been left behind. The low productivity of agriculture aggravated by widespread poverty, hunger, malnutrition, water scarcity, marginal and degraded natural resources and a changing global environment have further marginalized agriculture and livelihoods in the SAT.

By mobilizing cutting edge science for human development, food security, poverty alleviation and environmental protection, ICRISAT and its partners seek to redress this situation on behalf of poor rural families in SAT farming systems.



This document maps out a new vision and strategy of ICRISAT in 2006 to 2015 and beyond. This is a revised version its original vision and strategy to 2010 which was approved by the ICRISAT Governing Board in 2001. Structured in two major parts, ICRISAT's new vision and strategy is primarily guided by the Millennium Development Goals (MDGs), seven planks of the CGIAR vision and strategy, new CGIAR Systemwide priorities, its core competencies and thematic comparative advantages, strategic analysis of opportunities in the SAT and the new setting for international agricultural research.

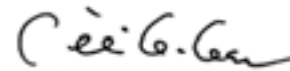
Part I outlines the context, task environment and the general, thematic and regional goals and strategies. Part II maps global action on how ICRISAT and its partners will pursue the vision and strategy as anchored on the new CGIAR priorities. The inputs of key staff, partners, stakeholders and ICRISAT's Governing Board were obtained through a series of workshops and consultations.

As an innovation-driven organization, ICRISAT realizes that it needs to proactively attune its strategic direction according to the changing times. During the last several years, ICRISAT's institutional context and task environment have significantly changed. The MDGs have tremendously broadened the agenda of international agricultural research beyond increasing food supply to embrace poverty and hunger reduction, environmental sustainability and social issues such as gender equality, health and nutrition.

Likewise, ICRISAT needs to respond to increasing market globalization, the on-going information and communication revolution, low prices of agricultural produce amidst soaring fuel prices, new intellectual property right regimes, the growing importance of institutional innovations, and the emergence of the Alliance of Centers of the CGIAR.

Correspondingly, the CGIAR vision and strategy indicate a strong imperative for ICRISAT to adopt a people and poverty focus, mobilize new science tools, address problems in sub-Saharan Africa's SAT, follow a decentralized approach to research management, 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, reducing rural poverty, sustainable natural resource management, improving policies and facilitating institutional innovation.

ICRISAT's strategic focus is to adopt a pro-poor growth strategy and attain impact through scientific excellence in agriculture in the SAT. Therefore, this new vision and strategy targets key opportunities to improve the well-being of the poor, with food security and poverty alleviation being fundamental. Above all, it recognizes the need for greater thematic integration and diversification of partnerships as core principles to mobilize cutting edge science and technology for human development. This ensures that ICRISAT's research will improve the lives of poor people inhabiting 48 developing countries in the SAT.



William D. Dar
Director General

Executive Summary

The onset of the Green Revolution in the late 1960s and early 1970s brought unprecedented increases in food production in favorable areas of the developing world. However, many regions in less-favored, rainfed areas such as the semi-arid tropics (SAT) were bypassed. The SAT covers parts of 55 developing countries populated by about 1.4 billion people, of which 560 million (40%) are classified as poor, and 70% of these live in rural areas. The SAT has very short growing seasons, separated by very hot and dry periods. Natural soil fertility is very low, and pest and disease pressure are intense. With persistent drought and land degradation as the overarching constraints, SAT farmers face perennial risks in improving their productivity and livelihoods.

On the whole, agriculture in the SAT faces gigantic challenges due to the lack of technological and institutional innovations and the unfinished transformation of subsistence agriculture. Many of the measures associated with the United Nations Convention to Combat Desertification (UNCCD) remain unimplemented. There is now an emerging pessimism among the world community that the Millennium Development Goals (MDGs) may not be achieved by 2015, especially in sub-Saharan Africa (SSA). Hence, the imperative of improving agricultural productivity using Integrated Genetic and Natural Resource Management (IGNRM) propelled by institutional innovations has become more compelling in the SAT.

ICRISAT seeks to address the foregoing situation by mapping out its vision and strategy to 2015. Being at the apex of global agricultural research for SAT areas in the Alliance of Centers of the CGIAR, ICRISAT refines its vision and strategy in synchrony with the UN International Year of Deserts and Desertification (2006).

Furthermore, it wishes to articulate more clearly its alignment with the MDGs, CGIAR strategic directions, the new CGIAR Systemwide priorities and the emergence of the Alliance of Centers of the CGIAR (ACC) as a third pillar of the CGIAR. In doing this, ICRISAT has solicited wide participation of partners and stakeholders. This document converges the vision and strategic thinking of three ICRISAT regions — West and Central Africa (WCA), Eastern and Southern Africa (ESA), Asia and four global research themes — Institutions, Markets, Policy and Impacts (IMPI), Biotechnology (Biotech), Crop Improvement (CI) and Agroecosystems (AE) as follows:

Vision

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

Mission

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

Goal

To mobilize with partners cutting edge science and institutional innovations for poverty alleviation, food security, human development and environmental protection for poor rural families in semi-arid production systems of Asia and sub-Saharan Africa.

Strategy

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

IGNRM is a powerful integrative strategy of agricultural research that seeks to maximize the synergies among the disciplines of biotechnology, plant breeding, agronomy, agroecosystems and social sciences with people empowerment at its core. In pursuing IGNRM as its overall strategy, ICRISAT recognizes the need for greater focus, thematic-regional integration, multi-stakeholdership and multi-level partnerships in mobilizing science and technology for the poor. Through the synergies catalyzed from IGNRM, ICRISAT will be strategically positioned to act regionally and yet produce international public goods (IPGs) with impact.

To pursue the foregoing, ICRISAT's four global research themes and three regional strategies have been integrated to help ICRISAT refocus its efforts to impact the needs of poor households and development partners in SSA and Asia. Similarly, ICRISAT recognizes that its vision and strategy must be anchored on concrete action. This will be achieved through the adoption of the five new CGIAR Systemwide priorities as the 'ribs' around which the 'flesh' of ICRISAT's global research and regional strategies will be attached. Consistent with the position of the ACC, 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. ICRISAT will provide custodianship to six mandate crops and improve germplasm and provide cutting edge options in diversifying SAT farming systems. These will be done to help national, subregional and regional institutions, private sector, civil society, advance research institutions and donors in achieving the MDGs.

During the past several years, the environment in which ICRISAT operates has significantly changed. 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. Publicly funded agricultural research has declined by more than 50%. At the same time, the private sector has assumed an increasing share of agricultural research and ownership of new technologies. The emergence of global markets, biotechnology, and information and communication technologies (ICTs) has had 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. We are witnessing a gradual convergence of the public sector's pro-poor development goals and the private sector's commercial interests. Similarly, new patterns of accountability and governance are changing the role of public agricultural research institutions and their relationships with the private sector and civil society. In harmony with this trend, ICRISAT will further intensify linkages with a wide range of strategic partners which include the ACC, advanced research institutes (ARIs), regional and subregional organizations, national agricultural research and extension systems (NARES), the private sector and civil society organizations. In SSA, our strategy has been synchronized with those of regional and subregional organizations, NEPAD, the Comprehensive African Agricultural Development Program (CAADP) once adopted, and SSA Challenge Program. In addition, ICRISAT will integrate its research with other fields of development such as education, human health, nutrition, and energy and water quality. ICRISAT will also intensify innovative public-private partnerships through its Agri-Science Park (ASP).

Towards 2015, ICRISAT's strategy for knowledge sharing will be in full gear along with the CGIAR's new priority on facilitating institutional innovations to support sustainable reduction of poverty and hunger. Towards this, the ICRISAT-led Virtual Academy for the Semi-Arid Tropics (VASAT) will be up-scaled with partners to enable dynamic linkages among diverse, distributed human and information resources in the SAT. Linkages will be established with partners such as the Global Open Food and Agriculture University (GOFU), advanced learning institutions and national open universities to develop courses in distance mode and other innovative learning opportunities.

Starting in 2006, ICRISAT seeks to effectively allocate \$30 M towards the fulfillment of its vision and strategy and may be approaching \$50 million by 2015. Since this is a large annual investment, ICRISAT recognizes the importance of rigorous research prioritization. This is clearly indicated in ICRISAT's series of rolling medium term plans (MTPs). The MTP for 2007-2009 has been prepared to pursue this strategic plan.

Abbreviations and Acronyms

ACC	Alliance of Centers of the CGIAR
AFLP	amplified fragment-length polymorphism
AMG	African Market Garden
ASP	Agri-Science Park
APAARI	Asia Pacific Association of Agricultural Research Institutions
APSRU	Agricultural Production Systems Research Unit
ARIs	advanced research institutes
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
AVRDC	Asian Vegetable Research and Development Center
BECA	Biosciences in East and Central Africa
BMZ	German Federal Ministry for Economic Cooperation and Development (Bundesministerium für Wirtschaftliche Zusammenarbeit Und Entwicklung)
CAADP	Comprehensive African Agricultural Development Program
CBO	Community-Based Organization
CIRAD/INRA	Centre for International Co-operation in Agricultural Research for Development
CGIAR	Consultative Group on International Agricultural Research
CORAF/WE CARD	West and Central African Council for Agricultural Research and Development
DFID	Department for International Development of the UK
DMP	Desert Margins Program
ECARSAM	Eastern and Central Africa Regional Sorghum and Millet Network
ESA	Eastern and Southern Africa
FAO	Food and Agriculture Organization of the UN
FARA	Forum for Agricultural Research in Africa
IARCs	international agricultural research centers
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICASA	International Consortium for Agricultural Systems Applications
ICRAF	International Center for Research in Agroforestry (World Agroforestry Centre)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICTs	information and communication technologies
IDRC/Bellanet	International Development Research Centre/Bellanet
IGNRM	integrated genetic and natural resource management
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
ILAC	institutional learning and change
IIASA	International Institute for Applied Systems Analysis
ILRI	International Livestock Research Institute

IMF	International Monetary Fund
IMPACT model	International Model for Policy Analysis of Agricultural Commodities and Trade
IPGs	international public goods
IPM	integrated pest management
INERA	Institut de l'Environnement et Recherches Agricoles
ISRO	Indian Space Research Organization
GAP	good agricultural practice
GITAs	global impact target areas
GOFAU	Global Open Food and Agriculture University
JIRCAS	Japan International Research Center for Agricultural Sciences.
MAS	marker-assisted selection
MDGs	millennium development goals
MTPs	medium term plans
NARES	national agricultural research and extension systems
NEPAD	New Partnership for Africa's Development
NGO	nongovernmental organization
NRM	natural resource management
OECD	Organisation for Economic Co-operation and Development (OECD)
OPVs	open-pollinated varieties
RFLPs	restriction fragment length polymorphism
REIA	Research Evaluation and Impact Assessment
SADC-FANR	South African Development Community – Food, Agriculture And Natural Resources
SAT	semi-arid tropics
SCLIMS	smallholder crop-livestock mixed systems
SDC	Swiss Agency for Development and Cooperation
SEF	Sahelian Eco-Farm
SMIP	Sorghum & Millet Improvement Program
SNPs	single nucleotide polymorphism
SPS	phyto-sanitary standards
SSA	sub-Saharan Africa
SSRs	simple sequence repeats
SWMnet	Soil and Water Management Network
TAC	Technical Advisory Committee
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Program
VASAT	Virtual Academy for the Semi-Arid Tropics
VLS	village level studies
WCA	West and Central Africa
WHO	World Health Organization
WSIS	World Summit on the Internet Society





PART I

ICRISAT's Vision and Strategy to 2015





Chapter 1

Context

Overview

A Green Revolution for the SAT in 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 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. 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 are in close accord 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 SSA, 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 IGNRM technologies is becoming more compelling. IGNRM is a powerful integrative philosophy of research that seeks to maximize the synergies between the disciplines of biotechnology, plant breeding, 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 to 2015

ICRISAT, as the apex dryland agricultural research organization for the global SAT areas in the Alliance of Centers of the CGIAR, 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 SSA 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 (knowledge management) and private sectors and finally the emergence of the Alliance of CGIAR Centers (including associated centers such as AVRDC and 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 IPG nature of the Center's research output. Hence, ICRISAT's work is now planned and executed in three principal regions — WCA, ESA and Asia — and integrated by global research themes. The regions and the themes seek to maximize the synergies that 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. Synergy is further 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 have been used as source material for this institutional expression at a global level. These documents include separate strategic papers for the three ICRISAT regions — WCA, ESA and Asia 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 that 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 the SAT

The SAT covers parts of 55 developing countries where the 75-180 day growing period has a mean daily temperature of more than 20°C. 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 2001). 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.

To clarify in layman’s terminology. The SAT has 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.

West and Central Africa

Agriculture in the region

In WCA, agriculture accounts for more than 30% of the gross domestic product, employs between 82 and 92% of the total labor force and is the main source of livelihood for the poor. Domestic food production has not kept pace with rising population. Between 1990 and 1999, the annual rate of growth per capita food production declined or remained modest, varying from -1.9% in Mauritania to +1.9% in Chad and Cape Verde.

Sorghum (*Sorghum bicolor*) and pearl millet (*Pennisetum glaucum*) remain the main staple foods for the over 100 million people living in the West and Central African SAT (WCA SAT). These crops account for 70% of the total cereal cropping area, 60% of cereal production, 75% of total caloric intake, 52% of per capita grain consumption and 1/3 of protein content. Since 1984, production of these crops has increased due to area expansion into the marginal areas, contributing to severe environmental degradation. Average yields of these crops, low by global standards, are decreasing, ranging from 300 to 1100 kg ha⁻¹ for pearl millet and 500 to 1300 kg ha⁻¹ for sorghum. Pearl millet and sorghum grain yields have increased in some countries and decreased in others. Average annual rainfall has decreased markedly over the past 30 years with estimates ranging from 100 to 200

mm annum⁻¹ in all the semi-arid areas. This has led to a shortening of the length of the growing season in all the agroecological zones. Coupled with the trends of more extensive production on marginal lands and reduced length of fallows, ICRISAT regards it as a positive achievement that cereal productivity could be maintained at these levels. Sorghum and millet residues are stored and fed to ruminants during the dry season. These crops are poorly traded in the national, regional and international markets.



Contemporary issues, challenges and opportunities

Poverty, food insecurity and malnutrition

Countries in the West African SAT cover an area of 5,339 sq km or about 22% of the total land area in SSA. In 2000, these countries had a population of over 100 million. All these countries are classified by the United Nations as being among the least developed in the world. The low level of economic activity coupled with high population growth rates over the past decade has led to negative or stagnant growth in real per capita incomes. In many Sahelian countries, more than 30% of the population falls below the international poverty line of \$1 a day and the same percentage is undernourished. Life expectancy at birth and the human development index indicate low levels of human welfare. Human population in these countries is projected to grow between 2.1 and 2.9% per year over the next 15 years.

Water, climate and soils

Water constitutes one of the most limiting factors to rainfed agriculture in the Sahel. The water limitation arises from low and variable rainfall, but is also partly due to high temperatures and solar radiation during the rainy season, which cause substantial evaporation and reduce available soil water. Rainfall distribution is erratic with frequent drought periods of up to two weeks or longer. Rainfall data show the tendency for abnormal years of rainfall (with successive periods of deficit or excessive water) to occur continuously for as many as 15 years.

However, the rainfall in West Africa shows some strong patterns of distribution, to which local varieties of cereals are very well adapted. It has been shown that the variability of the onset of rains is extremely high, and can occur from mid-May to mid-July, even in the Sudan Savannah zones. However, the end of the rainy season is much more stable, with a variability of 10 to 14 days for any one location. For each location the normal end of the rainy season is predictable, and is earlier in the more northerly locations, which also have a lower average annual rainfall.

The soils have low natural fertility. They are predominantly sandy with a low clay and organic matter content, and their effective cation exchange capacity is also low. Nitrogen and phosphorus are the most limiting nutrients; however other deficiencies (potassium, trace elements) and acidification are readily induced by intensified continuous cropping. Other physical properties of soils in the Sahelian systems that limit crop production potential include: (a) high bulk density and very low structural porosity; (b) a tendency to compact and harden during the dry season; (c) generally poor water infiltration due to rapid surface crusting of soils, except on eolian sandy soils, and; (d) increasing susceptibility to erosion with continuous cultivation. Annual losses of nutrients per hectare due to soil erosion and soil mining among other factors are important.

Genetic resources and crop improvement

The WCA SAT is a center of origin of pearl millet and the Guinea race sorghums. During the last 25 years, pearl millet, sorghum and groundnut improvement programs have developed and released a range of early-to medium-maturing new varieties that escape end-of-season drought and are tolerant/resistant to major pests (the parasitic weed *Striga*, head miner) and diseases (downy mildew, grain mold, foliar diseases, rosette, aflatoxin producing *A. flavus*). Some of these varieties have been released but their utilization by farmers remains low. Reasons for the low uptake may relate to the low productivity gains, the unsuitability of varieties to farmer or market preferences, poor access to information on modern varieties, low access to experimentation or mostly the underdevelopment of seed markets and lack of availability of seed.

In WCA, as elsewhere, varietal improvement for yield is based largely on conventional breeding methods. Promising approaches include the development of hybrids that exploit heterosis, the novel shorter-statured varieties based on highly adapted germplasm, and the characterization and use of a full range of genetic diversity. Molecular genetic tools are beginning to be applied; for example, molecular marker characterization of the structure of genetic diversity in Guinea race sorghums has been conducted.

A range of opportunities is available in the promotion of existing varieties preferred by farmers or required by the market. Farmers and processors need to be exposed to these technologies through participatory approaches. In addition, an assessment of institutional arrangements likely to improve a sustainable and consistent flow of seed to end-users is warranted.

Pests, diseases and weeds

Major sorghum insect pests include sorghum midge (*Contarinia sorghicola*) and a complex of head bugs (*Eurystylus immaculatus* and others). The major insect pests of pearl millet in West Africa are head miner (*Heliochelus albi punctella*), stem borers (*Coniesta ignefusalis*) and blister beetles (*Psadolytta* spp.). *Striga hermonthica* is a frequent parasitic weed of both sorghum and millet and constitutes a significant constraint, especially in areas where low soil fertility and continuous monocropping of cereals prevail. It has been estimated that *Striga* threatens grain production on 44 M ha in Africa, translating into a yearly economic loss of US\$ 3-7 billion.

Institutions, markets, infrastructure and policy

Regional surveys in the WCA SAT show that rural households have little access to key inputs (seed of improved varieties and fertilizers) because of poorly functioning, incomplete or underdeveloped markets and lack of infrastructure. When available, inputs are used on high-value crops. Furthermore, farmers are often not aware of the existence of technologies and their potential benefits. Policies that could encourage the use of inputs, the output markets and linkages between input and output markets are also lacking.

Farmers' livelihood strategies

Many studies in the SAT of West Africa show that households pursue a range of livelihood strategies and may diversify as a response to climatic, production and market risks. The returns to investment from cropping may be less than those from livestock activities or other alternative sources of income such as temporary migration, or off-farm agricultural employment. Therefore, farmers may not necessarily invest in cropping activities.

More than two decades have passed since the last village level studies (VLS) in Burkina Faso and Senegal. These studies helped to understand household production and consumption decisions and set research priorities. Since then, many changes have occurred which deserve further understanding and could have a significant impact on poor livelihoods. Renewed efforts are necessary to understand these changes, identify development pathways and reset research priorities and development interventions.

National capacity

In WCA, there is a weakness in agricultural R&D capacity not only at the national level but also in the NGO and private sectors, the latter being, as yet, barely developed. This lack of capacity is both at human and infrastructural levels and though the agricultural sector is recognized by

WCA governments, there is presently no corresponding recognition of the need to provide adequate funding to R&D in this sector.

Eastern and Southern Africa

Agriculture in the region

Agriculture constitutes the backbone of the economy in the ESA region, providing 60% of all employment, and is the main provider of industrial raw materials. In many of the countries, agriculture accounts for more than a third of the national gross domestic product. In rural areas, agriculture underpins livelihoods supporting 70-80% of the total population, including the majority of the extremely poor and malnourished.

Improvement of agricultural performance has the potential to increase rural incomes and purchasing power for large numbers of people. Thus, more than any other sector, agriculture can get people out of poverty on a massive scale. However, despite its dominant role in the economy, agricultural productivity has been either declining or stagnating behind population growth in several countries. The overlapping biotic and abiotic constraints and degradation of natural resources have often limited the productivity of smallholder agriculture.

Addressing these multiple constraints requires technical and institutional innovation and building local capacity to provide smallholder farmers with scientifically tested and knowledge-based options to improve productivity, competitiveness and harness changing market conditions.

Contemporary issues, challenges and opportunities

Poverty, food insecurity and malnutrition

Poverty, malnutrition, food insecurity and degradation of the natural resource base are major problems afflicting many countries in ESA. The region constitutes some 21 countries with a population of over 350 million people, more than half of which live in extreme poverty, making the region one of the highest concentrations of poor people in the world. Over the last decade, the region has witnessed increasing incidence of poverty through its various manifestations, including an increase in the number of hungry and malnourished people. About 75% of the population lives in rural areas that account for over 80% of the total extreme poor. Unless interventions are designed to reverse the situation, this trend is projected to continue into the coming decades, making it impossible to come closer to (much less to meet) the MDGs of halving the number of people in absolute poverty and hunger by 2015.

The incidence and severity of deprivation is highest in the less-favored semi-arid and marginal areas that suffer from poor infrastructure, geographical isolation, poor market access, and vulnerability to climatic variability and drought. High levels of soil erosion, nutrient depletion

and degradation of agroecosystems contribute to low productivity and declining ecosystem resilience in many areas. The magnitude of soil fertility depletion on arable lands is one of the highest in the world and by far exceeds the rates of nutrient replenishment through application of organic and commercial fertilizers.

Low productivity is due to degraded soils, lack of inputs and unfavorable weather conditions. Most of the resource-poor farmers grow their crops in degraded soils without inputs such as chemical fertilizers or pesticides. Rainfall in the SAT is extremely variable in amount and distribution, making rainfed agriculture risky and thus preventing farmers from

investing in inputs that enhance productivity. The area under irrigation is very low in SSA, only 3.7% compared to 10% in South America, 29% in East Asia and 41% in Southeast Asia.



Poor market access is a result of many factors such as the lack of a functioning marketing system that links the many small producers with domestic and international buyers. Several highly dispersed small producers supply nonhomogenous products to local markets. Given the low productivity, the volume of marketable surplus is very low, and hence the transaction costs of marketing for individual farmers are high. Varieties currently grown by farmers are not able to satisfy the quality attributes required by diverse markets. Africa has poor infrastructure — roads are few and not well maintained, the railroad length is under 2% of the world total and dilapidated, and storage and product handling systems are inefficient, all adding to the cost of doing business on the continent.

Poor dissemination of improved varieties is another challenge. Improved varieties that are adapted to target environments and both farmer and market needs have been developed but have not been disseminated. One of the major limitations of the technology delivery system is lack of an efficient and effective seed multiplication and supply system. While some effort is being made to improve seed availability by involving farmers and primary cooperatives in seed multiplication, the lack of quality control and low capacity at the local level are hurdles to progress. The extension systems in most African countries are weak, thus causing a bottleneck in technology dissemination.

Policy and institutional weakness is another hindrance to agricultural development. New capacities are required in both public and private sectors. A pro-poor agricultural policy is not in place and systems of rights of land tenure inhibit farmer investment in agriculture.

Capacity building in various sectors dealing with agriculture is weak, starting from research, extension, postharvest, linkages with markets and extending as far as trade-related negotiations. Investment in agricultural research and training is also inadequate.

Weak private sector: The private sector has a key role to play in agricultural development and economic growth in Africa. Many of the sub-Saharan countries have emerged from an economy dominated by the public sector in terms of research and provision of major services in input and output marketing of agricultural commodities. However, the dominance of the government and the public sector in African agriculture has not been effective in accelerating intensification of production and technology adoption and did not bring the desired growth. Despite the increasing interest in market development and private sector participation in agricultural transformation, many countries are far from achieving the desired outcomes.

HIV/AIDS pandemic: Sub-Saharan Africa is at the epicenter of the HIV/AIDS epidemic. The short-term effects have been a decline in agricultural labor, production and incomes and a concurrent and dramatic increase in expenditures on health and funerals. In the longer term, there will be loss in inter-generational transfer of knowledge and traditional social security mechanisms.

Asia

Agriculture in the region

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 nonagricultural 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 that 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 nonfarm 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 nonfarm 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 agroclimatic 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 MDGs, CGIAR vision and strategy to 2010, Systemwide research priorities to 2015 and the emergence of the ACC. 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 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 that 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 programmes; 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 ICTs.

Revisiting the CGIAR vision and strategy to 2010

Background

Even before the MDGs were endorsed, the CGIAR adopted a new vision and strategy in May 2000. Based on the 1998 System Review and other CGIAR reviews, TAC and CGIAR strategic studies, FAO's 2010 and IFPRI's 2020 studies, including the views of outside experts, it has the following major features:

Focusing strongly on poverty reduction at the regional level within a Systemwide priority setting framework.

Adopting modern research tools to complement or supersede conventional approaches to crop, livestock, forestry, fisheries, natural resources management, and policy and management research.

Articulating and integrating more closely CGIAR activities with those of its partners involved in technology generation, transfer, and utilization in regions having high concentrations of poverty.

Increasing capability of National Agricultural Research Stations (NARS) partners to share responsibility for research and research-related activities.

Highlighting an organizational design feature that augments the System's capability to respond flexibly and rapidly to changing environments.

Vision

A food secure world for all.

Goal

To reduce poverty, hunger and malnutrition by sustainably increasing the productivity of resources in agriculture, forestry and fisheries.

Mission

To achieve sustainable food security and reduce poverty in developing countries through scientific research and research-related activities in the fields of agriculture, livestock, forestry, fisheries, policy and natural resources management.

The above framework is comprised of a set of related goals:

1. At the apex, a food-secure world for all is identified as the CGIAR's ultimate vision, making explicit its global scope and hence the rationale for conducting IPG research as well as the focus on benefiting the poor.

2. To reduce poverty, hunger and malnutrition, the CGIAR will pursue the goal of fostering the sustainable increases in the productivity of natural resources that are needed to improve the livelihoods of the rural and urban poor.
3. Finally, the CGIAR's vision and goal will be realized through scientific research and research-related activities in the fields of agriculture, forestry, fisheries, policy and management of natural resources drawing upon its unique role and strength as a knowledge base organization.

Seven planks

- Plank 1 - *People and Poverty Focus*: The CGIAR reaffirms its goal of sustainably reducing poverty, hunger and malnutrition of people in developing countries.
- Plank 2 - *Modern Science*: Mobilize the new developments in social, biological and physical sciences so as to bring modern science to bear on the often difficult-to-address causes of poverty and food insecurity, related to production and institutions, that have proven intractable in the past.
- Plank 3 - *Geographic Priorities*: In determining the relative geographic priorities, the CGIAR will give highest priority to developing a concerted approach to address the needs of people in SSA and South Asia where poverty is concentrated and growing.
- Plank 4 - *Regional Approach to Research*: Adopt a regional approach to research planning and implementation in order to address the heterogeneous nature of the causes of poverty and food insecurity in different regions and integrate regional priorities with global priorities in international agricultural research.
- Plank 5 - *New Partners in Science and Development*: Give increased emphasis to seeking new types of partners and using new forms of partnership to improve the efficiency and effectiveness of problem identification, research, and dissemination of research outputs for poverty reduction and food security.
- Plank 6 - *Task Force Approach*: The CGIAR will adopt a task force approach to addressing major, clearly identifiable problems where there is an opportunity for an impact to be made and/or where there are intractable problems that need a concerted approach by multiple actors and agencies within and beyond the CGIAR System.
- Plank 7 - *Catalytic Role*: Strengthen the role of the CGIAR as a catalyst, integrator and disseminator of knowledge within the overall global agricultural research system.

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 IPGs; 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:

- Promoting conservation and characterization of staple crops
- Promoting conservation and characterization of underutilized plant genetic resources
- Promoting conservation of indigenous livestock
- Promoting conservation of aquatic animal genetic resources.

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

- Maintaining and enhancing yields and yield potential of food staples
- Improving tolerance to selected biotic stresses

Enhancing nutritional quality and safety
Genetically enhancing selected high-value species.

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

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

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

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

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

Improving science and technology policies and institutions
Making international and domestic markets work for the poor
Improving rural institutions and their governance
Improving R&D options to reduce rural poverty and vulnerability.

Emergence of the Alliance of Centers of the CGIAR as a third pillar of the CGIAR

Background

At the AGM '05, the CGIAR Centers formally established an Alliance of 15 Centers of the CGIAR (ACC). Built on existing governance mechanisms and the collective strength of 15 Centers, the Alliance aims to enhance effectiveness and efficiency in the System and serve as an instrument of reform in the CGIAR. A framework for collective action stipulates that the Alliance should be:

Built on existing CGIAR practices;
Informed by analysis of past constraints and a new vision;
Built on the Principles and Procedures as the platform for best practice in collaboration;
Guided by the Alliance Board and managed by the Alliance Executive; and
Supported by the ACC Office.

Mission

To enable the Alliance of Centers of the CGIAR to contribute more effectively and efficiently to the mission of the CGIAR by pooling their resources whenever and wherever needed.

Objectives

- Help evolve and improve the CGIAR System
- Be a collective, unified voice for the Centers on matters requiring a common position
- Strengthen and build on existing collective actions to create greater impact thereby strengthening the Centers' contributions to the CGIAR mission
- Create opportunities for enhanced collective action that uses the complementary skills and knowledge of the Centers and their partners and necessary economies of scale
- Serve as the authority for binding decisions to resolve conflicts among Centers that cannot be resolved by the Centers.

Functions

- Develop and sustain outstanding collective partnerships between Centers and external partners.
- Increase the effectiveness and efficiency of inter-Center collaboration and collective action.
- Position the Alliance of Centers of the CGIAR to manage organizational change.
- Resolve conflicts amongst Centers in disputes related to collective action.

Principles

- In conforming with the mission of the CGIAR, the allegiance of the Alliance is first and foremost to the poor
- All Centers are to become members of the Alliance
- Collective action implies mutual respect among Centers and no hierarchy of Centers
- The Centers will ensure transparency through open communication among themselves and with partners and stakeholders
- The problem to be addressed or the opportunity to be sought through collective action would get the best possible team(s) or mechanism assembled from Center resources and in cooperation with partners
- Priority setting, on issues that would benefit from a collective approach, should be based on open, transparent practices, including stakeholder consultation with participating Centers, R&D partners and investors
- For areas identified as a collective-action initiative of the Alliance, each participating Center is accountable to the collective-action's mechanism, which is accountable to the stakeholders
- While the principle of the Alliance is to promote harmonious collective action, any conflicts that arise in this context shall be resolved among the Centers through the collective action governing mechanism as enshrined in the contracts entered into by the participating Centers
- For each collective-action problem to be solved or opportunity to be captured, clear specifications and reachable objectives will be identified by the Alliance Executive or a cluster of it

Shared standards and practices (for administration and science) will be employed whenever justified to minimize transaction costs and increase efficiencies

Best practice in relation to conflicts of interest will apply to members of the Alliance Executive and Board in the conduct of the business of the Alliance.

Role of the Alliance of Centers of the CGIAR in the research for development continuum

During the CGIAR Annual General Meeting in December 2005, the ACC issued a paper outlining its position in the research and development continuum. The ACC views its basic function as:

- 1) Developing pro-poor technologies and knowledge in the areas of Centers' scientific competence.
 - Adding value to work carried out through partnerships by documenting, integrating and synthesizing knowledge at the global and regional levels.
 - Facilitating the development, implementation and sharing of the research for development agenda through the convening power of partnerships and international status of Centers.
 - Focusing research on poverty alleviation, hunger reduction and environmental stewardship.

The ACC recognizes that upstream research and its synthesis must be connected with the downstream application of new knowledge. It is only when all links in this chain are satisfied that donor investments will deliver impacts on human development. ACC's comparative advantage lies in enabling developing country partners to appropriate benefits of the advances in agricultural research. This is achieved by collaborating with advanced research institutions and a broad range of development actors.

The ACC is not a development agency, but an applied research and related capacity strengthening alliance focused on achieving development impacts. ACC's research products consist of a range of public goods to enhance individual, community and societal capacity to benefit the rural poor.

The ACC encourages experimentation with diverse research paradigms and approaches as a means of learning. The knowledge generated from this experimentation is an important IPG. Thus research on impact, not only ex post and ex ante but also on how to achieve it, is important on the development end of the continuum.

The ACC considers applied, action and participatory research to be a legitimate endeavor of Centers provided they create public goods beyond the singular event and thus advancing state-of-the-art knowledge.

The ACC embraces the Science Council as the guardian of quality and relevance of its work. If the Science Council is to be the guardian of research relevance as well as of quality, it needs to be systematically asking whether or not there is a plausible impact pathway for research to contribute to ACC's three main objectives.

Similarly, the Alliance should promote and accompany the scaling up of their research results and systematically document and share research experiences on achieving impact (both positive and negative) and innovations in impact pathways — such as through participatory plant breeding and collaboration with civil society organizations.

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, mobilize new science tools, address SSA, 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, 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 R&D 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 and 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 ICTs has had 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 ACC 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 to effectively allocate \$30 million for its new strategy and by 2015, this may be approaching \$50 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 one for 2007-2009 has been prepared to pursue this strategic plan. Currently, about 20% of resources are invested in biotechnology, 28% in crop improvement, 32% in agroecosystems and 20% in institutions, markets, policy and impacts. 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 SAT.





Chapter 3

Vision, Mission, Goal and Strategy

Vision

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

Mission

To reduce poverty, enhance food and nutritional security and protect the environment of the 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 semi-arid farming systems of Asia and sub-Saharan Africa.

ICRISAT will pursue the foregoing goal by enhancing the livelihoods of the poor in semi-arid farming systems through IGCRM 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 SAT systems; and 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, subregional 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*: Improving food and nutritional security and human and livestock health 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*: Mitigating the impact of acute and chronic crises from conflict, drought, desertification, degraded environments, and pests 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*: Empowering R&D partners 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 IGCRM as its overarching research strategy to attain scientific excellence in agriculture in the SAT, focusing on key livelihood and income opportunities to improve the well-being of the poor with equity, multidisciplinary, 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 SAT. 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 ACC, advanced research institutes, regional and subregional organizations, NARES, the private sector and civil society organizations. In SSA, our strategy will be synchronized with NEPAD and the Comprehensive African Agricultural Development Program (CAADP), including the SSA Challenge Program. 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. In SSA, for instance, it is estimated that nearly 50% of those living below the poverty line will be urban dwellers and that it is in such environments that the greatest concentration of poverty is likely to occur. 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

systemwide 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 (Tables 1 and 2). Consistent with the position of the ACC, 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 that 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 3). Global action that will pursue ICRISAT's research strategy anchored on the new CGIAR Systemwide priorities is detailed in Part II of this document.

Thematic goals and strategies

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 (GT), "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 GT on Biotech 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:

1. 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
2. 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 GT on Biotech 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 GT on CI 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 that the most appropriate technologies are being used in each case.

Towards 2015, the GT 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 in Part II of 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 plants. In order to address ICRISAT's vision 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, to reduce the cost of production.



The GT on CI 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, ESA, and WCA), catering to the needs of the national programs in the regions. Therefore, each region has a Regional Project addressing the priority needs of the region. Thus there are three regional projects — one each in ESA, WCA and Asia dealing with genetic improvement and diversification, pest and disease management, and where required, postharvest utilization. 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:

1. Collect, conserve, characterize and share germplasm within the global R&D community;
2. Undertake genetic diversification and enhancement of ICRISAT mandate crops for high and stable grain and fodder yield with improved quality;
3. Develop cost-effective and eco-friendly integrated pest management (IPM) technologies;
4. Address alternative crop produce utilization strategies, including food and feed safety issues, and the prospects for commercialization;
5. Increase adoption of improved varieties by farmers through farmer participatory methods, and sustainable seed-supply systems; and
6. Accelerate technology exchange and information sharing, using both conventional methods and ICTs 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 GT 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 agroclimatic 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.

An interdisciplinary research team will carry out research. Often, improved cultivars serve as catalysts for adoption of other technologies (agronomy, fertilizers, etc). Therefore, GT CI will work closely with the GT on AE (soil, water and biodiversity) and the GT on IMPI.

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

Agroecosystem 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 — IGCRM.

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 (NRM) in Asia, it was agreed that ICRISAT would continue to pursue these simultaneously and create a self-supporting NRM team in Asia. In this way, NRM scientists would continue to contribute to ICRISAT's IGCRM 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.

Goal and purpose

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

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

Strategy

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

Moreover, GT-AE will play multiple roles in its research on agroecosystem development. It will serve as a catalyst, facilitator and enabler of three broadly based consortia on the: (1) development of improved watersheds in Asia and sharing of lessons learned with Soil and Water Management Network (SWMnet) in East Africa; (2) agricultural implications of current climate variability and potential changes; and (3) Desert Margins Program(DMP). At the national level, ICRISAT will play the role of enabler and facilitator in developing and evaluating IGCRM

interventions that will help rural households to better cope with climate variability and alleviate food insecurity. In addition, ICRISAT's rich information base and network with International Agricultural Research Centers (IARCs) and ARIs will enable it to work closely with ILRI in developing alternative feed/fodder resources within crop-livestock systems.

Towards 2015, GT-AE 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 SWMnet for Eastern Africa, 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 SAT of Africa and Asia, the nexus between water and feed limitation is the primary constraint to effective livestock production.

ICRISAT in SSA 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. Project innovations that have resulted from interactions between ICRISAT staff from West Africa and Southern Africa include: better targeting of small doses of macronutrients (phosphorus in West Africa and nitrogen in Southern Africa), sale of fertilizer in smaller, more affordable packages; and new methods of disseminating information on technology options. 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.

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 IMPI (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 GT-IMPI 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 SAT.



Towards this, the theme aims to facilitate:

1. 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;
2. Adoption of alternative risk reducing, income diversification and commercialization strategies and innovations for improved livelihoods by SAT farmers; and
3. 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 GT-IMPI 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 SAT. It will widen and expand the scope of VLS both in Asia and Africa 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 VLS and Impact surveys. It will further strengthen participatory and multidisciplinary 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 and SSA.

Goal and strategy for knowledge sharing

National agricultural research and extension systems 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 (especially in SSA) 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 and sub-Saharan SAT. Amidst the continued decline of core resources, this task is a big challenge which calls for the design, development and up-scaling of innovative ways in capacity building. ICRISAT is committed to improving 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 harnessing innovative tools and concepts in learning, ICTs and KM 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 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 GOFU 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 KM 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 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. Notwithstanding this dynamism, production-related risk, poverty, natural resource degradation, and biodiversity 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 have placed greater demand on increasing crop/animal production and on 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 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 and SSA. 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 ongoing 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 M t, an increase of 29% from its current production level of 8.6 M t during 2003-04. Approximately 90% of the additional demand will come from Asia. New cultivars that combine early maturity and resistance to *Fusarium* wilt have recently been rapidly adopted in Ethiopia, Sudan and Kenya. 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% of world production, and Asia for about 68%. 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 strategies

West and Central Africa

As mentioned in the previous chapter, the low level of economic activity coupled with high population growth rates over the past decade has led to negative or stagnant growth in real per capita incomes in WCA. In many Sahelian countries, more than 30% of the population falls below the international poverty line of \$1 a day and more than 30% of the population is undernourished. Agriculture accounts for more than 30% of the gross domestic product, employs between 82-92% of the total labor force and is the main source of livelihood for the poor. Domestic food production has not kept pace with the rising population.

Goal and purpose

Our goal in WCA is to improve household income, food security and farmers' and consumers' health substantially above current levels and to make the ecosystems sufficiently resilient to cope with the shocks expected from climate vagaries. This is sub-divided into four intermediary development-oriented areas in accordance with ICRISAT's global strategy, and these are to:

- Achieve an improved, diversified and further commercialized agricultural production as well as improved food security and health status in the SAT of Africa;

- Improve the health and nutritional status of both people and livestock in the SAT, as these can be intimately associated with agricultural issues;

- Reduce the vulnerability of poor households to short-term shocks resulting from drought, pest and disease outbreaks by encouraging governments, NGOs and relief agencies to adopt more effective and efficient disaster prediction and relief strategies; and

- Increase the effectiveness of regional research partnerships and networks working on poverty reduction by enabling regional research partners to adopt and further adapt innovative R&D strategies.

Strategy

A primary driver for ICRISAT's strategy in WCA is to spur market demand. We will create incentives and opportunities for the poor to grow their way out of poverty through market-orientated production and value addition, in addition to ensuring their own food security. We will focus our research on enhancing and stabilizing yields. We will work to increase agricultural income for farmers with the expansion and increased viability of the commercial agricultural sector. We will also generate cutting edge innovations to help farmers reduce mycotoxin contamination, pesticide residues and other food contaminants and produce nutritionally superior crop and livestock products.

Moreover, we will implement the WCA priorities identified by the ACC based on the new CGIAR Systemwide priorities, which include sustaining biodiversity; maintaining and enhancing yields and yield potential of food staples; increasing income; integrated land, water and forest management at landscape level; and science and technology policies and institutions.

We will pursue our work using an IGCRM approach and by enhancing our network of collaborators and providing capacity building for our partners which include NARES, various subregional and regional fora (ie, CORAF/WECARD, FARA, NEPAD), Alliance of Centers of the CGIAR, advanced research institutes, civil society organizations and the private sector.

Eastern and Southern Africa

Of all the SAT regions, ESA is the only area where the UNDP human development index has remained unchanged since 1975. Nearly 30% of the region is semi-arid, more than half of the rural population lives in extreme poverty, and some 85% of these extremely poor people depend on agriculture to a greater or lesser extent for their livelihood. If there is to be any hope of achieving the MDG of reducing the proportion of people living on less than \$1 a day to half the 1990 level by 2015, there is a need for substantial investment in research for development in this region.

In developing our regional strategy, a number of factors were taken into consideration. The most important of these stressed that the research-for-development agenda should be driven by the priorities of African stakeholders and the specific requirements of end-users, ie, farmers, processors and traders. In this regard, ICRISAT recognizes the existence of two major groups of end-users in the SAT region: commercializing farmers that benefit from market opportunities, and largely subsistence-oriented and chronically poor and vulnerable households in less-favored areas and marginal environments.

Moreover, extensive dialogue was undertaken with stakeholders to ensure that our research priorities fully reflect the aspirations and priorities of the regional (FARA) and subregional organizations (ASARECA: Association for Strengthening Agricultural Research in Eastern and Central Africa, and SADC-FANR: South African Development Community – Food, Agriculture And Natural Resources). Similarly, cognizance was also taken of new initiatives by the NEPAD, African Union, Economic Commission for Africa and Inter-Academy Council for the UN Secretary General.

We also considered the 2003 ICRISAT External Program Review recommendation that ICRISAT should follow an IGCRM approach in developing regional research programs in SSA. Finally, we took into account the Systemwide priorities, which outlined five major priority and twenty sub-priorities areas for the CGIAR.

Goal and purpose

Improved rural livelihoods, increased food security, and sustainable IGNRM throughout SSA as a result of greater impact of agricultural research for development.

Strategy

Towards 2015, ICRISAT-ESA will emphasize development of alternative and targeted research products that meet the needs of market-oriented and commercializing farmers as well as subsistence-oriented and chronically poor rural households. We will also focus on improving institutions to make markets and service providers work for the poor and to develop strategies and policy options to improve livelihood security for vulnerable households.

Our programs will be guided by the IGNRM approach, strategically aimed at meeting the needs of the two major groups of farmers (commercializing and subsistence-oriented) to develop relevant solutions to the multifaceted agricultural development constraints that they face in the SAT. Strategic partnerships and alliances with private and public sector actors will be critical in developing holistic solutions that address the limiting factors along the resource management, production to marketing value chain.

ICRISAT-ESA's programs will deliver development impacts through the application of science and technology — developed by research — in a development context, and to provide ICRISAT with opportunities to conduct action research in support of development. Along with this, we will also address the institutional architecture of R&D and technology promotion as a way of improving poverty-focused developmental impacts. The regional programs will serve as a point of integration for ICRISAT's four global research themes to achieve clear and measurable impacts, and to help ICRISAT refocus its research agenda on issues that are of importance to smallholder farmers and development partners in the region.

We will also address the need to have a critical mass of scientists with competencies that complement those of our strategic partners to tap emerging opportunities to address existing and future challenges facing the region in a holistic manner. We will also provide capacity building support to our partners where necessary.

Asia

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, postharvest 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 ACC.

We will harness improved varieties and improved water use efficiency as major entry points in our IGCRM 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 SSA, particularly in the context of South-South collaboration.

Table 1. Alignment of ICRISAT's global research themes with the CGIAR Systemwide priorities.

CGIAR Systemwide Priorities	ICRISAT's Global Research Themes			
	Biotechnology	Crop Improvement	Agro-ecosystems	Institutions, Markets, Policy & Impacts
Priority 1- Sustaining biodiversity				
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 2- Producing more and better food at lower cost				
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 3- Reducing rural poverty				
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 4- Promoting poverty alleviation and sustainable NRM				
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 5- Improving policies and facilitating institutional innovations				
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			*	**
** Direct involvement				
* Potential involvement				

Table 2. Alignment of ICRISAT's regional research agenda with the CGIAR Systemwide priorities.

CGIAR Systemwide Priorities	ICRISAT's regional hubs		
	Western & Central Africa	Eastern & Southern Africa	Asia
Priority 1- Sustaining biodiversity			
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 2- Producing more and better food at lower cost			
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 3- Reducing rural poverty			
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 4- Promoting poverty alleviation and sustainable NRM			
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 5- Improving policies and facilitating institutional innovations			
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	**	**	**
** Direct involvement			
* Potential involvement			

Table 3. Achieving the Millennium Development Goals through ICRISAT's research.

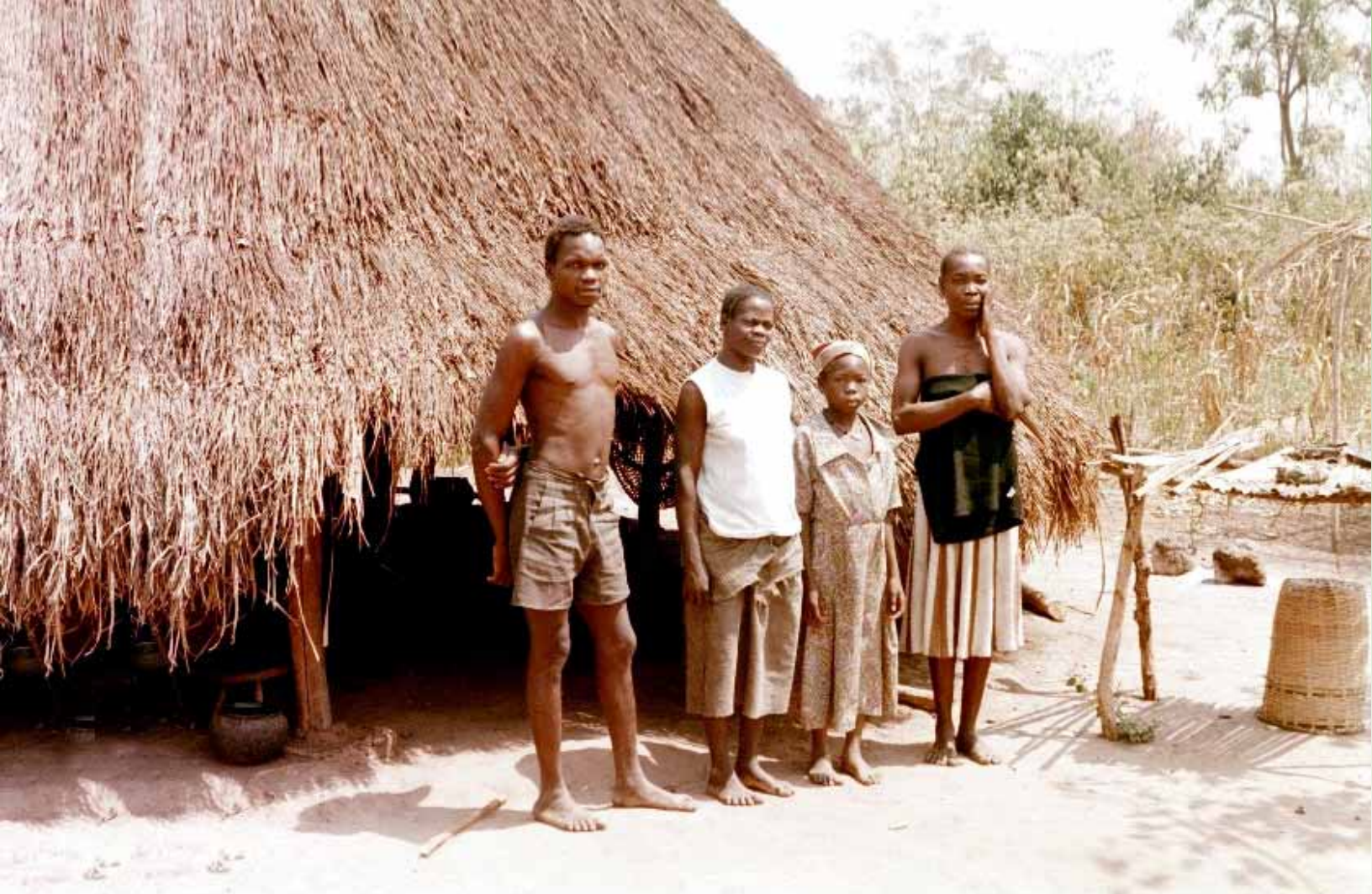
MDGs	ICRISAT's research thrust
1. Eradicate extreme poverty and hunger	The semi-arid tropics (SAT) is home to more than 800 million poor. ICRISAT contributes to improved food security, livelihood resilience and poverty reduction in this agro-ecological zone through its Integrated Genetic and Natural 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, <i>in situ</i> 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 Alliance of Centers of the CGIAR, advanced research institutes, regional and sub-regional organizations, NARS, international and national civil society organizations and the private sector through its Agri-Science Park.



Part II

Pursuing the Vision and Strategy





Chapter 1

Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger (System Priority 5)

Science and technology policies and institutions (Priority 5 A)

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 the twentieth century has shown that total factor productivity grew at an impressive pace in these countries. It has also caused a decline in the real costs of production per unit of output. Intensification of agriculture has also led to the generation of additional employment and to increases in real wages. Increased real wages and reduced real prices of food together have had a

strong impact on the reduction of poverty. All these positive developments occurred as a result of technological innovations developed by the IARCs, which were later fine-tuned and adapted to local conditions by the NARS. Several governmental and nongovernmental agencies helped take technologies to farmers and several supporting institutions and policies facilitated the processes of development. Rates of returns on the R&D investments were estimated to be quite high. These processes need to be carried forward with renewed vigor to achieve the CGIAR and Millennium Development Goals.



Improving incentives for technology generation, access and use (Priority 5A: Specific goal 3)

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

Improving food and nutritional security and combating poverty in the region would depend on policies and institutions that influence the capacity of national systems to generate or adapt technologies to local conditions and develop delivery systems for their widespread adoption. The national systems in many countries however remain weak and require substantial support in developing research priorities and intervention strategies to harness available and emerging technological and market opportunities. Lack of investment in agriculture in the semi-arid areas and its low productivity is partly because of lack of enabling policy and institutional frameworks that make it less favored for sustainable intensification and development. Research for science and technology policies and institutions is needed for facilitating technology exchange; harmonization of seed sector policies; incentive systems that enhance R&D

investments in dryland agriculture; development of regulatory systems for harnessing new technologies including bio-safety and food labeling; and provision of information on the changing environment and alternative futures for SAT agriculture environment.

What ICRISAT and its partners can achieve by 2015

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

- Harmonization of seed sector policies
- Facilitating public-private sector alliances for innovation
- Development of regulatory systems for harnessing new technologies
- Future commodity outlooks and investment priorities.

Outputs and outcomes to 2015

Outputs

Best practices for harmonization of seed-related regulations and policies suitable for the specific conditions of the SADC and ASARECA regions piloted, promoted and adopted. This would include harmonization of protocols related to (1) variety evaluation, release and registration, (2) seed certification, (3) phytosanitary regulations, (4) plant variety protection, and (5) laws and regulations governing development of the seed trade.

Innovative approaches for generation and utilization of new agricultural technologies and for facilitating innovation identified and promoted

Mechanisms for enhancing the utilization and market and non-market based exchange of germplasm developed and promoted

Bio-safety standards and food safety regulations developed and promoted.

Outcomes

Partners and policy makers internalize and take initial steps to harmonize protocols related to (1) variety evaluation, release and registration, (2) seed certification, (3) phytosanitary regulations, (4) plant variety protection, (5) laws and regulations governing development of the seed trade. Policy makers and NARS in the SAT endorse and implement best practices for harmonization of seed-related regulations and policies at regional level.

R&D stakeholders adopt innovative approaches and consortium models for generation and utilization of new agricultural technologies.

Countries in the SAT appreciate and endorse an agreed mechanism for enhancing the utilization and market and non-market based exchange of germplasm to promote conservation agriculture.

Countries in the region recognize the need for bio-safety standards and food safety regulations and take steps to develop and implement them.

Potential impact

The regulation of the seed industry, particularly if harmonized at a regional level, could have a very great influence on farmer's access to improved genetic material. This is presently a major constraint to development and if it can be overcome, it will be hugely beneficial.

ICRISAT's predominant capability

ICRISAT has taken a leading role in facilitating regionalized breeding and harmonization of seed policies. It has gained experience and credibility as a neutral facilitator of knowledge-based policy reforms in the agricultural sector. It also has a strong presence in biotech research that would help in developing bio-safety rules for ensuring food and environmental safety, and the associated social, economic and ethical concerns. ICRISAT also has established essential partnerships (e.g., IFPRI, FAO) for evaluating alternative futures for dryland agriculture in the SAT.

Counterfactual

If ICRISAT closes its activities in this area, the evolving momentum on harmonization of seed policies will be derailed or countries will fail to capitalize on the benefits of collective action in the regionalized breeding. Hence the anticipated research spillover benefits will not be realized. Improved seeds will largely remain in the informal sector, private sector participation in seed commercialization will remain at its infancy, and the poor smallholders will continue to lack access to improved agricultural technologies.

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

A set of outputs will be produced from this initiative including intensive capacity building through collaboration with SAT Asia and Africa regional and international researchers. Policy dialogues with governments on research priorities, institutional innovations and policy will be catalyzed.

Outputs and outcomes to 2015

Outputs

Participatory, pro-poor Monitoring and Evaluation (M&E) models (to measure impacts on the poor) developed for each research area ie, agroecosystems, biotechnology, crop improvement and social sciences and applied to research projects by ICRISAT and its partners.

Three models based on a coalition approach applying principles and methodologies of institutional learning and change (ILAC) developed, documented and implemented in select SAT countries with global and national partners.

Novel decision support systems and the required database on SAT agriculture developed for NARES and regional/global organizations for prioritization, investment decisions, monitoring

and evaluation and technology forecasting developed and tested and further refinement and enrichment of the databases and support systems.

Future outlooks for dryland agriculture, targeted research priorities and impact evaluation methodologies developed and shared with national and subregional agricultural research systems.

Outcomes

NARS refine models and test their application in three countries

Impacts of research by partners on the incomes and employment of poor farmers and agricultural labor quantified by local agencies

Three alternate models of ILAC used and adapted by partner institutions in the NARES in selected Asian and SSA countries

NARES partner institutions demonstrate benefits from improved and participatory methods of technology development and adaptation

Partners use ICRISAT-derived databases on research resource allocation, prioritization, monitoring and evaluation to improve research efficiency

NARES demonstrate ability to develop and maintain databases and decision support systems in selected Asian and SSA countries

Research partners and policy makers take informed decisions on alternative investment opportunities for improving agricultural productivity and sustainability in the semi-arid regions.

Potential impact

NARES demonstrate much enhanced research efficiency and knowledge is more freely available from their securely preserved databases.

ICRISAT's predominant capability

ICRISAT has earlier spearheaded Research Evaluation and Impact Assessment (REIA) exercises and shared the results with the NARS of Asia and SSA. The interdisciplinary approaches and international character of ICRISAT gives it a clear edge over other organizations in doing this work. ICRISAT has already 7-8 years of experience in implementing such models, and its ability to work with a variety of organizations has been well demonstrated. ICRISAT's researchers have already developed several databases on VLS, district level data, and impact assessment data and have the skills required to develop one on research management.

Counterfactual

There is little immediate likelihood of NARS partners developing M&E and ILAC models for application in SAT Asia and SSA. This activity will be delayed by at least a decade if ICRISAT does not take the lead.

Making international and domestic markets work for the poor (Priority 5B)

Enhanced livelihoods and competitiveness for smallholder producers and food safety for consumers influenced by changes in national and international markets (Specific goal 1)

Improved marketing environment for smallholders by improving the efficiency of domestic markets (Specific goal 2).

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 fish, 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 will also increase

both at 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 the 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 manufacture, etc is increasing and this trend is expected to continue in the foreseeable future. Niche markets for green and canned pigeonpeas,

bold-seeded and/or organically grown chickpeas, and edible (hand-picked, selected) groundnuts would be other opportunities for small farmers in the SAT.

There are, however, apprehensions about the ability of smallholders to take advantage of emerging opportunities. There are a number of reasons for low participation of small producers in the markets, such as there being only a small marketed surplus, thin markets often far away from production centers, exploitation by middlemen, and stringent food safety norms. Such issues escalate transportation and associated transaction costs. The agro-processing industry generally prefers to source its raw material in bulk and from nearby 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.

Under its institutional innovation research ICRISAT is experimenting with innovative institutional arrangements 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 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 ie, applicable to many commodities in several regions with only minor adaptive changes needed to meet local requirements.

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

What ICRISAT and partners can achieve by 2015

The next decade has to see enhanced participation of dryland smallholders in grain markets (mainly legumes and oil crops) that will generate higher incomes and accelerate commercialization of production. This will bring about multifaceted intervention strategy that will improve market access and competitiveness through improvements in efficiency, product quality, and adoption of good agricultural practices (GAPs).

The strategy will focus on the following elements:

- Grading and quality control systems
- Profitable marketing channels and outlets in domestic and international markets
- Future markets and commodity outlook studies
- GAPs that meet social, food safety and environmental standards
- Strategies that enhance farmer access to new technologies and services
- Institutional arrangements for better coordination of production and marketing
- Policies that enhance and encourage contract formation and enforcement
- Policies that support industry competitiveness and intra-regional trade.

Outputs and outcomes to 2015

Outputs

Trade prospects and outlooks for major commodities assessed and communicated to major producing countries in the region

GAPs that meet social, food safety and environmental standards for internationally traded commodities developed and promoted

Strategies that enhance farmer access and utilization of productive inputs and linked services that enhance competitiveness developed and promoted

Innovative arrangements for better coordination of production and marketing along the value chain for reducing transaction costs developed and promoted

Policies and strategies that encourage private sector investment in dryland agriculture through futures contract markets that provide more reliable markets for the poor and support contract enforcement developed and promoted

Policies that enhance the competitiveness of rural agribusiness enterprises, service providers, processors, exporters and permit enhanced intra-regional trade developed and promoted

Grading and quality control systems for all the tradable cereals and legumes established and adopted in the major growing countries

Profitable marketing channels and outlets for dryland grain legumes and tradable coarse grains in domestic and international markets identified and promoted.

Outcomes

Farmer organizations and small-scale producers will benefit from profitable marketing channels and outlets that reduce transaction costs for dryland grain legumes and tradable coarse grains
Policy makers and investors will take decisions informed by studies on trade prospects and outlooks for major commodities

Producer organizations and extension agents will adopt and implement GAPs that meet social, food safety and environmental standards

Agro-enterprises and farmer organizations will establish and adopt innovative institutional arrangements that enhance farmer access and utilization of productive inputs and linked services in rural areas

Policy makers and planners will adopt policies and strategies that encourage private sector investment through future markets that provide reliable markets for the poor and ensure contract enforcement

Policy makers and planners will take steps to implement policies that enhance the competitiveness of market agents and facilitate enhanced intra-regional trade

Policy makers, farmer organizations and traders will realize the benefits and adopt grading and quality control systems for grain marketing

The supply chain for tradable dryland commodities will be differentiated by grades and quality standards, opening opportunities for value addition and competitive exports to high-value niche markets.

Potential impact

The marketing industry, particularly if harmonized at a regional level, has the opportunity to transform agricultural performance in SAT countries. This is presently the major constraint to development and if it can be overcome, it will be hugely beneficial.

ICRISAT's predominant capability

ICRISAT is a major player in developing strategies, policies and innovations that facilitate commercialization of agriculture in the SAT of the region. It has initiated or completed a number of studies on improving market opportunities for dryland farmers, especially food legumes. The multidisciplinary research has clearly recognized the role of markets and the need to develop differentiated products that meet market requirements. This strong synergy between breeders, agronomists and economists is a rare and unrivalled capability that ICRISAT provides in making markets work for the poor.

Counterfactual

Closure of activities in this area would mean that smallholder farmers in the SAT would remain largely subsistence producers and fail to harness existing and emerging market opportunities at least for some of their vital commodities. In the era of globalization and liberalization of agricultural economies, lack of competitiveness will further marginalize dryland farmers and their commodities, leading to further exclusion, worsening poverty, livelihood insecurity and environmental degradation in these historically less-favored areas. Lack of market outlets and favorable policies would also undermine incentives for adoption of market-oriented agricultural innovations, thereby stifling the overall gain from research investments.

Global information on mandate crops and positioning the SAT in the WTO arena

World market price information 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. A set of outputs will be produced from this initiative, including intensive capacity building through collaboration with SAT Asia and Africa regional and international researchers. Dialogues with governments on policy options and suitable interventions will be catalyzed.

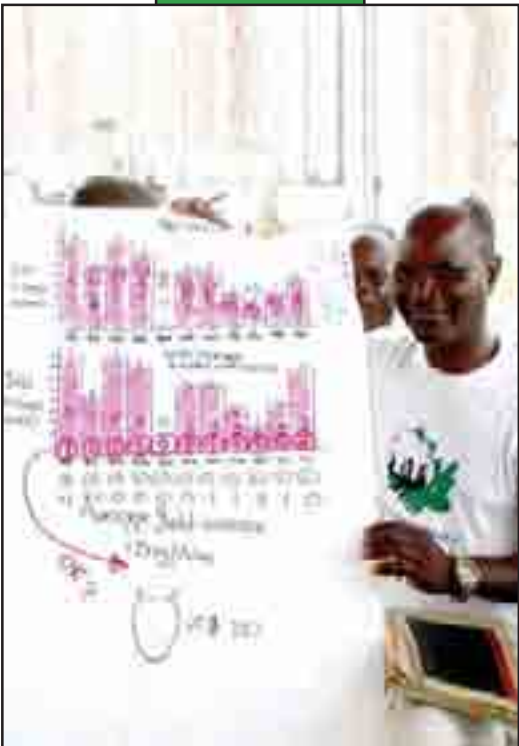
Outputs and outcomes to 2015

Outputs

Appropriate innovative/ vertical integration/ market linkage models identified, tried and adopted for selected commodities/ SAT mandate crops in at least three countries in Asia and SSA (the

selected models would enable participation and empowerment of small-scale farmers, taking on board gender and equity considerations). Development of forecasting models and analytical tools 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



Successful models used by partners in selected Asian and sub-Saharan African countries
Small and marginal scale farmers in Asia and SSA produce ICRISAT mandate crops for niche markets or alternative uses, ie, non-food uses and high-value food products
Small producers in the SAT demonstrate enhanced technical know-how, institutional linkages, bargaining power; reduced transaction costs and reduced market risk.
Model testing completed by target partners, refined and in use
Partners show informed decision making for SAT regions and commodities.

Potential impact

Supply and demand projections for SAT mandate crops 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 tailored to meet international quality standards for the benefit of small-scale farmers.

ICRISAT's predominant capability

In-house availability of multidisciplinary expertise for the mandate crops
Availability of varieties suitable for alternative uses and/or expertise on tailoring varieties for end uses
Hands-on experience in using a consortium approach for 3-5 years
Existing broad web of linkages with various partners across SAT Asia and Africa
International reach and political neutrality
Archived databases and 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 do not gain from the benefits of a consortium approach
- The area, particularly under mandate coarse cereals, may go down further with detrimental consequences for the environment, human health and livestock feed.
- Resource allocation by NARES not based on scientific forecasting of trends in SAT agriculture.

Increasing incomes from mixed crop-livestock systems

The consumption of animal products in the developing world increased dramatically between the early 1970s and the mid-1990s. This factor, corroborated by simulations using the IMPACT model (International Model for Policy Analysis of Agricultural Commodities and Trade), led ILRI/IFPRI to predict/confirm the beginning of the livestock revolution. The IMPACT model predicts that by 2020, developing countries will produce on average 38% more meat and 62% more milk per capita than in the early 1990s. Much of the increase in meat will come from monogastric livestock such as pigs and poultry. Meat and dairy production has doubled in the last three decades; and if sufficient feed could be produced, supply could multiply by 1.3 times for red meat, 4.3 times for white meat (pork and chicken), 1.8 times for milk, and 3.1 times for eggs between now and 2020.

Market information confirms these predictions. Developing countries, despite increasing production, are net importers of animal products. Along with the increase, the composition of trade in meat has changed significantly. Poultry imports are already larger than imports of all other meat products put together. This clearly indicates the increased demand for poultry and huge opportunities for livestock keepers in the SAT.

ICRISAT has traditionally focused on crops but in recent years the research agenda has expanded to include livestock. ICRISAT recognizes the importance of livestock — and crop-livestock synergies — in the smallholder farming systems of the region. With our experience in drought-tolerant smallholder crops, ICRISAT believes that as an institution it can make a vital contribution to alleviating poverty, improving agricultural sustainability, and facilitating market access of poor livestock keepers. ICRISAT and ILRI recently signed an agreement for collaborative research. The first stage examines developments in the region's livestock sector over the past 15 years.

Market development and access

The importance of market access cannot be overemphasized. Much of the degradation in southern Africa, and for that matter eastern Africa, can be ascribed to poor market access and poor market-related policies. Experience has shown that farmers are prepared to invest more in livestock (e.g. health care, feed supplements) if direct benefits accrue from these investments, than in crop production. Milk cows are often given additional feeds because milk can be sold for cash. Thus, in order for farmers to fully benefit from their livestock, access to markets is

crucial. These markets can either evolve autonomously, or in response to policy changes or greater demand for animal products. It is important to study the development of markets, from the informal sector to the large-scale commercial sector, for small-scale livestock production. For example: South Africa and Namibia have well developed markets for sheep and goats; but in adjacent Botswana and Zimbabwe, goats— which are key for poorer households — have almost no marketable value, except at the informal scale where prices are low. Interventions to improve livestock markets — particularly for small species — would go a long way in alleviating poverty, improving income, food security and human nutrition while also improving the environmental sustainability of mixed crop-livestock systems.

Outputs and outcomes to 2015

Outputs

Understanding is generated on how informal markets function, how small-scale livestock owners can engage in these markets and how it would benefit them and the regional economy and ultimately how these informal markets can develop into more formal institutions
Formal markets, both local and export, show how small-scale farmers can contribute in order for them to participate in mainstream economy.

Outcomes

Small-scale farmers show that they have increased access to markets, increased income and increased ability to cope with adverse natural and economic conditions
Farmers sell excess animals, and reduced impact on natural rangeland is observed.

Potential impact

An understanding of the functioning of formal and informal markets, how small-scale farmers may access and benefit from these markets is developed
Land degradation is reduced where alternative feeds are available for livestock
Risks and vulnerability to adverse natural and economic conditions are reduced.

ICRISAT's predominant capability

ICRISAT plays a leading role in developing small-scale agriculture in the SAT. Since extremely important work has already been done in studying market accessibility and commercialization, adding livestock to our repertoire would not be that difficult. We have active NARS and other partners with an established network of researchers within the DMP countries.

Counterfactual

If ICRISAT does not address these issues at a regional level, we will lose the comparative advantage that the ongoing studies with ILRI and BMZ has allowed us to generate. There are

no other regional organizations that have the capacity to engage on a regional level that could assist SADC in their objectives for livestock development at the regional level.

Rural institutions and their governance (Priority 5C)

Specific goal 1: Identify mechanisms for strengthening producers' organizations and for modes of participatory research

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

Recognition by the CGIAR of research on rural institutions and their governance is essential for establishing the enabling conditions and agents for facilitating agricultural transformation and market-led rural development. Rural institutions are pivotal in this process as they form essential channels for implementation of research interventions as well as facilitate the access of the rural poor to markets and to agricultural innovations. Farmer organizations can contribute towards coordinating production and marketing activities, dissemination of agricultural technologies, and provision of various service functions. One of the major challenges for commercialization of production in isolated rural areas has been lack of economies of scale resulting from the low volume of marketed surplus and the high costs of marketing both inputs and products. Smallholder farmers can circumvent this problem through collective action that would help them coordinate production and marketing decisions.

Many of the past cooperatives were established by the state to replace private commercial activities in the provision of essential services to the rural sector (including credit and inputs). Hence, they functioned primarily as 'service cooperatives' supported by governments rather than as business enterprises owned and managed by the members. With structural adjustment and economic reforms, many of the service cooperatives lost this special protection from the state, further reducing their viability in the competitive economic environment. Studies on past cooperatives in many sub-Saharan countries of Africa indicated that they often failed to develop into viable, self-managed and profitable organizations mainly due to lack of autonomy and a clear business plan. There are, however, some successful examples of well-managed and efficient farmer organizations (formal and informal) in the region.

Rural organizations require exogenous assistance in terms of capacity building to backstop new innovations that may be introduced to them; but the success of this depends on how well such capacity building will align with prevailing local knowledge, values and norms. Viable and effective rural organizations for providing essential services to the poor would also require measures for timely coordination of their functions, conflict resolution, consensus building, and protection of organizational goals, development of horizontal and vertical linkages, and monitoring and evaluation to identify constraints and take corrective measures. Moreover,

evidence suggests that HIV/AIDS may be contributing to an increase in the proportion of rural populations trapped in chronic food insecurity and poverty.

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



What ICRISAT can achieve by 2015

Characterization of selected rural institutional arrangements in selected countries and comparative analyses of their potentials for improving farmer access to markets and agricultural technologies for income growth and reducing vulnerability to shocks (HIV-AIDS, drought, etc)
Evaluation and identification of innovative institutional arrangements and farmer organizational models for enhancing smallholder access to markets and facilitating technology uptake

Institutional options for targeting technology and market interventions for poor and HIV/AIDS affected households.

Outputs and outcomes to 2015

Outputs

Alternative institutional topologies for adoption of technological and market innovations identified and characterized

Alternative institutional innovations to strengthen rural institutions that facilitate and enhance adoption of technological and market innovations developed and promoted.

Institutional arrangements that strengthen rural institutions (e.g. multi-stakeholder coalitions to address vulnerability) for mitigating the impacts of HIV/AIDS on household food security and incomes developed and promoted

Policy recommendations for formal and informal social networks to address vulnerability, gender and social exclusion in SAT farming systems developed and shared.

Outcomes

Policy makers, planners, extension and market agents realize the potentials of alternative institutional options for delivering technological and market innovations to smallholder farmers
Policy makers, planners, extension and market agents adopt and implement innovative institutional arrangements that strengthen rural institutions that facilitate technology adoption and/or make agricultural markets work for smallholder producers

Agencies for social protection and agricultural rehabilitation adopt and implement institutional innovations that strengthen local institutions that facilitate recovery and mitigate the impacts of HIV/AIDS on household food security and incomes

Policy makers adopt policy recommendations on how to strengthen rural institutions for addressing issues related to vulnerability, gender and social exclusion in SAT farming systems.

Potential impact

Development can only occur within a context in which rural institutions are strong and functional. This is not the situation at present in much of the SAT. Overcoming this constraint would greatly influence the further success of development programs.

ICRISAT's predominant capability

Lack of strong institutions in many less-favored and geographically isolated areas has prevented the poor from tapping technological and market opportunities. ICRISAT has realized the fast emerging and expanding future opportunities on the role of rural institutions in facilitating access to new technologies and markets in rural areas. Accordingly ICRISAT has already initiated research on understanding and developing ways to build and strengthen rural institutions that facilitate access to technologies and markets in remote villages. Its comparative advantage remains in developing institutional models and generating knowledge on ways to strengthen rural institutions through collective action and other innovations that enhance economies of scale, reduce transaction costs and help improve livelihood security in the SAT.

Counterfactual

Rural institutions bridge the access to new technologies and markets for the poor. If ICRISAT fails to take an active role in this area or closes down its current activities, the impact of its research on poverty and food security would be substantially reduced. The majority of smallholder farmers and vulnerable households in areas away from markets will fail to benefit

from technological and market opportunities and continue to suffer from marginalization and exclusion. Other agencies will not be able to fill the vacuum in terms of generating the required knowledge in the near future.

Improving research and development options to reduce rural poverty and vulnerability (Priority 5D)

Almost a billion people in SAT Asia and Africa are still engaged in small-scale agriculture. However, 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, greater human disease burden, unfavorable policies and practices and rapid urbanization. There are also tremendous changes occurring in the 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 R&D should monitor the impacts of technologies on 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. Farmer's 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 achieve by 2015

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

- Understanding the dynamics of poverty in the SAT and monitoring changes; identifying options for the rural poor to access, acquire, protect (in the case of shocks) and use assets to improve their livelihoods and using the information to inform future R&D strategies, assess priorities and impacts, and target efforts more effectively at the needs of 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 NRM practices and participation in higher-value product markets; as well as identifying binding constraints for agricultural transformation in the rural SAT with reference to the drivers of socio-economic, institutional and political change at the micro and macro level.

Determining specific opportunities or niches for ICRISAT to make a difference to the welfare of the SAT poor to include trade-offs underlying investments in crops and livestock, farm and nonfarm rural employment and enterprise, migration and remittances, labor efficiency and greater human disease burden including HIV/AIDS, market interventions and policy changes. Improving the quality of the context (markets and other infrastructure, institutions, public goods, policies and governance) where the poor use their assets and reducing 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.

Analyzing the effectiveness of public sector assistance programs and rural development strategies to improve livelihood resilience and reduce poverty; and designing new strategies to achieve those goals combining agricultural and nonagricultural sources of incomes and employment.

Outputs and outcomes to 2015

Outputs

Village level studies fully completed in the 10 original benchmark sites in India and methodologies/database shared with national and global partners; VLS initiated/expanded to two countries in SAT Asia to support the mapping of complex development pathways in the rural SAT economy

Similar follow-up of the longitudinal VLS panel in WCA (focusing on agricultural transformation in SSA) and in ESA (focusing on agriculture and HIV/AIDS) spearheaded with the support of the World Bank and Rockefeller Foundation

Case studies fully documented on uptake pathways of SAT technologies developed and shared with national program partners (from genetic enhancement, from biotechnology, from NRM and from social sciences); meta analysis and lessons learned on the constraints and mediating factors facilitating adoption of SAT technologies shared with partners globally

Policy package on risk management strategies (both ex-ante and ex-post) for mitigating the impact of risks inherent in rainfed agriculture developed; capacity building on risk management policy package for policy makers in SAT Asia.

Outcomes

NARS social scientists demonstrate enhanced research efficiency through use of ICRISAT promulgated methods

Policy makers are better informed on alternative development pathways for rural SAT economies ICRISAT and NARES show better targeting of research products in SAT Asia and Africa with effective pro-poor policies on risk management for SAT agriculture.

Potential impact

Hard factual information from the VLS and lessons learned from past success and failures have a major impact on ensuring more scientifically based decision making in matters concerning agricultural development in the SAT. As a result ICRISAT's and its partner contributions to the attainment of the MDGs is much enhanced.

ICRISAT's predominant capability

ICRISAT is a leader in this research area and in linking micro- and macro-level analysis to inform policy development

It is a Center of Excellence for developing technologies for SAT

It works in an interdisciplinarity and partnership mode and produces the necessary IPGs.

Counterfactual

Lost opportunity to contribute significantly to understanding the dynamics of poverty in SAT rural economies in collaboration with partners

No IPG contribution in enhancing the capacity of NARS in VLS and micro-level based policy formulation

Lack of targeted technology development

Lack of reflection of lessons based on past successes and failures at ICRISAT and in NARES research organizations

Technologies for the improved welfare of SAT farmers will not be documented by ICRISAT

Pro-poor strategies strengthened by village level insights will not have evolved.



Chapter 2

Sustaining biodiversity of sorghum, pearl millet, minor millets, groundnut, pigeonpea and chickpea (System Priority 1)

Conservation and characterization of staple crops (Priority 1A)

Overview

ICRISAT's Genetic Resources Unit is responsible 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 also obtained new and unique accessions of chickpea (2122) and sorghum (1619).

At ICRISAT-Patancheru, the entire germplasm collection is conserved in medium-term storage (MTS) (4°C, 30% RH). These collections will also be conserved in long-term storage (LTS) (-20°C) in a phased manner. By January 2006, 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.



ICRISAT-Niamey assembles and conserves genetic resources developed from research or obtained from collections, particularly from WCA. The genebank has stored 17,683 accessions in base collections. In order to safeguard the germplasm stored at ICRISAT-Patancheru, genebank duplicate samples are conserved at ICRISAT-Niamey gene bank. Efforts are underway to increase the characterization and use of these locally adapted genetic resources in crop improvement.

The ICRISAT-ESA regional genebank in Bulawayo holds sorghum and millet landraces and germplasm collected mainly from the SADC region and elsewhere, e.g., China and Yemen. As of May 2005, the genebank held 2407 accessions of sorghum and 2627 of pearl millet. The ICRISAT-Nairobi genebank holds sorghum and millets from East and Central Africa, as well as pigeonpea and groundnut from ESA, and those collected globally. The genebank has 1200 sorghum, 33 pearl millet, 940 finger millet, 329 pigeonpea, 90 chickpea and 19 groundnut accessions in MTS.

Institute-wide genebank upgrading activities supported regeneration of critical accessions as well as processing for further safety duplication. The program will continue to conduct collections where this has not been done, fill gaps, continue characterization and conservation, and incorporate landraces in the breeding programs. In order to facilitate fundraising for biodiversity conservation and utilization we will link these activities positively to use.

Supply of germplasm of ICRISAT mandate crops to the users is the mission that ICRISAT undertakes wholeheartedly. From the 1974 until 2006, a sum of 670,057 germplasm samples was supplied to scientists outside ICRISAT in 143 countries.

Outputs and outcomes to 2015

Outputs

- 100% of mandate crop in-trust germplasm collections transferred to LTS
- 40% of such germplasm safety duplicated
- Population structure of all five mandate crops established and published
- Mini-core collection of all five mandate crops established
- Trait-specific germplasm sets of all five mandate crops identified.

Outcomes

- Partners have access to and use of the full diversity of germplasm in small, breeder-efficient subsets (core and mini core collections)
- Partners have access to and use new, targeted germplasm sources for important traits.

Potential impacts

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

Capability

There is no other organization in the SAT with the IPG mandate, long track record, or capability of undertaking the storage and maintenance of the five ICRISAT mandate crops.

Counterfactual

Potential loss of priceless global germplasm collections and less efficient partner breeding programs.

Promoting global conservation and characterization of underutilized plant genetic resources (Priority 1B)

Overview

Besides germplasm of sorghum, pearl millet, chickpea, pigeonpea, and groundnut (staple crops), ICRISAT also conserves, characterizes and promotes the utilization of six small millets (finger-, foxtail-, barnyard-, kodo-, little-, and proso millet) that have regional and location-specific importance and are as such classified as under-utilized crops. ICRISAT's genebank is currently 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. Recently 61 new and unique foxtail millet germplasm samples (35 from China and 26 from Bangladesh) have been obtained.

The entire collection is conserved in MTS, and is being conserved in LTS in a phased manner. As of January 2006, 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 must be conserved in safety backup at a location outside India. As of January 2006, 4580 accessions of finger millet have been placed in a safety backup at the ICRISAT Regional Genebank at Niamey, Niger.

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 breeders' interest, which show large genotype x environment interactions and require replicated multi-locational evaluation. Developing core collections (e.g., 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.

Outputs and outcomes to 2015

Outputs

- 100% of germplasm collections transferred to LTS
- 70% of germplasm safety duplicated
- Population structure of finger and foxtail millet established
- New collection mission implemented to fill gaps and core collection of finger millet and sesame established and unique germplasm conserved
- Morpho-agronomic characterization of core collections of finger millet and sesame completed
- Trait specific germplasm for finger millet identified to meet industry and farmer needs
- Networks and institutional linkages established to link knowledge of under utilised plant genetic resources and their conservation and equitable use to communities and farmers
- 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 minor millets identified and made available to partners
- Passport, phenotypic and genotypic data on all crops curated in a public-accessible database(s).

Outcomes

- FAO acknowledges ICRISAT's responsibilities to its six minor crops are largely achieved in terms of storage and safety duplication.
- Partners have easy access to characterization data on the 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
Characterisation data and agronomic information on available germplasm of under utilised crops including sesame disseminated to breeders and other researchers who make use of this in agricultural diversification to increase income.

Potential impacts

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

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.

ICRISAT's predominant capability

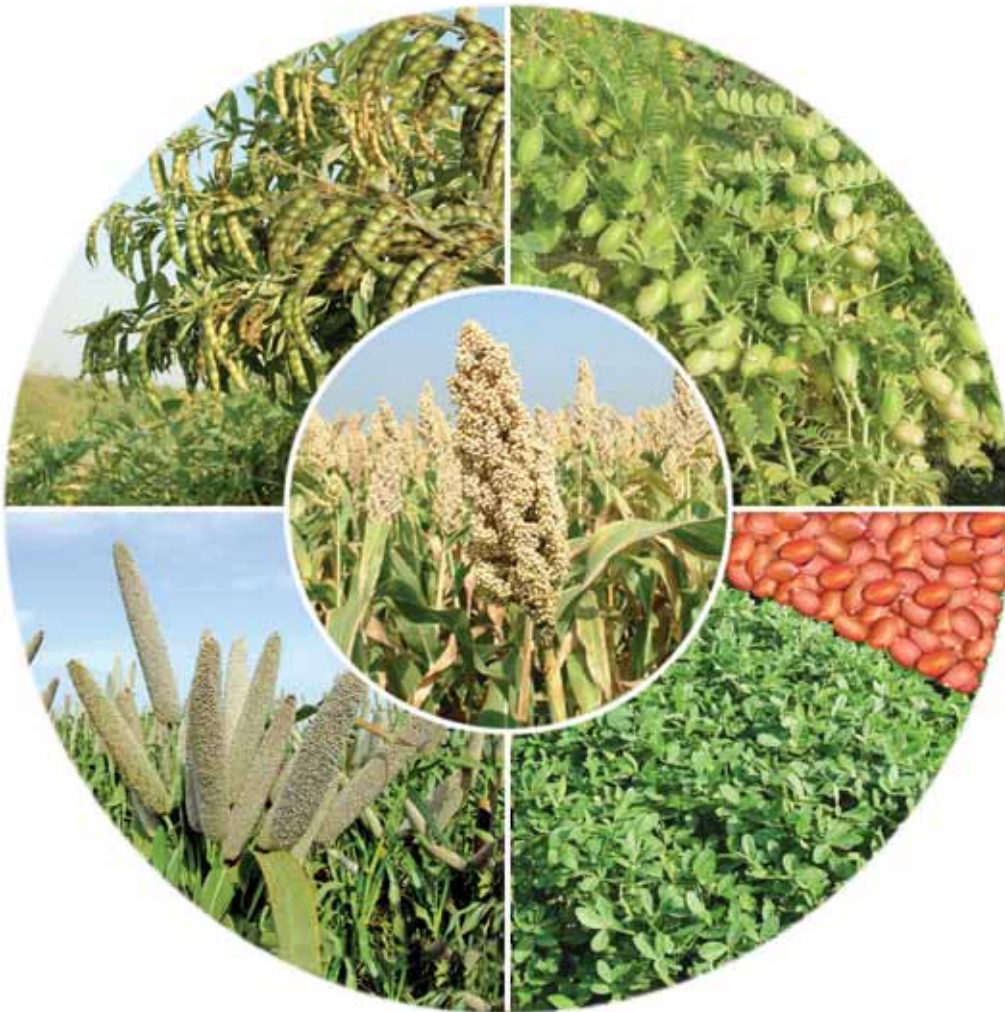
There is no other organization in the World with the IPG mandate to undertake the storage and maintenance of the five minor millets.

Counterfactual

Potential loss of priceless global germplasm collections and opportunities for improved breeding, crop diversification, improved nutrition and niche marketing lost.







Chapter 3

Producing more and better food at lower cost through genetic improvements
(System Priority 2)

Maintaining and enhancing yields and yield potential of food staples (Priority 2A)

Staple food crops of the SAT

ICRISAT mandate crops — sorghum, pearl millet, chickpea, pigeonpea and groundnut — are important for ensuring future food nutritional security and enhancing the livelihoods of poor people in the SAT. Of the global sorghum area of 43.7 M ha, Africa accounts for 57% (25 M ha) and Asia 26% (11.2 M ha). Globally 34.6 M ha of millets (pearl millet + minor millets) are grown, of which Africa accounts for 20.9 million (60%) and Asia 12.1 M ha (35%).

Chickpea (11.2 M ha globally) is mostly grown in Asia (10.2 M ha, including Central Asia and West Asia), with around 0.5 M ha cultivated in the African continent. Similarly pigeonpea is grown mostly in Asia (4.1 M ha, 90%), although Africa has 0.4 M ha of pigeonpea. Groundnut (24.6 M ha) is much more widely distributed across continents, with Asia accounting for 54% of area (13.3 M ha) and Africa 42% (10.2 M ha).

Enhancing the capacity and efficiency of genetic improvement programs through approaches linking characterization and use (Priority 2 A: Specific Goal 1)

Overview



ICRISAT believes in the potential of biotechnology to enhance the speed, precision, efficiency and value addition in many aspects of its crop improvement 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. Where possible we will seek the assistance of other advanced scientific partners who may have greater access to appropriate knowledge or

technology, for example, in the transformation or mapping of sorghum or pearl millet.

Specific target traits and crops are determined in collaboration with other crop improvement specialists and with ICRISAT's many partners. These close interactions ensure that the highest priority traits are being addressed in each crop, as well as that the most appropriate technologies are being used in each case. In certain instances, a high priority trait may not be a high priority for biotechnology applications given available conventional solutions and/or a lack of biotechnology approaches.

Potential impact

All breeding efforts using biotechnological tools will improve the rate and efficiency of bringing new genetic resources to the continuing fight against rapidly evolving fungi, bacteria, and viruses that are the causal agents of many biotic stresses. As such they are useful tools for the breeding community that will grow in importance over the next decade.

ICRISAT's predominant capability

ICRISAT is one of the very few organizations in the SAT that are capable of running a full scale, broad spectrum biotechnology project. With a dedicated genomics laboratory possessing an annual capacity of 1 million DNA samples per year and comparable laboratory and staff in wide crossing, genetic engineering and bioinformatics plus access to the SAT principal genebank for ICRISAT mandate crops and substantive field facilities for accurate phenotyping, ICRISAT rightly claims that it exercises a predominant capability in this research area.

Counterfactual

The absence of ICRISAT's biotechnology activities would have a major effect in reducing the present and future efficiency of cereal and legume breeding programs for semi-arid environments in Africa and Asia, which would in turn significantly compromise the likelihood of the achievement of MDG 1.

Wide crosses

Currently, ICRISAT has good techniques for embryo rescue, culture and plant regeneration for chickpea, pigeonpea and groundnut. These provide options to develop intra- and interspecific hybrids and backcross materials in each of these crop species. The program will focus on producing hybrids that require significant laboratory techniques (e.g. embryo rescue, chromosome doubling). Interspecific crosses in chickpea will be developed and evaluated for insect resistance as natural levels of resistance are lacking. Interspecific crosses in pigeonpea will be evaluated to provide additional genetic diversity for several traits, as the molecular evaluations have indicated extremely low levels of diversity within the cultivated species. In groundnut, specific attention will be given to producing "synthetic groundnut" germplasm. Being a tetraploid (AABB genome), it is feasible to cross the AA and BB genome species to "recreate" the conventional tetraploid species. Such an approach has been extremely successful in other polyploidy species such as wheat, and would produce tremendous diversity for further backcrossing and selection for numerous traits of interest.

Specific objective: Enhance the genetic diversity of ICRISAT's crops through the introduction of genomic segments from wild species.

Outputs and outcomes to 2015

Outputs

Hybrids and backcross germplasm between cultivated and wild species of chickpea and pigeonpea

Novel “synthetic” groundnut germplasm developed from diploid by diploid crosses

Molecular markers tagging specific genomic segments from wild species.

Outcomes

Partners adopt new options to enhance the resistance of chickpea, pigeonpea and groundnut varieties for a range of priority traits

Molecular screening methods for efficient introgression of specific genomic segments into cultivated varieties are employed by partners

Broadening of the genetic diversity deployed by partner breeders.

Structural and functional genomics

The major objective of structural and functional genomic applications is to identify, isolate and manipulate genes for traits of interest in ICRISAT’s mandated crops. To accomplish this, it is necessary to have a number of genomic resources available. Molecular markers of various types (e.g., RFLPs, AFLPs, SSRs, SNPs) are necessary for analyzing the molecular diversity in a species, and for locating specific genes and QTLs in the genome. Markers such as AFLPs can be developed from generic resources available commercially, while markers such as RFLPs, SSRs and SNPs require significant investment to develop. For ultimate ease of use in breeding, marker types based on simple PCR techniques (SSRs, SNPs) are desirable. The availability of each of the more important marker types for each mandated crop is listed in the table below.

Crop	RFLPs	SSRs	ESTs	BACs	Gene Sequences
Chickpea	+	++	++	++	+
Groundnut	+	++	+	+	
Minor millets	+	+			
Pearl millet	++	++	++	+	
Pigeonpea	+	+	+		
Sorghum	+++	+++	+++	+++	+++

For crops such as sorghum and chickpea, a large number of molecular markers are already available and the number is expected to continue to increase, especially for sorghum — it has recently been announced by the US Department of Energy that the sorghum genome will be sequenced starting in 2006. Pearl millet and groundnut have a number of markers available, although a much larger number is required to provide adequate coverage of the genome. For pigeonpea and most of the minor millets, the number is extremely limited and considered inadequate for most mapping and breeding purposes.

Molecular markers can be developed via a number of different strategies (e.g., from EST and/or BAC libraries). The specific strategy to be employed will depend on the status of various other genomic resources in the targeted species. In some cases, it will be desirable to target specific genomic regions to saturate a region known to contain gene(s) of interest. Some targeting could benefit from a comparative approach using a species such as rice, maize or soybean that have available high-density maps. It is envisioned that marker development would be developed in partnership with public (and private) collaborators in developed and developing countries (e.g., sorghum and pearl millet with USA; chickpea and pigeonpea with India; groundnut with Brazil, India and USA).

Specific objective: Public availability of genome-wide molecular markers for ICRISAT's crops for use in molecular tagging and selection programs.

Outputs and outcomes to 2015

Outputs

- At least 2000 PCR-based markers for each species
- Low-cost, high-throughput marker assays
- Global, public database with marker information.

Outcomes

- Partner researchers use molecular markers where appropriate to improve breeding efficiency in all crops globally
- Enhanced genome coverage for tagging genes and traits of interest is used by partners to enhance crop improvement.

Gene/QTL mapping

A major application of genomics is the use of molecular markers as indirect selection tools in a breeding program. Essentially, the goal is a better prediction of a particular phenotype from a determined genotype. To accomplish this, it is necessary to determine molecular markers that have a high predictive value for a particular phenotype or trait. Development of such markers requires that:

- Phenotyping methods are well established;
- Contrasting germplasm sources are available;
- Molecular markers are available;
- Segregating populations are produced; and
- Statistical methods are available.

Priority traits have been identified in collaboration with the Regional Programs and Crop Improvement GT. In most cases, adequate phenotyping methods are available, although for

some traits such as drought and salinity, these will be firmly established by 2007. Contrasting germplasm for use in developing segregating populations are available and in many instances, the required populations at various levels of inbreeding are available. Statistical packages for analyzing the molecular and phenotypic data are available and are being incorporated into a bioinformatics system (iMAS) to allow efficient handling of these datasets.

Specific objective: Public availability of reference maps and identified linked molecular markers for traits/genes of interest in ICRISAT's crop species.



Outputs and outcomes to 2015

Outputs

- Reference maps, populations and seed for each species
- Linked molecular markers for traits/genes of interest
- Global, public database with map and population information.

Outcomes

- Researchers use maps to make comparisons across populations and species globally to enhance crop improvement
- Partners make enhanced use of molecular markers in breeding programs for traits of interest.

Marker-assisted selection (MAS)

Ultimately, the goal of identifying linked markers is their use as indirect selection tools in the breeding programs. In addition to the identified linked markers, it is necessary to have a low-cost, high-throughput marker service facility and often to consider alternative breeding strategies to most effectively incorporate molecular approaches. The GT will continue to evaluate marker methods and adopt those that provide lower cost and higher throughput. At the moment, SSR markers are considered appropriate for most species. It is predicted that SNP markers may become attractive in the next few years and technology will need to be established in-house. A major limitation in MAS is the cost to select for the recurrent genome in the backcrossing programs (normally, only markers linked to the trait/gene of interest are used). Chip-based technologies such as DARTs or chip-based genotyping

may provide an effective system and will be evaluated for possible use. As MAS becomes a routine strategy, it will be necessary to establish a Service Lab to provide the high-throughput marker services on-demand to the breeding programs.

Specific objective: Marker-assisted selection for multiple traits of interest in crops.

Outputs and outcomes to 2015

Outputs

MAS derived germplasm for release to partner breeders

Low-cost, high-throughput MAS strategies for use by ICRISAT and its partners.

Outcome

Partner breeders make enhanced use of markers globally to improve the efficiency of their breeding programs.

Genetic engineering

For effective genetic engineering of any crop, it is necessary to have a number of tools available. These include:

- Genes and promoters;
- Transformation methods;
- Events;
- Phenotyping methods;
- Bio-safety labs, greenhouse & fields;
- Bio-safety regulations;
- IP licenses;
- Food, feed, environmental safety dossiers; and
- Marketing strategy.

ICRISAT is fortunate in that most of these are either available or are being addressed. The only current limitation is an effective transformation system for sorghum and pearl millet, although such systems do exist in other laboratories and ICRISAT has used biolistic transformation to produce a few transgenic sorghum lines. One of ICRISAT's strengths is its ability to transform chickpea, groundnut and pigeonpea using an *Agrobacterium* transformation system. Appropriate bio-safety containment greenhouses are available, and options for increasing the number of these do exist given appropriate resources. ICRISAT has also had experience with the initial field evaluation of transgenic chickpea, groundnut and pigeonpea on its campus at Patancheru, Andhra Pradesh, India. A number of bio-safety applications have been submitted and all approved by the internal and Indian bio-safety committees.

Efforts to date have focused on developing transformation systems and gaining experience in the evaluation of transgenic materials under approved greenhouse and field conditions. A number of traits have been targeted with various genes and promoters. Incorporation of these genes into the target species has been successfully accomplished and greenhouse and field trials conducted for many. Some genes have been determined to be promising and will be selected for product development. This will require the production of a large number of transgenic events, effective phenotypic and molecular screening of these, small and large-scale field trials for target trait and agronomic performance, and the development of the required regulatory dossiers.

Specific objective: Effective, commercializable and farmer-friendly transgenic events for high priority traits.

Outputs and outcomes to 2015

Outputs

- Virus and fungal resistant groundnut varieties
- Insect resistant chickpea and pigeonpea varieties
- Nutritionally-enhanced groundnut and pigeonpea varieties.

Outcomes

- NARS/private sector have the ability to provide farmers with non-restrictive, no-added cost transgenic varieties
- Increased public acceptance of transgenic technology for enhancing food security.

Bioinformatics

ICRISAT and its partners have generated extensive information on the genetic resources of its mandated crops. Recent and emerging developments in modern science, especially molecular genomics, have led to the generation of large datasets of genotypic and phenotypic information. In addition, enormous quantities of data already exist in databases and files generated by researchers for their own use. To be of optimal use to all scientists working on these crops and other crops specific to the SAT, all of this data must be collated and made accessible. Therefore, a major focus of the bioinformatics efforts will be to develop an information management system that provides the required entry, query and access interfaces to meet the demands of ICRISAT globally.

Currently, a workflow laboratory information management system (LIMS) is available that manages sample tracking of DNA through the genotyping process. The genotyping data from this system flows into a database (ICRIS) that has user interfaces for retrieving and generating simple reports from the genotypic data. Future efforts will focus on enhancing the existing LIMS and ICRIS systems with additional functionality and user interfaces. By 2010, it is projected that this system will be in place and functioning in ICRISAT's global locations.

Specific objective: Public, web-accessible crop information system for ICRISAT's mandated species.

Outputs and outcomes to 2015

Outputs

An integrated crop information system linking molecular, phenotypic and pedigree data
Supporting systems to provide quality assurance from laboratory operations.

Outcomes

Researchers and other partners worldwide have the ability to access and use information on ICRISAT's crops.

Identification and development of pro-poor traits in crops (Priority 2 A: Specific Goal 2)

Potential impact (generic)

The potential impact of ICRISAT improved germplasm for its five mandate crops in the public domain is exemplified by the very high proportion of newly released, improved cultivars worldwide that contain significant proportions of ICRISAT-bred material. This is mirrored by ICRISAT's major contribution to capacity building in this field worldwide. These two factors make a substantial contribution to the potential achievement of MDG 1.

ICRISAT's predominant capability (generic)

ICRISAT's crop breeding experience in all its mandate crops now exceeds thirty years in most instances and this incorporates experience from all the main crop-growing environments in SSA and South Asia. This, coupled to its expertise in biotechnology, its unique germplasm banks and extensive field facilities for the development and testing of improved parental lines, gives it a clear advantage to undertake development of varieties and hybrids both conventionally and biotech-assisted breeding in SAT environments.

Counterfactual (generic)

Should ICRISAT cease its hybrid and varietal breeding programs in its five mandate crops, the impact on partner breeding programs would be very substantial. Breeding progress in such crops would be much slowed down, less biodiversity would be used and the probability of new, improved material being treated as IPGs would be strongly diminished. The capacity and knowledge base of partner institutions to undertake this type of research would be diminished and the global crop improvement networks contributed to by ICRISAT would not function as well as at present. Thus the likelihood of MDGs 1 and 8 being achieved would be severely threatened.

Sorghum

Sorghum is a staple crop for millions of poor farmers in the SAT regions of Africa and Asia. Sorghum yields have decreased by 14% during the 1980s, before rising slightly in the 1990s. Production has been stagnant in many sorghum-growing countries in Asia, despite adoption of improved cultivars and crop management practices mainly due to a shift of the sorghum crop to marginal lands with poor soils (replaced by soybean and maize). Sorghum is a staple crop in the diet in all the major growing areas (ranging from 20 kg to 120 kg capita⁻¹ yr⁻¹). However, per capita consumption is declining due to a shift in consumer preferences brought about by subsidy for rice and wheat, urbanization, and non-availability of



sorghum products (flour) in the markets. A portion of sorghum grain is used as animal feed, while the green fodder and stover are fed to cattle. Demand for fodder and grain for animal feed is increasing due to increased demand for milk, egg and meat. Sorghum grain is also used in making alcoholic and non-alcoholic beverages. Other uses of sorghum include the manufacture of processed foods (bread, biscuits, etc.) and starch for industry. Sweet sorghum is emerging as a renewable source of ethanol for the biofuel industry.

Asia

As a result of release of 50 varieties (+ around 40 hybrids in India alone) by national programs using ICRISAT-bred germplasm, production has been stabilized using less land area. However, if sorghum has to remain a competitive crop, crop productivity and stability (by incorporating resistance to major pests and diseases) needs to be enhanced:

Enhanced use of new germplasm to widen the genetic base of varieties and hybrids

Improving grain/forage/sweet stalk yield: CMS-based seed parents will be diversified by creating separate gene pools using durra x Guinea, caudatum x bicolor/durra crosses. Among available CMS systems, A₁ and A₂ will be diversified for Guinea, feterita and durra races for grain yield, and dochna types for higher biomass (fodder and sweet stalk).

Incorporating resistance to biotic constraints: While conventional breeding may be effective for managing shoot fly and grain yield, use of MAS will complement and increase efficiency. The transgenic

approach appears to be the best option to tackle stem borer resistance. Grain mold resistance is complex; hence gene pyramiding will be deployed using molecular markers, where possible. Postrainy (*rabi*) sorghum is important as its grain is used mainly for human food. Progress in developing adapted varieties and hybrids has been slow. *Rabi* landraces with resistance to shoot fly and farmer-preferred grain quality traits will be introgressed to develop hybrid parents using A₁ and A₄ CMS systems.

Eastern and Southern Africa

Due to the successful implementation of the Sorghum & Millet Improvement Program (SMIP) and the ECARSAM network, several improved varieties have been released and adopted. A few varieties (such as Macia) have been released in more than one country. ICRISAT aims to develop high-yielding cultivars with quality traits (that meet the needs of farmers, end-user and markets) using both conventional and biotechnology approaches, for both varieties & hybrids:

Improve long-season photoperiod-sensitive sorghums for highlands with appropriate resistance to pests and diseases. Improving low and mid-level sorghum for high yield with resistance to *Striga* and stem borers.

The establishment of Biosciences in East and Central Africa (BECA) will allow molecular marker research and transgenic approaches to be deployed to improve efficiency of crop improvement, especially for traits that are difficult to handle by conventional breeding (such as resistance to *Striga* and stem borers).

Enhance regional variety registration as a key strategy, to be achieved through regional breeding networks involving concerned NARS.

Develop alternative seed delivery models, and test and promote them so that farmers have access to improved cultivars.

Enhance alternative uses of sorghum, through the market-chain approach to improve market access and profits to sorghum-growing farmers, and access to quality sorghum food by consumers.

West and Central Africa

Increasing cropping intensity with extensive sorghum production, decreasing fallow, soil mining, and weeds (including *Striga*) are making sorghum production unstable. In some areas intensification (mechanization, fertilizer use) is occurring. Sorghum grain is increasingly becoming an important source of income in addition to food security. Farmers are keen to have seeds of improved varieties, but quality seed is not available. The weakening agricultural research and extension system is leading to a situation where farmers' organizations are becoming important. Under this scenario, the sorghum crop improvement in WCA targets the improvement of production systems, rather than the commodity *per se*. The SAT of WCA offers a unique opportunity to target technology at agroecological zones that cut across the whole region in narrow bands: for example *Striga* and low phosphorus availability in the drier Sahelian/north Sudanian zones:

Enhanced use of germplasm to develop broad-based populations as source materials for further selection and improvement.

Development of Guinea-race hybrids and promoting seed production and adoption, in collaboration with both public and private sector partners in WCA countries.

Institutionalizing participatory breeding methods, for scaling up and scaling out for sustained and increased impacts.

Enhanced use of molecular marker technology for improving resistance to *Striga*. This will involve training and capacity building of partners to undertake MAS.

Molecular characterization of Guinea-race germplasm to understand genetic diversity to enable formation of new gene pools and heterotic groups.

Understanding photoperiod response and basis of adaptation to improve characterization and targeting of new varieties and breed new varieties.

Outputs

Annually, hybrid parents and varietal material with improved traits to counteract the principal constraints to sorghum growth and productivity in the SAT.

Outcomes

Partner breeders and NGO/CBO agencies in the public and private sector access improved germplasm at their request and improve the efficiency and quality of their breeding and seed multiplication efforts on behalf of farmers in the SAT.

Pearl millet

Pearl millet is a major staple cereal for millions of poor in the SAT of Asia and Africa, grown especially in the marginal environments. It is grown in the harshest environments, where maize and sorghum cannot be cultivated, and hence is important for the food and nutritional security of the poor people living in these critically dry and hotter parts of the SAT. Pearl millet grains have good storage quality, are highly nutritious (10.6% protein) and also contribute about one-third of iron and zinc requirements. Grains are mostly used for food. The crop residue is used as dry fodder for cattle and also as building materials. Area and production in WCA have been increasing slightly, but yield per ha has been stagnant. In ESA also yields have not increased because production is being pushed to marginal areas with poor soils. However, production in India has increased (5.7 to 6.9 M t) despite a reduction in area (from 12.1 to 9.4 M ha) due to increase in yield from 473 to 740 kg ha⁻¹ during 1970–2001. Food use has declined slightly in both Africa and Asia due to availability of subsidized food, and change in food habits of people due to urbanization. A small proportion of the grain is used for poultry feed in Asia and the Americas. With increasing demand for dairy products, the demand for pearl millet fodder will increase substantially, especially in Asia.

Asia

Constraints to pearl millet production vary considerably, although it remains a low input, subsistence crop in most areas. As indicated earlier, substantial progress has been made in India by improving productivity. However, with pearl millet being relegated to marginal areas, efforts will be made to sustain and increase yields by reducing losses due to various constraints. There is a noticeable trend of irrigated pearl millet production during the summer in India, and this will need increased heat tolerance during flowering and seed set. The following research areas will be emphasized:

Increased emphasis on hybrid parents' development to serve both public and private sector partners, using conventional genetic enhancement approaches. Diversification of the CMS system to the more productive A_4 and A_5 will be emphasized.

More targeted breeding for downy mildew (DM) resistance to multiple pathotypes, following both conventional and MAS to stay ahead of the fast mutating DM pathogen. An improved understanding of spatial and temporal patterns of virulence, pathotype-specific resistance and effective greenhouse screening will support this.

Targeting more marginal environments (Western Rajasthan, Gujarat and Haryana in India) that have been bypassed by hybrid technologies. This will require combining genetic potential for high yield and DM resistance along with drought tolerance.

There is an increasing interest and need by NARS for salinity tolerance as some of the traditional growing areas are becoming saline. Preliminary results of collaborative studies with ICBA have shown that pearl millet has a high degree of genetic variability in tolerance to saline soils. Although conventional breeding may be used in the medium term, MAS will be used extensively to enhance breeding efficiency for salinity tolerance.

Considering the increasing demand for fodder, and the value of pearl millet as fodder (high biomass, high water-use efficiency, tolerance to heat and drought, low anti-nutritional factors), the emphasis will be to develop hybrid parents for forage (both single and multi-cut).

West and Central Africa

Past research has produced improved open-pollinated varieties (OPVs), and these will be popularized through appropriate seed systems. Future strategy to increase pearl millet production and marketing in WCA will be based on the IGNRM approach. Participation of all stakeholders in technology development will be essential to achieve sustainable capacity building and long-term impact of R&D. The crop improvement research will focus on:

Identification of heterotic gene pools in locally adapted materials, for both population improvement and hybrid breeding. This approach is expected to result in higher yield and stability.

Development and implementation of a regionally coordinated strategy for both population improvement and hybrid parents, based on heterotic pools in each adaptation zone.

Development of regionally A lines based on A4 CMS systems.

Dynamic gene pool management for in situ conservation of pearl millet genetic resources and development of populations with specific adaptation to major production constraints.

Integration of genomics research and MAS into crop improvement, especially for complex traits such as *Striga* resistance, DM resistance and P uptake.

Enhanced seed systems research, with a better understanding of local and traditional seed systems of seed exchange, and superimposing lessons from other regions.

Eastern and Southern Africa



Pearl millet is a comparatively minor crop in the ESA region (2 M ha), with scattered production in areas with low rainfall and poor soils. Crop improvement efforts will be carried out in close collaboration with NARS partners in countries where this is a major crop:

Population improvement will be emphasized to cater to development of OPVs, and to derive hybrid parents. It is likely that improved OPVs (developed earlier by ICRISAT and partners) will be used in hybrid parent development. Test Asia region bred B lines for adaptation and use in A line development

Top cross hybrids (using adapted local landraces or OPVs as restorers to get hybrid seed on A lines) seem to be a viable option, compared to single cross or three-way hybrids. In addition to good heterosis, the top cross hybrids will have good adaptation and preferred grain quality traits, since an adapted local landrace or OPV is used as male parent. This needs to be conducted in

partnership with the private sector (PS) seed companies that can produce and market these hybrids.

As and when the PS seed industry is developed, more productive single cross hybrids will be promoted.

In view of the importance of fodder for livestock in many pearl millet growing areas, fodder varieties and hybrids will be promoted as appropriate.

MAS will be used to enhance breeding efficiency for resistance to *Striga*, downy mildew and drought, in partnership with NARS and BecA.

Outputs

Annually, hybrid parent and varietal material with improved traits to counteract the principal constraints to pearl millet growth and productivity in the SAT.

Outcomes

Partner breeders and CBO/NGOs in the public and private sector access improved germplasm at their request and improve the efficiency and quality of their breeding and seed multiplication efforts on behalf of farmers in the SAT.

Groundnut

Groundnut is an important food and cash crop for the resource-poor farmers in Asia and Africa. It is primarily grown for edible oil (48-50%) and also for direct consumption as food by people. Groundnut haulms are excellent fodder for cattle, and groundnut cake (after oil extraction) is used as animal feed and also helps to improve soil fertility through nitrogen fixation. Sale of groundnut products contributes significantly to household food security and cash income. Groundnut productivity in WCA and ESA is below the world average yield of 1.4 t ha⁻¹. Although the groundnut productivity in Asia (1.8 t ha⁻¹) is above the world average, it is still lower than the yields in developed countries (3 t ha⁻¹). Area under groundnut in ESA has increased dramatically from 2.3 to 3.3 M ha during 2000 to 2004; in Asia also there is an increasing trend in China and Vietnam, but there was a decline in India during 1991-2004. There is a slight decline in area in WCA. Although the productivity has shown a positive trend globally, this needs to achieve far greater improvement in future.

Asia

The overall projection for area, production and productivity for groundnut in Asia is positive. However, further increase is possible through both genetic and crop management to address production constraints:

- Enhanced utilization of groundnut using core and mini-core collections to broaden genetic diversity

- Breeding for early maturity (to escape terminal drought) with good yield potential and resistance to major diseases will be a priority for different niches, including rice-based cropping systems. Good resistance is available for rust. However, the moderate level of resistance to early and late leaf spot will need enhancing, including by gene transfer from wild *Arachis*. Integrated disease management practices will need to be promoted in conjunction with moderately resistant cultivars.

- Non-availability of quality seed is a major bottleneck for adoption of improved varieties. ICRISAT will explore linking the formal and informal seed sectors and develop alternative models to enhance seed supply.

- Resistance breeding for peanut stripe virus and bacterial wilt disease will be carried out in collaboration with NARS partners in South East Asia (especially China), where disease screening can be carried out.

- The transgenic approaches to overcome aflatoxin contamination will be explored.

Eastern and Southern Africa

Considering that groundnut is emerging as a cash crop for smallholder farmers, efforts will be targeted to enhance productivity in these farming systems:

Developing early maturing cultivars for short-season environments with erratic rainfall will continue. Early-maturing Spanish varieties with fresh seed dormancy are required where the crop may be exposed to rain at maturity. In addition, we will concentrate on medium-duration varieties for areas with good rainfall regimes and favorable growing conditions. Continued efforts are needed for breeding cultivars with resistance to groundnut rosette disease. Good sources of resistance are currently available. Combining resistance to the three factors responsible for resistance to rosette disease (GRAV, GRV, and its satellite RNA) and resistance to the aphid vector will be pursued vigorously.

Resistance to foliar diseases (especially early and late leaf spot, and to rust) is essential in all breeding material (both short- and medium-duration cultivars). Some of the *Arachis* species have high levels of resistance to ELS and these need to be incorporated into cultivated groundnut using wide-hybridization techniques.

Integrated management is essential to reduce aflatoxin contamination

Incorporation of drought tolerance is essential in areas experiencing erratic rainfall.

West and Central Africa

Groundnut is important for food and income generation in WCA, as it generates up to 60% cash earnings and up to 70% rural employment in many countries in the region. However, productivity and incomes have remained low due to various production constraints. Genetic enhancement activities will be geared towards alleviating some of these constraints in the next decade, so that groundnut production becomes more profitable to smallholder farmers:

The emphasis will be on developing breeding lines with high yield potential and multiple resistances (major disease, pests and drought tolerance) to ensure wide adaptability of the cultivars.

Breeding short-duration varieties to escape terminal drought will be a high priority

Managing aflatoxin through an integrated approach to management should enhance market opportunities.

Outputs

Annually, varietal material with improved traits to counteract the principal constraints to groundnut growth and productivity in the SAT.

Outcomes

Partner breeders and NGO/CBO recipients in the public sector access improved germplasm at their request and improve the efficiency and quality of their breeding and seed-multiplication efforts on behalf of farmers in the SAT.

Chickpea

Chickpea is the third most important legume globally, and second in importance in Asia. It is also an important legume crop in ESA (in Ethiopia, Kenya, Malawi, Mozambique and Sudan). About 90% of global area and 88% of production is in Asia. Chickpea has one of the best nutritional compositions of any dry edible legume, and is mainly used for human consumption. The desi type (colored seed coat) is usually de-hulled and split to make *dhal* or flour (besan), while Kabuli type (white or cream colored seed coat) is often cooked as whole grain. The haulms are used for animal feed. Chickpea improves soil fertility through nitrogen fixation (up to 140 kg N ha⁻¹). Chickpea area has slightly decreased globally, but has been stable at 9 M ha in Asia for the past 25 years. However, production in Asia has increased by 39% due to a 32% increase in productivity. Even then, the current average yield in Asia (0.8 t ha⁻¹) is low, and far below the potential yield (5 t ha⁻¹) or research station yields (3.5 t ha⁻¹). The global demand for chickpea in 2010 is estimated at 11.1 M t (from the current 8.6 M t). A combination of productivity enhancement through crop improvement and integrated crop management and expansion of area to new niches and production systems can help achieve this target.

In ESA, chickpea is cultivated after a cereal crop (maize, rice or wheat) and under residual soil moisture. The production in Africa has been increasing significantly as farmers embrace the idea of crop diversification. Presently, it is produced in Ethiopia, Kenya, Malawi, Tanzania and Mozambique. Large commercial enterprises such as Mozambique Leaf Tobacco are interested in including eco-friendly legumes crops such as chickpea in rotation with tobacco. The major constraints in chickpea production in ESA are diseases such as Fusarium wilt and stunt virus. *Helicoverpa* pod borer, nematodes and bruchids are major pests, while drought is the main abiotic stress. The strategy would be to identify specific constraints in prospective agroecological zones in ESA and initially evaluate germplasm from India in these production areas. Most of the constraints are being addressed by the ICRISAT-Patancheru chickpea breeding program. Advanced lines have been received for agronomic performance testing and release. Later, a breeding program will be initiated in the region with backstopping from India.

ICRISAT has the global mandate for chickpea research, while ICARDA has a regional mandate for West Asia and North Africa. Much of the basic crop improvement for both Asia and ESA (and other continents) is conducted at ICRISAT-Patancheru. Advanced generation breeding lines are evaluated by NARS (through a Regional Program in ESA for the countries in the region) for further selection, evaluation and release for farmer cultivation:

Enhanced utilization of chickpea germplasm using core and mini-core collections to enable scientists to screen and use lines to broaden the genetic base.

Development of more efficient and rapid screening techniques to identify stable sources of resistance, especially for Ascochyta blight, Botrytis gray mold, and salinity-, drought- and cold temperature tolerance. Trait-specific germplasm sets will be characterized to identify genes/alleles of interest, especially for resistance.

Development of breeding lines with enhanced productivity and adaptation, in both desi and kabuli types. Emphasis will be on restructuring plant type by incorporating morpho-

physiological traits to make plants more efficient in use of natural resources and inputs. Seed traits preferred by consumers and the market will be given priority. Resistance to Fusarium wilt will be mandatory, along with all possible levels of pod borer resistance. Resistance to Ascochyta blight and Botrytis gray mold will be incorporated for materials designed for cooler and humid areas (medium and long duration).

Introgression of genes from wild *Cicer* spp. for resistance/tolerance to biotic and abiotic stresses, where resistance in cultivated chickpea is low or not available. This will need further refining of embryo rescue techniques to make crosses with incompatible species in secondary and tertiary gene pools. Studies on molecular diversity indicate that chickpea has a narrow genetic base, and will need introgression to widen it.

Use of MAS to improve efficiency and precision of plant breeding, especially for traits difficult to select directly such as root traits, and for pyramiding genes from different sources (Ascochyta blight), or for

bringing together genes conferring different mechanisms of resistance for pod borer.

Exploiting transgenic technology for incorporating genes to drought (DREB gene), resistance to pod borer, tolerance to salinity and cold, and for transferring antifungal genes for resistance to fungal diseases.

Development and promotion of efficient integrated pest and disease management practices to supplement host-plant resistance, especially when levels of available resistance are low.

Promotion of chickpea in cereal-based cropping systems for crop diversification and improving sustainability of the production system. This includes growing chickpea in rice fallows or in a rice-wheat system. Nearly 14.3 M ha rice fallows in South Asia offer good scope for enhancing chickpea production, and similar opportunities exist in some SSA countries. These systems will need short duration varieties, with added resistance to collar rot.

Outputs

Annually, varietal material with improved traits to counteract the principal constraints to chickpea growth and productivity in the SAT.



Outcomes

Partner breeders and NGO/CBO agencies in the public sector access improved germplasm at their request and improve the efficiency and quality of their breeding and seed-multiplication efforts on behalf of farmers in the SAT.

Pigeonpea

Pigeonpea is a versatile and multipurpose crop. It is one of the major food legumes in the tropical and subtropical regions of Africa, Asia and the Caribbean countries. Its green pods and seeds are consumed as a vegetable, and the dry grains are cooked whole or after dehulling (as dhal). The foliage is used as fodder, and the dry sticks are used for fencing, thatching, and as firewood. It fixes atmospheric nitrogen, and the extensive leaf fall adds organic matter to the soil. Dry grain is also used for animal feed. Because of the ability of pigeonpea roots to penetrate hard soils, it is used for soil conservation in rocky mountain slopes. About 90% of the global pigeonpea area (4.4 M ha) is in Asia (about 86% in India). Other major Asian pigeonpea-growing countries are Myanmar, Nepal, Bangladesh, Pakistan and China. In SSA, pigeonpea is grown in Uganda, Kenya, Malawi, Mozambique, Zimbabwe, Zambia, South Africa, Sudan and Ethiopia, but reliable statistics are not available. Pigeonpea production has shown only a marginal increase during the past two decades (2.2-2.9 M t during 1980-98). However, productivity has remained stagnant at 0.7 t ha⁻¹, mostly because it is intercropped with cereals or cotton and receives no or little inputs; or gets relegated to marginal and poor soils, often where no other crop can be grown.

In ESA, pigeonpea is cultivated as an intercrop in cereal-legume systems in which there is little or no competition for soil moisture while the cereal benefits from the fixed nitrogen. Partly because of the increase in the frequency of droughts in ESA, smallholders have preferred this highly drought-tolerant crop in order to secure food supplies in situations where traditional cereal crops fail. Although ICRISAT has developed varieties with resistance to some pathogenic races of wilt disease, the presence of different races in the region has imposed limitations on breeding for resistance.

Pigeonpea is sensitive to photoperiod and temperature, which affect the periods from sowing to flowering and to maturity, which are important for productivity and adaptation. Short-duration (SD) types are relatively insensitive to photoperiod but sensitive to temperature (optimum is 24°C), with low temperatures (<20°C) causing significant delay in flowering and maturity, thus preventing the growing of SD types in cool areas. Both medium-duration and long-duration types are sensitive to photoperiod and temperature. Long-duration lines are sensitive to temperature, with high temperature delaying or inhibiting flowering and thus rendering them susceptible to terminal drought. In cool areas, maturity in long-duration pigeonpea is accelerated and severe competition occurs between intercropped maize whose maturity is delayed and pigeonpeas, resulting in yield reduction of both crops.

The major share of the pigeonpea improvement effort is at ICRISAT-Patancheru, with limited crop improvement work (especially for photoperiod and temperature sensitivity for highlands) being conducted in ESA in Kenya. The Asia program targets hybrid parent breeding (using newly identified CMS lines) with limited varietal improvement research (for all regions globally), while ESA targets varietal development with the possibility of hybrids in the future:

Enhanced utilization of pigeonpea germplasm. Although the genebank holds more than 13,500 accessions, only a very small proportion of the germplasm has been used in pigeonpea improvement. A core collection of germplasm has been established, and we envisage developing a minicore in the next 2-3 years. This will enable scientists to screen and use germplasm to enhance traits of interest besides broadening the genetic base.

Enhanced productivity through hybrid cultivars, using the newly developed CMS system. Among them, the A_4 system is considered to be the best source for commercial exploitation, since it is stable and has good fertility restoration. Experimental hybrids have shown high heterosis (>60% over the better parent). The technology for large-scale hybrid seed production needs to be fine-tuned and shared with partners. This technology will have spillover effect in ESA as and when the seed industry is ready to market hybrids.

Stabilization of pigeonpea production by incorporating resistance to Fusarium wilt and sterility mosaic disease is mandatory. Additional sources of resistance are needed for pod borer and pod fly.

Since existing levels of resistance to pod borer in cultivated pigeonpea are low, efforts will be made to pyramid different mechanisms of resistance using MAS. High level of resistance is available in wild species, and efforts are underway to introgress resistance genes in to cultivated pigeonpea. Transgenic protocols are now available, and some transgenic plants are already under field testing. This approach will be exploited to the fullest.

Development of short and extra-short duration pigeonpea varieties to enhance pigeonpea cultivation in newer niches and cropping systems. An example is the pigeonpea-wheat rotation in the rice-wheat cropping system in the Indo-Gangetic plains of India. Other niches include pigeonpea for soil conservation (especially in degraded mountain slopes) as being popularized in southern China.

Development of pigeonpea as an alternative fodder crop, especially in dry areas where other green fodder for animal production and dairying is important.

Enhanced seed system to ensure that quality seed of improved pigeonpea varieties (including hybrids) are available. We will enhance linkages among NARS, NGOs, the private sector and farmers organizations to promote appropriate seed production and distribution systems.

Outputs

Annually, hybrid and varietal material with improved traits to counteract the principal constraints to pigeonpea growth and productivity in the SAT made available to NARS and private sector breeders and seed bulking agencies.

Outcomes

Partner breeders and NGO/CBO agencies in the public and private sector access improved germplasm at their request and improve the efficiency and quality of their breeding and seed-multiplication efforts on behalf of farmers in the SAT.

Networking and capacity building

Resources for crop breeding are declining both at the national and international institution levels, particularly in SSA. Preliminary ICRISAT achievements towards pursuance of efficiency in crop breeding include broad delineation of agroecological zones, and stratification of sites to identify and use only a few key representative testing sites. The strategy of engaging NARS scientists to assume leadership in agreed regional activities is pursued as the lead NARS approach and also through networking of NARS and led by one NARS. This approach is expected to bring efficiency in crop improvement strategies.

Output

Sustainable regional breeding networks for cereals (sorghum and millets) and legumes (groundnuts, pigeonpea and chickpeas) established and capacity for NARS and partners enhanced.

Outcome

Countries with weak NARS breeding programs in ICRISAT mandate crops benefit from shared knowledge regionally precipitated by ICRISAT's IPG mode of collaborative action.

Improved forage and fodder cultivars.

Although crop residues are an important source of feed their nutritive value is low. 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 smallholders. Fodder (stover, haulms) from ICRISAT mandate crops is an important source of livestock feed in the SAT. 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. For example, 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 oilseeds that have higher fodder yields and superior fodder quality and reduced aflatoxin content. 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 and

sorghum haulm/stover quality has contributed to higher productivity of animal products.

Outputs and outcomes to 2015

Outputs

High-yielding forage hybrid parents and varieties, and hybrid parents and varieties with improved stover quality in elite, diverse genetic backgrounds resistant/tolerant to major biotic stresses made available for use by partners and associated capacity building measures completed.

Outcomes

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.



Counterfactual

Reduced options for small, resource-poor farmers to increase production and nutritional quality of animal feed reducing opportunities for diversification of household income sources.

ICRISAT's predominant capability

ICRISAT's joint programs with ILRI focusing on improvement of fodder resources in Asia and SSA, with its unique access to crop genetic resources, excellent scientific facilities, linkages to private and public sector national programs, and focus on IPGs, cannot be easily substituted within the national programs in the SAT.

Tolerance to abiotic stresses (Priority 2B)

Abiotic stresses severely limit agricultural production. In groundnut, drought is believed to be responsible for losses worth about \$500 million in India alone. There is a clear consensus that drought, salinity and low phosphorus availability are among the most severe stresses in Asia, ESA and WCA. They are also the stresses that ICRISAT crops face repeatedly. The needs/challenges in the area of abiotic stress research are 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 MAS
- Use the MAS products to progress in understanding of tolerance mechanisms.

The contribution of germplasm resources in abiotic stress tolerance might be perceived as possible through association studies. So the needs/challenges from the genetic resources are to:

- 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.

Drought

Water capture by roots and water use efficiency are probably two of the components of yield architecture that are important for crops growing under terminal drought conditions, which is the case for most SAT crops. Drought avoidance (ie, getting more water or using it more efficiently) is likely to be the major trait of interest to expand production to presently uncropped areas and postrainy fallows in Asia.

For root traits, we need progress in understanding in those crops where roots have already proved to be beneficial for yield under terminal drought (chickpea), and then explore those crops where little information on roots is available (the other mandate crops). Specifically, there is a need to understand the dynamics of roots, how they contribute to the overall water budget, and in particular how they contribute at the time of grain filling. Recent studies by 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 HI (thereby a link between roots, ie, 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 conventional breeding approach that should increase the chances of reaching our goals. The comparative advantage of ICRISAT in this area is the availability of trained manpower 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 and affects 5-7% of arable lands, ie, approximately 77 M ha worldwide. Most crops are sensitive to salt stress at all stages of development, including seed germination, vegetative growth and reproductive growth. Legumes, in general, are sensitive to salinity, and within food legumes, chickpea, faba bean and pea are more sensitive than others. The problem of salinity is increasing, particularly in areas where irrigation is a common practice. Management options exist to alleviate salt effects; however, these are often in contradiction with the immediate economic choices of the concerned farmers, and so crop improvement for salt tolerance appears to be the only alternative.

The problem of salinity is essentially twofold. In one case, soil is saturated with sodium (Na) and soil pH remains within an optimal range for crop growth. This type of salinity is referred to as coastal or dryland salinity. These soils get saturated with sodium because an existing saline ground water table is rising (due to proximity to the sea or salt that have accumulated down in the soil profile), bringing the salt to the surface. In the second case, soil is both saturated with Na (exchangeable sodium percentage, ESP, > 6) and pH has reached levels above 8.5-9.0. This type of salinity is also called transient salinity, and is hereafter 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 micronutrients (low availability/solubility of micronutrient salts at these pH levels), the soil structure and porosity (poor drainage, tendency for waterlogging, and little oxygenation, because of saturation of the exchange complexes in the soil by sodium). Most studies so far have focused on salinity, and only a few on sodicity.

Despite the importance of salinity on 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 in 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 to fill the gap between the knowledge acquired on plant responses to salinity and the paucity of efforts made to breed salt tolerant crops and to 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

Outputs

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.

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

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

Heat tolerance in pearl millet (especially to high air temperatures of 46°C) during flowering and seed set important for summer pearl millet production.

Outcomes

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

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.

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

The potential for improved productivity and food security in dry, marginal areas is increased. Varieties with improved salinity tolerance “colonize” areas previously unsuited to agriculture. Broader range of target environment is reached by improved products because of a larger portfolio of “adaptability” in improved products.

ICRISAT's predominant capability

ICRISAT, which has a team of full time crop physiologists enmeshed in a greater supporting group of biotechnologists and breeders, is in a strong position to undertake the difficult task of providing abiotic stress tolerance. Coupled with the availability of the unique ICRISAT germplasm collection, knowledge of the structure of the collections, controlled environments and access to rain out shelters and root study facilities gives ICRISAT the ability to tackle these tasks in a professional manner. There will be few other institutions in the SAT with the capacity to compete in this respect. The private seed sector is not very keen on developing these products for economic reasons. Collaborating NARS have solicited ICRISAT to take the lead in developing these types of 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.

Major legume staple and cash crops remain inaccessible to molecular breeding, leading to reduced and slower prospects of improving crops for abiotic stress. As a consequence, the interest of public-private partnership to develop improved varieties decreases.

Major crop losses due to abiotic stress continue into the future.

Enhancing nutritional quality and safety (Priority 2C)



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 dubious quality and safety of foods that are often contaminated by microbial toxins due to improper pre- and postharvest conditions in the SAT.

In view of the acute malnutrition present in the SAT and to help developing countries attain food security and reduce poverty and malnutrition, it is important that ICRISAT focuses its research on 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. This has been an area somewhat neglected globally in the past and ICRISAT seeks to become one of the World Leading Institutions in this area that is so critical for the well-being of the poor.

Increasing the content of micronutrients in the edible parts of plants through improved biotechnologies and breeding (Priority 2C: Specific goal 1)

Micronutrient malnutrition, often called “hidden hunger”, is primarily the result of diets poor in bio-available vitamins and minerals, and results in clinical deficiency and associated diseases such as respiratory and

immunodeficiency diseases, impaired cognitive development of children, and childhood diseases such as measles besides blindness and anemia (and even death). Levels of anemia among inhabitants of the savannah zones of West Africa are alarming, the most badly affected being children (88%) and women of reproductive age (63%). Iron deficiency is one of the most important causes of childhood anemia and zinc deficiency ranks fifth among the leading 10 risk factors in developing countries. Iron and zinc deficiency with children inhibits optimal cognitive and motor-skill development, and chances for later recovery are limited. Childhood mortality is high, since their weakened immune systems are unable to fight off malaria and diarrhea.

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 SSA. 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 healthcare systems. Past programs to combat micronutrient malnutrition have relied primarily upon food fortification and to some extent on supply of vitamins and mineral pills as a 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, Zn and beta-carotene contents through a 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 to 2015

Outputs

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 and methodologies, bioavailability, toxicity, stability, processing techniques, consumption patterns and public acceptance of biofortified foods published and used for capacity development at NARES and NGO request.

High-yielding and micronutrient dense hybrids/improved population/varieties 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

Enhanced awareness, both in the public and private sectors nationally, and crop improvement programs use improved material to focus on breeding of micronutrient dense hybrids/ population/varieties from eco-regionally adapted cultivars.

Enhanced awareness among rural women and food processors about processing techniques used to keep micronutrients of the grain intact in food.

Increased numbers of micronutrient 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 for commercial cultivation.

Potential impacts

Biofortified hybrids/ varieties released for consumption by rural poor and urban consumers. Increased awareness of 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 SAT. 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 bioavailability and metabolic efficiency.

ICRISAT's predominant capability

The NARS currently do not have the capability or capacity to undertake work on crop biofortification, especially through transgenic approaches. ICRISAT has a comparative advantage as over the years it has built in-house capacity in terms of human resources and infrastructure to undertake such product development and training, such as well-established analytical laboratories for Fe and Zn analysis, well-equipped tissue culture and genetic transformation laboratories with optimized protocols for transgenic research.

Counterfactual

Micronutrient enhancement in food grains is not a recognized priority in the national programs of Asia and SSA. 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 cheap and sustainable micronutrient sources.

Reducing the content of constitutive or microbial toxins in selected staples that affect quality, food safety and human health (Priority 2C: Specific goal 3)

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 immunosuppressive 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 very high percentages of the population 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 have been 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. Studies on interactions between vitamins and aflatoxin have reported that levels of several vitamins, including vitamin A, decrease with increased level of aflatoxin in the livers of animals.

Aspergillus flavus, which produces aflatoxin, in groundnut is widely distributed in nature. Climatic factors, crop management and the genetic vulnerability of the plant all play a role in the susceptibility of crops to *Aspergillus*. Solutions to aflatoxin contamination are best provided through an integrated approach using aflatoxin-tolerant cultivars, and implementing appropriate pre- and postharvest technologies that reduce the risk of aflatoxin contamination in food/feed. In spite of these efforts, aflatoxin contamination remains a problem in the SAT and a holistic approach is needed to translate technological breakthroughs into safer production and consumption patterns of, for example, groundnut. Dissemination of information is critical, since the great majority of farmers are unaware of the problems of aflatoxin contamination. Once awareness is increased, preventive measures can be more easily adapted.

To deal with mycotoxin contamination, ICRISAT emphasizes an IGNRM strategy by developing mycotoxin-tolerant cultivars of mandate crops, particularly groundnut, and appropriate pre- and postharvest technologies that reduce the risk of food/feed contamination. These involve genetic enhancement through both conventional plant breeding and biotechnology applications; better pre- and postharvest crop management technologies including agronomic practices, biological control and postharvest techniques, and development of simple and low-cost mycotoxin diagnostic tools.

There is also a need to profile the extent and intensity of mycotoxin contamination and related socioeconomic and health affects in different agroecosystems of SAT Asia, on different staple and high-value crops, including ICRISAT mandate crops. To motivate 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 expected that these activities will further enhance our efforts to improve the nutritional status and health of the poor in SAT by providing them with both a better quality and a better quantity of food.

Outputs and outcomes to 2015



Output 1

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 the SAT.

Outcome 1

Mycotoxins better regulated in foods and feeds through continued and routine use of diagnostic tools by NARS and the private sector 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 foodborne 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.

ICRISAT's predominant capability

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 awareness and develop aflatoxin reducing technologies
ICRISAT has over the years 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 reduced; 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 and therefore marketing will remain difficult without cost-effective diagnostic tools.

Output 2

Food and feed quality enhanced through *A. flavus* resistant/reduced aflatoxin 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.

Outcome 2

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.

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 foodborne illnesses in humans and animals and enhanced market opportunities for produces from developing countries

Awareness of 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 5-10% income gains

Policy support to provide incentive mechanism in the market to encourage the production of aflatoxin-free produce.

ICRISAT's predominant capability

NARES outreach is limited to specific regions within the country, while 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 that 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.





Chapter 4

Reducing rural poverty through agricultural diversification and emerging opportunities for high-value commodities and products
(System Priority 3)

**Increasing income from fruit and vegetables
(Priority 3A)**

Enhancing production of selected fruit and vegetables through improvement of farming systems in WCA (Specific goal 2)

Food security and reduction of poverty at the farm level can be achieved through increased efficiency of the farming system, diversification into higher-income-generating crops, opening new markets and adding value to farm products. Traditional food plants such as fruit

trees, pulses and leafy vegetables are showing promising economic potential and therefore need technical and scientific support, through domestication, to improve their production and adoption in SAT farming systems. This research area will rely heavily on ICRISAT facilitating the spillover of knowledge from Asia to Africa and from Africa to Asia and will take advantage of this process of transfer of technology to improve the profitability and sustainability of small-scale agricultural enterprises.

Development of more efficient farming systems

- *The African Market Garden (AMG)* is a low-pressure drip irrigation system particularly suitable for small farmers. It has all the advantages of the conventional drip irrigation systems at a fraction of their normal cost. The AMG can increase farm profits per unit area over traditional dryland farming systems by a factor of seven. Over the last three years, ICRISAT has disseminated 1,500 AMG units in eight countries of WCA and the effort is continuing through an ongoing project in Burkina Faso and Ghana.



- *The Sahelian Eco-Farm (SEF)* is an integrated dryland tree-crop-livestock system designed to provide solutions to major constraints of current millet based production systems. Three versions of the SEF are currently under investigation. The system is still under development in partnership with the NARES of Burkina Faso (INERA) and Ghana and with pilot farmers in Niger. Results of four years of research at Sadore, Niger demonstrated that this system could increase farm profits per unit area by a factor of five as compared to the traditional system. ICRISAT is proposing to study mechanisms to allow a large-scale dissemination of the system.

Crop diversification

Crop diversification activity involves improvement of traditional crops and native plants and the identification of new income-generating crops:

- Domestication of *Acacia senegal*, the tree that produces Gum Arabic
- Promotion of traditional vegetables
- Selection of dual-purpose cowpea varieties

Promoting Roselle (*Hibiscus* sp.) as a cash crop for export
Production of watermelons on stored soil moisture
Pomme du Sahel: The introduction to the Sahel of the domesticated *Ziziphus mauritiana*
Introduction of dates for the Sahel
Introduction of new species and quality varieties of fruit trees
Introduction of heat-tolerant quality vegetable varieties.

Outputs and outcomes to 2015

Outputs

AMG technology and high quality vegetable seeds made available to NARES and private sector partners
Crop diversification strategies in combination with improved land use technologies (e.g. Sahelian Eco-farm) promoted, published and disseminated to partners with associated capacity building measures
Traditional vegetables and tree crop germplasm for integration in the agricultural production systems made available to partners
Vegetable production and plants propagation technique capacity building made available to partner organizations.

Outcomes

Strengthened partners diffuse AMG technology and improved vegetable seeds and they are adopted by farmer enterprises with access to water
Strengthened partners adopt and promulgate SEF dryland technologies, improving the resilience of agricultural systems and increasing farmer income through value-added vegetable, fruit and tree crops.

Potential impact

Farmers' annual income, system resilience and food production increased through adoption of new technologies and crop diversification systems. Improved nutrition of rural and urban populations through greater consumption of fruit and vegetables. Traders and exporters benefit from greater competitiveness in local, regional and international markets.

ICRISAT's predominant capability

ICRISAT is well placed to organize information and legal germplasm exchanges between partners from different countries.
Highly trained interdisciplinary research teams at Bamako and Niamey are in an excellent position to implement regionally coordinated projects in partnership with NARS.
Optimal conditions for seed storage and plants propagation are available (e.g. regional nursery and regional gene bank) at ICRISAT-Sadore
Developing partnership with the World Vegetable Center is in place and functioning.

Counterfactual

The dryland farming systems of the Sahel will continue to have a tendency towards monocropping of pearl millet, which is unlikely to be sufficiently profitable on smallholdings to enable farmers to grow themselves out of poverty. Malnutrition among vulnerable groups will probably continue to be an unresolved issue.

Enhancing production of selected fruit, vegetables and plant products through improvement of farming systems in Asia (Priority 3A: Specific goal 2)

Diversification: Agriculture and energy

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 IGNRM approach, ICRISAT is able to demonstrate the enhancement of livelihoods on a sustainable basis in rainfed areas particularly through the introduction of high-value fruit and vegetables and value-added plant products and with options for supplemental irrigation. ICRISAT is now also keen to stress its growing expertise in the area of agriculture and energy, particularly in the provision of substitutes or dilutants for oil and petroleum. This is likely to be an area of potential expansion in the future.

Earlier studies show that livestock are important 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.

Development of sustainable and efficient farming systems

Sweet sorghum for ethanol production

In partnership with NARS, ICRISAT has identified high-yielding sweet sorghum lines and developed varieties and hybrids that 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 able to meet market demand. The water requirement (4000 m³ for sorghum against 36000 m³ 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 the former can be grown in the drylands with low-volume irrigation facilities. Farmers can get higher

income from sweet sorghum cultivation—both from the sale of stalks to distilleries and the sale of the grain for food or feed use. Besides developing sweet sorghum hybrid parents and varieties suitable for ethanol production, ICRISAT facilitates the incubation of ethanol production technology from sweet sorghum in the private sector. 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 agroecosystems in collaboration with national programs. Further, strategic research on the relative performances of hybrids vis-à-vis varieties for maturity duration, response to photoperiod variation, adaptability and biomass-producing ability in various agroecosystems will receive priority at ICRISAT.

Improved livelihoods through biodiesel plantations

Common property resources (CPR) in the villages are degraded and in urgent need of rehabilitation. These CPRs are not fulfilling their original purpose of providing fodder and fuel for villagers, particularly for the landless. With the rise in the prices of fossil fuel and also the increasing concentration of global atmospheric CO₂, there is an urgent need to develop alternative energy sources. In Asian countries, an alternative source of biodiesel is non-edible oils. *Pongamia*, a N₂-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 candidates for biodiesel production. Our watershed consortia have initiated work to rehabilitate the degraded CPRs and low-quality private lands by 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 as a by-product after extracting oil as an organic source of plant nutrition provides a good income to the rural poor as well as minimizing land degradation.

Diversification through vegetables and fruit

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*, *Cassia angustifolia*, and *Withania somnifera*. 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

crop 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.

Outputs and outcomes to 2015

Outputs



Annually, sweet sorghum hybrid parents and varieties available to partners.

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.

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

Outcomes

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 R&D programs. 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.

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.

Potential proof of concept for use of environment-friendly alternative sources of energy using biodiesel and ethanol from sweet sorghum in the target countries (India, Thailand, and Philippines).

Value addition and better quality (healthy) products from agriculture enhance marketability and incomes for the farmers.

Stronger public-private partnerships and seamless integration of R&D initiatives promote development in the region.

High-quality hygienic products benefit human and animal health and green fuel options protect environmental quality.

ICRISAT's predominant capability

ICRISAT has unique expertise in its ability to breed and produce ultra-sweet sorghum hybrids and can use our existing parental material to do this. ICRISAT's pro-poor stance is also highly apposite for its work on biodiesel as this often can only be grown on the most marginal land on which many poor are dependent for their livelihoods. Also, ICRISAT has a comparative advantage of working at watershed/catchment scale through its consortium approach. Its international nature along with its multidisciplinary team of scientists enables it to act as a facilitator and honest broker trusted by partners to advocate strongly the introduction of necessary policy and institutional changes in 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.

Overdependence on fossil fuel with increasing prices will push developing countries on a downward spiral of development and also increase environmental pollution through release of greenhouse gases.





Chapter 5

Poverty alleviation and sustainable management of water, land and forest resources
(System Priority 4)

**Integrated land, water, forest and livestock management at landscape level
(Priority 4A)**

To develop analytical methods and tools for the management of multiple use landscapes with a focus on sustainable productivity enhancement (Specific goal 1)

Background

Landscapes/watersheds are to communities what farms are to individuals — they provide a familiar, recognizable physical setting for the

execution of daily activities and mold significant portions of human life spans. Yet the distribution of resources and diversity of interests that impinge on livelihoods are far more complex at the landscape level than at the farm level. Landscapes harbor a range of competing, often conflicting, processes that affect ecological sustainability, livelihood security, resource productivity and social well-being, particularly in the trade-offs between the production of crops and livestock. Most of the world's resource-poor and marginalized people in the SAT derive their livelihoods from land, water, forest and livestock resources.

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, and need to be replenished and

more efficiently used. 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.

Strategic thrusts

Development of predictive, spatially distributed models for tradeoff analysis and decision support

A realistic assessment of solutions available to farmer communities requires the abandonment of compartmentalized, disciplinary investigations in favor of holistic approaches that embrace the largest breadth of challenges faced by these communities. Such a shift calls for a new modeling paradigm driven by careful simplification and interfacing of existing thematic (plant physiology, soil physics, social/behavioral, econometric, etc.) modules inside spatially explicit frameworks. ICRISAT works with leading partners on agricultural landscape modeling, including pioneer studies on the use of ensemble data assimilation for a more realistic understanding of the probabilistic nature of risk and decision-making at multiple time scales.

Elaboration of monitoring and evaluation protocols for ecosystem services

There is a potential for the development of environmental services by farmer communities, as evidenced by the growing regional interest of international NGOs targeting emerging global funding mechanisms. One



such example is carbon sequestration in biomass and soils through improved agroforestry and land management (notably: water harvesting) practices. New very high-resolution sensors can monitor tree biomass accretion (e.g. *Acacia senegal*), the distribution of crops and soil/water conservation practices (e.g. contour ridge tillage for enhanced crop growth), and therefore have potential for verifying farmer compliance in future contracts.

Popularization of baseline land use/land cover (LU/LC) change studies

Direct application of simple, validated classification methodologies can document LU/LC trajectories and assess the magnitude of these critical drivers of systems productivity and sustainability, such as the encroachment process of cropland onto natural vegetation and marginal lands. Capacity in the use of satellite data needs to be strengthened in NARS, and there is a need to raise awareness among a wider range of scientific disciplines.

Exploration of landscape genetics approaches

At the interface of molecular population genetics and landscape ecology, this emerging field aims to study the interactions between landscape features and micro-evolutionary processes, such as gene flow, genetic drift and selection. It provides a unique opportunity to exploit ICRISAT's longstanding expertise on genetic resources to investigate, for example, the environmental benefits and risks associated with the introduction of genetically modified (GM) crops in selected agroecologies against their benefits for poor farmers food and livelihood security.

Outputs and outcomes to 2015

Outputs

At least one leading mechanistic model adapted for spatial simulation of African sorghum/ millet phenology and biomass partitioning and made available to partners, along with updated genotype databases and simplified framework for up-scaling varietal performance to larger recommendation domains.

One predictive toolset based on assimilation of in situ measurements and satellite observations with models made available to partners for evaluating options for soil C sequestration at both farm and cropping system scales, including the role of livestock on C and nutrient balances.

At least one stochastic assimilation method extended to incorporate expected advances in seasonal regional climate forecasting and made available to partners; subsequent augmentation of farmer decision portfolios assessed.

Other 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 landscape/watershed scale in the SAT.

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 landscape/watershed management for increasing productivity and incomes of rural poor and enhancement of environmental quality in the SAT.
Capacity building measures associated with the foregoing points.

Outcomes

Advanced encapsulation of specialist knowledge into spatially distributed agricultural models well underway at the landscape and aggregate levels and models being employed by partners.

NARES research approaches show a paradigmatic shift from deterministic to stochastic research

Enabling policies and budgetary allocation in place and used nationally and locally for the promotion of Integrated Watershed/Landscape Management in selected regions in the SAT. New tools, approaches and technology options for sustainable development and improved livelihoods incorporated into the policy and implementation guidelines used by NARES partners in the SAT.

Potential impact

NARS researchers are capable of addressing complex landscape level issues and have access to new tools to undertake this task

In rainfed areas increased resilience to climate variability through Integrated Watershed Management. Agricultural productivity and incomes will be increased substantially in target countries. 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.

ICRISAT's predominant capability

ICRISAT's strategic position at the nexus of IGNRM research including diversified and active collaborations with leading modeling networks and teams (e.g. ICASA, IIASA, APSRU, CIRAD/INRA)

ICRISAT's longstanding experience of grassroots constraints allows for a bottom-up appraisal of advanced geospatial modeling technologies as powerful tools in service of the resolution of concrete farmer problems, and not objects of research in themselves

ICRISAT, being an apolitical, multidisciplinary dedicated institution, has the ability to act as a preferred facilitator and honest broker. ICRISAT has already gained a competitive edge in R&D initiatives through establishment of benchmark sites in different countries and already has forged strong partnerships.

Counterfactual

Slower progress towards the integration of specialty knowledge (notably: genotype x environment interactions) into spatially explicit models

Deepening closure problem in research undertakings between advanced and developing countries

If ICRISAT ceases its watershed/landscape level work today, there will be a reduced opportunity to consolidate the lessons learned from the consortium approach in India and its spillover to Asian countries and the eventual promotion of watershed approaches in Africa, resulting in continued decline in natural resources, decreased production and increased water scarcity.

It is envisaged that without ICRISAT's watershed team's active championing of consortium approaches for enhancing agricultural productivity and livelihood options, watershed work will revert back to the isolated and compartmentalized approaches of the 1980s and 1990s by individual institutions, states and countries, which will make then only a small contribution to meeting the MDG of halving the number of poor and hungry people by 2015.

Improving water productivity (Priority 4C)

Improved management practices that enhance the productivity of water (Specific goal 1)

Increasing water productivity in rainfed environments to enhance livelihood aspirations of rural poor Smallholder agriculture in the SAT is largely rainfed, and thus risky, with recurrent droughts and dry spells. Potential evapotranspiration exceeds rainfall for more than six months of the year. Rainfall is seasonal and highly variable both within space and time. Annual rainfall for a single site can vary by up to 1000 mm from year to year — although a drought year may easily record less than 250 mm, such as the 2004-2005 season in southern Zimbabwe and Mozambique. By the end of the dry season, ie, just before planting, the top 0.3 m of the soil horizon frequently holds negligible water content. Furthermore, a number of climate change models predict that areas in the SAT shall experience significantly reduced precipitation and runoff over the next fifty years — with food shortages as a result.

Increasing access to irrigation will help, but is not the only solution and cannot reach a majority of farmers. Therefore, food production and rural livelihoods will continue to rely on rainfed agriculture. To achieve this, water productivity and crop yields have to be improved in rainfed farming systems. It has been determined that short dry spells are often the major cause of low yields. There is a general consensus that technologies to improve crop and water productivity under rainfed farming systems in the SAT are relatively well known (improved crop varieties, timely planting, fertilization, weed management, conservation agriculture, rainwater harvesting, supplemental irrigation). Although much is known on the technical side, the real developmental challenge is to integrate these technologies into the smallholder farming systems through an adaptive research and extension process.

Outputs and outcomes to 2015

Outputs

Increased availability and utilization of knowledge, information, and technologies for enhancing the productivity and conservation of soil and water resources for agriculture in ECA are published and promulgated by SWMnet.

Strategies for improved water productivity in the SAT are published by ICRISAT and its Water and Food Challenge Program (CP) partners.

Outcomes

SWMnet partners use new knowledge and demonstrate improved efficiency in their research aimed at improving water productivity and capacity in this research area throughout the SAT.

Partners in Water and Food CP projects adopt improved practices for enhancing water productivity and actively scale these out to wider stakeholders in the SAT.

Potential impact

Pressure on the supply of water for irrigated land is reduced as dryland agriculture achieves more of its potential to be a major food/feed producer in the SAT. Capacity of SAT NARS to undertake successful research in this area is enhanced.

ICRISAT's predominant capability

Strong networks presently exist with SWMnet and the Water and Food CP projects. ICRISAT plays an integral part within these. In addition, ICRISAT along with IWMI is

facilitating the process of developing collaborative links between East and Central Africa and the Indian Council of Agricultural Research (ICAR) to share and benefit from each other's experiences in the area of soil and water management. We also have active NARS and developing partnerships with a range of NGOs committed to the long-term recovery and rehabilitation of the SAT ecosystems. ICRISAT is a useful apolitical, multidisciplinary institution with the ability to act as facilitator, honest broker and fearless inquisitor of accepted norms.



Counterfactual

If ICRISAT and its partners do not undertake this work, the capacity of countries to cope with the severe water productivity problems that are confronting the SAT will be reduced, particularly in SSA, which will undermine our potential contributions to improving the livelihoods of farmers at a watershed level.

Sustainable agroecological intensification in low and high potential environments (Priority 4D)

Improve understanding of degradation thresholds and irreversibility and the conditions necessary for success in low productivity areas (Specific goal 1)

Identify domains of potential adoption and improvement of technologies for improving soil productivity, preventing degradation and for rehabilitating degraded lands (Specific goal 3)

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

Design methods to manage and enhance biodiversity to increase income, reduce risk and vulnerability through integrated pest management (IPM), crop diversification (and rotations), and genetic diversity within crop species (Specific goal 6).

Introduction

The SAT has agroecological 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 socioeconomic 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 then affect evaporation and evapotranspiration. Apart from water shortages, SAT soils 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.

A large proportion of the SAT population resides in rainfed areas. This is unlikely to change as the cost of developing additional irrigated land ranges from US\$2 000 to \$10 000 per ha. Growing environmental concerns, and long-standing social and equity issues demand that urgent and substantial investment in R&D 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.

Soil degradation in the SAT takes place due to water and wind erosion, which not only removes soil but also the best pool of organic matter and nutrients, and limits the capacity of the soil 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 in both dry and irrigated areas. Inherent poor soil fertility and drought constitute major constraints to agricultural production in the SAT.

The fertilizer micro-dosing technology, which consists of the application of small quantities of fertilizers close to plants, is an innovation that is applicable in both low and high potential areas where farmers have difficulty in affording sufficient inorganic fertilizer. This strategic application enhances fertilizer use efficiency and improves productivity, thereby enabling intensification of agriculture and increases in productivity from initially very low levels. Efforts will be made to work closely with farmers' organizations, NGOs and the private sector to scale out and scale up this technology using farmer field schools, on-farm demonstration trials and modern tools such as GIS.

Improvement of traditional crop-livestock systems is also an important research target, because livestock are efficient miners of precious nutrients from fallow lands. It is very important to elucidate the role of organic matter in the sustainability of soils for the development of sustainable technologies for soil fertility and crop production.

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

the environmental impacts of livestock on rangeland. 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 not inherently confined to low potential environments; there is increasing evidence of progressive degradation of intensified systems in high potential areas as well. 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 agroecological 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. This research area will rely heavily on ICRISAT facilitating the spillover of knowledge from Asia to Africa and from Africa to Asia and will take advantage of this process of the transfer of technology to improve the profitability and sustainability of small-scale agricultural enterprises.

Outputs and outcomes to 2015

Outputs

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 the poor in low and high potential environments.

Fertilizer micro-dosing technology widely disseminated for increased crop productivity

Crop rotations involving legumes for system diversification tested and reported

The role and function of organic matter in sandy soils elucidated and technical options for more efficient and sustainable application of organic matter on sandy soils developed and promoted

Community-based models developed and promoted to partners for rehabilitating degraded common lands for selected regions in the SAT.

Capacity of stakeholders (farmers, women, CBOs, NGOs, NARS scientists) strengthened and engendered in multiple watersheds in many countries for implementing improved IGCRM practices for intensifying and diversifying systems.

Capacity of partners to use new tools (simulation models and GIS) to construct realistic scenarios for simulation and formulation of new research initiatives enhanced.

Outcomes

Partners promote better practice in using macro and micro nutrients, fertilizer micro-dosing, genetic resources (particularly in legumes), and IPM strategies in sustaining productivity in dryland and irrigated areas
Scaling up methods used by NARES partners, NGOs and development agencies to widely disseminate improved soil fertility management technologies

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

NARES partners undertake the effective implementation and scaling-up of watershed technologies in the SAT

NARES partners' capabilities to formulate and implement research-for-impact through collaborative activities and training shows positive enhancement.



New tools, approaches and technology options for sustainable development and improved livelihoods incorporated into the policy and implementation guidelines of NARES partners to strengthen their R&D programs for smallholder farming systems in drought prone areas.
The drivers of land degradation understood by government extension services, private sector, NGOs and CBOs and more sustainable policies developed that acknowledge the tradeoffs within livestock and mixed crop-livestock systems.

Potential impact

Crop intensification and yields increased and incomes of rural households increased

Land degradation reduced and more fodder available for animals

Risks and vulnerability to adverse conditions reduced

Greater and better targeted investment in rainfed agriculture by a range of stakeholders (district policy makers, private sector, micro-finance institutions, extension services, meteorological departments, development NGOs).

ICRISAT's predominant capability

ICRISAT plays a leading role in developing small-scale agriculture in the SAT. Extremely important work has already been done linking the logics

of participatory research with simulation modeling to construct and evaluate realistic crop management interventions for vulnerable households. Highly trained and experienced inter- and multidisciplinary research teams from ICRISAT and collaborating institutes based at ICRISAT such as JIRCAS, ILRI and ICRAF, supplemented by postgraduate students and postdoctoral fellows all involved in IGNRM research operating in ICRISAT's high quality research and laboratory facilities and dedicated to the production of regionally functional IPGs give the institution predominant capability over its potential regional substitutes. ICRISAT also has the advantage of being an apolitical, multidisciplinary institution, with the necessary ability and technical capacity to act as key facilitator and honest broker in a volatile politico-developmental situation such as watershed/ farm/field/range development that ranges from field to landscape scales.

Counterfactual

If ICRISAT ceases its watershed and NRM work today, opportunities for the formation and maintenance of effective R&D consortia may be lost. NARES may continue their historic tendency towards location specific, disciplinary oriented NRM studies that makes scaling up to wider agroecological zones in the SAT very difficult.

Protecting the livelihoods of rural livestock keepers in low potential areas (Priority 4 D: Specific goal 2)

Alternative feed and fodder resources

The use of, and demand for, crop residues has increased dramatically in recent years. Unchecked population growth is forcing an expansion of crop area, at the expense of rangelands, while livestock numbers are simultaneously increasing. Chronic dry season feed shortages and increasingly frequent die-offs during dry years indicate a worsening shortage of feed and fodder. There is clearly an urgent need for additional, alternative feed and fodder resources. Past interventions to improve rangeland management have often failed, because it is extremely difficult to manage what has become effectively an open-access communal system. Improved range management is crucial. However, providing livestock keepers with alternative and more productive feed and fodder sources may be a faster, more effective way to reduce the number of animals depending entirely on natural vegetation.

An important trend is starting: farmers are increasingly investing in alternative feed and fodder sources. This should be encouraged as global warming and increased aridity will continue to be a hazard that may increase the risk of cropping enterprises, while livestock enterprises based on perennial pasture may be more resilient. Not only will this improve animal conditions, preventing starvation during the dry season; it will also increase productivity and improve human livelihoods. The key research question is, to what extent are farmers prepared to invest in alternative feed, for which livestock species, and which type (e.g. draft animals, milk animals, pregnant or sick)? This type of information will enable ICRISAT to identify potential feed resources and management strategies, and promote their incorporation into farming systems.

There is the dimension of poverty to also consider — wherever fodder markets have developed, poorer households are proportionately more active in these markets than richer ones; fodder production offers new livelihood opportunities for non-livestock owners. ICRISAT and ILRI in partnership consider this aspect is crucial in developing a strong, sustainable livestock sector.

Outputs and outcomes to 2015

Outputs

Alternative feed and fodder optional strategies within mixed crop-livestock systems developed and promulgated to maintain animals during drought and for increased production.

Outcomes

Partners help small-scale farmers to adopt new sustainable feeding strategies to reduce livestock mortalities during droughts, and improved animal condition and increased production from both the livestock and cropping enterprises is experienced.

Reduced negative impact on natural rangeland.

Potential impact

Improved livestock condition during dry seasons and droughts will cause reduced mortality and increased productivity

Degradation of both crop and grazing land reduced, more fodder available for animals.

Risks and vulnerability to adverse natural and economic conditions reduced

Counterfactual

If ICRISAT does not address these issues at a regional level, environmental degradation will continue to increase, and livestock productivity will continue to decline in semi-arid areas. Fewer resource-poor households will be able to maintain or restock after droughts, or other disasters, especially for cattle. This will adversely affect the ability of farmers to plow and manure their fields and plant staple food crops.

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

Impacts of climate-induced risk

The System Priorities document recognizes that climate change is a major crosscutting theme and components of research can be identified from many of the existing 20 research priorities that comprise a climate change portfolio. However, throughout the SAT, rainfall variability and

production uncertainty have specifically coping and adaptation strategies of farmers and pastoralists. Such strategies have evolved over generations and allow them to plan for anticipated uncertainty and respond to the rainy season as it unfolds. However, it is precisely this uncertainty that constrains beneficial 'investment' decisions, required not only from farmers and farming communities, but also from a wide range of additional agricultural stakeholders. Such stakeholders often overestimate the impact of climate-induced risk. As a result, they show understandable reluctance to invest in potentially more sustainable, productive and economically rewarding practices when the outcomes and returns seem so uncertain from year to year. Such uncertainty will be exacerbated by climate change.

In recent years, a range of innovative tools has been developed and proven. These tools allow a far greater understanding of the agricultural implications of climatic variability and hence the development of an integrated climate risk management strategy specific to the needs of a broad range of stakeholders. Such an integrated strategy would comprise:

Decision-support frameworks that provide a longer-term strategic understanding of the temporal and spatial distribution of climatic variability and its impact on the probability of performance and profitability of existing and innovative agricultural practices.

Seasonal climate and agricultural forecasting to enable farmers and support agents to fine tune investment strategies on a seasonal basis and thus plan tactically and farm more effectively in the context of variable weather.

Information on the extent to which climate change is impacting, or is likely to impact, the nature of climate variability and the implications for rainfed farming systems and their future development and productivity.

Currently ICRISAT and partners are working with selected agricultural stakeholders in the SAT to develop an initial set of integrated climate risk management projects. These stakeholders were selected on the basis that they meet the following four important criteria:

They are directly involved in activities aimed at improving the livelihoods of rural communities who are largely or totally dependant on agriculture.

They have expressed a clear need for an integrated approach to climate risk management to enhance the effectiveness, efficiency and targeting of their interventions.

They are keen to undertake pilot projects to evaluate such climate risk management approaches.

Upon the successful outcome of pilot projects, they are well placed to scale up the climate risk management approaches that they have validated.

Outputs and outcomes to 2015

Outputs

The value of using information on climate-induced risk and potential climate change in long-term strategic and seasonal tactical investment planning evaluated and reported through pilot

projects that will have been scaled up to impact directly on the livelihoods of many hundreds of thousands of small-scale farmers.

Outcomes

Partner stakeholder and farmer planning and investment strategies embody integrated climate risk management resulting in greater returns from more diversified and better targeted investments by stakeholders and farmers in SSA.

Potential impact

Greater investment by farmers in improved farming practice including soil fertility maintenance, soil conservation, on-farm water management, income generating crops, improved varieties, fodder production and pasture management.

Greater and better-targeted investment in rainfed agriculture by a range of stakeholders (district policy makers, private sector, micro-finance institutions, extension services, meteorological departments, development NGOs).

ICRISAT's predominant capability

ICRISAT has current and historic strengths in climate risk management approaches and is coordinating, together with ASARECA, a consortium of 15 national, regional and international organizations who have endorsed (together with NEPAD) a program entitled "*Investing in rainfed farming systems of sub-Saharan Africa: Evaluating the agricultural implications of current climatic variability and planning for future climate change*".

Counterfactual

If a better understanding of the constraints and opportunities of climatically induced risk is not provided to key stakeholders and farmers alike, investment in the rainfed agricultural sector in the SAT is likely to remain at its current low and inadequate level, resulting in persistent poverty and vulnerability of rural populations.



Chapter 6

Knowledge management and sharing

Background

Knowledge management, originally a collection of primarily information-sharing processes in the corporate sector, has evolved in the last 10 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/Bellantet to promote KM 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 systemwide effort in ICT and KM, 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 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 important, 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 weblogs 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. Nonlinear

onset of climate change-related phenomena were evident throughout the year 2005, and floods have caused major damage in regions which had been in the grip of severe drought for almost half a decade. The potential spread of new hybrids, even GMOs, and the increases in globalization of commodity markets have also led to increasing pressure on NARES partners to develop rapid, knowledge-intensive responses. 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 NGOs 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 SSA. The two-part World Summit on the Internet Society (WSIS) organized by the UN has generated new global partnerships that aim to utilize the power of digital technologies to achieve the MDGs. 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, alongside 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 has 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 Microsoft and Sun Microsystems 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, and Coca Cola). 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.

Outputs and outcomes to 2009-2015

Outputs by 2009

Development of an architecture and building an infrastructure for advanced research informatics which will include

- Web-based information services to enable instant publishing (*e.g.* GT-BT-Bioinfo, LIMS; GT-CI-genebank, varietal information; GT-AE-GIS, soil and meteorological data, MPI-VLS).
- Mainstreaming support systems to take advantage of tacit knowledge (based on Media Wiki and Blogs).
- 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 postsecondary 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 the SSA.
- Developing video conferencing as a routine method of transaction between the three regional hubs and two SSA-based country offices.
- Developing 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 12 per year.

By 2015

Outputs will vary significantly between SAT-Asia and SSA because of anticipated economic and technological changes in Asia and the Pacific:

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.

ICRISAT, in conjunction with two ARIs, the GOFU, and two Asia-based Open Universities, will have established new in-country learning systems for 100 professionals in six countries in the SSA (three each in WCA and ESA).

Every ICRISAT faculty is a global knowledge entrepreneur with a readily available array of online tools and techniques, and can virtually be an institution.

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 being the development for which the research is intended.

ICRISAT's 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 presently a risk that the current players addressing this issue will do so in a piecemeal fashion that 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 that 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
icrisatnc@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