CGIAR Thematic Area 3:

Sustainable crop productivity increase for global food security
Proposal for a CGIAR Research Program on Rice-Based Production Systems

September 2010

Global Rice Science Partnership (GRiSP)

IRRI

AfricaRice

Africa Rice Center
Centre du riz pour l'Afrique

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture
Consultative Group on International Agricultural Research

An evolving international alliance with Cirad, IRD, JIRCAS, and hundreds of research and development partners worldwide

GRiSP Themes and R&D Product Lines

Theme 1: Harnessing genetic diversity to chart new productivity, quality, and health horizons

- PL 1.1. Ex situ conservation and dissemination of rice germplasm
- PL 1.2. Characterizing genetic diversity and creating novel gene pools
- PL 1.3. Genes and allelic diversity conferring stress tolerance and enhanced nutrition
- PL 1.4. C4 rice

Theme 2: Accelerating the development, delivery, and adoption of improved rice varieties

- PL 2.1. Breeding informatics and multi-environment testing
- PL 2.2. Improved donors and genes/QTLs conferring valuable traits
- PL 2.3. Rice varieties tolerant of abiotic stresses
- PL 2.4. Improved rice varieties for intensive production systems
- PL 2.5. Hybrid rice for the public and private sectors
- PL 2.6. Healthier rice varieties

Theme 3: Ecological and sustainable management of rice-based production systems

- PL 3.1. Future management systems for efficient rice monoculture
- PL 3.2. Resource-conserving technologies for diversified farming systems
- PL 3.3. Management innovations for poor farmers in rainfed and stress-prone areas
- PL 3.4. Increasing resilience to climate change and reducing global warming potential

Theme 4: Extracting more value from rice harvests through improved quality, processing, market systems and new products

- PL 4.1. Technologies and business models to improve rice postharvest practices, processing, and marketing
- PL 4.2. Innovative uses of rice straw and rice husks
- PL 4.3. High quality rices and innovative rice-based food products

Theme 5: Technology evaluations, targeting and policy options for enhanced Impact

- PL 5.1. Socioeconomic and gender analyses for technology evaluation
- PL 5.2. Spatial analysis for effective technology targeting
- PL 5.3. Global rice information gateway
- PL 5.4. Strategic foresight, priority setting, and impact assessment for rice research

Theme 6: Supporting the growth of the global rice sector

- PL 6.1. Innovation in learning and communication tools and extension capacity development
- PL 6.2. Effective systems for large-scale adoption of rice technologies in South Asia
- PL 6.3. Effective systems for large-scale adoption of rice technologies in Southeast and East Asia
- PL 6.4. Effective systems for large-scale adoption of rice technologies in Africa
- PL 6.5. Effective systems for large-scale adoption of rice technologies in Latin America and the Caribbean

Acronyms and Abbreviations

ACIAR	Australian Center for International Agricultural Research
ADB	Asian Development Bank
AfricaHarvest	Africa Harvest Biotech Foundation International
AfricaRice	Africa Rice Center
AfDB	African Development Bank
AGRA	Alliance for a Green Revolution in Africa
APAARI	Asia-Pacific Association of Agricultural Research Institutions
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
ASEAN	Association of Southeast Asian Nations
AWD	Alternate wetting and drying (water-saving irrigation technology)
BECA	Bioscience East and Central Africa
BMGF	Bill and Melinda Gates Foundation
BMZ	German Ministry for Development Cooperation
CA	Conservation agriculture
CAADP	Comprehensive Africa Agriculture Development Program
CAAS	Chinese Academy of Agricultural Sciences
CARD	Coalition for African Rice Development
CDM	Clean Development Mechanism (for climate change mitigation through carbon trading)
CEMAC	Communauté Economique et Monétaire des Etats de l'Afrique Central (Economic and Monetary Community of Central African states)
CIARD	Coherence in Information for Agricultural Research and Development initiative
CIAT	International Center for Agriculture in the Tropics
CIDA	Canadian International Development Agency
CFC	Common Fund for Commodities
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
Cirad	Centre de coopération internationale en recherche agronomique pour le développement (French Agricultural Research Centre for International Development)
COM	Council of Ministers (AfricaRice member countries)
COMESA	Common Market for Eastern and Southern Africa
CORAF	Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricoles – West and Central African Council for Agricultural Research and Development
CORRA	Council for Partnership on Rice Research in Asia (IRRI)
CPWF	Challenge Program on Water and Food
CRP	CGIAR Research Programme (within a Thematic Area) of the CGIAR Strategy and Results Framework
CRS	Catholic Relief Services
CSISA	Cereal Systems Initiative for South Asia
CSO	Civil Society Organization(s)
CTA	Technical Center for Agricultural and Rural Cooperation
CURE	Consortium for Unfavorable Rice Environments (IRRI)
DFID	Department for International Development, UK
EAFF	Eastern Africa Farmers Federation
ECOWAS	Economic Community of West African States
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
FAO	Food and Agriculture Organization of the United Nations
FARA	Forum for Agricultural Research in Africa
FLAR	Latin American Fund for Irrigated Rice (CIAT)
FORAGRO	Foro de las Américas para la Investigación y Desarrollo Tecnológico Agropecuaro (Forum of the Americas for Agricultural research and technology Development)
FONTAGRO	Fondo de Tecnología Agropecuaria (Regional Fund for Agric. Technology; LAC)

GCARD	Global Conference on Agricultural Research for Development
GCDT	Global Crop Diversity Trust
GCP	Generation Challenge Program (CGIAR)
GFAR	Global Forum on Agricultural Research
GFRAS	Global Forum for Rural Advisory Services
GRiSP	Global Rice Science Partnership
GSR	Green Super Rice (CAAS-IRRI-AfricaRice project)
HarvestPlus	HarvestPlus challenge program (CGIAR)
HRDC	Hybrid Rice Development Consortium (IRRI)
ICAR	Indian Council for Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRA	International Center for Development-oriented Research in Agriculture
ICRISAT	International Center for Crop Research in the Semi-Arid Tropics
IFAD	International Foundation for Agricultural Research
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INGER	International Network for Genetic Evaluation of Rice
INQR	International Network for Quality Rice
IRD	Institut de recherche pour le développement (French research institute for development)
IRRC	Irrigated Rice Research Consortium
IRRI	International Rice Research Institute
IVC	Inland Valley Consortium (Africa)
IWMI	International Water Management Institute
JICA	Japan International Cooperation Agency
JIRCAS	Japan International Research Center for Agricultural Sciences
LAC	Latin America and the Caribbean
MAFF	Ministry of Agriculture, Fisheries and Forestry, Japan
MDG	Millennium Development Goal
NARES	National agricultural research and extension system
NARS	National Agricultural research system
NEC	National Experts Committee (24 AfricaRice member countries)
NEPAD	New Partnership for Africa’s Development
NGO	Nongovernmental organization
OC	Oversight Committee of GRiSP
PDL	Product Development Leader in GRiSP
PL	Research or development product line in GRiSP
PLAR	Participatory learning and action research
PPMT	Program Planning and Management Team of GRiSP
PPP	Purchasing power parity
RCT	Resource-conserving technologies
RiceTIME	Training, Information Management and Extension linkages Unit of AfricaRice
RKB	Rice Knowledge Bank (CKB – Cereal Knowledge Bank)
ROPPA	Réseau des organisations paysannes et des producteurs de l’Afrique de l’Ouest (Network of Farmers' and Agricultural Producers' Organizations of West Africa)
RWC	Rice-Wheat Consortium for the Indo-Gangetic Plains
SADC	Southern Africa Development Community
SDC	Swiss Development Corporation
SSA	Sub-Saharan Africa
SSNM	Site-specific nutrient management
STRASA	Stress-Tolerant Rice for Africa and South Asia
TA	Thematic area of the CGIAR Strategy and Results Framework
TRRC	Temperate Rice Research Consortium (IRRI)
USAID	United States Agency for International Development
WB	The World Bank
WorldFish	The World Fish Center

Contents

Executive Summary

This proposal for a Global Rice Science Partnership (GRiSP) represents, for the first time ever, a single strategic and work plan for global rice research and how it can contribute more effectively to solving development challenges at regional, national and local level. It streamlines current research for development activities of the CGIAR, aligns it with numerous partners, and adds new activities of high priority, in areas where science is expected to make significant contributions. GRiSP provides new opportunities for partnerships in research and development, bringing together advanced research institutes and universities, national research, education and extension systems, international and regional fora and development organizations, CGIAR centers, emerging strong national research systems, the private sector, and civil society organizations involved in grass-roots work with male and female farmers. GRiSP provides new opportunities for partnerships in research and development, bringing together advanced research institutions, national systems, the private sector and civil society organizations involved grassroot work with male and female farmers.

The urgency to re-orient and align the world's main research efforts on rice-based agricultural production systems is illustrative of the crop's importance to the world's growing population. For every one billion people added to the world's population, 100 million tons of rice (paddy) need to be produced more annually —with less land, less water, and less labor, in more efficient, environmentally-friendly production systems that are more resilient to climate change and also contribute less to greenhouse gas emissions. Projected demand for rice will outstrip supply in the near to medium term unless something is done to reverse current trends of slow productivity growth and inefficient, often unsustainable management of natural resources. Steep and long-term price increases would wreak havoc on the lives of the poor and send dangerous tremors across the political and economic landscapes in the world's most populous regions. This is the fundamental challenge for another, greener Green Revolution in the world's major rice-growing areas, to which GRiSP will make vital contributions.

Tomorrow's rice plants and management practices will be different from today's. Traditional rice systems with large water consumption will be made more eco-efficient. Where possible, such systems will diversify more through the widespread adoption of mechanized, resource-conserving technologies aimed at saving water and labor. Ecologically sound management principles will accompany the further intensification and diversification of rice systems, particularly in Asia. In Africa and Latin America, where there is still more land and water available for growing rice and other crops, efforts to expand both area and yield growth rates must focus on sustainable management solutions. Across the world, rice will have to tolerate extremes of temperature, both high and low, droughts, floods, and salinity. The delta regions, from which much recent gain in production comes, will be particularly susceptible to sea-level rise and stronger tropical storms. Considering the enormous environmental footprint made by the more than 150 million hectares of rice fields, any effort to mitigate the impact of agriculture on the global environment must include rice-based systems.

GRiSP has enormous potential to generate benefits for the poor, the hungry and the environment. Key anticipated impacts from GRiSP investments include:

By 2020:

- Expenditures on rice by those under the $1.25 (PPP) poverty line will decline by nearly PPP $5 billion annually (holding consumption constant).

- Counting those reductions as income gains means that 72 million people would be lifted above the $1.25 poverty line, reducing the global number of poor by 5%.
- As a result of increased availability and reduced prices, 40 million undernourished people would reach caloric sufficiency in Asia, reducing hunger in the region by 7%.
- Approximately 275 million tons of CO_2 equivalent emissions will be averted.

By 2035:

- Expenditures on rice by those under the $1.25 (PPP) poverty line would decline by PPP $11 billion annually (holding consumption constant).
- Counting those reductions as income gains means that 150 million people would be lifted above the $1.25 poverty line, reducing the global number of poor by 11%.
- As a result of increased availability and reduced prices, 62 million undernourished people could reach caloric sufficiency in Asia, reducing hunger in the region by 12%.
- Nearly 1 billion tons of CO_2 equivalent emissions will be averted.

These are impressive numbers, considering that they arise from an aggregate global 25-year inflation-adjusted investment of roughly $3.0 billion, or $20 per person lifted above poverty. Very few other development investments have similar efficacy in poverty eradication.

GRiSP's mission, in accordance with that of the CGIAR, is *to reduce poverty and hunger, improve human health and nutrition, reduce the environmental footprint and enhance ecosystem resilience of rice production systems through high-quality international rice research, partnership, and leadership*. It aims to achieve this mission through fostering high-quality, impact-oriented research and development activities in a global context. The key entry points for achieving this mission lie in lifting the productivity and resource efficiency of rice production systems to unprecedented levels. This will enable farmers to enter a virtuous circle, allowing them to also invest more in diversification and sustainable management practices.

GRiSP has three objectives, aligned with the CGIAR strategic objectives and contributing to achieving quantitative outcomes stated in its vision of success toward 2020 and 2035. These objectives will be achieved through a set of six interconnected research and development themes.

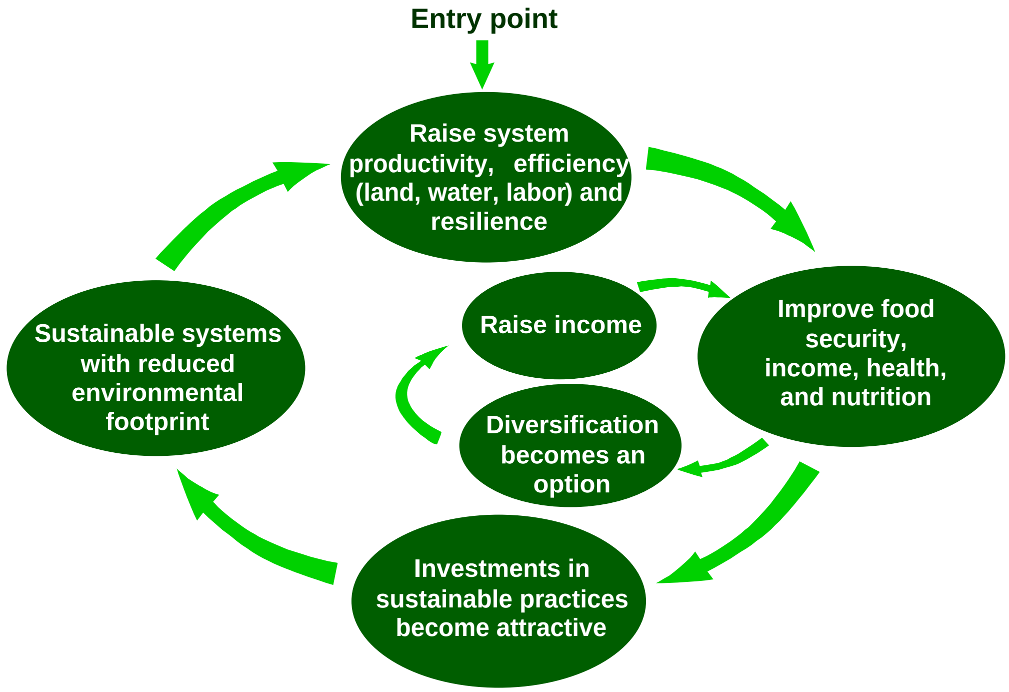
Objective 1: To increase rice productivity and value for the poor in the context of a changing climate through accelerated demand-driven development of improved varieties and other technologies along the value chain (addressed through Themes 1, 2, 3, 4, and 6).

Objective 2: To foster more sustainable rice-based production systems that use natural resources more efficiently, are adapted to climate change and are ecologically resilient, and have reduced environmental externalities (addressed through Themes 3, 4, and 6).

Objective 3: To improve the efficiency and equity of the rice sector through better and more accessible information, improved agricultural development and research policies, and strengthened delivery mechanisms (addressed through Themes 5 and 6).

In pursuing the objectives, the focus will be on poverty reduction and the livelihoods of poor farmers. Gender issues are inherent in all three objectives, and capacity building in rice science and extension are emphasized to ensure adequate skilled personnel for future rice development.

Enabling farmers to enter a virtuous circle is the core goal of GRiSP



Rice-based production systems and value chains will form the overarching organizing principle of the partnership. All research will use an interdisciplinary approach in which targeting and prioritization are based on a clear understanding of the different environments, management systems, and market segments targeted. On the one hand, this will need a broad range of scientific, or upstream, partners to seek out innovations and, on the other hand, many partnerships at the grass-roots level for both dissemination and feedback. The result will be accelerated development of international public goods across the whole rice sector. Based on these considerations and for effective management of the R&D process, the program components are structured into six major rice research and development themes:

Theme 1: Harnessing genetic diversity to chart new productivity, quality, and health horizons
Theme 2: Accelerating the development, delivery, and adoption of improved rice varieties
Theme 3: Ecological and sustainable management of rice-based production systems
Theme 4: Extracting more value from rice harvests through improved quality, processing, market systems and new products
Theme 5: Technology evaluations, targeting and policy options for enhanced impact
Theme 6: Supporting the growth of the global rice sector

At the core of GRiSP's approach lies a thorough understanding of the socioeconomic and biophysical factors that drive what farmers, agri-businesses, small entrepreneurs, consumers, and many other actors in the value chain need from research. Theme 5 focuses on this, providing the innovative tools and information needed for evidence-based targeting in GRiSP R&D themes that focus on the development of new products, their adaptation and adoption. Theme 5 also provides the necessary feedback on adoption patterns, constraints, and true impact. Capacity building and gender are fully integrated in all GRiSP themes, but will also be supported through centrally managed GRiSP funds.

Under each theme, R&D product lines are defined as families of products or deliverables that provide global or regional options for next, intermediate, and final users. Product-oriented, interdisciplinary activities are carried out with partners to develop innovative products and facilitate their uptake. Products can be global or regional in their targeted usage, but they must be based on evidence for large impact potential. The interaction between the GRiSP themes is established through projects and networks that cut across several GRiSP themes and are often of regional nature, addressing local, national or regional development needs and bringing the different activities and partners together on the ground. Many such regional initiatives or consortia exist already and they will be further strengthened in GRiSP, also in linkage with other CGIAR Research Programs and in collaboration with regional fora and development organizations.

GRiSP will have a 25-year vision of success, which will be implemented through 5-year rolling work and business plans addressing the six research and development themes described above. The proposed products and product lines are seen as a starting point, aiming to accelerate R&D pipelines so that impact can be achieved faster. In addition, GRiSP will make investments in research for the next generation of future rice production systems—the scientific breakthroughs that will be needed 20 or 30 years from now to ensure food security and enable better environments. GRiSP will evolve over time, re-defining its priorities and approaches based on evidence, focusing on how international R&D can make the greatest contributions to the development of rice production systems and value chains and thus improving the livelihoods of the people involved in those. The GRiSP work and business plans will thus be continuously refined, seeking an even better alignment with but also contributions from all major national research and extension systems, global and national development NGOs, the research communities in major developed countries, and the private sector.

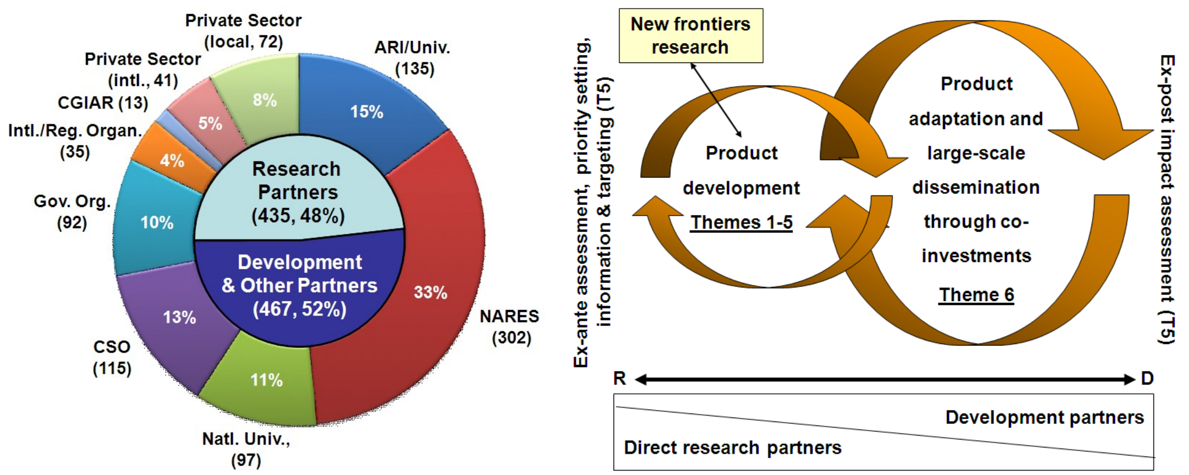
Partnerships will be the main drivers for reaching GRiSP's vision of success and GRiSP will provide a new umbrella for strengthening and expanding partnerships. At present, the six international centers and organizations in GRiSP (IRRI, AfricaRice, CIAT, JIRCAS, Cirad, IRD) have about 900 rice research, development, and other partners representing many institutional and societal sectors worldwide. About 48% of the GRiSP partners mainly play a role as research partners, whereas 52% are "boundary partners", mainly involved in the agricultural development sector. Hence, the roles of partners in the various GRiSP themes variy widely, from upstream research to grassroot level dissemination work and political support.

IRRI is the lead center for GRiSP and also leads the activities in Asia, with AfricaRice leading the work in Africa and CIAT the work in the Latin America & Caribbean region. Other internationally operating research organizations such as Cirad, IRD and JIRCAS will play a strategic role in GRiSP. Likewise, strong national rice R&D systems such as those of China, India, Japan and Brazil are expected to make significant contributions to GRiSP, primarily by connecting their national research programs better with the global themes addressed in GRiSP. GRiSP will seek to expand its partnerships with the CSO sector, including global, regional, national, and local NGOs, farmers' associations, and other groups representing the agricultural, social, and environmental sector. Active partnerships with the private sector, both in upstream research as well as in delivery of new technologies will be an integral part of GRiSP.

GRiSP will be linked in various ways with other CGIAR Research Programs that focus on a wide range of commodities, production systems, and health and environmental issues, but that often also include rice. Through its own activities and through collaborative projects, co-investment from/in other CGIAR Research Programs, and active participation by IRRI, AfricaRice, and CIAT and their partners in other CGIAR Research Programs, GRiSP will be fully integrated in the

Strategy and Results Framework of the CGIAR Consortium. Several other CGIAR centers will be involved in GRiSP-related projects and activities, including regional and national initiatives that cut across different CRPs. Examples include ongoing and future collaboration with CIMMYT, IFPRI, ILRI, IWMI, ICARDA, ICRISAT, IITA, and WorldFish and systemwide programs such as the GCP, which have been integrated in the GRiSP.

Current partners and their roles in GRiSP



Program management in GRiSP will largely be done through existing research management and administrative support systems of IRRI, AfricaRice, CIAT, and their strategic partners. In addition, GRiSP will have a small Oversight Committee (OC) and a Program Planning and Management Team (PPMT). Global leadership and coordination will be provided by a Program Director (PD) and small Program Management Unit (PMU).

GRiSP, like most other CRPs, will start from a basis of current research, which is to 80% locked into existing restricted grants. Hence, up to 80% of the initial proposed allocation of funds is based on ongoing research, plus a number of new priorities that were identified during the CRP development process. Over time, as current restricted grants run out or are replaced by Window 1-3 funding or new bilateral grants, more flexibility in resource allocation according to the new priorities will emerge. In a scenario in which no additional research resources can be provided for high-priority areas, but all other inherent program and system costs are included, the annual GRiSP budget is US$ 95.4 million in 2011, and rises to US$ 112.6 million in 2015 (30% increase over 2010). In a growth scenario, in which an additional 5%/yr is made available for investment in GRiSP research themes, the projected annual budget is US$ 99.8 million in 2011, rising to US$ 139.2 million in 2015 (increase of 61% over the comparable 2010 figures). This growth scenario is essential for achieving the GRiSP vision of success. Although it represents a significant increase in funding over time, it still falls far short of stated international goal to double funding for agricultural research and development. Annual co-investments by three strategic partners in GRiSP (Cirad, IRD, and JIRCAS) are expected to exceed USD 20 million. Additional co-investments are expected to come from other key partners, for research as well as large-scale delivery of new technologies to farmers. GRiSP will provide an efficient platform for leveraging these much larger co-investments in order to reach its vision of success.

Justification

Importance of rice and rice research

Rice (*Oryza sativa*) is a tropical cereal that was domesticated from the wild grass *Oryza rufipogon* some 10,000 to 14,000 years ago. It is among the world's first domesticated crop plants and formed the nutritional underpinnings for the great early civilizations in East and South Asia. The two main subspecies of rice, indica (prevalent in tropical regions) and japonica (prevalent in the subtropical and temperate regions of East Asia), are now believed to have been derived from independent domestication events. Another cultivated rice species, *O. glaberrima,* was domesticated much later in West Africa. Rice is a spectacularly diverse crop – genetically, in the way it is grown and how it is used by humans.

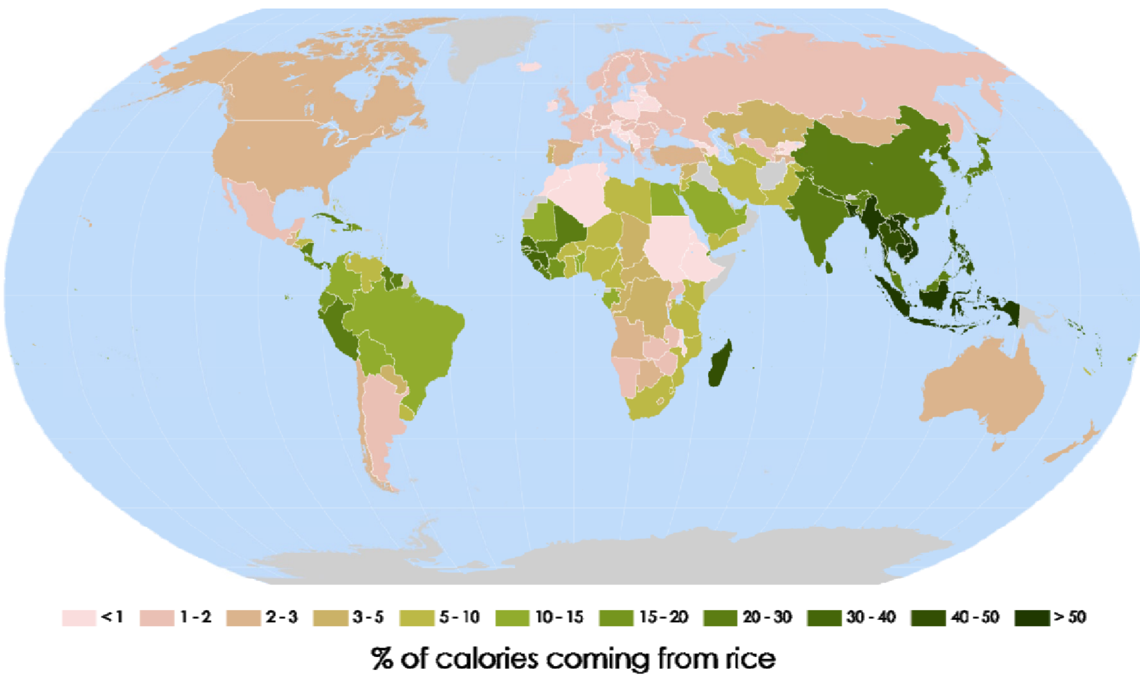


Fig. 1. Share of rice of total calories consumed (Sources: FAO and World Bank, 2010).

Staple food of the world's poor. Rice is the most important food crop of the developing world and the staple food of more than half of the world's population, many of whom are also extremely vulnerable to high rice prices. Worldwide, more than 3.5 billion people depend on rice for more than 20% of their daily calories. Rice consumption can be very high, exceeding 100 kg per capita annually in many Asian countries. For about, 520 million people in Asia, most of them poor or very poor, rice provides more than 50% of the caloric supply (Fig. 1). In sub-Saharan Africa, urban dwellers who only a few decades ago rarely ate rice now consume it daily. Per capita consumption has doubled since 1970 to 27 kg. In South America, average per capita consumption of rice is 45 kg. In the Caribbean it has already risen to over 70 kg.

One fifth of the world's population, more than 1 billion people, depends on rice cultivation for livelihoods. Harvested from 158 million hectares annually, rice has twice the value of production in the developing world of any other food crop: more than $150 billion per year. Nearly 560 million people living on less than US$1.25 (purchasing power parity [PPP]) per day are in rice-producing areas, far more than for any other crop (Fig. 2).

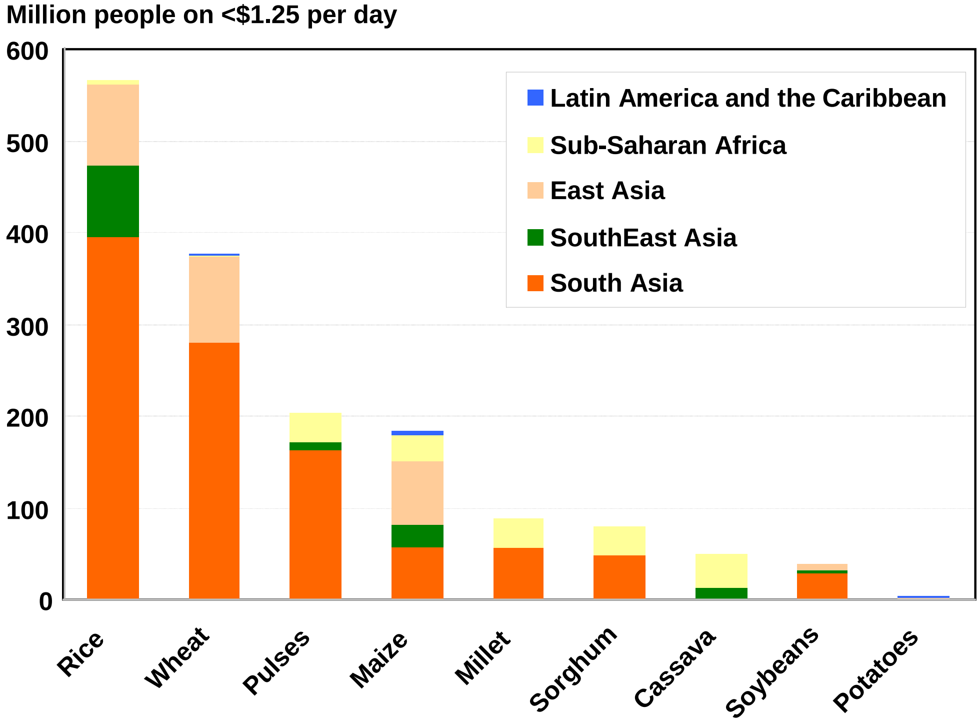


Fig. 2. Number of people below the $1.25 per day (purchasing power parity) poverty line who live in areas dominated by different crops (2005 data). Numbers are based on areas more than 10% covered by the dominant crop. Some areas have more than one dominant crop and thus overlap.

Asia, where about 90% of rice is grown, has more than 200 million rice farms, most of which are smaller than 1 hectare. Rice-based farming systems are also the main economic activity for hundreds of millions of rural poor, many of whom do not own their own land. For the extreme poor (less than $1.25/day), rice accounts for nearly half of their food expenditures and a fifth of total household expenditures, on average. This group alone annually spends the equivalent of $62 billion (PPP) for rice.

In Africa, rice is the fastest growing food staple. The gap between demand and supply in sub-Saharan Africa, where rice is grown and eaten in 38 countries, reached 10 million tons of milled rice in 2008, costing the region an estimated $3.6 billion for imports. Rice is also one of the most important and fastest growing staple foods in Latin America, especially among urban consumers and particularly the poor. Like Africa, the region is a net importer of rice, with a projected annual deficit of 4 million tons by 2015.

In most of the developing world, rice availability is equated with food security and closely connected to political stability. Changes in rice availability, and hence price, have caused social unrest in several countries, most recently during the food crisis of 2008. The World Bank estimated that an additional 100 million people were pushed into poverty as a result of that crisis.

***Unique production systems and ecosystem services*.** Rice production systems are unique and the longevity of rice farming speaks for itself. Irrigated lowland rice, which makes up three-quarters of the world rice supply, is the only crop that can be grown continuously without the need for rotation and can produce up to three harvests a year—literally for centuries, on the same plot of land. Farmers also grow rice in rainfed lowlands, uplands, mangroves, and deepwater areas.

Rice remains productive in environments where most other crops would fail. In irrigated and rainfed lowland systems, rice is grown in anaerobic (flooded) soil, which is disturbed after each crop; fields are periodically submerged and the soil softened. The aquatic phase reduces soil acidity and improves nutrient availability, and biological nitrogen fixation; it brings with it a host of arthropods, snails, and frogs and other beneficial fauna and flora in cycles that have their origins millennia ago. Fish and ducks can be raised in the fields. Apart from these provisioning ecosystem services are also regulatory services: flood buffering and trapping of sediments and nutrients, and moderation of air temperature; supporting services: irrigated fields are "human-made wetlands" that support a rich biodiversity; and cultural services: many ancient communities were founded around rice irrigation areas where rice remains an important cultural icon.

The phrase "rice is life" is not to be taken lightly because the grain figures in many creation beliefs across Asia and is deeply embedded in social practices and customs. Thus, rice shortages affect society far beyond the cold statistics that price, caloric intake, yield growth rates, and international trade suggest. Any significant disruptions of rice supplies can and do have far-reaching social and political ramifications.

Whichever way rice is viewed—quantity, productivity, value of production, number of farmers, number of consumers, affordability to the poor, or dietary importance—it will remain the dominant feature of the nutritional and agricultural landscape of many developed and developing countries far into the foreseeable future. What will have to change, however, is the way how rice is grown. Traditional cultivation methods, particularly the heavy water footprint of rice, cannot continue in many parts of Asia, where water and labor scarcity are becoming major drivers of change. There is need to reduce the overall environmental footprint of rice through more efficient management systems. At issue is what future rice-based farming systems should look like, how they should be managed to achieve the multiple goals of food security, less poverty, and protecting the environment. Finding solutions for that is at the heart of GRiSP.

The largest source of documented past international agricultural research impact . Rice research is the single largest documented source of agricultural research benefits in the developing world. Documented *annual* economic benefits from rice productivity-enhancing research by CGIAR centers and their partners exceed $19.5 billion.[1] By the late 1990s, Asian annual gains from the adoption of modern varieties of rice from IRRI, largely through the national systems, were $10.8 billion, nearly 150 times the combined annual investment in rice research by IRRI and national systems. Moreover, rice research is the source of roughly half of all documented benefits from the CGIAR system, even though it has usually received less than 10% of CGIAR expenditures.[2]

Other analyses have also shown that productivity-enhancing research on rice is the largest expected source of future impact for the poor among focal crops for agricultural research. For example, analysts in the World Bank's Development Research Group have found that, comparing a common rate of productivity growth across commodities, productivity growth for rice has more than double the global poverty reduction potential of any other agricultural product.[3] Similarly, in the Global Conference on Agricultural Research for Development

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1 Sum of Asian estimates adjusted to 2010 prices from Evenson RE, Gollin D (eds.) 2003. Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research, CABI and Latin American estimates from Sanint LR, Wood S. 1998. Impact of rice research in Latin America and the Caribbean during the past three decades. In: Pingali P, Hossain M (eds.) Impact of rice research, p 405-428. Bangkok, Thailand Development Research Institute and International Rice Research Institute.

2 Raitzer, D. and T.K. Kelley. 2008. Benefit-Cost Meta-Analysis of Investment in the International Agricultural Research Centers of the CGIAR. *Agricultural Systems* 1-3(96): 108-123.

3 Ivanic M, Martin W. 2010. Promoting global agricultural growth and poverty reduction. Conference of the Australian Agricultural and Resource Economics Society, Adelaide, Australia, 10-12 February 2010.

(GCARD) sub-regional analysis for Southeast Asia, productivity enhancement for rice was found to have nearly as much poverty reduction potential as all other agricultural products combined.[4]

As the agricultural product associated with the largest proportion of the income, expenditures, and food intake of poor populations, rice research has been a key source of agricultural research impact poverty reduction and food security. Moreover, those benefits are uniquely equitable, as widely adoption rice technologies from international research have been scale neutral, and in a number of important cases have higher adoption levels among smaller farmers than larger farmers.[5] For example, The NERICA varieties developed by AfricaRice and partners have gained rapid ground across the African continent in both upland (conservative estimates put the area under NERICA upland varieties at 300,000 ha since their first release in 2001) and rainfed lowland conditions with positive effects on farmers' livelihoods.

Less is known about the environmental impact of past rice research. On one hand, the Green Revolution and intensive rice systems in particular are often perceived as causing excessive use of fertilizers and pesticides, reducing biodiversity, drawing down precious water resources, or emitting large amounts of greenhouse gases such as methane. On the other hand, this research has also prevented 13 million hectares of agricultural expansion, potentially saving a commensurate area of natural ecosystems from being brought under cultivation, with attendant environmental benefits.[6] Moreover, in recent years research has yielded many new technologies that address precisely these issues and are designed to make rice cropping systems more productive and eco-efficient. It has been demonstrated in research and in first adoption studies that rice can be grown profitably with little use of insecticides, site-specific nutrient management that leads to 30-50% increases in nitrogen use efficiency, or water-saving irrigation techniques that result in 30% less water use and also reduce methane emissions. GRiSP will place large emphasis on these new management solutions and also thoroughly assess where they may work best and what their impact is.

Challenges for future rice production.

For every one billion people added to the world's population, 100 million tons of rice (paddy) need to be produced more annually –- with less land, less water, and less labor, in more efficient, environmentally-friendly production systems that are more resilient to climate change and also contribute less to greenhouse gas emissions. Projected demand for rice will outstrip supply in the near to medium term unless something is done to reverse current trends of slow productivity growth and inefficient, often unsustainable management of natural resources. Steep and long-term price increases would wreak havoc on the lives of the poor and send dangerous tremors across the political and economic landscapes in the world's most populous regions. This is the fundamental challenge for another, greener Green Revolution in the world's major rice-growing areas, to which GRiSP will make vital contributions.

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4 Raitzer DA, Roseboom J, Maredia MK, Huelgas Z, Ferino MI. 2009. Prioritizing the agricultural research agenda for Southeast Asia: refocusing investments to benefit the poor. Southeast Asia Subregional Review for the APAARI/ADB/GCARD Asia Pacific Consultation on Agricultural Research for Development

5 Hossain M, Lewis D, Bose ML, Chowdhury A. 2007. Rice research, technological progress, and impacts on the poor: the Bangladesh case. *In* Adato M. and Meinzen-Dick RS. (eds.) Agricultural research, livelihoods, and poverty: studies on economic and social impact in six countries. The Johns Hopkins University Press: Baltimore, MD USA.

6 Evenson, R. and M. Rosegrant. 2003. The economic consequences of crop genetic improvement programs. *In* Evenson RE, Gollin D (eds.) 2003. Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research, CABI

A variety of factors that threaten rice-based farming systems must be overcome, from falling yield growth to inefficient us of natural resources and inputs, socioeconomic change or climate change.

Declining yields and less land, water, and labor. Yield growth has fallen, partially as a result of the decline in investment in productivity research since the early 1990s, from 2.2% during 1970-90 to less than 0.8% in the 1990s and 2000s. Rice area in the major production countries has been decreasing because of the conversion of land for other purposes. Competition for water is becoming increasingly fierce. Fewer hands are available for farming as young people prefer to look for jobs outside the agricultural sector. Although there is still scope for expansion of rice area in the three regions, conservation of natural ecosystems must remain a high priority. Increasing rice yields on existing land must remain the primary strategy for increasing production. Particularly for African and South American farmers, another challenge will be to make greater use of largely unused lowlands while preserving their ecosystem services and taking the pressure off of fragile upland systems.

Effects of economic growth. Rapid economic growth in large countries, such as China and India, has heightened demand for cereals, both for consumption and for livestock production, and this has pushed up the price of cereals in general. Economic growth is often accompanied by diversification of food demand, which creates opportunitiesfor diversification of rice-based systems to include higher-value crops and livestock, but also reduces the amount of land available for rice. The rice-related tensions that developing countries face are growing more complex as their economies grow: between poor rice farmers and poor consumers, between small-scale and large-scale rice-based farms, between rice and more lucrative/cash crops, between edible crops and biofuels, between crops and other land uses, and between crops and other water uses. Prices of fertilizer are bound to stay high, especially for phosphorus, given the current status of known reserves.

Pressure on land use. As a consequence of economic growth, current rice cultivation areas are likely to be lost to urban expansion, land conversion to biofuels, and diversification into other agricultural products. This all means that sufficient production to meet growing future demand will have to come from smaller and smaller areas, particularly if diversification is to be possible while keeping rice prices affordable to poor consumers. In turn, this adds urgency to the need to improve productivity.

Water scarcity. By 2025, 15–20 million ha of irrigated rice will suffer some degree of water scarcity, which results from competing water uses and climate change, and requires rethinking of current management paradigms. In northwestern India, declining groundwater levels pose a serious threat to one of the world's most important grain baskets. In fact, rice systems draw much of their ecological resilience from intensive water use and new solutions need to be found for water-scarce conditions.

Climate change. Global climate change has potentially grave consequences for rice production and, consequently, global food security. Land-use systems in most developing countries are highly vulnerable to climate change and have little capacity to cope with its impacts. Conditions for rice farming will deteriorate in many areas, through water shortages, low water quality, thermal stress, sea-level rise, floods, and more intense tropical cyclones. An International Food Policy Research Institute (IFPRI) study forecasts a 15% decrease in irrigated rice yields in developing countries and a 12% increase in rice price as a result of climate change by 2050. Moreover, flooded intensively managed rice systems release large amounts of methane, but also sequester carbon in soil organic matter, whereas more diversified rice-based cropping systems release less methane, but more nitrous oxide and carbon dioxide. Africa is expected to be very vulnerable to erratic weather patterns arising from climate change, but most disconcerting is that more than half of the growth in Asian rice production over the past decades came from the “delta countries,” such as Vietnam and Bangladesh—precisely the countries most vulnerable to sea-level rise and climatic extremes. Many unique ecosystem services in wetland rice culture are now under threat from increasing water scarcity, further aggravated by climate change. What will change in these systems if farmers diversify cropping or switch to “aerobic” water management? Will these systems be resilient and productive enough over the longer term? What will be the sustainable rice-based cropping systems and crop management practices of the future?

Impacts on women in rice. Women participate in various degrees in the cultivation of rice and often have specific tasks such as transplanting, weeding, or harvesting. Economic development and technological response options affect women in different ways, depending on whether they are paid or unpaid laborers. Migration of men to work in urban areas often results in women being left behind to do drudgeries work in rice fields. A shift from transplanting to direct seeding may specifically affect the livelihoods of women since transplanting is their traditional task in most Asian and African societies. If they are unpaid laborers, the shift will remove the drudgery and back-breaking burden of transplanting. But if they are paid laborers, it will deprive them of a source of income. The same reasoning holds for weeding. Water scarcity and response options such as alternate wetting and drying and aerobic rice may promote weed growth and increase the need for manual weeding. Thus it is important to include a gender perspective in the development of alternative response options or technologies of rice production. The same holds true for the development and deployment of new rice varieties. Women should be specifically included in activities such as participatory varietal selection, as they often have different perceptions of relevant crop traits, for example, grain quality and feed quality of the straw (in many cases, it is women who tend the livestock).

Global and regional rice demand

Global rice consumption remains strong, driven by both population and economic growth in many Asian and African countries. In Asia, which accounts for 90% of global rice consumption, total rice demand continues to rise despite declining per capita consumption in many high- and middle-income countries. Among high-income Asian countries such as Japan, Taiwan, South Korea, and Hong Kong, a significant decline in per capita consumption has been witnessed in the last four decades. Similar patterns have started to emerge in middle-income countries such as China, Malaysia, and Thailand in the last two decades as their people have been consuming more meats and vegetables and less cereals. But, in many other developing Asian nations, including India, Vietnam, and Indonesia, per capita consumption in recent years has started to decline at a rather slow pace with rising income. On the other hand, many other middle- to low-income Asian countries, including the Philippines, Myanmar, Cambodia, Bangladesh, and Laos, continue to witness rising per capita consumption over time.

Despite this variation in the Asian per capita rice consumption trend, it is widely expected that per capita consumption in a majority of Asian countries will start or continue to decline in the future with rising income as people diversify their diets. But, it is naïve to assume that all Asian countries will behave like Japan, Taiwan, and South Korea in the future with rising disposable income. For a country such as India with a large number of ovo-vegetarians, it is unrealistic to assume that their rice consumption will follow the patterns of the Korean, Chinese, and Japanese populations with rising standards of living. Even other developing Asian countries such as Bangladesh, the Philippines, and Vietnam are likely to adopt consumption patterns different from what has been witnessed in the past. The key question is how the consumption patterns of each country will change as income rises and a rapid increase in urbanization influences food habits.

Outside Asia, where rice is not a staple yet, per capita consumption continues to grow. This is particularly true for most countries in sub-Saharan Africa, where high population growth with changing consumer preferences is causing rapid expansion in rice consumption. In the least developed African countries such as Nigeria, Tanzania, and Niger, people are moving away from tubers and cassava to rice with rising income. Similar strong consumption growth has also been evident among Middle Eastern countries with almost doubling of rice consumption in the last two decades. Along with strong population growth, rapid rise in per capita consumption also contributed to such rapid growth in rice demand. Rice consumption also continues to grow in Latin America and the Caribbean region with 40 percent increase in the last two decades as a combination of both population growth and steady rise in per capita consumption. Even in developed countries/regions such as United States and the European Union, per capita consumption continues to grow partly because of switching away from protein to more fibers and also immigration from Asian countries.

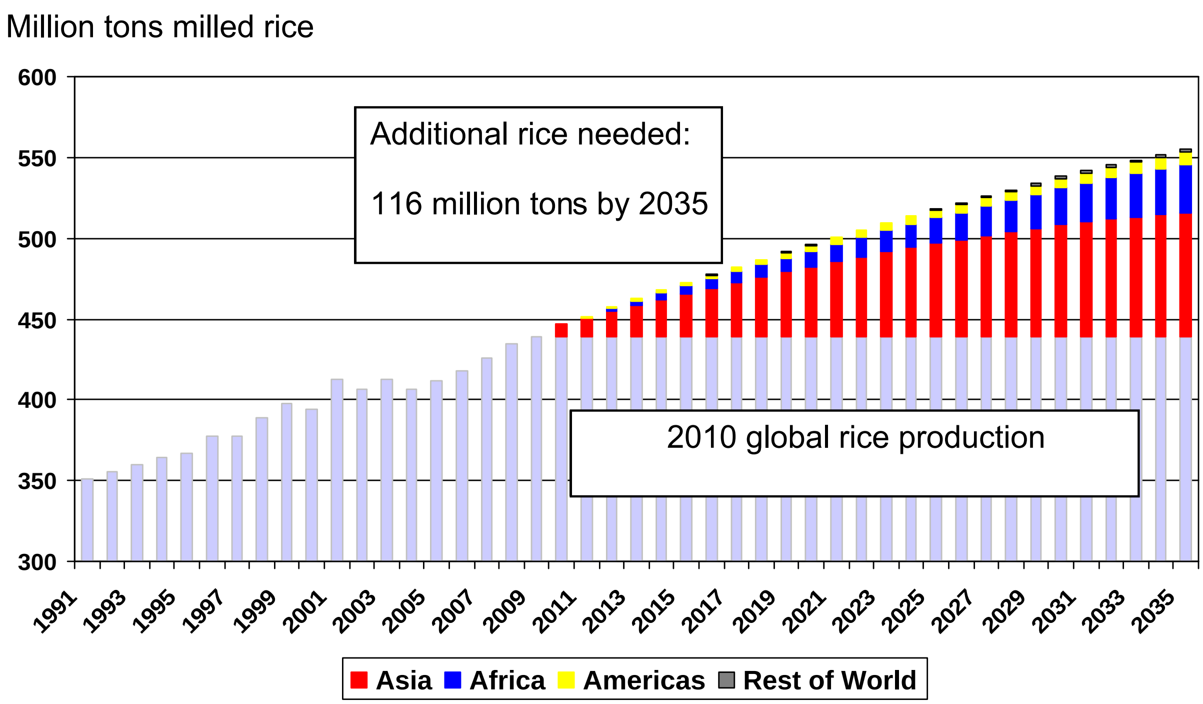

Fig. 3. Global rice production increases needed to meet demand by 2035.

Using the population projections from the United Nations and income projections from the Food and Agricultural Policy Research Institute (FAPRI), global rice demand is estimated to rise from 439 million tons (milled rice) in 2010 to 496 million tons in 2020 and further increase to 555 million tons in 2035 (Fig. 3). This is an overall increase of 26% in the next 25 years, but the rate of growth will decline from 13% for the first 10 years to 12% in the next 15 years as population growth drops and people diversify from rice to other foods. Among the various rice-consuming regions, Asian rice consumption is projected to account for 67% of the total increase, rising from 388 million tons in 2010 to 465 million tons in 2035 despite a continuing decline in per capita consumption in China and India. In addition, 30 million tons more rice will be needed by Africa, an increase of 130% from 2010 rice consumption. In the Americas, total rice consumption is projected to rise by 33% over the next 25 years.

With further area expansion unlikely, global rice yields must rise faster than in the recent past if world market prices are to be stabilized at affordable levels for the billions of consumers (Fig. 4). Globally, farmers need to produce at least 8–10 million tons more paddy rice each year—an annual increase of 1.2–1.5% over the coming decade, equivalent to an average yield increase of 0.6 t/ha during the next decade. Over the longer run, global rice consumption growth is expected to slow down but yields will have to continue to grow faster than at present because of pressure on rice lands in the developing world from urbanization, climate change, and competition from other, high-value agriculture. Rice yield growth of 1.0–1.2% annually beyond 2020 will be needed to feed the still-growing world and keep prices affordable.

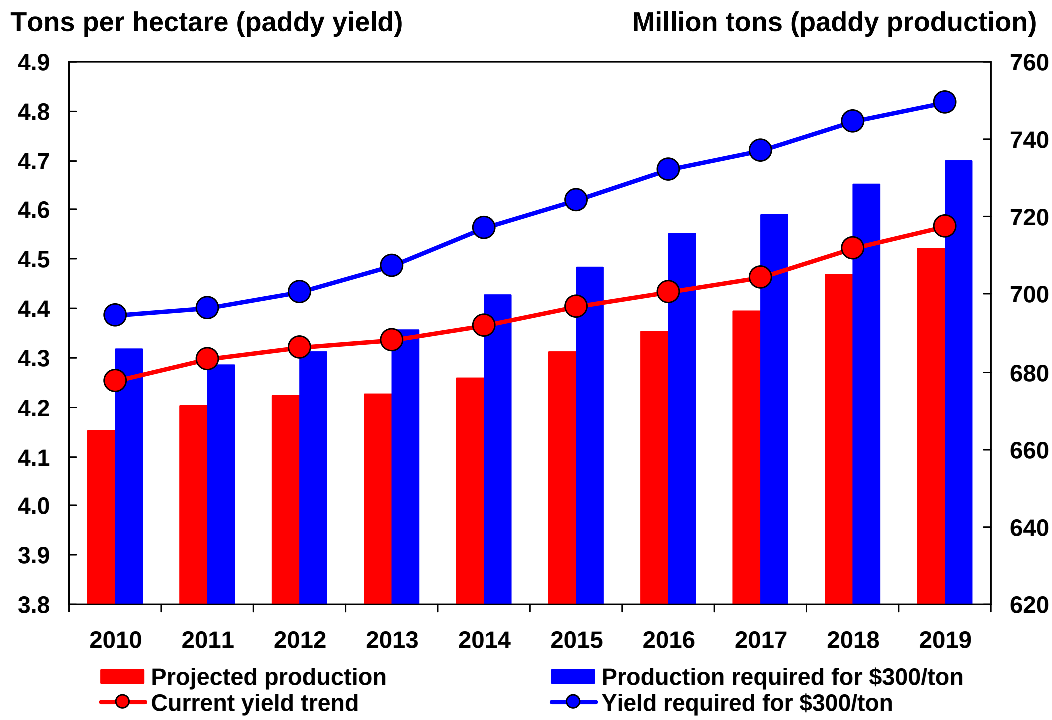

Fig. 4. What the world needs to keep rice prices affordable at around $300 per ton (red columns and lines: current rice production and yield growth rates, respectively; blue columns and lines: yield and production growth required to stabilize rice prices at $300 per ton). Simulation was done using the Arkansas global rice model.

Reliance on imports or additional rice area to feed the poor is bound to fail, given incessantly growing populations in the developing world together with a tight global rice supply-demand situation and a general decline in rice lands in Asia, the major rice-producing region. Thus, there is a compelling need to develop new rice technologies worldwide that will maintain or increase productivity sustainably on existing and newly developed rice land, and that are climate-resilient.

The constraints to increasing rice production are largely of a nature that spans borders. CGIAR centers, national systems, advanced research institutes, and the private sector have been making uneven and fragmented progress in overcoming these constraints. Fragmentation also describes the components—research, production, and marketing—of the rice sector itself and results in unfocused research, production losses, and market distortions. Little wonder that coherent and comprehensive policies to manage the sector are frequently absent at all levels. Global problems need global solutions, but they must be flexible enough to meet local needs.

Hence, a global effort to increase rice production will require not only new tools, it must also change the practices and mindsets of millions of farmers to accept the challenges in their fields. And, although more than enough commonalities underpin a global program, some needs, opportunities, and priorities differ, as seen above, in the different regions. However, the adoption of rice technologies and approaches may be stalled if the policy environment is unfavorable. Harmonized and enabling rice-related legislation worldwide will be essential if farmers and other rice-sector stakeholders are to take advantage of new and improved production systems adapted to climate change.

Finally, knowledge of such production systems must reach the many, especially poor, producers. This will require increased numbers of knowledgeable extension personnel and information sources to keep them informed. And, because women play large and crucial but often unrecognized roles across the sector, extra efforts are needed to ensure they have the same opportunity as men to access new technologies.

Assessing the expected benefits of GRiSP for the poor and food-insecure

Background. The starting point for determining potential GRiSP contributions is an analysis of global needs for increased rice productivity (summarized above, in the section on "Global and regional rice demand"). In turn, this analysis is based on an assessment of supply and demand forecasts, so as to identify the net yield growth needed to maintain a stable real milled rice price of $300 per ton in international markets—the price prevalent before the recent food crisis. This was identified through IRRI's global rice trade model (described below) to equate to an annual average growth of approximately 60 kg/ha/year.

The next step was to identify what portion of this growth GRiSP could feasibly contribute through globally coordinated R&D investments. Ex post impact assessment studies of rice research provided reference levels for comparison. Evenson (2003) reports a crop genetic improvement contribution to rice yield growth of 0.79% annually and an IARC contribution of 0.31–0.35% annually from 1960 to 1998.[7] Estimates of portions of total rice yield gains attributed to genetic improvement generally have been about 45% in Asia.[8] Note that these estimates do not include the effects of crop management research, but they do include the original replacement of traditional varieties (TVs) by modern varieties (MVs). Looking forward, we expect that crop and resource management research will also make substantial additional contributions to future impact, while genetic improvement will continue to offer gains, albeit perhaps at a slightly lower level than occurred with original MV/TV replacement. Thus, as a plausible conservative estimate, we target that GRiSP will contribute 0.36% annually to future yield growth, including the effects of all research areas, or roughly 25% of the growth required to keep market prices stable at the targeted level. This equates to an annual average net attributable yield increase of 15 kg/ha/year of paddy production.

To further assess whether such a target is feasible, and how it will be achieved through "best-bet" technologies, detailed assessments have been performed for South Asia and sub-Saharan Africa—regions where poverty is most prevalent (see Boxes 1 and 2 as well as Appendix 1 for details).

7 Evenson R. 2003. Production impacts of crop genetic improvement. In: Evenson RE, Gollin D, editors. Crop variety improvement and its effect on productivity: the impact of international agricultural research, CABI.

8 Hossain M, Gollin D, Cabanilla V, Cabrera E, Johnson N, Khush GS, McLaren G. 2003. International research and genetic improvement in rice: evidence from Asia and Latin America. In: Evenson RE, Gollin D, editors. Crop variety improvement and its effect on productivity: the impact of international agricultural research, CABI.

Box 1. Expected GRiSP impacts in South Asia.

As an initial priority assessment effort, a set of yield loss parameters was compiled for rainfed and irrigated environments of South Asia affected by yield reductions and yield limitations. For each constraint, one or more research product solutions have been identified, along with the expected portion of the losses to be averted in the affected areas and on-farm costs associated with adoption. In addition, possibilities to improve yield potential through inbred, hybrid, and C_4 rice were estimated. Adoption has been projected for 2011-35 on the basis of assumptions reflecting research product availability, nature of the technology, target environment, and historical patterns of technology diffusion.

This analysis shows that aggregate discounted gross annual research benefits for the subregion would reach $1.5 billion by 2020 and $5.0 billion by 2035, largely as a result of a $40 million annual investment in GRiSP for South Asia, as well as complementary efforts and investments by national and local partners. Figure 5 provides a breakdown over time by constraint and opportunity addressed. As a result of this increased productivity, there is a 4.5% increase in net rice production by 2020 and a 29.9% increase by 2035.

A conservative estimate of GRiSP's specific contributions to the development and dissemination efforts by others was calculated as the difference between gross annual research benefit flows and scenarios in which those flows are delayed by 5 years in irrigated environments and by 8 years in rainfed environments. This shows that, by 2020, $5.1 billion of discounted attributable benefits will be generated by $400 million of investment, whereas $32.4 billion of discounted attributable benefits will be generated by $1.0 billion in investment by 2035. Productivity growth specifically attributable to GRiSP would be 4.3% by 2020 and 13.6% by the end of the period under these assumptions. Additional details are given in Appendix 1.

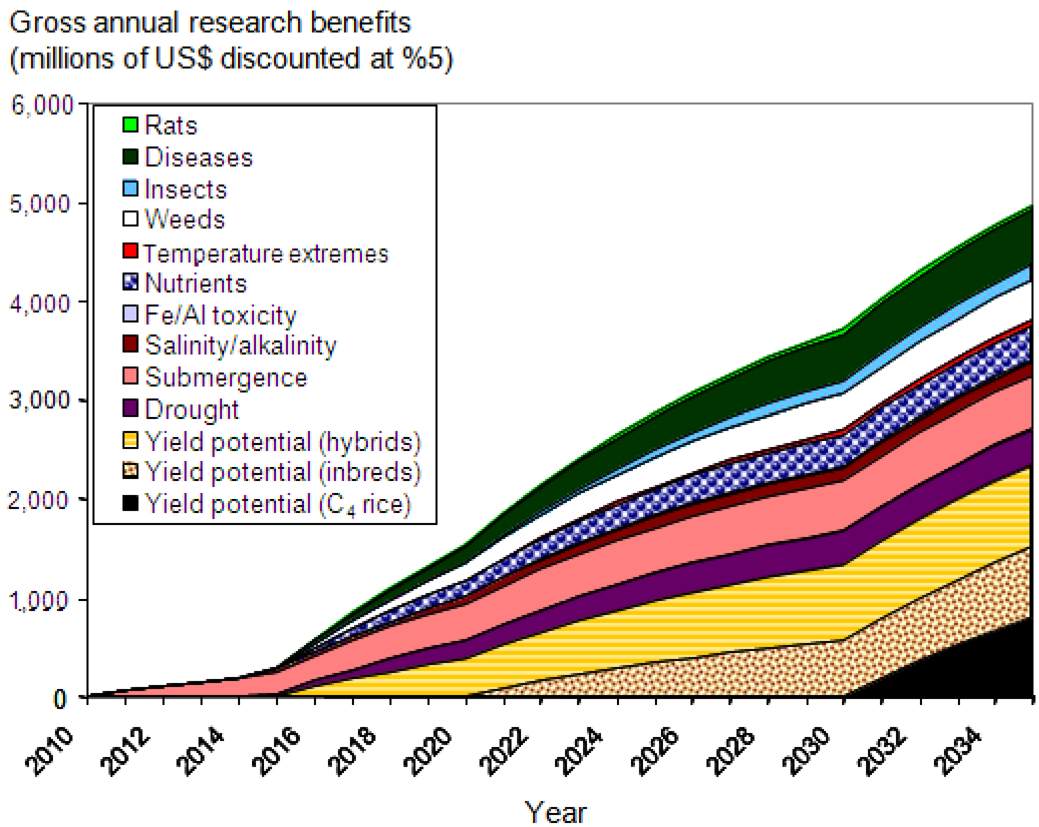

Fig. 5. Attributable gross annual research benefits expected over time from the adoption of GRiSP-developed "best-bet" technologies to address constraints and raise yield potential in Sub-Saharan Africa.

Box 2. Expected GRiSP impacts in Sub-Saharan Africa.
Gross GRiSP research benefits in Africa and expected poverty impacts for rice-producing farmers (as distinct from the analysis of benefits for rice consumers) were assessed for 31 rice-producing countries. Data from farm household surveys conducted in 2007 and 2008 in 12 countries were used. The major stresses found across the countries surveyed were rats/rodents, diseases, insects, weeds, nutrients/soil, flooding, drought, and birds. These constraints were reported by more than 90% of the surveyed farmers. The constraints cause yield losses of up to 35% when experienced. Scientist expert opinion has been used to estimate yield loss reductions expected from GRiSP technologies in the region, as well as initial availability to farmers. Adoption of GRiSP research products is assumed to follow a logistic diffusion curve with different parameters for the eight stresses, with peak adoption rates ranging from 5% for rats/rodents to 45% for diseases.

Autoregressive empirical models of total household annual income and village-level poverty headcount index with the contemporaneous yield losses caused by the eight major stresses as additional explanatory variables were used to assess gross annual research benefits and the number of poor farm household members lifted above the poverty line.

The results show that the aggregate discounted gross annual benefits for adopting rice farmers in the 31 countries reach $159 million by 2020 and $2.6 billion by 2035 (Fig. 6). This corresponds to an aggregate average annual nominal income gain of about $256.4 million per year during 2015 to 2035. The highest impacts are observed for research that addresses yield loss caused by weeds, birds, rats, insects, and lack of nutrients. As a consequence, it is projected that, by 2020, 6.16 million African rice farmers under the PPP $1.25 poverty line will be lifted out of poverty, growing to 14.75 million by 2035. Additional details are given in Appendix 1.

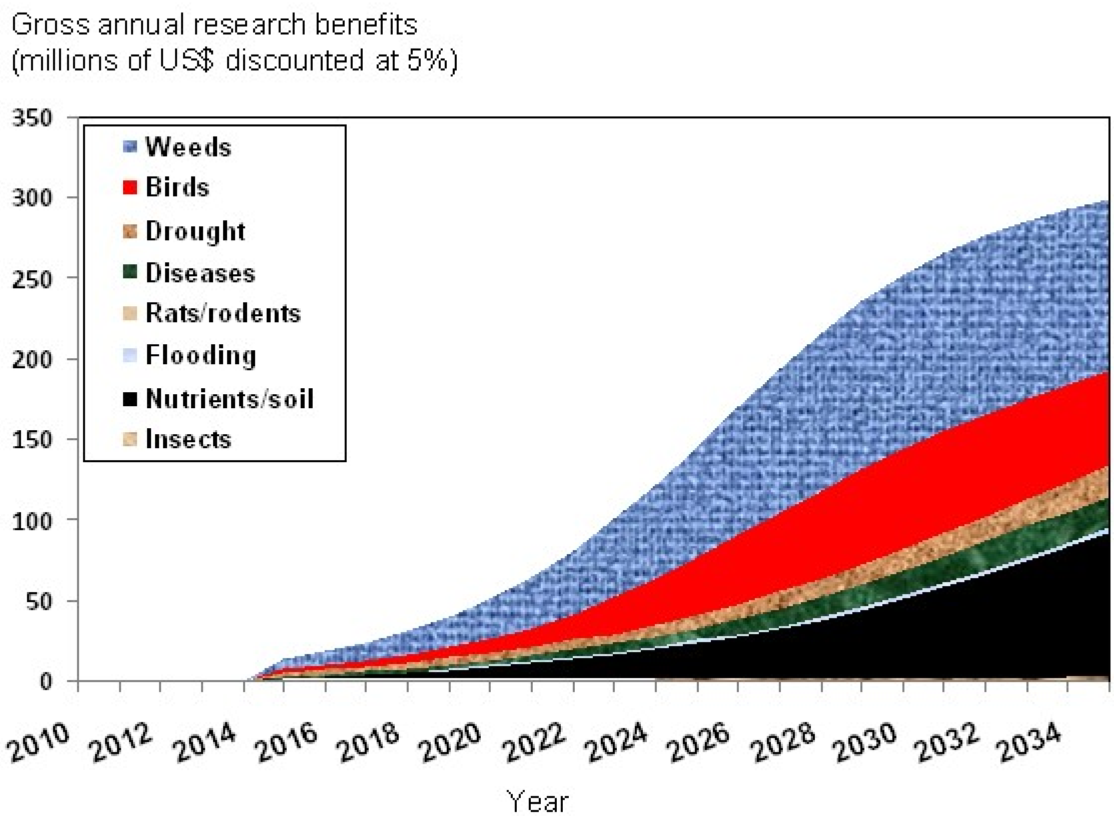

Fig. 6. Attributable gross annual research benefits expected over time from the adoption of GRiSP-developed technologies to reduce yield and efficiency gaps in Sub-Saharan Africa.

Modeling price effects of productivity increases. IRRI's new global rice trade model is a partial equilibrium structural econometric model of the major rice-producing, rice-consuming, and rice-trading countries. The representative country model includes supply, demand, trade, ending stocks, and market equilibrium conditions. Rice production is modeled by estimating separate area and yield equations. The model incorporates the regional supply response of rice and different competing crops in most producing regions to capture climatic differences and regional heterogeneity in the availability of water and other natural resources that influence the mix of crops in various parts of a country. The econometric model was used to develop a baseline projection of supply, demand, and prices for rice under a set of exogenous assumptions. Baseline projections normally assume the continuation of current policies and normal weather. The model uses a forecast of macroeconomic variables such as gross domestic product (GDP), consumer price index (CPI), exchange rate, and population. Once the baseline was developed, the model was then simulated by increasing yield to assess GRiSP contributions.

In sub-Saharan Africa, the consumer benefit calculations included the population of nonrice farmers only as the benefits for rice producers are estimated separately below. For nonrice farmers, the potential impact of GRiSP was estimated under the price effects estimated for five representative African countries (Côte d'Ivoire, Egypt, Kenya, Mozambique, Nigeria), of which four are sub-Saharan, using the IRRI rice trade model. The extrapolation to the other 26 African countries has been on the basis of their subregions (UEMOA countries, ECOWAS, etc.).

Translating price effects into benefits for the poor and food-insecure. This analysis determined how the rice price effects projected from GRiSP's effects on productivity by the global trade model translate into poverty and food security impacts by calculating expenditure savings on rice by poor consumers and the amount of additional caloric consumption enabled for the food-insecure, relative to their caloric insufficiency.

Headcount poverty measures of those living on less than $1.25 (PPP) per day, along with average poverty gaps, were compiled from the World Bank's PovCalNet data resource for Asian countries and for sub-Saharan Africa. Household rice expenditure shares for those under $1.25 per day were calculated from various national expenditure surveys conducted in the mid-2000s, assembled by the World Bank for Asia and the African Development Bank for Africa. Aggregate expenditure savings were converted to additional rice consumption enabled and then to calories to calculate the number of people lifted out of hunger in Asia.

Results in terms of price effects and supply response. National price effects calculated through the model are presented in Table 1. The results suggest that domestic prices in major Asian countries are expected to be on average 6.7% lower than the baseline level by 2020 and 13.1% lower by 2035 if sufficient investments are made in GRiSP. For the four sub-Saharan African countries included in the model, prices are 5.6% to 9.0% lower by 2020 and 9.6% to 17.1% lower by 2035. Lower prices with the GRiSP result in rice area declining by 1.8 million hectares by 2020 and by 5 million hectares by 2035 relative to the baseline scenario.

Results in terms of poverty and food security impacts. Using the national price effects determined through the trade model in the poverty and food security calculations described above yields the estimates of poverty and food security impacts attributable to GRiSP in Tables 1 and 2. As a result of GRiSP, expenditures on rice by those under the $1.25 (PPP) poverty line decline by $4.0 billion annually by 2020 and by $8.4 billion (PPP) by 2035 in Asia (holding consumption constant). Adding those reductions to income means that, by 2020, 64 million Asians are lifted above the $1.25 poverty line, reducing poverty by 7.4%. By 2035, 125 million Asians are lifted above the $1.25 poverty line, thus reducing the overall number of poor by 15%. As a result of increased rice availability and reduced prices, 40 million undernourished Asians can afford to reach caloric sufficiency by 2020 and 62 million by 2035, thus reducing the number of food-insecure by 20%.

Table 1. Benefits to the Asian poor and food-insecure from improvement in rice productivity attributable to GRiSP by 2020 and 2035. (Modeling done by S. Mohanty and D. Raitzer, IRRI; data on food insecurity are from FAO, poverty data are from the World Bank, rice expenditure shares have been provided by O. Dupriez of the World Bank, and price effects have been calculated via IRRI's global rice trade model.)

					Impacts by 2020				Impacts by 2035			
Country	**Number of food insecure (2004-2006)**	**Pop below $1.25 a day (million) (2005)**	**Poverty Gap** (%)	**Pop below $1.25 a day, rice expenditure share (%)[1]**	**Price decline due to productivity gain (from trade model)**	**Reduction in aggregate annual expenditure by those earning less than $1.25 per day (consumption constant; millions of $ PPP)**	**Number of people lifted above the $1.25 PPP poverty line (millions)**	**Number lifted out of hunger (millions of people)**	**Price decline due to productivity gain (from trade model)**	**Reduction in aggregate annual expenditure by those earning less than $1.25 per day (consumption constant; millions of $ PPP)**	**Number of people lifted above the $1.25 PPP poverty line (millions)**	**Number lifted out of hunger (millions of people)**
Cambodia	3.50	5.61	11.32	22.2%	9.40%	47.31	0.46	0.38	15.53%	78.16	0.76	0.50
China-Rural	121.69	198.37	6.46	22.4%	7.38%	1398.39	23.72	12.08	16.64%	3,153.01	53.49	22.03
China-Urban	5.71	9.32	0.45	10.5%	7.38%	32.67	7.96	0.28	16.64%	73.66	9.32	0.51
Indonesia	36.70	21.44	4.56	24.1%	4.87%	109.72	2.64	6.62	9.10%	205.03	4.93	8.13
Lao PDR	1.00	2.02	8.85	40.4%	4.87%	16.53	0.20	0.18	9.10%	30.89	0.38	0.23
Malaysia	ns	0.14	0.06	12.3%	4.87%	0.38	0.14		9.10%	0.71	0.14	
Philippines	12.70	19.13	5.48	20.1%	8.51%	141.36	2.83	0.87	16.67%	276.91	5.54	1.66
Thailand	10.70	0.25	0.03	12.1%	10.42%	1.45	0.25	1.44	17.48%	2.42	0.25	1.87
Vietnam	11.20	18.96	4.85	24.4%	10.78%	216.58	4.89	1.49	17.69%	355.41	8.03	1.71
Bangladesh	40.20	77.36	14.17	26.2%	7.07%	562.19	4.35	4.67	13.22%	1,051.23	8.13	7.74
Bhutan	na	0.17	7.22	13.1%	5.44%	0.52	0.01		11.39%	1.09	0.02	
India-Rural	189.19	342.88	10.66	15.5%	5.44%	1179.08	12.12	8.96	11.39%	2,468.69	25.38	13.55
India-Urban	62.31	112.92	10.16	8.7%	5.44%	218.51	2.36	1.66	11.39%	457.50	4.93	2.51
Nepal	4.20	14.82	19.45	21.3%	5.44%	63.03	0.36	0.32	11.39%	131.97	0.74	0.49
Pakistan	36.50	35.19	4.35	2.9%	7.66%	33.64	0.85	0.48	17.82%	78.26	1.97	1.06
Sri Lanka	4.10	2.03	1.78	20.7%	5.44%	10.27	0.63	0.31	11.39%	21.50	1.32	0.47
Total	**539.70**	**860.60**				**4,031.63**	**63.76**	**39.74**		**8,386.44**	**125.33**	**62.46**

In sub-Saharan Africa, as a result of the availability of GRiSP research, annual expenditures on rice by nonrice farmers under the $1.25 (PPP) poverty line will decline in Africa by $870 million (PPP) by 2020 and by $2.6 billion (PPP) by 2035 (holding consumption constant). Adding those reductions to income means that 8.4 million and 24.6 million African nonrice farmers will be lifted above the $1.25 poverty line in 2020 and 2035, respectively.

Note that these estimates can be considered conservative, as they do not include producer benefits and they omit Latin America, where rice consumption is highest in the countries with the greatest poverty. These preliminary results are meant to illustrate the potential impact of GRiSP and how it can be assessed. The strategic assessment team in GRiSP is currently conducting a detailed systematic, quantitative analysis of production constraints, impact of technology options, and R&D priorities for rice under Product Line 5.4.

Table 2. Benefits to African poor rice consumers (nonrice farmers, NRF) from improvement in rice productivity attributable to GRiSP by 2020 and 2035. (Modeling done by Aliou Diagne and Didier Alia, poverty data are from the World Bank, rice expenditure shares have been provided by the African Development Bank, and indicative price effects have been calculated via IRRI's global rice trade model and extrapolated to similar countries.)

		Impacts by 2020				Impacts by 2035			
Country	**Pop. below $1.25 a day, rice expenditure share**	**Nonrice pop. below $1.25 a day (by 2020, million)**	**Price decline due to productivity gain (extra-polated from trade model)**	**Reduction in aggregate annual expenditure by NRF earning less than $1.25 per day (consumption constant, millions of $ PPP)**	**Number of NRF lifted above the $1.25 PPP poverty line**	**Nonrice pop. below $1.25 a day (by 2035, million)**	**Price decline due to productivity gain (extra-polated from trade model)**	**Reduction in aggregate annual expenditure by NRF earning less than $1.25 per day (consumption constant, millions of $ PPP)**	**Number of NRF lifted above the $1.25 PPP poverty line**
Benin	3.0%	6.2	8.13%	5.9	0.08	11.6	13.70%	18.3	0.24
Burk. Faso	9.1%	11.2	8.13%	30.4	0.34	20.7	13.70%	94.6	1.07
Cameroon	2.9%	6.1	6.88%	5.1	0.14	8.7	12.39%	13.0	0.36
CAR	6.9%	3.0	6.88%	4.6	0.03	3.9	12.39%	10.7	0.08
Chad	4.5%	8.8	6.88%	9.4	0.09	16.3	12.39%	31.5	0.29
Comoros	26.0%	0.2	8.99%	1.7	0.02	0.3	17.09%	4.9	0.05
Congo, DR	3.7%	48.7	6.88%	42.8	0.37	87.9	12.39%	139.0	1.20
Congo, Rep.	5.3%	3.0	6.88%	3.9	0.04	5.3	12.39%	12.4	0.12
Côte d'Ivoire	8.2%	3.3	8.13%	9.4	0.36	4.5	13.70%	21.5	0.82
Ethiopia	0.1%	38.5	6.45%	0.6	0.01	55.3	9.58%	1.4	0.03
Gabon	6.8%	0.1	6.88%	0.2	0.04	0.1	12.39%	0.4	0.10
Gambia	16.7%	0.5	8.13%	3.0	0.06	0.9	13.70%	8.5	0.18
Ghana	6.5%	8.7	8.13%	18.8	0.39	13.0	13.70%	47.6	0.99
Guinea-B.	21.3%	0.3	8.13%	2.1	0.03	0.5	13.70%	5.4	0.09
Guinea	25.9%	5.2	8.13%	33.7	0.23	9.3	13.70%	102.3	0.70
Kenya	2.1%	9.8	6.45%	5.6	0.20	15.6	9.58%	13.2	0.47
Liberia	23.6%	1.5	8.13%	7.5	0.04	2.0	13.70%	16.4	0.08
Madagascar	51.5%	11.4	8.99%	177.4	1.47	19.4	17.09%	573.0	4.74
Malawi	0.1%	12.2	8.99%	0.4	0.00	18.8	17.09%	1.2	0.01
Mali	25.1%	3.6	8.13%	27.0	0.32	6.4	13.70%	81.6	0.95
Mauritania	6.8%	0.5	8.13%	1.3	0.09	0.9	13.70%	3.8	0.28
Mozambique	7.7%	17.1	8.99%	37.7	0.28	24.7	17.09%	104.1	0.76
Niger	9.8%	14.0	8.13%	36.5	0.29	26.9	13.70%	118.8	0.93
Nigeria	14.4%	111.3	5.62%	295.9	2.30	170.9	11.07%	895.0	6.96
Rwanda	3.3%	8.7	6.88%	5.8	0.04	12.3	12.39%	14.7	0.09
Senegal	16.9%	5.1	8.13%	28.8	0.58	8.2	13.70%	77.4	1.57
Sierra Leone	30.4%	0.1	8.13%	0.8	0.01	0.2	13.70%	2.8	0.03
Swaziland	2.3%	0.8	8.99%	0.5	0.00	1.0	17.09%	1.2	0.01
Tanzania	9.8%	34.2	6.45%	59.8	0.33	49.3	9.58%	128.2	0.72
Togo	2.7%	3.2	8.13%	2.9	0.06	5.4	13.70%	8.2	0.16
Uganda	2.6%	24.4	6.45%	15.3	0.18	48.8	9.58%	45.3	0.52
Total		**401.8**		**874.8**	**8.4**	**649.0**		**2596.2**	**24.6**

Assessing GRiSP benefits for the global climate. Improved sustainability is an essential goal of the GRiSP. As one aspect of this, climate change mitigation is an important expected environmental impact of a wide array of GRiSP activities, from rice with reduced cooking time, to management methods that reduce greenhouse gas emissions, more efficient use of fertilizers and intensified production. For illustrative purposes, we illustrate how GRiSP can mitigate the emissions equivalent of about 1 billion tons of carbon dioxide, focusing only on two GRiSP contributions to the mitigation of greenhouse gas emissions: 1) the expected reduction in methane emissions associated with the diffusion of "smart" alternate wetting and drying (AWD, Box 3); and 2) reduced deforestation as a product of the contraction in rice area driven by the decline in rice prices attributable to GRiSP induced supply shifts (Box 4). It should be noted that these only comprise a subset of potential GRiSP climate benefits. A wider array of expected GRiSP environmental impacts, including these other climate effects is being assessed as part of the priority assessment analysis under Product Line 5.4.

Box 3. Smart AWD and reduced methane emissions

Adoption of AWD (pioneered by IRRI from 1989 onwards) was estimated for the dry season of irrigated ecologies for the period 2011 to 2035. Total likely adoption is estimated to reach 7.5 million hectares by 2020 and 32 million hectares by 2035. For each hectare of adoption, current methane emissions and reductions in emissions associated with intermittent aeration have been calculated in accordance with the IPCC Guidelines for National Greenhouse Gas Inventories. For this ecology, the current methane emissions equate to 5 tons per hectare of CO_2 equivalents, while the "scaling factor" for "intermittently flooded – multiple aeration" reflects a 48% net reduction in such emissions in irrigated environments[9]. To be conservative, the analysis reduces this by 20% to reflect the offset of increased N_2O emissions associated with AWD under imperfect nutrient management[10]. This yields an emissions reduction of 1.92 tons of CO_2 equivalent per ha of AWD adoption, or a reduction of 60.8 million tons annually at 2035 adoption levels. If the adoption curve is linear from 2011 to 2020 and from 2020 to 2035, 87.7 million cumulative tons of CO_2 equivalent emissions are avoided by 2020 and 675 million tons are avoided by 2035. At a CO_2 value of $15 per ton[11], this equates to $1.32 billion of climate benefits by 2020 and $10.1 billion by 2035.

Box 4. Averted conversion of natural ecosystems as a result of reduced rice area

Productivity enhancing GRiSP technologies reduce the unit cost of rice production, leading to a "supply shift", which reduces equilibrium market prices for rice. The reduced rice price reduces the profitability of cultivation in marginal areas, which have less productivity potential, and, accordingly, less absolute opportunity for gain from productivity enhancing technologies. As a result, expansion into these areas is avoided, as the returns to rice cultivation fall below the opportunity cost of labor, reducing demand for agricultural land and agricultural incursion into remaining natural ecosystems.

Through IRRI's global rice trade model, the area decline stemming from the rice price decline attributable to GRiSP has been estimated to reach 1.8 million hectares by 2020 and 5.00 million hectares by 2035. This analysis makes the simple assumption that the reduced land pressure has equal propensity to affect all forms of land use. Thus, the proportion of this averted expansion that translates into averted deforestation is assumed to be equal to the proportion of forest cover in a particular country. Using this approach, 491,000 hectares of deforestation is averted by 2020, and 1,202,000 hectares is averted by 2035.

From a climate change perspective, deforestation for annual crop production leads to the eventual emissions of carbon stored in the forest's above ground vegetative biomass. More than 75% of the estimated averted deforestation takes place in Southeast Asia, which is dominated by tropical rainforest (reference aboveground IPCC biomass values of 280-350 tons/ha) and tropical moist deciduous forest (reference values of 180-290 tons/ha), so an average value of 250 tons of biomass per forest ha is utilized[12]. As this is 47% carbon, this equates to 431 tons of avoided CO_2 equivalent emissions per hectare of avoided deforestation. Considering the total deforestation avoided by 2020, this equates to 212 million tons of avoided CO_2 emissions, and 518 million tons by 2035, valued at $3.18 billion and $7.77 billion, respectively.

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9. Lasco, R.D., Ogle, S., Raison, J., Verchot, Wassman, R., Yagi, K., Bhattacharya. S., Brenner, J.S., Daka, J.P., Gonzalez, S.P., Krug, T., Li, Y., Martino, D., McConkey, B.G. Smith, P., Tyler, S.C., and Zhakata, W. 2007. Chapter 5 Cropland. Volume 4: Agriculture, Forestry and Other Land Use. IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. Geneva, Switzerland.

10 Akiyama, H., Yagi, K. and Yan, X. (2005) Direct N_2O emissions from rice paddy fields: summary of available data. Global Biogeochemical Cycles 19, GB1005.

11 As of August 2010, CER prices are approximately $17/t CO_2 equivalent.

12 Aalde, H., Gonzalez, P., Gytarsky, M., Krug, T., Kurz, W.A., Ogle, S., Raison, J., Schoene, D., Ravindranath, N.H., Elhassan, N.G., Heath, L.S., Higuchi, N., Kainja, S., Matsumoto, M., Sanchez, M.J.S., and Somogyi, Z. 2007. Chapter 4 Forest Land. Volume 4: Agriculture, Forestry and Other Land Use. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. Geneva, Switzerland.

Summary of potential key impacts. Based on these preliminary analyses of a subset of expected GRiSP benefits, the following key impacts are forecast from the GRiSP:

By 2020:

- Expenditures on rice by those under the $1.25 (PPP) poverty line will decline by PPP $4.9 billion annually (holding consumption constant).
- Counting those reductions as income gains means that 72.2 million people would be lifted above the $1.25 poverty line, reducing the global number of poor by 5%.
- As a result of increased availability and reduced prices, 40 million undernourished people would reach caloric sufficiency in Asia, reducing hunger in the region by 7%.
- Approximately 275 million tons of CO_2 equivalent emissions will be averted.

By 2035:

- Expenditures on rice by those under the $1.25 (PPP) poverty line would decline by PPP $11.0 billion annually (holding consumption constant).
- Counting those reductions as income gains means that 150 million people would be lifted above the $1.25 poverty line, reducing the global number of poor by 11%.
- As a result of increased availability and reduced prices, 62 million undernourished people would reach caloric sufficiency in Asia, reducing hunger in theregion by 12%.
- Nearly 1 billion tons of CO_2 equivalent emissions will be averted.

These are impressive numbers, considering that they arise from an aggregate global 25-year inflation-adjusted investment of roughly $3.0 billion, or $20 per person lifted above the poverty line. Even in CO_2 terms alone, the price per ton of averted emissions ($3) is but a tiny fraction of market prices. Very few other development investments have similar efficacy in poverty eradication and environmental protection. These preliminary results are meant to illustrate the potential impact of GRiSP and how it can be assessed. The strategic assessment team in GRiSP is currently conducting a detailed systematic, quantitative analysis of production constraints, impact of technology options and R&D priorities for rice under Product Line 5.4.

Opportunities for a new global strategy

Gaps between yields currently obtained by farmers and what could be achieved with improved management and varieties are still large, certainly in Africa, but also in Asia and Latin America. Postharvest losses may be as high as 20–30%. Efficiencies of nitrogen fertilizer or water remain 30–50% below levels that can be achieved with good management. Hence, closing yield and efficiency gaps, reducing postharvest losses, and adding more value to cropping or farming systems constitute clear opportunities to enhance rice production, increase farmers' income, and do good for the environment. These "quick wins" will require mostly applied research based on solid partnerships at the grass-roots level to adapt prototype technologies to local settings and gender concerns. South-south knowledge exchange between the three regions involved in GRiSP will be facilitated to help identify such opportunities.

Nearly all rice farmers worldwide depend on rice varieties that have been improved by scientific breeding since the Green Revolution. Rice breeding is a slow process, but new technologies have cut the time needed to test and validate new varieties by about 30%, and this trend is likely to continue to reduce the time from trait identification to varietal transfer. Scientific advances in genomics and marker-assisted breeding mean that genebank materials can be explored on a large scale to identify and embed the genes responsible for ever more complicated target traits. Transgenic technologies offer the potential to engineer new plants that were previously unthinkable, such as rice using a new photosynthetic pathway. Meanwhile, improvements in sensors, processing, communications, and possibly nanotechnology offer the potential to revolutionize how field experiments are conducted, and can enable a precision-agriculture revolution in input-use efficiencies. Hence, investments are needed now to also address the "best-bet" technologies needed 10 and 20 years from today (Fig. 7). New information and communication technologies have made the time ripe for maximum exploitation of the economies of scale possible in rice research.

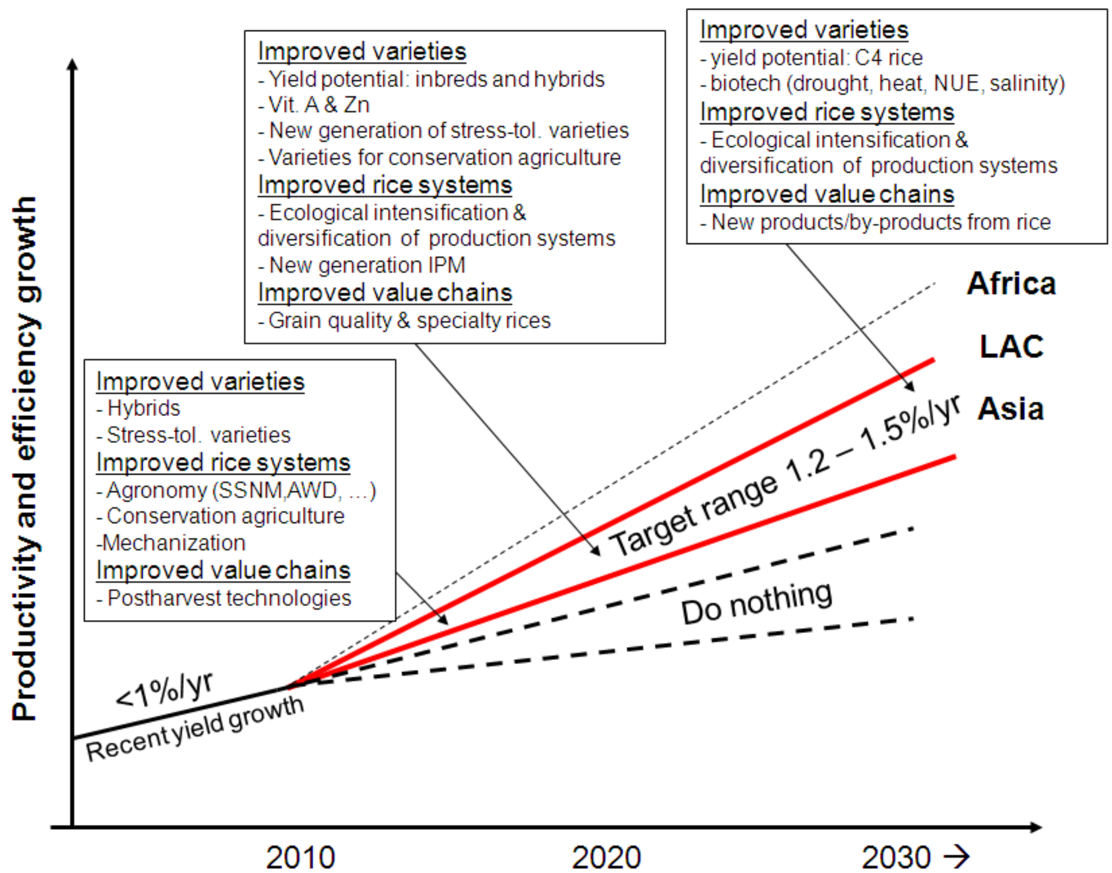


Fig. 7. Pipeline of anticipated "best-bet" technologies addressed in GRiSP as key entry points for increasing the productivity, resource efficiency, resilience and environmental sustainability of rice-based systems.

Specific advantages of a new, globally aligned and coordinated research effort include

- An interdisciplinary approach to global rice research and development from genes to policies and across the value chain to address critical regional development challenges;
- More room for joint discovery research that can lead to future new impact;
- Greater ability to align CGIAR research with that of other major players working on rice, involving strong national research systems (e.g., Japan, China, India, Brazil) and related international research organizations, such as Cirad, IRD, and JIRCAS, that constitute a powerful voice to influence global rice policies;
- More synergy through common research themes, thus avoiding duplication and redundancy; streamlining of center research by allowing centers to reliably shift components to partners for which they, individually, do not have the critical mass;

- More efficient flow of information, communications, and cross-learning from the experiences of different geographical regions;
- A unified global rice platform with a greater potential to influence global funding for rice research;
- A single line of reporting to donors, resulting in greater visibility and ease of monitoring and evaluation; and
- Clear focus on an area of research with extremely high impact potential and a documented record of benefits.

The time for fragmented, uncoordinated efforts to increase world rice production and improve the sustainability and resilience of rice ecosystems has passed. Individual efforts of the many research, development, and extension organizations that are attempting to redress this situation are critical but insufficient. Fortunately, advances in science, technology, and communications in very recent years have opened up new opportunities to speed up rice production growth to the needed extent by enabling radical improvements in the way rice farming is carried out and in the rice plant itself. A Global Rice Science Partnership that takes full advantage of new scientific, technological, and communication advances, primarily for the benefit of poor rice producers and consumers, is urgently needed.

GRiSP: an evolving global partnership

For several years, the three CGIAR centers involved in rice research for development, IRRI, AfricaRice, and CIAT, have actively looked for ways to align their rice research programs, at first focusing on sub-Saharan Africa. AfricaRice and IRRI launched a joint Eastern and Southern Africa Rice Program (ESARP) during the Annual General Meeting (AGM) of the CGIAR in December 2008. It was at that time and within the context of the CGIAR change process that thinking evolved toward the development of a truly global rice R&D program, a partnership that would go beyond “just” enhanced collaboration among the three CGIAR centers. Such a global partnership would enable greatly enhanced efficiency and impact of rice R&D worldwide by combining expertise, avoiding duplication, addressing the lack of critical mass, and resulting in economies of scale and cross-learning between and within regions. The first sketch of the Global Rice Science Partnership (GRiSP) was therefore developed shortly afterward.

Over the next one and a half years, numerous consultations and meetings have taken place and feedback has been collected from many organizations, including farmer associations, NGOs, NARES, regional and subregional research organizations, the private sector, and regional economic communities involved in rice research and development worldwide, on the overall vision and strategy for GRiSP. A first draft of a GRiSP vision and strategy was developed in May 2009 and shared widely. During the remainder of 2009, the concept was discussed with major regional fora and research partners worldwide, who provided strong endorsement as well as important feedback. Early in 2010, three other institutions with an international mandate and with substantial rice research activities in Africa, Asia, and Latin America joined the three CGIAR centers as the main architects of GRiSP: JIRCAS, Cirad, and IRD. Further discussions were held with key stakeholders in Africa during the Africa Rice Congress in Bamako and during GCARD in Montpellier in March 2010.

The first full GRiSP work plan and proposal was submitted to the Consortium Board in May 2010. In the months thereafter further consultations took place with a number of key partner countries, including India, China, Japan and Brazil, and major revisions were made in response to receiving feedback from the Consortium Board, the ISPC, donors and partners.

The current work plan combines the rice research programs of IRRI, AfricaRice, CIAT, Cirad, IRD and JIRCAS, linking about 900 rice research and development partners worldwide. It is important to realize that GRiSP is an ‘open’ partnership. GRiSP objectives, products and milestones and the roles of different partners will evolve over time. It is anticipated, for example, that strong national systems will increasingly take on a lead role in the development and diffusion of GRiSP products. Likewise, GRiSP will seek to expand its partnerships with Civil Society Organizations (CSO), both in terms of priority setting and cooperating at the grassroot level.

Progress made will be rigorously evaluated and future plans will be adjusted accordingly. For that reasons, a first strategic assessment of rice research priorities, using a transparent, quantitative, evidence-based methodology, was already started for Asia and Africa, with first results to become available in late 2010. This exercise will be expanded to the LAC region in 2011. Results will be utilized to further inform all stakeholders in GRiSP and adjust GRiSP R&D priorities over time.

In summary, through a continuing process of strategic assessment and consultations with our partners, research themes, approaches and partnerships in GRiSP will evolve. Our vision for GRiSP is that of a dynamic umbrella mechanism, seeking to align strategic partners toward a harmonized global rice research strategy that aims to maximize research efficiency and impact to the benefit of poor rice producers and consumers world-wide.

Vision of Success and Objectives

The Global Rice Science Partnership (GRiSP), led by IRRI, AfricaRice, and CIAT in collaboration with CIRAD, IRD, JIRCAS, and 900 research and development partners worldwide, is proposed as a CGIAR Research Program to answer a specific pressing need: to increase the production, value, and quality of rice and rice products worldwide, while ensuring a healthy rice production environment for future generations.

GRiSP’s mission, in accordance with that of the CGIAR, is *to reduce poverty and hunger, improve human health and nutrition, reduce the environmental footprint, and enhance the ecosystem resilience of rice production systems through high-quality international rice research, partnership, and leadership*.

The partnership’s vision of success reflects the three CGIAR system-level outcomes:

Lifting productivity and reducing poverty. By 2020, adoption rates of the latest input-efficient, stress-tolerant, higher-yielding, and enhanced-quality rice varieties will have accelerated. Rice will have become a much better engine for economic growth and employment through better integration of rice production, processing, and marketing, thus significantly adding value, reducing rural poverty, and enhancing livelihoods, particularly in sub-Saharan Africa and South Asia.

As a result, global average rice yield will rise to at least 60 kilograms of paddy rice per hectare per year through 2035, as a result of increased productivity of the world’s rice land and reinforced by reduced postharvest losses. At least 25% of this increase is directly attributable to faster availability of better technologies, production methods, and policy improvements, as a result of GRiSP. As a consequence, by 2020, rice prices paid by the urban and rural poor will be at least 6% lower than without investing in GRiSP, saving approximately PPP $5 billion in annual expenditures by those under the $1.25 per day poverty line, and lifting at least 70 million people above that poverty line. By 2035, these expenditure savings grow to $11 billion annually, with 150 million people lifted out of PPP $1.25 per day poverty.

Hunger reduction and improved nutrition. By 2020, rice production will consistently meet demand as the world will be able to sustainably supply 85 million additional tons of paddy, leading to price reductions that can enable 40 million hungry people to attain caloric sufficiency.

By 2035, the world will be capable of producing an additional 170 million tons compared with 2010, matching the projected total demand of around 830 million tons of paddy. Africa, where demand growth is highest, will be able to feed itself in terms of rice production. As a result of GRiSP's contributions to increased supplies and reduced rice prices, at least 60 million undernourished people can afford to reach caloric sufficiency, thus reducing hunger by more than 12% in target regions. A significant proportion of world rice production will better meet local food preferences. Nutritional enhancement will save millions of disability-adjusted life years, formerly lost because of vitamin A, iron, and zinc micronutrient deficiencies.

Sustainability and resource efficiency. By 2020, the vast majority of the genetic diversity of rice species will have been collected, preserved, and characterized, and genomes of the world's key collections of rice genetic resources will be available to all. The price effects of increased productivity will reduce the threat of conversion of natural ecosystems into riceland. In Africa, enhanced rice yields in mixed cropping systems under rainfed upland conditions will have stabilized or even reduced the use of fragile uplands for slash-and-burn agriculture for annual crops, in favor of more productive lowlands.

Rice-based cropping systems will be sustainable and will operate with greater farming efficiency, while maintaining ecosystem services. These systems will have essentially been climate-proofed, showing resilience to climatic extremes and gradual change in the world's climate. Water, nitrogen, and labor efficiencies in rice systems will start to be improved on a wide scale, saving 7 billion cubic meters of irrigation water annually by 2020. Nearly 300 million tons of carbon dioxide equivalent greenhouse gas emissions will have been avoided due to these changes in irrigation and reduced rice area.

By 2035, input efficiencies will have grown by at least 30% in key high-input rice-growing areas of Africa, Asia, and Latin America, annually saving at least 4 million tons of nitrogen fertilizer and 30 billion cubic meters of irrigation water. By 2035, rice area will be 5 million hectares less than without GRiSP, saving more than a million hectares of natural forests from clearance. As a result of the combined effects of better water management and averted deforestation, about 1 billion tons of carbon dioxide equivalent greenhouse gas emissions will have been averted.

Capacity building and partnerships. A new generation of rice professionals, at least 30% of them women, will have been trained to be capable of leading the development of the world's rice sector. Capacity-building efforts will also have greatly enlarged the numbers of extension personnel who effectively engage female farmers to extend appropriate practices for increasing rice productivity and production sustainably. Public-private partnerships will have become a key component of rice sector development by both contributing to stable funding for rice research and providing a multitude of improved and self-sustained technology development, adaptation, and diffusion mechanisms for continued growth. Improved partnerships are built and nurtured among rice development stakeholders, in particular farmer organizations, and research and extension communities facilitating research feedback, participatory learning and action research, rapid and equitable out-scaling of rice knowledge and technologies, and quality feedback to research.

To achieve this vision of success, GRiSP has three main objectives, aligned with the CGIAR strategic objectives (food for people, environment for people, and policy for people):

Objective 1: Increase rice productivity and value for the poor in the context of a changing climate through accelerated demand-driven development of improved varieties and other technologies along the value chain (addressed through themes 1, 2, 3, 4, and 6).

Objective 2: To foster more sustainable rice-based production systems that use natural resources more efficiently, are adapted to climate change and are ecologically resilient, and have reduced environmental externalities (addressed through themes 3, 4, and 6).

Objective 3: To improve the efficiency and equity of the rice sector through better and more accessible information, improved agricultural development and research policies, and strengthened delivery mechanisms (addressed through themes 5 and 6).

These objectives will be achieved through a set of six interconnected research and development themes. The six themes are described below in the section on Program Design.

Program Design

Global rice environments

Rice is grown in more than a hundred countries, with a total harvested area of approximately 158 million hectares, producing more than 700 million tons annually (470 million tons of milled rice). About 90% of the rice in the world is grown in Asia (nearly 640 million tons). Sub-Saharan Africa produces about 19 million tons and Latin America some 25 million tons. In Asia and sub-Saharan Africa, almost all rice is grown on small farms of 0.5- 3 ha. Yields range from less than 1 ton per hectare under very poor rainfed conditions to more than 10 t/ha in intensive temperate irrigated systems. Small, and in many areas shrinking, farm sizes account for the low incomes of rice farm families. Rice grows in a wide range of environments and is productive in many situations where other crops would fail. Most classifications of rice environments are based on hydrological characteristics. Figure 8 shows the global distribution of irrigated and rainfed rice environments.

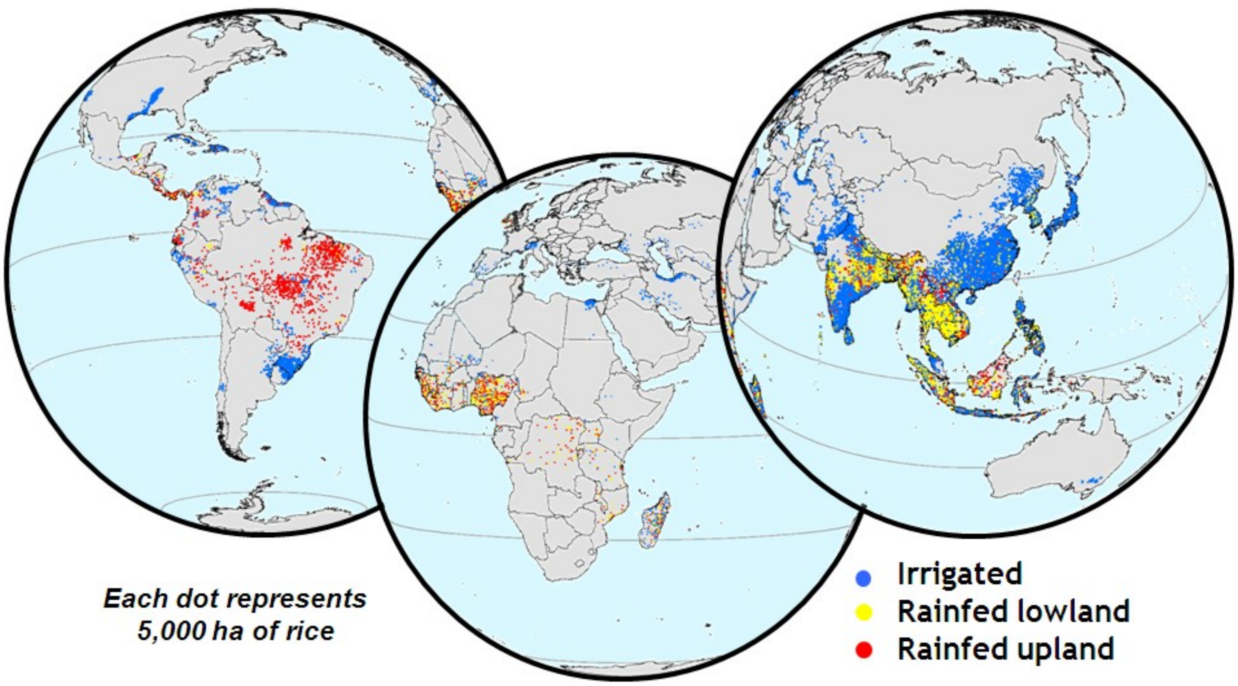


Fig. 8. Major global rice growing areas and ecosystems.

Irrigated rice environments. Worldwide, about 80 million ha of irrigated lowland rice provide 75% of the world's rice production. These systems remain the most important rice production systems for food security, particularly in Asian countries. Irrigated rice is grown in bunded fields with ensured irrigation for one or more crops a year. Farmers generally try to maintain 5–10 centimeters (cm) of water ("floodwater") on the field. By and large, irrigated rice farms are small, with the majority in the 0.5 to 2 ha range. In many humid tropical and subtropical areas, irrigated rice is grown as a monoculture with two or even three crops a year. Significant areas of irrigated rice are also grown in rotation with a range of other crops, including about 20 million ha of rice-wheat systems. Irrigated rice receives about 40% of the world's irrigation water and 30% of the world's developed freshwater resources. At present, average irrigated yields are about 5.4 t/ha. In temperate climatic regions, a single irrigated rice crop is grown per year, with high yield that can reach 8–10 t/ha or more.

Rainfed lowland environments. Rainfed lowland rice is grown in bunded fields that are flooded with rainwater for at least part of the cropping season. About 60 million ha of rainfed lowlands supply about 20% of the world's rice production. Rainfed rice environments experience multiple abiotic stresses and high uncertainty in timing, duration, and intensity of rainfall. Some 27 million ha of rainfed rice are frequently affected by drought. Up to 20 million ha may suffer from uncontrolled flooding, ranging from flash floods of relatively short duration to deepwater areas that may be submerged under more than 100 cm of water for a few months. Deepwater rice and floating rice are found in flood-prone environments, where the fields suffer periodically from such excess water. Further constraints arise from the widespread incidence of problem soils with poor physical and chemical properties. Salinity is widespread in coastal areas. Rainfed lowland rice predominates in areas of greatest poverty: South Asia, parts of Southeast Asia, and essentially all of Africa. Because the environments are so difficult and yields so unreliable, farmers rarely apply fertilizer and tend to not grow improved varieties. Thus, yields are very low (1–2.5 t/ha) and farm families remain trapped in poverty.

Rainfed upland environments. Upland rice is grown under dryland conditions in mixed farming systems without irrigation and without puddling. It covers about 14 million ha but, because of many constraints that cause low yields (typically only about 1 t/ha), it contributes only 4% of the world's total rice production. Upland environments are highly heterogeneous, with climates ranging from humid to subhumid, soils from relatively fertile to highly infertile, and topography from flat to steeply sloping. With low population density and limited market access, shifting cultivation with long (more than 15 years) fallow periods was historically the dominant land-use system. Some 70% of Asia's upland rice areas have made the transition to permanent systems where rice is grown every year and is closely integrated with other crops and livestock. In Central and West Africa, the rice belt of Africa, upland areas represent about 40% of the area under rice cultivation and employ about 70% of the region's rice farmers. As market access remains limited, most of the world's upland rice farmers tend to be self-sufficient by producing a range of agricultural outputs. Poverty is widespread in these upland areas.

Research strategy and themes

Product-oriented production systems approach. Through a wide range of research and development partnerships, GRiSP aims to become a global, demand-driven R&D program in which the primary emphasis is on improving rice-based production systems and value chains. Tomorrow's rice plants and management practices will be different than today's. Traditional rice systems with large water consumption will be made more eco-efficient. Where possible, such systems will change and diversify through the widespread adoption of mechanized, resource-conserving technologies aimed at reducing tillage and saving water and labor. Ecologically sound, precision management principles will accompany the further intensification and diversification of rice systems, particularly with regard to fertilizer and pesticide management. In Africa and Latin America, where there is still more land and water available for growing rice and other crops, efforts to expand both area and yield growth rates must focus on sustainable management solutions. Across the world, rice fields will have to tolerate extremes of temperature, both high and low, droughts, floods, and salinity. The delta regions, from which much recent gain in production comes, will be particularly susceptible to sea-level rise and stronger tropical storms. The future rice systems will also contribute less to global greenhouse gas emissions.

The key entry points for achieving the GRiSP mission lie in lifting the productivity, resource efficiency, and resilience of rice production systems to unprecedented levels. This will enable farmers to enter a virtuous circle, allowing them to also invest more in diversification and sustainable, eco-efficient management (Fig. 9).

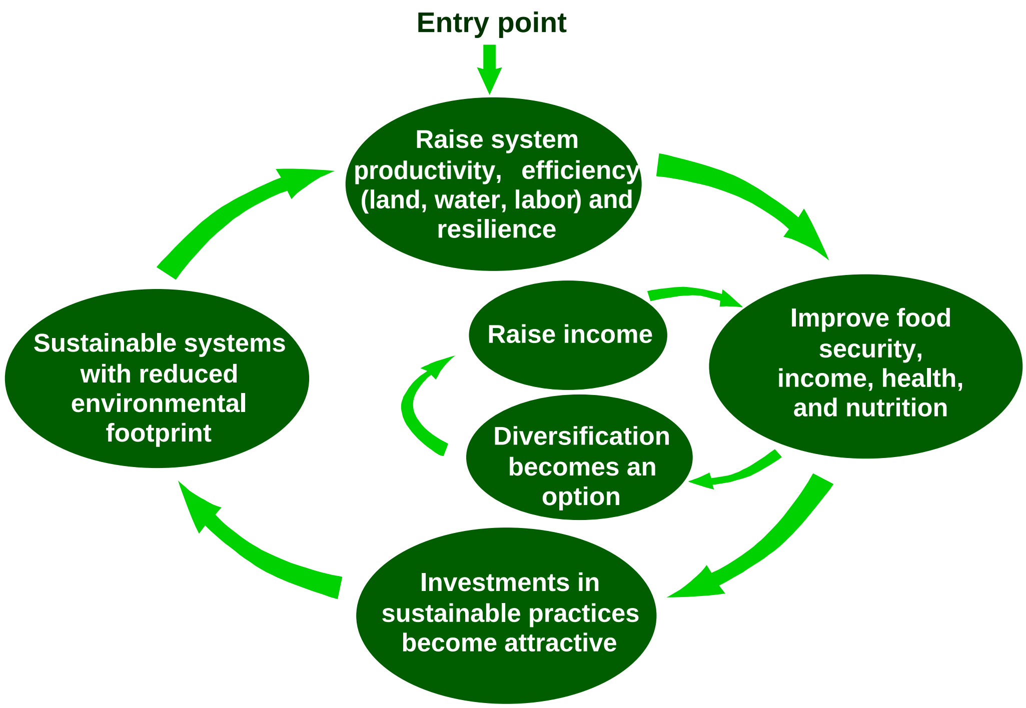


Fig. 9. GRiSP focuses on enhancing productivity, resource efficiency and resilience of rice-based production systems as the key entry point for enabling farmers to enter a virtuous circle of sustainable production and living.

Production systems and value chains will form the overarching organizing principle of the partnership. Research in GRiSP is based on a clear understanding of regional and subregional development challenges, farmers' needs, and thus priorities for research. GRiSP will have an initial 10-year (2011 to 2020) evidence-based strategic plan and road map. Research will use an interdisciplinary approach based on understanding of the different environments, management systems, and socioeconomic market segments targeted. On the one hand, this will need a broad range of scientific, or upstream, partners to seek out innovations and, on the other hand, many partnerships at the grass-roots level for both dissemination and feedback. The result will be accelerated development of international public goods across the entire rice sector.

At the core of the GRiSP strategy is a thorough understanding of the specific target environments for each product, in terms of both socioeconomic and biophysical factors that drive what farmers, agribusinesses, small entrepreneurs, consumers, and many other actors in the value chain need from research. Hence, socioeconomic research and evidence-based ex ante assessment and priority setting provide the basis for targeting of R&D activities in GRiSP (Fig. 10).

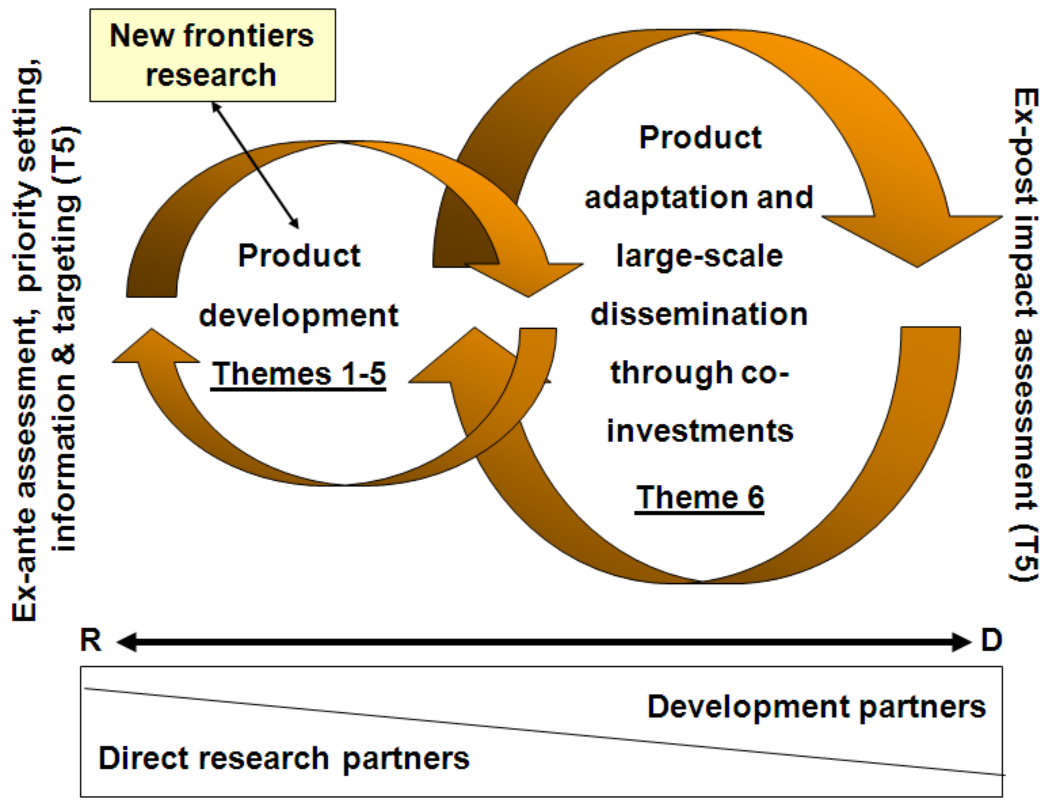


Fig. 10. Overall R&D strategy employed in GRiSP and the interlinked roles of research and development partners in product development and dissemination.

Based on these considerations, and for efficient management of demand-driven R&D processes in a global and regional context, GRiSP will be implemented through (Fig. 10)

- Six interlinked **global R&D themes**.
- An initial set of 26 **global and regional R&D product lines** (3–6 product lines per theme), that is, families of products or deliverables that provide global or regional options for next, intermediate, and final users, based on understanding of regional, subregional, and even local needs and impact pathways.
- Product-oriented, interdisciplinary activities carried out with partners to develop innovative **products** and facilitate their uptake; products can be global or regional in their targeted usage, but they must be based on evidence for large impact potential.
- Milestones that provide measurable targets for each product and its uptake.
- New frontiers research to explore potential future breakthroughs and products.

Theme 1: Harnessing genetic diversity to chart new productivity, quality, and health horizons. This research aims to uncover new traits in the rice genome—particularly traits related to water stress, because water is the main concern for future rice-cropping systems—and make them available to breeding programs worldwide. The research will fully tap the rice gene pool and will involve large-scale genotyping and phenotyping of the world's rice genetic resources, which will require the combined efforts of many partner laboratories across the globe. In support of this objective, special attention will be given to ex situ conservation of rice germplasm and to consider the different roles and needs of men and women in seed systems with a view to conserving the biodiversity of rice species and varieties, an issue that is becoming increasingly important in the light of climate change, as well as to broaden the available gene pool for trait discovery. Theme 1 will also address research areas with very large long-term impact potential, such as re-engineering photosynthesis in rice to create a C_4-rice.

Theme 2: Accelerating the development, delivery, and adoption of improved rice varieties. Theme 2 uses the products of theme 1 in international and regional breeding programs to speed up the development and delivery of improved and climate-resilient germplasm. The aim is to transform public-sector breeding programs to become better targeted to the demands of different stakeholders—farmers, consumers, processors, and the marketing sector—but also better serve the needs of private-sector breeding programs that use germplasm from GRiSP. The breeding programs will focus on using traits for improving yield, tolerance of abiotic and biotic stresses, grain quality, and adaptation to future cropping systems, particularly conservation agriculture and water-saving irrigation. New efforts will be made to increase rice yield potential. Adapting rice to climatic extremes and climate change and support for hybrid rice development will be major endeavors. Healthier rice, enriched with pro-vitamin A, Zn, or iron, will become a reality in the attempt to overcome nutritional deficiencies among the poorest of the poor. New regional breeding task forces, supported by precision-breeding informatics tools, biotechnology applications, and testing networks, will enable faster progress in genetic enhancement.

Theme 3: Ecological and sustainable management of rice-based production systems. Theme 3 sits at the core of GRiSP because advances in rice production and optimizing the environmental footprint of rice will require developing integrated options for managing production systems. Hence, theme 3 provides feedback to and uses the new varieties from theme 2 to develop and extend rapidly to farmers improved management technologies that make rice systems more energy-efficient, more profitable, more sustainable, and more resilient to stresses. Rice ecosystem services and greenhouse gas emissions from rice and their fate under different future scenarios will be examined with a view to finding the right balance between productivity growth and environmental impact. New science concepts and technologies to reduce the gap between actual and potential yields through improved agronomic practices will be explored, including decision-support tools to help both farmers and scientists maximize crop yields. Theme 3 addresses all these matters through linking basic research on designing future production systems (new experimental platforms) with participatory adaptive research conducted at research stations and in farmers' fields worldwide.

Theme 4: Extracting more value from rice harvests through improved quality, processing, market systems, and new products. This theme builds on and provides feedback to themes 2 and 3 by investigating ways to increase harvest value and developing mechanisms to support and harmonize the activities of producers, processors, and marketers, while ensuring equitable benefits for poor male and female farmers. Marketing and market information systems using modern communication methods will be developed and links to micro-financing will be strengthened to allow farmers to maximize their economic yields from rice. New ways will be investigated to prevent postharvest losses of grain. Novel products may include rice varieties that cook faster, exploring the genetic diversity for specialty rice and value chains for it, and the use of rice straw and husks for small-scale bioenergy generation or other products.

Theme 5: Technology evaluations, targeting, and policy options for enhanced impact. Theme 5 provides important feedback to all other themes in GRiSP by helping to clearly understand the needs of male and female farmers from different socioeconomic categories and other actors, as well as the likely consequences of labor-saving technologies for their employment and income. Social scientists and agricultural economists will work side by side with agronomists, breeders, pest management specialists, or engineers in order to not only understand current constraints that poor male and female farmers face but also provide clear guidance on research priorities for now and the future. Theme 5 also aims to influence policymakers and other decision makers to improve the functioning of the rice sector.

Theme 6: Supporting the growth of the global rice sector. Theme 6 brings together the emerging new technologies and knowledge resulting from activities in the other themes with large-scale regional and national investments in order to reach the desired production and food security outcomes. Although international agricultural research centers cannot play a major role themselves in outscaling new technologies to millions of farmers, they can make significant contributions to supporting the growth of the rice sector through (1) a technical and human resource base to enable a far better interface between GRiSP products and the regional, national, and within-country investment programs for food security; (2) catalyzing and initially also facilitating public-/private-sector partnerships for delivery that involve multiple sectors at the subnational level; (3) supporting extension capacity building to provide a cadre of more agronomically competent extension personnel who can work in a responsive manner with a range of client farmers and extension and research organizations; and (4) providing coherent, up-to-date knowledge in a format that is most useful for extension specialists and farmers.

New frontiers research. The proposed products and product lines are seen as a starting point, aiming to accelerate R&D pipelines so that impact can be achieved faster, toward reaching the GRiSP vision of success. In addition, GRiSP will make significant investments in research for the next generation of future rice production systems—the scientific breakthroughs that will be needed 20 or 30 years from now to ensure food security and enable better environments. Priorities will be continuously assessed and new opportunities will be aggressively pursued, leading to an evolution of the GRiSP R&D portfolio over time.

Although seemingly disciplinary in nature, these GRiSP themes are well connected and aim to provide integrated system-level options for the world's most important rice-based production systems, from genetic improvements to better management and processing. Figure 11 illustrates the R&D approach in GRiSP, using the product line (2.3) on stress-tolerant rice varieties as an example. The main breeding work on the key products of this product line is conducted through regional breeding programs that involve many partners, including some from the private sector. Feedback from GRiSP themes 3, 4, 5, and 6 is the key driver for designing the breeding programs so as to meet the demand of farmers, processors, and consumers in the target environments and markets. Theme 1 provides critical genetic innovations to these breeding programs. In practice, this means, for example, that breeders are never just breeders, but they work closely with soil scientists, physiologists, agronomists, nutritionists, plant pathologists, entomologists, social scientists, and many others, in a production systems and market context. Breeding will thus increasingly be done in specific market segments and changing production environments. In GRiSP, the interaction with the other themes is established through projects and networks that cut across several GRiSP themes and are often of regional nature, bringing the different activities and partners together on the ground. Many such regional initiatives or consortia exist already, as outlined in the section on partnerships.

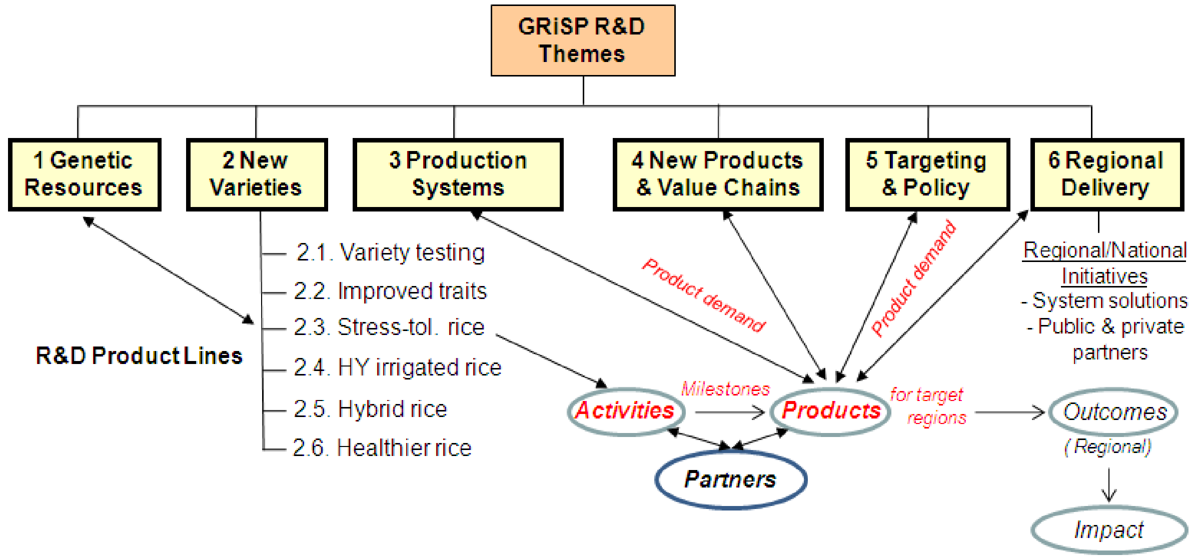


Fig. 11. Outcome-driven innovation through interdisciplinary, product-oriented R&D in GRiSP.

Targeting and regional priorities. In many Asian countries, rice is the fundamental and generally irreplaceable staple, especially of the poor. Declining natural resources currently threaten rice production in many parts of South Asia, whereas conditions are relatively better in other parts of Asia. In sub-Saharan Africa, rice is an exciting and, in some regions, new convenience food. With nearly half of the rice imported, mainly from Asia, big opportunities exist to expand production within sub-Saharan Africa, replace costly (notably in currency exchange) imports, and help offset malnutrition and poverty—if suitable seed and technologies are available. South Asia and sub-Saharan Africa have the highest poverty and malnutrition rates. Producers and consumers are better off in Latin America, but all rice-producing regions will have to contribute to increasing rice stocks in the future if we are to avert further availability crises. Latin America, with its ample land and water resources, may ultimately become transformed into a major exporter of rice, thus helping to stabilize the global rice market.

Investments by themes will thus vary across the different world regions. Regularly conducted strategic and impact assessments will guide the prioritization process (see below). High priority will be given to the poorest areas of South and Southeast Asia and sub-Saharan Africa, where improved varieties and farming technologies are urgently needed to fuel production. In regions where most varieties still have a significant yield gap, improved rice farming systems and value chains (themes 3 and 4) should be emphasized before investing more in other constraints and traits. Work in higher-value products (theme 4) is a relatively new area and will initially focus on Asia.

GRiSP also responds to numerous recent calls—such as from the World Development Report (2008), the G20 Pittsburgh declaration (2009), the International Assessment of Agricultural Knowledge, Science, and Technology for Development (IAASTD, 2008), and the first Global Conference on Agricultural Research for Development (GCARD, 2010)—for a new era of agricultural research and development investment to ensure food security through new, sustainable production systems. GRiSP responds to these calls by addressing the global, regional, and local needs of poor farmers and consumers of a crop that is central to the accomplishment of critical development objectives. It involves partners from many sectors and history has shown repeatedly that rice research is indeed research for development. GRiSP is emblematic of the kind of change that was envisioned several years ago when the CGIAR change process began.

Climate change strategy

Another example of how the themes interact is GRiSP's approach to climate change. Addressing the adaptation and mitigation aspects of climate change will involve developing climate-change-resilient traits and cropping systems that can be applied widely. Such work will bring together different parts of GRiSP and a host of other research, development, and extension organizations

Background. Climate change represents an additional burden on the world's agricultural and natural resource systems that must already cope with the growing food demand driven by population growth in developing countries. The temperature and precipitation changes that accompany climate change will require farmers to adapt. At the same time, as a significant contributor of greenhouse gases (GHG) and a potential sink for atmospheric carbon, agriculture and rice production systems in particular can also help mitigate climate change.

The challenge is compounded by the uncertainty and pace of climate change and its effects regionally. There are still considerable gaps in our knowledge of how agricultural systems will be affected directly or indirectly by the changing climate, and what implications these changes will have for rural livelihoods. The implications of climate change on rice production will play a key role in determining future food security in large parts of the developing world. Especially in Asia, where rice is the staple food of billions of rural and urban poor, detrimental effects on grain yields and availability of rice will directly translate into major food shortages. In comparison to other cropping systems, rice production systems show specific traits in terms of both resilience as well as vulnerabilities. Approximately 50 % of the rice land is irrigated. While irrigation could to some extent cushion the impact of short-term deficits in rainfall, many irrigation facilities are already close to their supply potential under present climatic conditions. At the same time, higher water demand from other sectors, e.g. residential areas, is aggravating the risk of losses in irrigated rice triggered by less rainfall or changing rainfall patterns.

Rice is also a widespread farming system in many environments that are considered 'hot spots' of climate change impacts. Most notably, the mega-deltas of Asia will be broadly exposed to more flooding and salinity intrusion due to sea level rise. The expanded deltas of Ganges-Bahmaputra, Irrawaddy, Mekong and Red River are the rice granaries of Bangladesh, Myanmar and Vietnam, respectively. Future production constraints caused by sea level rise or other consequences of climate change in these delta regions will affect the domestic rice markets as well as international rice trade. Vietnam is the 2nd largest rice exporter and the bulk of the exported produce derives from the delta regions.

Moreover, rice is often grown in drought-prone and flood-prone rainfed lowland regions where production risks will increase under aggravating climate extremes. As for temperature stress, rice plants have a fairly good resilience during the vegetative stage, but relatively low temperature thresholds (ca. 35 ^{o}C in humid climates) during latter stages. Rice is predominantly grown in the tropics and subtropics, so that temperature regimes are already close to these thresholds in many rice growing areas. Moreover, rice yields are adversely affected by higher night-time temperatures, declining by 10% for every 1 ^{o}C increase in temperature.

Rice production is a relatively large source of the greenhouse gas methane due to anaerobic conditions in the soil. Flooding of the soil is a pre-requisite for sustained emissions of methane. Mid-season drainage, a common irrigation practice adopted in major rice growing regions of China and Japan, greatly reduces methane emissions. In addition to management factors, methane emissions are also affected by soil parameters and climate. Just as other cropping systems, rice fields also emit nitrous oxide generated from soil and fertilizer nitrogen. On the other hand, flooded rice fields store large amounts of soil carbon that could be released as carbon dioxide in case of conversion of rice paddies to upland cropping systems, particularly under intensive tillage for growing upland crops.

Climate change research in GRiSP will step up current research on climate change impacts on rice as well as possible adaptation and mitigation strategies. It will be done in synergy and close linkage with other CRPs – in particular with CRP 7 on climate change.

Assessment of climate change impacts. GRiSP pursues a comprehensive impact assessment for rice production ranging from improved understanding at plant level to projected rice production under climate change at broader geographic domains. The physiological nature of climate stresses will mainly be addressed in GRiSP theme 1 (PL 1.3) which will encompass studies on stress physiology and identification of physiological pathways for improved resilience. In this field, GRiSP will explore joint activities with other CRP's on comprehensive approaches to elucidate stress tolerance across different crops, e.g. a comparative assessment of heat tolerances in major food crops.

As for the geo-spatial impact assessments under climate change, the work in GRiSP will capitalize on model development (theme 3, PL 3.4) and the new global rice information gateway (theme 5, PL 5.3). GRiSP will closely cooperate with theme 4 (Analytical and Diagnostic Framework) in CRP 7 to utilize relevant climate change information at multiple scales. The key element for this endeavor is downscaling of climate and global socio-economic processes to a resolution that suffices for decision making in agriculture. GRiSP will cooperate with CRP 7 and other CRPs to conduct case studies on climate change impacts in rice-baed systems that can then be upscaled to broader, regional and cross-regional domains, e.g. for the rice-dominated landscapes of Asia and Africa.

Adaptation. Several approaches of germplasm development and improved resource management have proven track records of decreasing susceptibility to climate induced stresses. Thus, the adaptation work in GRiSP will cut across several themes and mainly focus on Asia and Africa. Theme 1 (PL 1.3) and 2 (PL 2.3) will explore and develop improved germpasm with greater tolerance to extreme climatic conditions, including drought, heat, cold and submergence, but also salinity. These GRiSP themes will thus provide improved rice cultivars with resilience to direct and indirect impacts of climate change.

GRiSP theme 3 is at the core of the farming systems-oriented adaptation work, focusing on integrated germplasm x management solutions for better resilience to climatic extremes or avoiding them. PL 3.4. explicitly aims at climate change adaptation strategies (alongside with mitigation). However, the other production system PLs in theme 3 also show strong links to climate change research due to the specifics of the respective production system in terms of adaptation (and mitigation, see below). Intensive rice monoculture systems (PL 3.1), diversified intensive systems (PL 3.2) as well as stress-prone rainfed lowlands and uplands (PL 3.3) exhibit vastly different vulnerabilities as well as crop management options to cope with climate change impacts. Integrated pest management represents a cross-cutting issue of all PLs in theme 3 and offers promising approaches for strengthening climate change resilience of the rice production system through enhanced agro-biodiversity at landscape scale. Work on new concepts for ecological resilience is embedded in PL 3.4.

Technology solutions developed in themes 2 and 3 will be scale dup and out in collaboration with research and development partners in theme 6. The GRiSP work on adaptation will be closely aligned with the work of CRP 7 theme 1 (Adaptation to Progressive Climate Change) and theme 2 (Adaptation through Managing Climate Risk). GRiSP will contribute the ‘rice component’ for an integrated research program that includes analysis of current farming systems in identifying suitable technologies and practices. Jointly with CRP 7 and other CRPs, GRiSP will incorporate improved rice germplasm and technologies into comprehensive approaches for strengthening the adaptive capacities of rice farmers through a variety of strategies ranging from diversification of production systems to improved institutional settings.

Mitigation. The mitigation work embedded in GRiSP theme 3, PL 3.4 will concentrate on rice systems in Asia and combine different approaches to increase resource use efficiencies – for water as well as for nutrients – in order to develop highly productive rice technologies with low carbon foot prints. Several management options for reducing GHG emissions have been tested and were shown to be technically feasible. Changing water management appears among the most promising option and is particularly suited to reduce emissions in irrigated rice production, i.e. the rice ecosystem with the highest emission potential. Insofar, the development of Alternate-Wetting-and Drying (AWD) as a means to save irrigation water in rice production offers enormous opportunities to reduce GHG emissions in parallel. This approach carries a risk of higher nitrous oxide emissions as long as fields are heavily fertilized, but proper nitrogen management, e.g. through Site Specific Nutrient Management, can curtail these increments. New site-specific nutrient management approaches have quadruple environmental benefits: (i) they reduce the amount of reactive nitrogen cycling back into biogeochemical cycles, (ii) they directly reduce N_2O and NH_3 emissions, (iii) they reduce CO_2 emissions associated with manufacturing mineral fertilizer and (iv) they contribute to increased soil carbon sequestration via increased biomass production.

GRiSP will give special emphasis to water and nitrogen management options. Key for success will be tailoring these mitigation technologies to the site-specific conditions in the vastly different rice growing environments. The diversity of natural and socio-economic settings requires decision support systems to identify the most suitable combination of crop management measures within a local context.

Moreover, the GRiSP work on mitigation extents into several research topics of themes 4 and 5, such as work on bioenergy solutions from rice straw or husks (PL 4.2), rice that may require less energy for cooking (PL 4.3) or policy incentives and mechanisms for mitigation (PL 5.1). Financial incentives will be crucial for adopting mitigation strategies, so that innovative sourcing of funds and fundamental policy changes have to be explored. Mitigation projects implemented as ‘Clean Development Mechanism’ could be one avenue to achieve broader adoption of AWD techniques and possible use of rice straw as bio-energy. Given the small size of typical farm holdings of rice producers, this will require new approaches to bundle ‘carbon emissions certificates’ for larger farmer groups or administrative units. Based on current trends of eco-labeling, e.g. in the EU market, it is expected that the labeling of agricultural produce will also include the respective carbon footprint. For marketing rice products this may offer risks (due to the high background emissions) as well as new chances (accentuating of good management practices).

The cooperation with other CRPs will mainly be channeled through CRP 7 Theme 3 (Pro-Poor Climate Change Mitigation). Joint work will encompass regional projects on the adoption of mitigation technologies, i.e. identification of conducive socio-economic settings as well as possible constraints. The focus of the mitigation work of CRP 7 is on pro-poor approaches, so that rice farmers will be the core beneficiaries in many regions of the world. Rice production systems have to form an integral part of low carbon agricultural development pathways – otherwise such efforts will be bound to fail in effectively all rice growing countries. The same applies to the new institutional frameworks for effective participation of the poor in the carbon market which can be achieved by direct interaction with rice farmers that constitute the majority of rural poor in vast parts of the developing world.

Exploring new frontiers

The proposed products and product lines are seen as a starting point, aiming to accelerate R&D pipelines so that impact can be achieved faster, toward reaching the GRiSP vision of success. In addition, GRiSP will make investments in research for the next generation of future rice production systems—the scientific breakthroughs that will be needed 20 or 30 years from now to ensure food security and enable better environments. Exploratory research will therefore play a significant role in GRiSP and regular horizon scans of potential new, high-impact breakthroughs are needed, including looking well beyond the agricultural sciences sector.

Some blue skye research with a clear product roadmap is already embedded in various GRiSP product lines, for example on gene discovery and C4 rice in theme 1. Other such research still requires more exploration, also in terms of establishing the most promising directions to take. Hence, a more flexible research fund for new frontiers research will be created as part of the overall GRiSP budget. This mechanism will be used, in a non-bureaucratic manner, to issue seed grants for more basic, exploratory research in promising new, cutting-edge research areas, which may later evolve to become full new R&D products or even PLs in GRiSP. Priorities will be continuously assessed with the strategic partners in GRiSP and new opportunities will be pursued, leading to an evolution of the GRiSP R&D portfolio over time.

Below, we provide some first examples for such potential exploratory research areas. This list is provided to stimulate further thinking. It is by no means exclusive.

Engineering rice with biological nitrogen fixation. Rice accounts for nearly 20% of global N-fertilizer consumption, but, on average, only 30–40% of the N applied is absorbed by the rice plant. The rest is lost and it is these “reactive” forms of nitrogen that have many undesirable impacts on the environment. Building on earlier research and recent advances in science, GRiSP will explore engineering new rice varieties with the capability for biological nitrogen fixation (BNF), which is a very energy-intensive process. Therefore, having such a BNF trait, possibly even in a future C4-rice (see PL 1.4), would allow saving N fertilizer without sacrificing yield. Advanced research institutions with active research interest in nitrogen fixation will be involved in exploring several strategies of enabling rice to fix its own N: (i) improving the endophytic associations between rice and nitrogen-fixing bacteria, (ii) genetic engineering of rice plants capable of forming legume-like symbiosis/nodules with rhizobia. The latter, for example, aims to redirect the existing arbuscular mycorrhizal symbiosis in rice to induce spontaneous nodule formation. In order to activate nodulation we will transform rice plants with Medicago, Casuarina and rice deregulated CCaMK genes using the native promoters. We hypothesize that the introduction of a deregulated CCaMK gene in rice will trigger the appropriate downstream signalling pathway leading to spontaneous nodule formation.

Understanding and engineering plant development and stress response. Nearly 50% of all eukaryotic proteins are glycosylated. Studies abound in mechanisms of glycosylation and in identifying proteins and glycan moities. However, studies on how glycosylation alters protein characteristics are few and far between as are those relating such alterations with plant development and stress response. Differential protein glycosylation is an unexplored aspect of epigenetic regulation, which must be addressed to obtain an insight into the overall function and response of cell to developmental and environmental cues.

Epigenetics: potential roles in controlling agronomically important traits. For a long time, genomic DNA sequence has been considered the primary blueprint for gene regulation and eventual expression of phenotypes. However, recent research has highlighted the importance of non-genetic transmission of information between generations, a process called epigenetics which mediates heritable changes in gene expression and phenotypes without direct changes in DNA sequence. Epigenetic regulation of gene expression is now known to be largely accomplished by DNA methylation, histone modifications, and chromatin remodeling. Of practical interest is whether epigenetics have any influence on agronomical traits relevant to agriculture. Does epigenetics play a role in the expression of genotype by environment interactions for complex agronomic traits? Can epigenetics become a tool to answer “big” questions concerning agricultural production? The depth of genetic diversity and extensive phenotype data across environments available in rice make it a suitable candidate for investigating the potential roles of epigenetics in controlling agronomic traits. As a first step, we propose to convene a consultation workshop to assess the current status of epigenetics research and its relevance to agriculture.

A new look at apomixis in rice. Apomixis is asexual reproduction, which in plants can produce seed that gives rise to plants genetically identical to the maternal parent. Apomixis fixes hybrid vigor, because it avoids aspects of the sexual reproductive processes, such as meiotic recombination, that lead to genetic variation. The economic and agronomic advantage that apomixis could bring to crop plants worldwide is well recognized. The first step is to achieve apomeiosis in rice (production of diploid gamete genetically identical to their mother). This breakthrough has recently been achieved in Arabidopsis in cumulating 3 mutations (Spo11-Rec1-Osd1) creating the MiMe phenotype. The second step is to trigger parthenogenesis from the diploid female gamete using an engineered system mimicking in vivo haploid induction in cereals, but allowing endosperm development and reaching a 100% embryo development frequency.

Modifying the floral structure of the rice plant as a novel system for hybrid production. Most plants, including rice and several major cereal crops, have perfect flowers with both pistils and stamens. Maize, however, is monoecious, separating flowers with just pistils or stamens into different inflorescences. This floral partitioning promotes outcrossing and makes efficient hybrid seed production possible. An effort is ongoing to extend novel hybrid technologies to rice using a variety of genetic and molecular approaches. One approach is to investigate monoecy genes of maize in rice and cereal crops to understand functional differences that exist. A second approach is to exploit natural floral variation in related species to rice that exhibit degrees of monoecy. The third approach is to create pistillate and staminate florets in rice by introducing transgenes capable of eliminating either pistils or stamens, thereby generating a synthetic system for hybrid seed production.

Increasing the yield potential in rice using genomic approaches. Using conventional breeding and selection breeders have not been able to break yield ceiling in rice since the release of first semi-dwarf variety IR8 in 1966, in tropical and sub-tropical environments. To break the yield barrier in rice, gene-based approaches have not yet been tried systematically, although a number of genes for yield related traits have been reported. Therefore, wewish to explore using genomic approaches to systematically pyramid genes/QTLs for major yield component traits, including tillering, number of spikelets per panicle and grain weight.

Slower digesting rice varieties – a healthier option. Slow digesting starches lower the body’s insulin response, thus helping people with diabetes to normalize their blood sugar. Currently, 285 million people, mostly in developing countries, have Type II diabetes and another 344 million are at risk of developing it due to impaired glucose tolerance. If diabetes is undiagnosed, it leads to chronic conditions and death. Consumption of cereals is not necessarily a cause of Type II diabetes, but cereals containing particular structures of starch offer a solution for prevention and management of the condition. In the late 1990s, scientists developed a collection of new non-GM barley grains and assessed them for their potential to improve health by delivering high levels of slow digesting starch and other dietary fibre components. From this research one particular gem emerged – a new type of barley grain that went on to capture a significant proportion of the breakfast cereal market because of its visible clinical effect.. Preliminary work at IRRI suggests that the rate of digestibility of rice starch is highly variable, suggesting it is possible to develop new products that can be used to manage blood glucose and could assist in managing the global pandemic of Type II diabetes.

Rice cooking time: minutes mean millennia. The cooking time of rice is determined by the temperature at which the crystalline structures of the starch begin to melt. This is called gelatinization temperature (GT) and it ranges from 55 to 85 °C in rice. Rice with high GT takes a long time to cook and the cooked rice has an unacceptable texture; low-GT rice takes a shorter time to cook and the cooked rice is more palatable. Recently, a key gene affecting GT has been discovered: *starch synthase IIa* (*SSIIa*). This discovery allows us to breed rice varieties with lower GT, which could decrease average cooking time by up to 4 minutes. Although this might initially seem insignificant, computing the number of times rice is cooked in any one day by the millions of households around the world, a decrease of just 4 minutes for each cooking event could save more than 10,000 years of cooking time each day. This represents massive potential for global energy savings.

Prepare genetic stocks. The development of genomic tools, especially in rice, has followed an exponential curve in recent years, and we may still be at the beginning of this curve. In the very near future, the bottlenecks for gene discovery will reside in 1) appropriate genetic stocks, 2) large-scale phenotyping, 3) lab organization (LIMS, DNA extraction, storage, etc.) and 4) bioinformatics and IT. We will explore novel ways for developing large numbers of genetic stocks that encompass the natural genetic diversity of A-genome rice species. Series of CSSLs, NAM, iBridges, MAGIC populations will be developed from large numbers of well chosen cultivated and wild accessions. These materials will be re-sequenced. This will provide an extraordinary platform for discovering new alleles from any A-genome rice species. It requires novel strategies and investment in terms of crossing effort and population management but these stocks will be used for multiple purposes and many years.

Unraveling the genesis of red rice and mitigation using next generation sequencing technologies. Weedy rice (widely referred to as red rice) is an invasive and nonspecific relative to cultivated rice, distinguishable by the key weedy traits of rapid vegetative growth, grain shattering and variable dormancy. Its ability to invade agricultural fields in a wide range of agroecologies costs millions of dollars in yield decrease and weed management efforts worldwide. Recently some Nerica varieties, derived from interspecific hybridization between O. sativa and O. glaberrima, were reported to give typical red rice plants during the process of seed production year after year. The objective is to use the O. sativa x O. glaberrima model and Nerica varieties to identify the underlying causes of such a reversal towards wild phenotypes. We propose to use the next generation genome sequencing technologies to extensively characterize genomic and transcriptomic changes introduced during the weedy process. With this 'complete' catalogue of data, we will be able to propose alternative pre-breeding strategies to reduce the weedy change in interspecific crosses.

Integrated biorefining strategy to add value to rice by-products. There are attempts to use rice husks for power generation, similarly attempts are being made to convert straw into ethanol, and there is also small scale extraction of rice bran oil (15-20% of the bran, used as food and biodiesel), proteins and vitamins. But to date rice by-products are not fully valorized. Integrated biorefining aims to develop process architecture that supports full utilization of rice residues instead of the current “single product” based process such as oil extraction from rice bran. It will offer the opportunity of multiple product options, including biofuels. Based on soft operating conditions (no organic solvent used) such processes will have low environmental impacts and result in high quality products.

General impact pathway of GRiSP

Rice research is the single largest documented source of international agricultural research benefits in the developing world,[13] mainly through productivity-enhancing research and in particular new varieties. Expanding on this track record, the challenge for GRiSP is to, on the one hand, improve existing research to impact pathways, and, on the other hand, maintain a continuous stream of innovations in international public goods, developed through cutting-edge science and partnerships that could not occur without GRiSP’s presence. An overview of GRiSP impact pathways is provided in Figure 12. More specific descriptions of the key uptake and impact pathways for each product line in GRiSP can be found in Appendix 3.

Theme 1 is the long-term source of genes that can lead to innovations in terms of revolutionary advances in the rice plant, such as changes in the photosynthetic mechanism to the C_4 pathway for increased yield potential, improvements in root structures for drought tolerance and nutrient uptake, and improved micronutrient content in the rice grain. These genes can be used by more advanced partners in larger NARES, as well as the public sector for introgression into varieties that they are developing as immediate outcomes. The genes will also be employed in the development of finished varieties and parental materials developed under Theme 2.

Theme 2 applies molecular and conventional breeding to embed genes from theme 1, as well as innovations in host-plant resistance, abiotic stress tolerance, quality, yield potential, and integration with new management and cropping systems in more advanced breeding inputs and finished varieties. Theme 4 will complement this genetic improvement with traits targeted toward specialty value-added markets, which can give farmers higher prices. Finished varieties are principally targeted toward dissemination in less favorable environments and areas with weaker NARES, whereas breeding inputs are intended for use in varietal development by stronger NARES and the private sector as short-term outcomes. The varieties developed are intended to be multiplied and disseminated by private and public seed companies, and they will further diffuse through retailers, extension systems, NGOs, and farmer-to-farmer sharing of seeds as mid-term outcomes.

Theme 3 complements themes 2 and 3 with innovations in crop management practices that can increase input-use efficiency, offer options for mitigating abiotic constraints, manage pest and weed dynamics, increase labor efficiency, increase sustainability, and intensify production. In doing so, specific genotype by management by environment interactions will be exploited. As short-term outcomes, these practices will be locally adapted and disseminated by national agricultural research institutes, extension systems, NGOs, and private-sector companies, and will be backstopped by changes in private-sector machinery supply chains. Such delivery will take place through the incorporation of management innovations into agricultural development projects by partners that employ on-farm demonstration activities, farmer field visits, and other experiential pedagogic approaches. In addition, novel communications approaches, such as the use of mass media, including television and radio, as

[13] Raitzer DA and Kelley TG. 2008. Benefit-cost meta-analysis of investment in the international agricultural research centers of the CGIAR. Agricultural Systems 96(1-3):108-123.

well as mobile phone and Internet-based decision support tools, will be used to promote specific management recommendations.

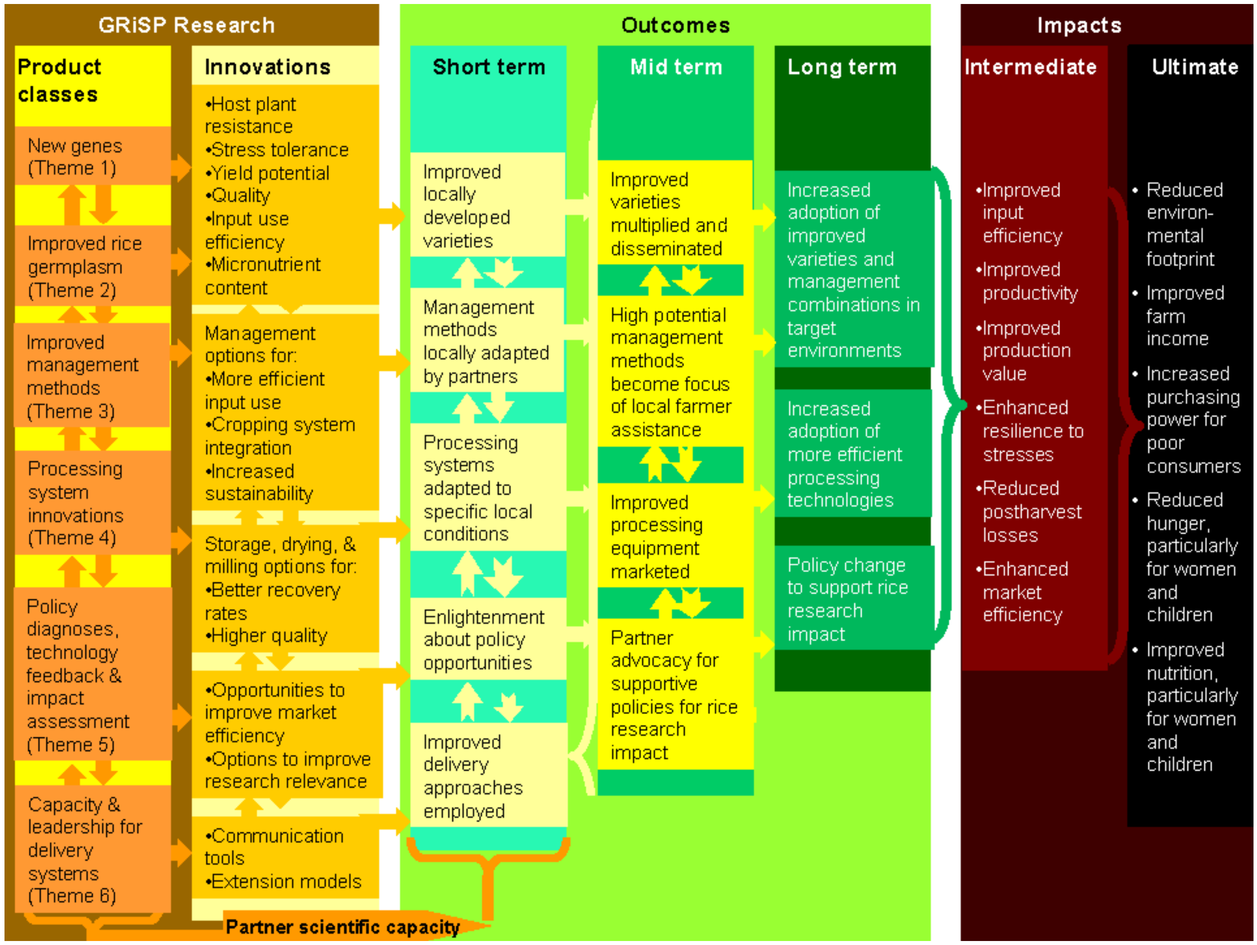


Figure 12. Overall pathways from GRiSP to impacts.

As a result of these innovations and short-term outcomes, as long-term outcomes, farmers will widely adopt improved combinations of varieties and management practices. These outcomes will lead to impacts for farmers in terms of improved income, reduced vulnerability to disturbances, increased food availability for self-consumption, reduced pesticide exposure, improved micronutrient intake, and sustained future productivity. Farmers, particularly the poor, will thus also be enabled to invest more in environmental stewardship, education, health care, and other social development. More productive rice land and more valuable rice products will also enable farmers to set aside land for growing other crops, and thus further raise their income through diversification of farming systems, which also results in diversifying risk. As a result of reduced production costs, increased supplies of rice will bring equilibrium prices down, thus reducing food expenditures by poor consumers and reducing hunger, which afflicts women more than men.

Much of Theme 4 complements farm-level technologies with processor-level postharvest technologies and other opportunities for added value. Key innovations will include storage, milling, and drying techniques that reduce postharvest losses or make use of waste products, such as husks. These techniques will be supported by outcomes that include changes in the storage, milling, and drying equipment provided by private-sector machinery producers and retailers. In turn, as longer-term outcomes, millers and processors will buy and operate this equipment, thereby reducing losses, increasing rice availability in local markets, and creating new job opportunities in machinery and processing chains. Increased rice availabilitywill reduce prices, thus benefiting poor consumers, while the use of waste products for energy will create new avenues of employment and reduce greenhouse gas emissions as impacts.

Complementing these technological products will be real-time data on the rice market and instruments to contain rice price volatility for national policymakers from theme 5. One intended outcome is advocacy by partners that leads to policy influence, and consequent trade policy shifts that help avoid high deadweight losses, such as expensive government procurements or export bans. Another is to reduce information asymmetry that allows particular traders and speculators to exploit and capture the benefits of price "bubbles" by making market information more broadly available. Such outcomes will lead to higher price for poor producers in the short run, more stable and lower prices for poor consumers in the long run, and increased resources available for government interventions that benefit poorer segments of society.

To backstop the overall process of fostering impacts, theme 5 also provides evidence on impact potential and impacts achieved to help shift actors in research and extension systems into alignment on global and regional priority areas, creating further synergies that improve impacts for target beneficiaries. Adoption studies offer further feedback for researchers and disseminators in the global rice research system to improve research product relevance and performance, as well as diagnosis of extension and policy constraints. In turn, use of this feedback should help to improve the overall impact potential of GRiSP activities.

Theme 6 will help to ensure that the technologies, once locally adapted, become key components of effective local delivery systems described in this section. It will do so by expanding and augmenting existing consortia and regional initiatives, such as Asian rice consortia (on unfavorable environments, irrigated areas, hybrids, etc.), the Africa Rice Breeding Task Force, and FLAR in Latin America, which will also form channels for feedback for further product development.

In subsequent chapters on the specific R&D themes in GRiSP, eight concrete impact pathway examples are provided for eight product lines to illustrate specific GRiSP technologies and differences in the research to impact pathways:

- Box 10: Submergence-tolerant rice (product 2.3.2 in PL 2.3)
- Box 12: Site-specific nutrient management (product 3.1.2 in PL 3.1)
- Box 13: Rice dryers (product 4.3.1 in PL 4.3)
- Box 14: Parboiled rice in West Africa (product 4.3.3 in PL 4.3)
- Box 15: Real-time crop monitoring (product 5.3.1 in PL 5.3)
- Box 17: Alternate wetting and drying irrigation in Asia (product 6.3.2 in PL 6.3)
- Box 19: Seed delivery in Africa (product 6.4.1 in PL 6.4)
- Box 20: Outscaling of better agronomic practices in Latin America (product 6.5.1 in PL 6.5)

Strategic planning and impact assessment

Rice-specific foresight, priority setting, and ex ante impact assessment are integral elements of GRiSP and they will be primarily implemented through product 5.4.1 in Theme 5, and will be a direct input into planning by the GRiSP Program Planning and Management Team. Analyses will be primarily conducted at the regional level. This is an “apex” product, which integrates tools, resources, data and insights from an array of disciplines and other GRISP products.

To inform priority setting, participatory, structured, and quantitative approaches will be used to obtain estimates of economic, poverty, health, and environmental benefits per dollar of investment in potential research areas in each of the regions. To mainstream impact culture, this analysis will be done by a multidisciplinary strategic assessment task force, led by an impact assessment specialist and composed of experts (from centers and strategic partners) from all themes, who engage even broader arrays of scientists. Components include assessment of projected yield gaps under future climatic conditions and disaggregation of yield gaps into efficiency gaps, abiotic yield limitations, and biotic yield reductions for particular agroecologies and countries (Box 5). These are complemented by assessments of quality gaps, analysis of potential improvements in yield potential, and identification of losses due to inappropriate policies.

For each problem area and target environment, CGIAR center and partner scientists will identify potential research products, their probabilities of scientific success, associated resource requirements, likely on-farm productivity and environmental effects, and expected adoption profiles over time. These data will be used to assess unit cost reductions, subnational price effects, area response/land-use implications, environmental effects, and benefits to poor consumers and producers from alternative research products. In the process, specific assumptions regarding outcomes and impact pathways will be defined and translated into milestones, which will form the basis for subsequent program adjustments, monitoring, and evaluation.

Results generated by early 2011 will be used to make adjustments to the GRiSP portfolio during the first 5-yr research planning cycle (2011-2015) with respect to (i) investment levels/portfolio balance, (ii) products or product lines to be phased out, and (iii) new products or product lines to be considered for investment. It is our goal to prioritize funding allocations within GRiSP based on transparent evidence so that GRiSP research focuses on areas of greatest comparative advantage for the centers and partners involved. Parameters underpinning the assessment will be regularly reviewed and updated by the strategic assessment task force, which will oversee subsequent revisions to the priority-setting study. As more information becomes available, updates will become less and less time-consuming in subsequent assessments. The next update will be done in 2015. New research opportunities will be evaluated for inclusion in the GRiSP portfolio as they arise, in response to major drivers of change and progress made in new technologies. To do so, impact pathway delineation and ex ante impact assessment will be jointly conducted by impact assessment specialists of the three CGIAR centers, in conjunction with GRiSP scientists.

Linkages with priority setting and impact assessment at the CGIAR system level will be maintained through regular interaction with the strategic foresight and impact functions of the CGIAR Research Program on Policies, Institutions, and Markets for Enabling Agricultural Incomes for the Poor (CPR 2).

Box 5. Strategic assessment of rice research priorities: methods and approach for Asia.
In 2010/11, IRRI is leading a strategic priority assessment to identify where the greatest potential for rice research to benefit the Asian poor lies, and what specific areas of research can contribute. Simultaneously, a parallel assessment will be conducted for Africa by AfricaRice. These assessments will utilize participatory, structured, and quantitative approaches to obtain estimates of economic, poverty, health, and environmental benefits per dollar of investment in potential research areas. In GRiSP, the same approach will also be used for other world regions.

Step 1: Background analyses

- 1.1 Definition of rice agro-ecologies
- 1.2 Yield gaps
  - modeling of yield potential under current and 2035 climate conditions
  - mapping of rice agro-ecologies
  - comparison with current and projected actual yields to identify magnitude of yield gaps
- 1.3 Emerging technologies and opportunities
- 1.4 Documented impact/adoption to date

Step 2: Disaggregate problem causes

- 2.1 Yield reducers (biotic) – pathogens, weeds and animals
- 2.2 Yield limiters (abiotic) – drought, extreme temperature, salinity/alkalinity, submergence, etc.
- 2.3 Efficiency gaps (water, nutrients and labor)
- 2.4 Quality and nutritional content (including postharvest losses)
- 2.5 Policies and markets
- 2.6 Yield potential

Step 3: Assessment of scientific solutions

- 3.1 Involvement of array of scientists
- 3.2 For each constraint, identify array of possible research product solutions
- 3.3 For each solution appraise
  - investment required (IRRI + partners)
  - years of research to product
  - probability of success
  - alternative suppliers
  - course of research progress without IRRI
  - expected on farm costs and benefits of adoption by season/ecology/subregion
  - expected on farm environmental effects
  - delivery and extension requirements
  - likely adoption profiles by ecology & subregion

Step 4: Translating scientific opportunities to impact

- 4.1 Calculate unit cost reductions and supply and demand shifts
- 4.2 Use shifts in rice trade model to estimate price effects and consequent area effects
- 4.3 Estimate effects on environmental services
- 4.4 Use price effects and shifts in economic surplus equations to estimate attributable economic benefits
- 4.5 Identify portion of benefits accruing to poor producers and consumers and poverty effects
- 4.6 Estimate health/nutrition effects based on changes in DALYs

Step 5: Analyze results

- 5.1 Feedback and validation
- 5.2 Compare patterns of expected impacts with current resource allocation
- 5.3 Conclusions/recommendations for resource allocation by high priorities

Partnerships

GRiSP will make a significant contribution to achieving Millennium Development Goal 8: to develop a global partnership for development. Partnerships with organizations along the two-way research to development continuum contribute to iterative cycles of research priority setting, technology development, adaptive research and diffusion, monitoring and evaluation, and impact assessment and funding. The three main CGIAR centers in GRiSP, IRRI, AfricaRice, and CIAT, have an excellent track record in generating international public goods through upstream areas of rice improvement, their ability to conduct upstream and downstream research on production systems across borders, their research on environmental issues, certain aspects of socioeconomic and policy research, providing information, and science capacity building. They preserve most of the world's rice genetic resources and their collections are already seamlessly integrated with breeding and gene discovery programs, leading to new lines and varieties of rice that are made widely available to the poor. These centers are also experienced in leading strategic research across the rice sector. They have built up partnerships and regional networks of rice scientists over decades that enable knowledge exchange across countries; in support of this, they are also experienced in bringing rice information together and making it widely available. Research networks and consortia coordinated by the three centers already weave virtually every rice-producing country in the world into a rich partnership fabric. CGIAR centers are viewed as "honest brokers" by a wide range of stakeholders, a role that will be important with increasing involvement of the private sector and also essential to help move innovations beyond boundaries, so that advances by leading national research and extension systems can become global public goods.

GRiSP aims to further strengthen the existing partnerships as well as develop new partnership mechanisms to reach out to all sectors involved in R&D on rice-based farming systems and value chains. Broadly speaking, partners may fall into three major categories with regard to their roles in GRiSP:

- **Research partners** are more directly involved in GRiSP research, usually through a collaborative agreement, and thus also accountable for certain GRiSP outputs. Research partners play an active role in the product development teams in GRiSP themes 1–5. Some of these research partners, particularly those with large rice R&D systems and/or those with broader international involvement, may also lead specific research activities in GRiSP (milestones, whole products) or otherwise act as strategic partners in terms of providing significant resources to the GRiSP mission.
- **Development partners** are partners that are more indirectly involved in the research (local adapters) and/or play a significant role in the dissemination and adoption process (disseminators). Typically, such development partners need to be influenced by the research partners to mobilize their own resources for taking up GRiSP outputs. They do not necessarily receive much funding from GRiSP and are thus also not directly accountable for certain GRiSP outputs. Development partners may be associated with any PL in GRiSP, but they are also the majority of partners in GRiSP theme 6, where success in out-scaling new information and technologies will largely depend on the resources mobilized by these partners.
- **Other partners** may not be directly involved in developing, adapting, or disseminating GRiSP products, but they are in need of information on GRiSP and its outputs for various purposes. This includes, for example, certain international or regional associations or organizations, media, development funds, regional development banks, donors, and political organizations.

Taken together, development and other partners may also be referred to as **boundary partners**, that is, ones that are not directly accountable for delivering or using GRiSP outputs but should know about them and could adapt and adopt them. The power to influence development rests with them. GRiSP is on the boundary of their world.

A bottom-up inventory of GRiSP partners was made in September 2010, with information provided by the product research teams on currently ongoing partnerships, including those that will be strengthened more in GRiSP. At present, the six international centers and organizations in GRiSP (IRRI, AfricaRice, CIAT, JIRCAS, Cirad, IRD) have about 900 rice research, development, and other partners representing many institutional and societal sectors worldwide (Fig. 13). About 48% of the GRiSP partners mainly play a role as research partners, whereas 47% are mainly development partners and 5% are other boundary partners. See Appendix 2 for a partner breakdown by major GRiSP regions. A complete database of partners by GRiSP product lines is available upon request.

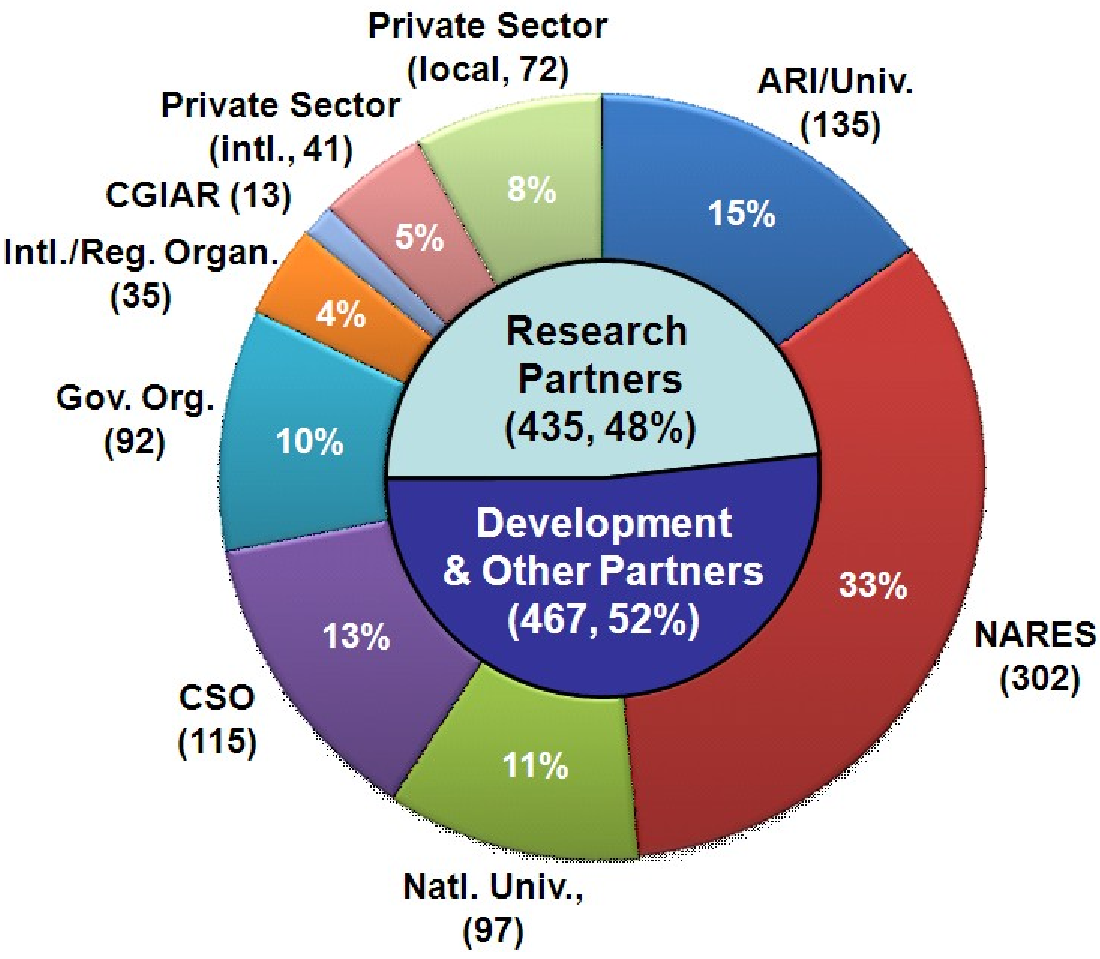


Fig. 13. Current rice research, development, and other partners of IRRI, AfricaRice, CIAT, Cirad, IRD, and JIRCAS in GRiSP. The inner circle provides the breakdown by partner roles (research vs. boundary partners). The outer circles provides the classification by organizational categories. Source: partner inventory by GRiSP products and product lines, September 2010.

National agricultural research and extension systems. The NARES have been the key partners of CGIAR centers for decades, primarily through collaborative projects, networks or consortia, and science and extension capacity building. These partners range from NARES that emerge from national conflicts (such as Liberia) and thus require major assistance to NARES with strong national rice R&D capabilities in Africa (e.g. Egypt), Asia (e.g., China, India, others) and Latin America (e.g., Brazil) that will play a key role in many activities (see below). NARES are instrumental in this new global partnership—GRiSP will be conducted to a large extent through their active involvement in research priority setting and implementation of R&D activities on the ground. Many partnerships with NARES and other sectors will be implemented through existing regional networks, projects, and consortia, which, through their steering committees composed of a wide range of partners, also play an important role for setting priorities, overseeing GRiSP research, and linking it with national systems and investments. Examples for Asia are the Cereal Systems Initiative for South Asia (CSISA; https://sites.google.com/a/irri.org/csisa), the Irrigated Rice Research Consortium (IRRC, 11 countries in Asia; www.irri.org/irrc), the Consortium for Unfavorable Rice Environments (CURE, South and Southeast Asia; www.irri.org/cure/cure.htm), and the Temperate Rice Research Consortium (TRRC, 12 countries, global). Examples for Africa are the Inland Valley Consortium (IVC, 10 countries in West Africa, AfricaRice, Cirad, IITA, ILRI, FAO, WUR, and others; www.africaricecenter.org/IVC-CBF) and the AfricaRice Rice R&D Task Forces to be formed under GRiSP. A key steering mechanism in Latin America is the Latin American Fund for Irrigated Rice (FLAR, 15 members; www.flar.org). On a global scale, various networks connect hundreds of scientists from many countries, for example, in the International Network for the Genetic Evaluation of Rice (INGER, global; http://seeds.irri.org/inger) and the International Network for Quality Rice (www.irri.org/inqr), which also connects NARES researchers with many advanced research institutes.

One concrete example is the currently ongoing project on Stress-Tolerant Rice for Africa and South Asia (STRASA), led by IRRI and AfricaRice. This project largely operates through research and delivery partnerships, with 12% of the budget allocated to a series of partners in public, private, and civil society. The project has about 200 partners that are engaged, mostly part-time, in project activities. Many of those are development partners involved in seed production. There are 129 recognized partners in seed production in South Asia alone, allowing rapid out-scaling of new seeds and information through multiple channels. Indirect and direct co-investments by these partners exceed the funds coming from the project by far.

Emerging strong national research systems. The national research systems in the so-called "BRIC" countries (Brazil, Russia, India, China) are vast and they have made rapid advances in recent years. In Africa, Egypt has excellent rice R&D capacity that has resulted in the highest average rice yield in the world and this experience needs to be tapped in irrigated rice-based systems in sub-Saharan Africa. Hence, these countries are expected to increasingly play a more strategic role in international research, including GRiSP. At issue is what these new roles will be and what mechanisms can be found to more effectively use the strengths of these national systems for CRPs such as GRISP.

Key partners for GRiSP in **Brazil** are the Empresa Brasileira de Pesquisa Agropecuária (Embrapa—the Brazilian Agricultural Research Corporation) and the Instituto Rio Grandense do Arroz (IRGA), but also selected universities. Collaboration with Embrapa will focus on functional genomics (theme 1), breeding of stress-tolerant varieties (theme 2) improving upland systems, including aerobic rice grown in rotation with other crops (theme 3), value-chain solutions (theme 4), and information platforms (theme 5). Moreover, GRiSP also wishes to cooperate with Embrapa in the Africa-Brazil Agricultural Innovations Marketplace. IRGA specializes on intensive, mechanized irrigated rice production under temperate conditions. Collaboration with IRGA will focus on germplasm and staff exchange, varietal development (including hybrid rice), management concepts and solutions for ecological intensification (theme 3), and out-scaling of agronomic best management practices, including extension strategies and learning alliances (theme 6).

Rice area in **Russia** is relatively small. Partnerships with GRiSP will concentrate on germplasm improvement for temperate rice systems and training of young Russian scientists at IRRI. Russia, through the All-Russian Rice Research Institute, also plays a leading role in the TRRC, and has also recently become a new donor to this consortium.

India is one of the most important partner countries for GRiSP. At present, some 170 partnerships exist between IRRI and Indian institutions and organizations. This includes over 40 research institutions belonging to the ICAR system (e.g., DRR, CRRI, CSSRI, IARI), universities and others. On the other hand, some 130 active partnerships on adapting and disseminating new technologies and information involve other government entities such as the National Food Security Mission (NFSM), the National Seed Corporation (NSC), many state agricultural and other universities, the departments of agriculture of 11 Indian states, about 25 district-level extension centers (KVK), 25 grass-roots-level NGOs and farmers' associations, and nearly 40 small and large private companies involved in seeds, machinery, and other inputs. Many of these are local development partners participating in recent regional initiatives such as CSISA and STRASA, with emphasis on new delivery systems. Programs such as GRiSP can thus play a significant catalytic role for enabling new multisector partnerships in India, supporting other and usually much larger government investments in the development of the rice sector. ICAR wishes to act as a nodal point for GRiSP research activities in India and has identified GRiSP product lines 1.2, 1.3, 2.2, 2.3, 2.4, 2.5, 3.1, 3.2, 3.3, 3.4, and 5.1 as areas of major interest for research collaboration. To develop strong partnerships, it is suggested to concentrate on focused joint research in some of these areas, such as yield potential under low light intensity (PL 2.4), sheath blight resistance (PL 2.2.), genomics and gene discovery (PL 1.2 and 1.3), and hybrid rice development (PL 2.5). GRiSP will hold regular review and planning meetings with ICAR and other key research partners in India to prioritize research, ensure active participation of Indian scientists in specific GRiSP products, and improve funding and support mechanisms for collaboration. Moreover, ICAR is also interested in participating internationally, for example, through staff exchange and seconding scientists and other professional staff to Africa and other regions, for which GRiSP may provide an appropriate new umbrella. Science capacity, including sandwich scholarships, internships, and short courses, will also be a major component of GRiSP–India collaboration.

China has the world's largest rice research capacity and is increasingly engaged in rice systems development work outside China. Nearly 40 Chinese research institutions, universities, and other entities will collaborate with GRISP, particularly in areas such as gene discovery for molecular rice breeding (PL 1.2 and 1.3), C_4 rice (PL 1.4), development of stress-tolerant varieties and hybrids with high yield potential (PL 2.4. and 2.5), water, nutrient, and pest management concepts and technologies for ecological intensification and diversification (PL 3.1 and 3.2), ecological engineering for biological control of pests (PL 3.1), and climate change (PL 3.4). China may also contribute significant new infrastructure to global genotyping and phenotyping efforts. The Chinese molecular rice breeding network will lead the development of new Green Super Rice varieties and make those available to partners in Asia and Africa (PL 1.3, 2.1–2.5). China will also play a significant role in capacity building, including sandwich scholarships for Chinese and foreign students (between Chinese universities/institutions and IRRI, AfricaRice, and CIAT). One such program, supported by the Chinese Scholarship Council (CSC), already exists with IRRI. Moreover, the national Natural Science Foundation of China (NSFC) will issue annual competitive calls for research proposals focusing on selected GRiSP

PLs. Each year, two new 3-year grants will be awarded to joint research teams of Chinese and IRRI or other GRiSP scientists.

Egypt is expected to play a lead role in hybrid rice development in Africa (PL 2.5) and in capacity building at the Rice Technology Training Center (RTTC) for rice scientists and extension staff (PL6.1 and 6.4). Egypt will also be involved in developing new irrigated rice-based systems responding to water scarcity and climate change (PL 3.1 and 3.4).

Advanced research institutes and universities in developed countries. Partners from this sector are mainly involved as direct research partners in GRiSP, particularly in themes 1–5. Initially, GRiSP will have collaborative research activities with over 130 such institutions in Europe, North America, Asia, and Australia. Their main role lies in conducting basic research that is beyond the capacities and comparative advantages of CGIAR institutions and other GRiSP partners. Hence, mobilizing some of these institutions in the framework of GRiSP will be of great importance to deliver on anticipated science-based innovations. Most of the partnerships with these institutes are bilateral and specific to certain GRiSP products, but some also represent larger upstream research networks that include advanced research institutes in developed and developing countries. Key examples for such worldwide partnerships in basic research are the C_4 Rice Consortium (http://c4rice.irri.org), the International Rice Functional Genomics Consortium (http://irfgc.irri.org), the OryzaSNP Consortium (www.oryzasnp.org), and the International Network for Quality Rice (www.irri.org/inqr). As examples, below, we describe the strategic roles of Japan and France in GRiSP, which both have an internationally oriented rice R&D system. France and Japan have contributed greatly to the development of GRiSP and are expected to play a leadership role:

Japan will be a strategic partner for GRiSP because it has one of the largest rice research and development systems in the world, with a long history of outstanding achievements. For example, the annual rice R&D budget of the National Agriculture and Food Research Organization (NARO) is about $100 million, making rice the most important crop in the NARO system. Numerous Japanese rice researchers work internationally, including in projects with IRRI, AfricaRice, and CIAT as well as in long-term bilateral rice sector investments in many countries of Asia and Africa.

JIRCAS, an incorporated administrative agency under the Ministry of Agriculture, Forestry, and Fisheries (MAFF) of Japan, will act as a gateway for GRiSP to the Japanese rice research community. The mission of JIRCAS is to improve technologies for agriculture, forestry, and fisheries in developing regions. It conducts a number of joint research projects on an equal footing with collaborative partners in 25 countries of Asia, Africa, and Latin America. Among the 107 JIRCAS researchers, 23 work on important rice research issues such as molecular biology, breeding, agronomy, modeling, water management, food science, and socioeconomics. The improvement of rice production in Africa also has high priority for JIRCAS. The current JIRCAS representative in GRiSP is also in charge of developing the new JIRCAS MTP for 2011-15, which will provide opportunities for further alignment.

Existing and new mechanisms will be employed to enhance collaboration with the wider Japanese rice research community and thus connect its strengths in advanced research to products being developed in GRiSP for poor rice farmers worldwide. This may include (1) participation in joint GRiSP activities/projects, (2) advanced research funded and conducted primarily in Japan but with a link to GRiSP, and (3) research collaboration through graduate students and staff exchange. GRiSP now cooperates with about 15 Japanese research and development organizations, institutions, and universities. Key areas for research collaboration with JIRCAS, various research institutes belonging to the NARO system (e.g., NIAS, NIAES, NICS), and Japanese universities include functional genomics (PL 1.2–1.4), molecular rice breeding for abiotic and biotic stress tolerance (PL 2.2–2.4), temperate rice systems, including the TRRC (PL 2.4), climate change (adaptation and mitigation, PL 3.4), new products from rice (PL 4.2 and 4.3), and socioeconomic research (PL 5.1 and 5.3).

In recent years, under the general CAADP process, Japan has also taken on the leadership role for establishing the Coalition for African Rice Development (CARD, http://riceforafrica.org) through JICA, an Independent Administrative Agency for development cooperation. GRiSP will work closely with CARD to support the development and implementation of national rice development strategies in the CARD priority countries. JICA will be a key partner for development of the rice sector, particularly in Africa (PL 6.4), with an emphasis on extension capacity building and small-scale mechanization. GRiSP will provide technical support to JICA development projects or implement them on behalf of or with JICA and national partners. The Japanese private sector will also be a partner in several GRiSP activities, for example, on mechanization (PL 6.4) and new products from rice (PL 4.2 and 4.3).

In **France**, the Centre de coopération internationale en recherche agronomique pour le développement (Cirad) and the Institut de Recherche pour le Développement (IRD, formerly known as ORSTOM) will be strategic international research partners in GRiSP and also act as gateways to the larger French national agricultural research and extension system. Cirad is a French targeted research center working with developing countries and regional and international organizations to tackle international agricultural and development issues. Its operations, from field to laboratory and from local to global scale, are based on development needs. Its 800 scientists have joint operations with more than 90 countries. Cirad provides the national and global scientific communities with extensive research and training facilities in Montpellier and in several platforms overseas. Rice is the first target plant/crop/commodity for some 60 Cirad scientists, of whom 25 are outposted in Africa, Asia, and Latin America. As a member of Agreenium, Cirad is also the gateway for mobilizing other French agriculture-related research and higher education institutions for the benefit of rice science. In GRiSP,Cirad and its partners will mainly focus on rice breeding and the associated "-omic" sciences (themes 1 and 2); unified frameworks for analysis of environmental impact of rice production systems and their adaptation to climate change (theme 3); sustainable water and land management, conservation-agriculture-based rice cropping systems, and modeling tools at various scales (theme 3); grain quality issues, and innovative use of rice co-products, including "green chemistry" (theme 4); and information systems and analysis of public policies and dynamics of rice commodity chains (theme 5).

IRD is a public science and technology research institute, reporting to the French ministries in charge of research and development cooperation. Working throughout the tropics, IRD conducts three missions (research, training, and consultancy) in close cooperation with its numerous partner countries to contribute to the economic, social, and cultural development of the countries of the south. IRD has outposted staff at CIAT. IRD researches aim to respond to the major development challenges regarding societies, health, environment, and living resources through priority topics such as nutrition, emerging diseases, education, migration and poverty reduction policies, environmental hazards, global warming, management of marine and continental ecosystems, desertification, water resources, and food security. IRD has important facilities and equipment in dedicated research centers in France and in French overseas territories but also in 22 intertropical countries. IRD is strongly involved in the national research system, including universities and other advanced research institutes (INRA-CNRS-INSERM). Recently, IRD was entrusted with the founding and the management of AIRD (The Interestablishment Agency for Research for Development) to intensify and coordinate French scientific policy concerning the development of southern countries through research. IRD has a long past research experience on rice in the domains of genetic resource preservation and evaluation mainly in Africa and in collaboration with CG centers. In GRiSP, IRD's contribution will focus on themes 1 and 2, particularly the development of interspecific hybridization and pre-breeding for gene discovery, genome analysis of African rice species *O. glaberrima*, and cloning of genes of interest with emphasis on pathogen resistance genes.

Civil society organizations (CSO). Civil society, including nongovernmental organizations, farmers' associations, farmer clubs, and many others, is widely involved at the downstream end of rice production and value chains and will be an essential partner for dissemination. It also plays an important role for providing feedback to researchers and policymakers on setting the right research and investment priorities in order to meet the demands of poor women and men farmers. GRiSP now has active partnerships with well over 100 CSOs in over 20 countries, mainly as development partners in themes 2, 3, 4, and 6. Some international NGOs, such as the World Wildlife Fund and Catholic Relief Services, are also involved in more upstream aspects of rice development and environmental issues. Generally speaking, CSOs have a comparative advantage in operating at the grass-roots level and are thus well placed to ensure full participation of farmers and other stakeholders in GRiSP activities. Their participation is crucial to achieve impact. Such organizations will also complement capacity building for voice at the grass roots. ROPPA (the Network of Farmers' and Agricultural Producers' Organizations of West Africa) has observer status at AfricaRice's Council of Ministers and National Expert Committee meetings.

GRiSP will seek to expand its partnerships with the CSO sector, including global, regional, national, and local NGOs, farmers' associations, and other groups representing the agricultural, social, and environmental sector. In all GRiSP regions, we seek to engage actively with leading CSOs in implementing grass-roots-level development work, as captured in theme 6. GRiSP will seek more interaction with the CSO sector on effective mechanisms for priority setting and collaboration. Two specific initial measures will be taken to foster this: (1) in 2011, GRiSP will aim to hold a summit with CSOs in Southeast and South Asia to discuss future directions and mechanisms for strengthening collaboration, and (2) funds will be made available from the central GRiSP Support and Coordination budget to catalyze new partnership development, particularly with CSO partners.

The private sector. The expansion of the rice seed sector is leading to an increased diversification of rice R&D systems. The private sector is making substantial investments in specific rice R&D areas such as gene discovery and molecular breeding for hybrid rice development, crop protection, new machinery, and rice processing/new products from rice. It is thus generating intellectual property (IP) that could also be of advantage to the public sector. Moreover, private companies are developing and operating increasingly sophisticated delivery channels through which it may also be possible to disseminate certain public-sector know-how better and faster. Hence, new formal research partnerships and contractual relationships are emerging among the public and private sector and those will be of high priority for GRiSP.

The six international centers and organizations in GRiSP (IRRI, AfricaRice, CIAT, Cirad, IRD, JIRCAS) already have active partnerships with over 110 private companies or organizations representing different areas of the private sector (Fig. 13). More than 60% of those are small to medium companies operating nationally or locally, cooperating with GRiSP on adapting and disseminating new technologies or information to farmers and others. These partnerships cut across all GRiSP themes, from upstream gene discovery research in theme 1 to partnering with numerous small local companies and entrepreneurs on delivery (theme 6). GRiSP will play an active role in forming and facilitating such partnerships at global, regional, national, and local levels. Key models for collaboration with the private sector include

- Joint bilateral research implemented through Scientific Know-how and Exchange Programs (SKEP), focusing on research areas that are part of the GRiSP mission and are of mutual interest, IP sharing, scientist-to-scientist interaction, and capacity building for young scientists. Such SKEPs do not involve commercialization agreements, that is, the outcomes of this work are available to both parties. Examples include SKEPs between IRRI and DuPont (Pioneer), Bayer CropScience, Syngenta, and Devgen.

- Multilateral, public-/private-sector consortia with innovative, self-sustained business models for such partnerships and managing intellectual property in the interest of all participants and to the benefit of poor rice farmers and consumers. An example for this is the international Hybrid Rice Development Consortium (Box 6), which consists of 25 seed companies and 25 public-sector institutions.
- Licensing of IP, from the private sector to the public sector and vice versa. This is an emerging area and it requires clear guidelines, including for product stewardship. GRiSP, in accordance with the IP policies of the participating centers and institutions, will strive to develop transparent mechanisms for sharing of IP to the benefit of poor farmers and consumers. This will also include guidelines for joint licensing of IP, in cases where several partners may have contributed to a discovery or development of a product.
- Local delivery partnerships that capitalize on expertise and networks for delivering products and services effectively and efficiently to farmers. By working with private-sector partners on a nonexclusive basis, another channel for delivering public research solutions is enabled. In such cases, GRiSP research partners provide initial technical support and assistance with capacity building for delivering new technologies, whereas private companies, like other partners, use their own resources to deliver these technologies to farmers and also provide feedback for further improvement. In South Asia, for example, GRiSP collaborates closely through the CSISA and STRASA initiatives with numerous private companies and NGOs involved in new agribusiness for providing farm services and knowledge—seeds and other inputs, farm machinery, customized services (crop establishment, harvesting), market information, storage, procurement, facilitation of finance, contract farming, and other commercial services.

Box 6. Hybrid Rice Development Consortium (HRDC)

Worldwide, about 13% of all rice grown is hybrid rice—varieties in which seeds of the first generation of crosses have higher yield potential—commercially marketed to farmers. Since the initial release of hybrid rice in the mid-1970s in China, IRRI and its national partners in Asia have led research, development, and use of hybrid rice technology in the tropics for almost 30 years. Many large multinational and smaller national seed companies are now engaged in hybrid rice breeding and commercialization. Thus, the public sector should now focus on fostering public-private partnerships in which public institutions concentrate more on pre-breeding, basic research on key traits, information, and capacity building, whereas commercialization is mainly done by small and large private enterprises, which need to have equal access to new traits, hybrid parental lines, pilot hybrid varieties, information, and other technologies developed by the public sector.

For this reason, the international Hybrid Rice Development Consortium (HRDC) was established by IRRI as a new model for public-private partnerships in 2008, with current membership of 25 seed companies, one NGO, and 25 public-sector institutions. Private-sector members of the HRDC provide the demand-driven feedback for IRRI's hybrid rice research, but also the financial support needed for sustaining it, in collaboration with IRRI's national partners. They receive the products of this research through fee-based, nonexclusive licensing mechanisms, whereas the public sector continues to have free access. This has allowed IRRI to double its hybrid rice breeding capacity. HRDC members can also participate as sponsors of specific projects and seek bilateral collaboration with IRRI through scientific know-how and exchange programs (SKEPs), which focus on joint research and capacity building. GRiSP will extend such partnerships with the aim of providing farmers with more and better hybrids, quality seed, and knowledge and services provided by both the private and public sector. In this way, GRiSP will also contribute to the emerging hybrid rice sector in Africa and Latin America.

CGIAR centers. Several other CGIAR centers participating as collaborators in GRiSP projects will bring in their expertise, too, for example:

- IFPRI participates in research on food supply-demand modeling, adoption studies, cereal systems in South Asia, aspects related to nutrition and nutritionally enhanced crops, value chains, and policy concerns (themes 2, 3, 4, and 5 in GRiSP).
- CIMMYT, ILRI, ICARDA, and ICRISAT participate in research on improving cereal-based systems in South Asia (CSISA, CRP 1.1, and CRPs under TA 3), including diversification (maize, pulses) and crop-livestock interactions (themes 3 and 6).
- IWMI and IITA participate in the sustainable development of inland valley systems in West and Central Africa (IVC) through CRP 1.2.
- WorldFish will collaborate with GRiSP (and vice versa) in projects on coastal zones and other aquatic systems that involve rice and fish (through CRP 1.3).

International and regional fora and development organizations. GRiSP will collaborate closely with all major regional fora and economic communities with a major interest in development of the rice sector. This includes

- Regional fora involved in GFAR (e.g., FARA, FORAGRO, APAARI at continental level and CORAF and ASARECA in Africa at sub-regional level).
- Higher-level political bodies and development initiatives targeting food security and poverty, such as CAADP (NEPAD), CARD, ASEAN, SAARC, and APEC.
- Regional economic communities such as the Economic Community of West African States (ECOWAS). GRiSP will seek active linkages with RECs in regions where rice is considered a priority commodity (such as in West Africa) to assist with policy formulation and building of rice research and extension capacity.
- International and regional development funds and banks, including IFAD, the World Bank, ADB, AfDB, and IDAB. Many of those directly contribute as donors to GRiSP through the CGIAR Fund/Consortium mechanisms. In addition to that, GRiSP may also provide technical expertise and support to large-scale bilateral or multilateral investments of these agencies in agricultural sector development in high-priority countries.

International organizations and centers such as FAO, other UN agencies, CABI, or ICRA. Collaboration with **FAO** will focus on good agricultural practices (theme 3), rice information systems (PL 5.3), knowledge management for dissemination and innovative ICT approaches (PL 6.1; collaboration with the CIARD, www.ciard.net; virtual extension and communication networks), and large-scale dissemination of new seeds and management technologies in Asia and Africa (PL 6.2–6.4). Collaboration with **CABI** (and through it benefits for its 44 member countries) will focus on unique global ICT products and capacity building for plant health (themes 3, 5, and 6). GRiSP will contribute rice content to CABI's Plantwise initiative. Partnership with **ICRA** (International Center for Development-oriented Research in Agriculture) will focus on capacity building for persons working in multistakeholder platforms for technology development or dissemination (theme 6). GRiSP will also establish linkages with other international multisector initiatives involved in extension advisory systems, such as the Global Forum for Rural Advisory Services (**GFRAS**, www.g-fras.org).

Capacity building

GRiSP cannot achieve its objectives and expected impact without qualified, motivated people on the ground. Human resources for agricultural science and extension in national agricultural research and extension systems (NARES) remain weak in many countries. In Asia, many countries will soon face a generation problem, with experienced scientists and extension workers retiring or not having sufficient knowledge of modern technologies, including information technology. Rice research and extension capacity in Africa is generally weak, with the notable exception of Egypt. No sub-Saharan African country hosts a national institute working entirely on rice. In 2008, only 250–275 researchers (15 women) were involved to some extent in rice research. In order to double rice production by 2018, at least 500 rice researchers and 1,000 trained technicians would be needed in 12 priority African countries. Nigeria, one of the world's leading rice importers and with a population about twice that of Egypt, had only two rice breeders but would need 88 researchers, including 30 breeders. Too often, researchers in Africa are not able to apply what they learned abroad in their home country. Curricula at universities and technical schools need to be updated and made more relevant to the realities of the agricultural sector in Africa. Capacity needs to be developed on a sustainable basis across all aspects of the rice production sector, both public and private; in research, development, and extension. Needs differ between and among the regions but all have common elements, allowing excellent opportunities for economies of scale in the design and implementation of courses and materials.

Capacity building will be integrated into all six themes of this GRiSP and all research activities will include specific capacity-building milestones. The science capacity building will link to cross-center initiatives, such as the international doctorate school for the plant breeding domain that is being developed by Cirad. For specific skills for careers in plant breeding management, there will be links to the "Semences et plants méditerranéens et tropicaux" (*SEPMET*) program of Cirad. A specific effort in capacity building for rice research and extension will be made in sub-Saharan Africa, where there is a dearth of expertise.

In all capacity-building activities, GRiSP will encourage the participation of women by requiring that at least 30% of the participants be women. Capacity building will not end with the completion of postgraduate degree study or internship or short-course training; the centers will have active links with scholars and extension persons in their own country through networks and other joint research and activities involving alumni of the different capacity-building programs.

A brief overview of key capacity-building programs in GRiSP is provided below. Box 7 summarizes the key capacity-building targets in GRiSP. The description of theme 6 and its product lines (Appendix 3) provides further information on the extension capacity-building efforts.

Enhancing global rice science capacity. The challenges in the face of climate change, reduced land and water resources, and population pressure require a renewed global rice science research capacity and national research capacity. The international centers will work closely together with leading universities worldwide, the national rice and education policymakers, the private sector, and advanced research institutes in building a new cadre of rice scientists. Capacity-building efforts will link closely with other initiatives such as the AWARD program for African women. The following initiatives will ensure a comprehensive approach:

- Global Rice Science Scholarship**:** This will develop research capacity at the PhD and MSc level. Scholars will be capable of designing, conducting, and reporting on research that addresses farmers' needs within national priorities and within a global context. The academic programs will be regionally based and will link in-country universities with the international centers. Preference will be given to a sandwich program approach in which the research agenda focuses on local issues that also contribute to global knowledge. The scholars' time will be part in-country and part at one of the international centers. The centers will strengthen links with professors from collaborating universities through exchange visits and visiting scientist placement. Capacity building will link to cross-center initiatives such as the Cirad international doctorate school for plant breeding. The global rice science scholarship program will augment the current PhD and MS project-based program that is limited to projects. Less-represented countries and research disciplines will receive priority.

Box 7. Key capacity-building goals in GRiSP

Assuming that sufficient funding can be raised from the Fund and from bilateral sources, GRiSP aims to achieve the following annual capacity-building goals by 2015:

- 100 PhD and MS scholars graduate each year (Asia 60, Africa 30, and LAC 10) through expanded scholarships programs with international centers), with 30% of graduating scholars being women.
- 30 graduates each year obtain a Master's in Rice Science Leadership degree (18 from Asia, 10 from Africa, and 2 from LAC, of whom 30% are women).
- Cirad's new international doctoral schools for plant breeding accept at least 5 GRiSP scholars annually.
- Scholarships for 200 persons per year for short-course science capacity building for NARES institutions, CSOs, and the private sector (Asia 100, Africa 60, and LAC 40), with 30% women.
- Rice Research to Production course for 30 young scholars per year, with field placement for 15 students per year in project locations across Asia, Africa, and LAC.
- Each year, 50 internships of up to 6 months offered to promising young students and graduates (Asia 25, Africa 20, and LAC 5) to gain experience through research and development partnerships with NARES institutions, CSOs, and the private sector.
- Annual leadership training course for women in rice science and development (20 participants).
- Science education lab established at IRRI for providing rice science exposure for students.
- Rice agronomy and postharvest training center established at AfricaRice Senegal.
- Accreditation schemes for certified extension-agronomists and inputs' dealers are operating in three countries.
- New training modules and information tools for extension leaders in Asia, Africa, and LAC, including local knowledge banks and learn-IT solutions.
- Extension methodology courses are available online, on CD, and face-to-face.
- Each year, at least 5 young extension leaders from each of 12 priority African countries complete season-long training and communications training.
- Each year, at least 25 persons in each region complete capacity for inclusive participation for research for development that is coupled with ongoing engagement within projects.
- Need-based training of local women leaders who will provide training to women farmers on farm management, technical information, and skills from production to postharvest.
- Trained resources provide continuous training for at least 1,000 grass-roots extension leaders.

- <u>Master's in Rice Science Leadership:</u> In collaboration with the University of Leuven, Belgium, this new program will be available via distance education and on-site courses at IRRI. Students, in addition to their disciplinary scientific degree, will be trained as well-rounded future science leaders using a new curriculum being developed in 2010. They will obtain a secondary degree in leadership from the University of Leuven. This new program will be offered to students currently completing their PhD as well as to scientists in NARES. By 2015, at least 30 graduates will complete the Master's program. This program is open to students from other disciplines and we expect that it could be expanded to other CGIAR CRPs.
- <u>Short courses and internships</u>**:** Research capacity will be built in specific areas for individual scientists through a range of short-term courses, capacity building through research partnerships, and internships. This is inclusive of specific programs such as the Cirad

functional genomics training. Special attention will be given to region-specific needs such as capacity building of research technicians in Africa.

- Attracting new talent to rice research: It is critical that there be a continual influx of high-quality people into careers in rice research. Scholarships for a Rice Research to Production course conducted at IRRI will provide exposure to 30 young scholars each year. The current program received funding from NSF USA, Gatsby Fund UK, and sponsorship from individual projects. At the request of participants, it is planned to expand the program to provide opportunity for 6–12-month placements across Asia, Africa, and LAC, working in projects with a wide range of GRiSP research and development partners. The program provides a strong science and social development interface for participants. In 2011, with support from the private sector, IRRI will establish an education learning lab in rice science for preuniversity to expose young people to the excitement of rice science.

Support for extension capacity building. The second key to impact is timely uptake by farmers. There is high demand for a capacity-building program that develops a network of ‘practical extension personnel in rice production and postharvest and processing in each country—officers skilled in assessing farmers’ needs, working with men and women farmers and local organizations, sourcing research-based solutions, and effectively coordinating delivery of new technologies to farmers through public and private partnerships across the wider extension community. Through theme 6 in GRiSP, capacity building of extension personnel will be undertaken through developing, with public- and private-sector partners, certified crop agronomist programs and upgrading extension agronomists to lead training of trainers. In collaboration with the American Society of Agronomy and the agricultural business communities, a new, self-sustained certified crop advisor program that provides accreditation for extension agronomists will first be introduced in India in 2010 and expanded to other countries beginning in 2011. This will support agencies, public, private, and civil society, that are actively involved in technology diffusion at the farm level. These agencies will lead the capacity building of dealers, service providers themselves, and grass-roots extensionists.

Capacity for inclusive participation. Enhanced science and extension capacity building will be coupled with capacity for persons and organizations to effectively function within multistakeholder platforms that are now characteristic of research and dissemination for development. The partnership between AfricaRice and the International Center for Development-oriented Research in Agriculture (ICRA) is illustrative of the commitment to partner-enabling. ICRA as an institute has a commitment to stimulate rural innovation in the south by strengthening the abilities of people and organizations in research, education, and development to collaborate and learn from each other. For themes 3, 4, and 6, there is a strong emphasis on building learning alliances for both adaptive research and large-scale dissemination. Empowerment through participatory capacity building will underpin these activities in each region (for example, the hub-level technical working groups in South Asia in the CSISA project). IRRI and AfricaRice will employ such approaches as developed under IRRC and CURE and former projects such as PETRRA. There will be a partnership in capacity building that taps the skills within the region and within partners (e.g., CRS). It is recognized that a voice for resource-poor farm households and women does not just happen. Capacity building for empowerment of organizations working with vulnerable households will take place within the context of on-the-ground activity. In other words, whether it is capacity for public-private partnership or a voice for women or resource-poor farm households or civil society mobilization, the practice will be one of action and reflection.

Gender strategy

The UN Millennium Declaration resolves "to promote gender equality and the empowerment of women as effective ways to combat poverty, hunger, and disease and to stimulate development that is truly sustainable" (United Nations, 2000). The policy and institutional environment should be supportive of women in order to recognize the significance of their contribution and the ability to realize empowerment through their own skills and capacity. Thus, the objectives of the gender strategy in GRiSP is to ensure that gender issues are identified through rigorous gender analysis with emphasis to differential access to assets and technologies, technology impact assessment, and involving both men and women (at least 30% of the participating farmers) in adaptive research (from needs assessment, technology design, evaluation, assessment of outcomes, and dissemination) along the whole rice value chain, as well as in capacity enhancement programs with a view to enhancing productivity and incomes, and empowering women farmers to remove gender inequities.

Rigorous studies on different roles and responsibilities of men and women from different socioeconomic groups in rice-based agriculture (crop, livestock, agroforestry, fisheries) in Asia, Africa, and Latin America and the Caribbean revealed that women contribute significantly in rice-based agriculture, in relation to men. Their roles and those of rural men are conditioned by several interrelated socioeconomic (including class, ethnicity, age, religion), political, and environmental factors and are known as “gender roles.” However, these roles are dynamic and can change over time depending on changes in other factors noted above. Culture is not “static”, but dynamic; cultural “norms” also change over time depending on other environmental (abiotic stresses, climate change) and socioeconomic changes (labor outmigration, increasing mechanization, declining land size, etc.).

Women’s participation in rice production varies by country, production systems, type of household (nuclear or extended), social and economic status, and availability of male family members. Studies on the gender division of labor in rice production also reveals that women in Southeast Asia contribute 25% to 60% and in South Asia 60-80% in India and Nepal. In Africa, 80% of Africa’s food is grown by Africa’s 100 million rural women. Women undertake much of the work in traditional rainfed, mangrove, and upland rice in Africa. They are mainly responsible for ensuring household food, health, and nutritional security. The participation of women in crop and natural resource management increases with poverty and environmental stresses (drought, submergence and problems soils). Thus, women in semi-subsistence farming in Asia, Africa, Latin America and the Caribbean play crucial roles as producers/farmers and consumers, farm managers, income earners, and processors of small-scale value-adding activities for rice products. They are often responsible for food storage and seed selection/storage. Despite women’s important contributions in farming and livelihoods, women have less access than men to knowledge and skills, productive assets, including agricultural inputs, improved seeds, land, credit, agricultural extension services, and small equipment/light machinery. Similarly, in the world of national and international agricultural research, women continue to be underrepresented and their contributions are not fully tapped.

Mainstreaming gender concerns in the various themes will build on the success of the earlier experiences of IRRI’s Women in Rice Farming Systems (WIRFS) program and sustained leadership in promoting gender equality in IRRI’, Participatory Research and Gender Analysis (PRGA) led by CIAT and the African Women in Agricultural Development (AWARD) of the Gender and Diversity program of the CGIAR. Capacity enhancement for women researchers, extension and development workers will build on IRRI’s experiences in conducting a leadership course for Asian and African Women in research, development and extension. The focal points on gender in GRiSP will also work with other international and national agricultural research institutions with expertise on gender audit, gender mainstreaming and on strategic research on gender issues. In collaborations with NARES in Asia, Africa and Latin America Participatory varietal selection (PVS) in representative stress-tolerant rice environments will build on the past experience of IRRI, AfricaRice, and CIAT, involving men and women in participatory plant breeding, varietal selection, and natural resource management. IRRI's experience in conducting PVS in stress prone rice environments revealed gender differences in knowledge, needs, and priorities, as well as differences in access to control of resources. Thus gender concerns in rice varietal improvement need to be considered in the research agenda, particularly in technology design, testing, evaluation, impact assessment, and dissemination. Men's and women's preferences for varieties may be similar or different depending upon the gender-specific tasks and livelihood use of rice and degree of market orientation. Aside from high and stable grain yield and tolerance of stress, women look for other traits, for example, quality of rice straw for animal fodder, eating and cooking quality traits for rice as food and as special food products, postharvest quality and duration so that they can grow other crops after rice.

GRiSP will address gender issues in all the GRiSP themes. Strategic research on gender issues in rice research will be conducted under theme 5 (technology evaluations, targeting, and policy options to enhance impact). Theme 5 will focus on gender analysis and gender differentiated constraints and enabling factors for adoption of technologies (stress-tolerant rice lines/varieties, crop and resource management options, diversified cropping systems, seed health improvement, postharvest technologies, etc.), and resource-conserving technologies in South Asia, Latin America, and West Africa. In Bangladesh, poverty dynamics with a focus on changing gender roles as well as access to and control of resources due to adoption of technologies by socioeconomic groups will be examined through high-frequency longitudinal data sets of 12 Bangladeshi villages. Impact of technologies on women's employment, income and empowerment as well as family welfare will be assessed. The impacts of technologies in intensive cereal systems on gender inequalities, asset disparities, and rural livelihoods will be evaluated. Findings from this study will be used in identifying best practices for improving women's access to and control of major productive assets (land, livestock, agricultural machinery). Women from small farming households will be involved in adaptive on-farm trials on rice varietal improvement and associated crop management technologies for stressed environments (drought, submergence, and salt-affected soils). Indicators for measuring reduction in gender inequalities in access to and control of resources and women empowerment due technology adoption will be developed.

In theme 2, new promising tolerant breeding lines for stress-prone environments in lowland and upland areas will be evaluated through PVS with male and female farmers in Asia, Africa, and LAC. To ensure women's participation, at least 30% of the farmers in these trials will be women farmers. This will improve the understanding of men's and women's criteria for varietal selection, reduce gender inequalities in access to seeds of stress-tolerant breeding lines, and increase technical knowledge in all aspects of rice production, including the production of high-quality seeds. In theme 3, the consequences of climate variability on resource management of men and women among rice-farming households in Asia, LAC, and Africa will be assessed. Women farmers will be involved in validating farm management innovations for lowland systems in Africa, Asia, and LAC. In theme 4, women-friendly parboiling technology will be developed in relation to women's associations managing the parboiling industry in West Africa. Value-chain analysis and assessment of specialty rice and products of lower-value rice will be done by male and female farmers. Women's knowledge will also be considered in the development of post harvest machinery and seed storage technologies. In theme 6, men and women will be included in new models for jointly building extension capacity with NARES partners.

To increase women's participation in rice science and involvement in the research teams of the various themes (Themes 1 to 5), opportunities for women to participate in training courses on scientific research, scholarships for MS and PhD students and Post Doctoral fellowships will be provided. Capacity-building support for extension agencies will target 30% women. Thus, consideration of gender issues in GRiSP is expected to greatly enhance the efficiency and impact of research as well as reduce gender inequalities in access to technologies.

Gender inequalities in access to resources and technologies will be examined through the following outcomes in different themes, such as

Theme 5. Technology evaluations, targeting, and policy options for enhanced impact

- Analysis of on-farm performance, gender-disaggregated constraints, and social and economic effects of technologies in South Asia and Latin American countries.
- Analysis of adoption patterns and constraints to adoption of rice varieties in South Asia, Latin America, and Africa (Mozambique and Tanzania).
- Assessment of enablers and constraints to adoption of good agricultural practices in Southeast Asia and Latin America.
- Analysis of supply-chain constraints to the adoption of improved technologies and best management practices in South and Southeast Asia.
- High-frequency longitudinal data set of 12 Bangladeshi villages for understanding poverty and gender dynamics in South Asia.
- Farmer livelihoods analyses in representative rice-growing environments in South and Southeast Asia and LAC.
- Analysis of changing roles of gender due to climate change, migration, and widespread technological changes in Southeast Asia, South Asia, and LAC.
- Assessment of farmers' coping mechanisms during *monga* or seasonal hunger in northwest Bangladesh.
- Consumer (male and female) survey in the Philippines for determining perceptions and acceptability of Golden Rice.
- Consumer (male and female) preferences studied among different categories of populations of two West African countries.

Existing household survey data sets (including collection of micro-level and macro-level gender-disaggregated information for gender-responsive policies) updated and made available online.

Theme 2. Accelerating the development, delivery, and adoption of improved rice varieties

- 60 new promising drought-tolerant breeding lines developed and distributed to NARES for PVS evaluation by male and female farmers in Asia.
- 50 promising lines with tolerance of submergence and stagnant flooding developed and disseminated to NARES for PVS evaluation by male and female farmers in Asia.
- 100 new promising salt-tolerant lines developed and distributed for evaluation under PVS system by male and female farmers in Asia.
- 50 elite and 200 advanced lines from STRASA phases 1 and 2 available for PVS in West and Central Africa and ESA. At least 30% of PVS participants are women.
- 50 elite upland lines from STRASA-2 and fixed from GCP-MARS available for PVS in West and Central Africa and ESA. At least 30% of PVS participants are women.
- Cold-tolerant upland varieties developed in Madagascar introduced in the PVS network of STRASA phase 1. At least 30% of PVS participants are women.
- Two elite cold-tolerant upland varieties and one lowland variety introgressed with three blast resistance genes released in Madagascar and introduced in the PVS network of STRASA phase 2. At least 30% of PVS participants are women.
- 80 elite lines from STRASA phase 1 crosses and from Madagascar populations improvement by RS available for PVS in the target countries. At least 30% of PVS participants are women.

Theme 3. Ecological and sustainable management of rice-based production systems

- Knowledge of the consequences of climate variability on resource management of men and women among rice-farming households.
- Knowledge of impact of new crop and resource management technologies on women

Theme 4. Extracting more value from rice harvests through improved quality, processing, market systems and new products

- Women-friendly parboiling technology developed in relation to women's associations managing the parboiling industry in West Africa.
- Value-chain analysis and assessment of specialty rice and products of lower-value rice by male and female farmers

Theme 6. Supporting the growth of the global rice sector

- Needs-based training of local women leaders who will provide training to women farmers on farm management, technical information, and skills for production to postharvest (25 persons per year) in South Asia.
- Trained resources of milestones 6.1.4.1 provide training for at least 100,000 grass-roots extension persons, including women in South Asia.
- Needs-based training of local women leaders who will provide training to women farmers on farm management, technical information, and skills from production to postharvest (25 persons per year) with emphasis on production of high-quality seeds in Southeast Asia.

Linkages with other CGIAR Research Programs

GRiSP aims to develop integrated solutions for a wide range of farming systems that include rice, but often also other crops and commodities. GRiSP will therefore work closely with other CGIAR Research Programs (CRPs) as summarized in Table 3. As more information about these CRPs becomes available, the specific linkages and boundaries of each of them and GRiSP will be evaluated in more detail in order to avoid duplication and ensure full synergy. This process will benefit from input from the sub-regional and regional research fora.

To maintain focus, integrity, and efficiency of the product-oriented research approach, rice research, even as part of more complex farming systems, will largely be conducted under the GRiSP umbrella, but the products of this research will also make significant contributions to the objectives pursued in other CRPs, and vice versa. Moreover, it should be noted that GRiSP does not include the entire rice research agenda of the CGIAR. Research on natural resource management and climate change in rice-based landscapes will be conducted in CRP 5 and CRP 7, in which IRRI, AfricaRice, and CIAT will also participate. CGIAR centers and Research Programs can interact in many ways. We distinguish three major forms:

- Full participation of IRRI, AfricaRice, CIAT, and other GRiSP partners in other CRPs that address rice-related issues beyond the focus of GRiSP and require wider collective action (e.g., CRP 5 and CRP 7).
- Collaboration in which GRiSP interacts with other CRPs through research collaboration (and vice versa) in the thematic areas that are also addressed by other CRPs, but require a systems approach. Often this is done through cross-cutting regional projects such as CSISA (see below) and the Inland Valley Consortium that focus on a wide range of commodities, production systems, and health and environmental issues, but that often also include rice.

- Co-investment from other CRPs into GRiSP (or vice versa), through which outputs of one CRP are also cross-listed as outputs in another; this model may be preferred for research that is better conducted in another CRP, but contributes to the thematic area of the sponsoring CRP. One may also refer to that as "outsourcing."

Table 3. Interaction of GRiSP with other CGIAR Research Programs.

Thematic area/CRP	Interaction	GRiSP Product Lines
1.1 Drylands	Regional project collaboration in South Asia (crop-livestock systems, with ILRI) and in the CWANA region (rice germplasm for irrigated drylands, through the TRRC); CRP 1.1 is likely to operate at the fringes of major rice-growing environments such as the Indo-Gangetic Plains, which are a key target region for GRiSP and CRPs such as WHEAT.	2.4, 3.2, 4.2, 5.1, 6.2
1.2 Humid tropics and highlands	Regional project collaboration in Africa on inland valleys development (IVC, with IITA, IWMI, and others).	3.3
1.3 Coastal and aquatic ecosystems	Regional project collaboration on coastal zones development and other aquatic systems that include rice (with WorldFish and others); major work on coastal zones in which rice is the key entry point is fully contained in GRiSP for greater efficiency.	2.3, 3.3, 6.2
2 Policies, institutions, markets	Project collaboration and co-investment by CRP 2 into GRiSP. GRiSP, through theme 5, will provide rice-specific outputs for CRP 2 such as (i) models and data for analyzing trends and scenarios for food, poverty, markets, environmental conditions, risks; macroeconomic factors affecting particular rice; (ii) cross-country analyses of production and technology policy across various commodity systems; (iii) Institutional arrangements for agricultural research and extension services; (iv) rice value and postharvest chains.	4.1, 5.1–5.4
3.2 Wheat	Project collaboration on rice-wheat and rice-maize systems in South Asia and China (see description of CSISA, below). Both GRiSP and CRP WHEAT will follow a joint regional strategy for developing and disseminating resource-conserving technologies for cereal systems. Collaboration on comparative physiology research for heat tolerance and raising the yield potential, including comparative genomics studies.	1.4, 2.1, 3.2, 3.4, 5.1, 6.1, 6.2
3.3 Maize	Project collaboration on rice-maize systems in South Asia (see above for wheat)	3.2, 6.1, 6.2
3.4 Pulses and legumes	Project collaboration on rice-pulses systems in South Asia (see description of CSISA, below).	3.2, 6.2
3.5 Roots, tubers, bananas	Project collaboration in South Asia in systems that involve rice and tuber crops	3.2, 6.2
3.6 Millets, sorghum, and barley	Project collaboration in South Asia in cereal systems of more semi-arid environments, but also on pulses as part of rice-wheat systems (see description of CSISA, below)	3.2, 6.2
3.7 Livestock & fish	See CRP 1.1, may be overlapping	2.3, 3.2, 6.2
4 Agriculture, nutrition, and health	Co-investment by CRP 4 into GRiSP for biofortification rice breeding (Harvest+), but the breeding is part of IRRI's and AfricaRice's mainstream breeding program. Hence, GRiSP directly contributes these outputs to CRP 4.	2.6
5 Land, soils, water, and ecosystems	Full participation (see below). IRRI, AfricaRice, and CIAT contribute to large-scale research on land and water resources, irrigation systems, and ecosystem services in CRP 5. GRISP feeds technologies and know-how into CRP 5.	3.1, 3.2, 3.4
6 Forests and trees	None, except for minor collaboration on upland and highland systems improvement and ecosystem services.	3.3
7 Climate change and agriculture	Full participation (see below). IRRI, AfricaRice, and CIAT contribute to large-scale research on climate change vulnerability assessment, modeling, adaptation strategies, etc. GRiSP feeds technologies and other know-how into CRP 7.	2.3, 2.4, 3.1–3.4, 4.2, 5.1, 5.2, 6.1–6.5

Cereal Systems Initiative for South Asia (CSISA). Through the Rice-Wheat Consortium (RWC) and Irrigated Rice Research Consortium (IRRC), CGIAR centers and their national public- and private-sector partners have made significant progress in South Asia on developing advanced management practices that are also based on principles of conservation agriculture, such as laser leveling, residue management, intercropping, reduced tillage, and direct seeding. CSISA was established in 2009 as a new regional platform for developing and disseminating the next generation of solutions for South Asia's most important cereal systems, from genetic improvement to improving cropping systems and market and public-private delivery systems.

CSISA is currently led by IRRI and involves CIMMYT, IFPRI, ILRI, and WorldFish as CGIAR centers. It operates in 10 large hubs across South Asia, in Pakistan, India, Bangladesh, and Nepal, and involves more than 200 local public-, CSO, and private-sector partners. Cropping systems targeted include rice-wheat, rice-rice, rice-maize, rice-pulses, cotton-wheat, maize-wheat, and many variants of them, including crops such as potato, pulses, jute, and sugarcane. In many areas, crop-livestock interactions also play an important role, and integrated farming systems with aquaculture are being studied in southern Bangladesh.

CSISA plays a key role for connecting many CGIAR Research Programs targeting the intensive agroecologies in South Asia. Major linkages with other CRPs include

- CRP 1.1: on delivery activities in some (drier) areas, including mixed crop-livestock systems.
- CRP 1.3: CSISA activities on coastal zones improvement and rice-fish systems in Bangladesh are part of CRP 1.3.
- CRP 2: cereal systems policy research in CSISA is part of CRP 2.
- CRPs under TA 3 (rice, wheat, maize, pulses, livestock and fish): CSISA activities on those in India, Pakistan, Bangladesh, and Nepal (breeding, conservation agriculture, socioeconomic research, capacity building) are all part of these CRPs.
- CRP 5: expected contribution to this CRP on water resource management.
- CRP 7: South Asia is a priority region for CRP 7. CSISA research on future cropping systems' contributions to better understanding of adaptation and mitigation strategies in CRP 7.

In summary, CSISA is an integrated, regional initiative that effectively links many CRPs and disciplines. CSISA provides a new model and the necessary resources on the ground for seamless integration of research with delivery activities conducted by a multitude of partners. The main target regions for CSISA are different from those in CRP 1.1, which emphasizes drier areas, and CSISA follows an approach in which research is conducted in two-way interaction with delivery activities, in the CRPs that have a comparative advantage to do this in the most efficient manner. CSISA (and similar regional research to impact initiatives) should therefore be viewed as an alternative model for connecting CRPs for larger regional impact.

Linkages with CRP 5 (water and land resources). GRiSP theme 3 will interact with the Best Bet "Revitalizing Surface Irrigation" and the Best Bet "Ecosystem Services." In the "Irrigation Best Bet," we will contribute to the output[14] "A toolkit of options and capacity-building materials for improving the management, design, and performance of surface irrigation, including options for institutional arrangements, practices to improve water productivity and real water savings, and methods to enhance ecosystem services to meet multiple objectives beyond provision of water to crops."

In Asia, most rice-based irrigation systems are designed for continuously flooded rice (supplemental irrigation in rainy seasons mainly) and such systems are also important in parts

[14] Based on submitted CRP 5 version of September 2010.

of Africa (e.g. Egypt, Sahelian West Africa). In GRiSP, a number of water-saving technologies are developed at the field level—such as alternate wetting and drying (AWD), raised beds, aerobic rice, direct seeding—that do not require continuous flooding. Most of these technologies mainly reduce seepage and percolation losses, which means that more water can be retained in the canal system upstream and be available for use downstream where water availability is usually limited. For adoption to improve the performance of irrigation systems in CRP 5, we propose to address the following research questions: How do water savings at field scale translate throughout an irrigation system? How much water can be saved by reduced seepage and percolation upstream and be available in the canal system for downstream use? How much "real" water savings by reduced evapotranspiration can be accomplished? Can new irrigation systems effectively be designed based on water-saving technologies at the field level rather than on the principle of continuous flooding? Can rice-based irrigation systems be more effectively managed by reuse of water lost by seepage and percolation, for example, by pumping downstream from shallow groundwater or from creeks and drains? What are the associated costs, and how can cost/benefit equity be realized among upstream farmers (who may "spill water" for free) and downstream water users (who may need to pay pumping costs for recapturing "spilled" water)? How does water reuse compare with the adoption of water-saving technologies in terms of water productivity and costs?

Because of their flooded nature, rice environments provide unique—but as yet poorly understood—ecosystem services such as the regulation of water (groundwater recharge, erosion control, buffer against flooding), the preservation of unique aquatic and terrestrial biodiversity, and centuries-old cultural services. In CRP 5, we propose to use GRiSP-generated knowledge and expertise to identify, quantify, and map ecosystem services from paddy landscapes, and generate strategies to retain or improve these services in the face of major drivers of change (water scarcity, climate change, intensification). Key questions include: How will water scarcity affect ecosystem services of rice landscapes? What implications will the adoption of water-saving technologies have for ecosystem services? Periods of nonflooding (or aerobic soil conditions) will have implications for flora and fauna, soil nutrient supply, greenhouse gas emissions and carbon sequestration, groundwater recharge, etc. How can these impacts be factored into the analysis of ecosystem services?

Linkages with CRP 7 (climate change). Climate change research in GRiSP will step up current research on climate change impacts on rice as well as possible adaptation and mitigation strategies. It will be done in synergy and close linkage with CRP 7. GRiSP pursues a comprehensive <u>assessment of climate change impacts</u> that encompasses close cooperation with theme 4 (Analytical and Diagnostic Framework) in CRP 7 to use relevant climate change information at multiple scales. The key element for this endeavor is downscaling of climate and global socioeconomic processes to a resolution that suffices for decision making in agriculture. GRiSP will cooperate with CRP 7 and other CRPs to conduct case studies on climate change impacts in rice-based systems that can then be upscaled to broader, regional, and cross-regional domains, for example, for the rice-dominated landscapes of Asia and Africa.

The GRiSP work on climate change <u>adaptation</u> will be closely aligned with the work of CRP 7 theme 1 (Adaptation to Progressive Climate Change) and theme 2 (Adaptation through Managing Climate Risk). GRiSP will contribute the "rice component" for an integrated research program that includes analysis of current farming systems in identifying suitable technologies and practices. Jointly with CRP 7 and other CRPs, GRiSP will incorporate improved rice germplasm and technologies into comprehensive approaches for strengthening the adaptive capacities of rice farmers through a variety of strategies ranging from diversification of production systems to improved institutional settings.

The thematic and logistic links of the GRISP <u>mitigation</u> work with other CRPs will mainly be channeled through CRP 7 theme 3 (Pro-Poor Climate Change Mitigation). GRiSP will develop highly productive rice technologies with low carbon footprints based on enhanced resource-use efficiencies—for water as well as for nutrients. The focus of the mitigation work of CRP 7 is on pro-poor approaches, so that rice farmers will be the core beneficiaries in many regions of the world. Rice production systems have to form an integral part of low-carbon agricultural development pathways; otherwise, such efforts will be bound to fail in effectively all rice-growing countries. The same applies to the new institutional frameworks and new financial mechanisms for effective participation of the poor in the carbon market, which can be achieved by direct interaction with rice farmers that constitute the majority of rural poor in vast parts of the developing world. The diversity of natural and socioeconomic settings in the developing world requires decision support systems to identify the most suitable combination of land-use systems and crop management measures within a local context—a task that can best be accomplished in a comprehensive mitigation approach as envisaged for CRP 7 theme 3.

Generation Challenge Program (GCP). GRiSP integrates a number of ongoing projects funded by the GCP, including two projects under the drought and comparative genomics challenge initiatives and major work on a molecular breeding platform. GRiSP fully supports the transition strategy presented by the GCP leadership team. The ongoing GCP-funded projects will be completed under themes 1 and 2 of GRiSP. For example, the GCP project on improving drought tolerance in rice in Africa aims to establish, within four years, the drought profiles of the target population of environments in inland valley lowlands, identify traits of interest for targeted environments using novel phenotyping methodologies, and integrate the information on drought profiles with novel phenotyping methodologies in a marker-assisted recurrent selection (MARS) scheme to develop better adapted cultivars for each major target environment. This project will also facilitate the transfer of molecular breeding technology know-how to the region, strengthen partnerships and capacity, and deliver more efficient breeding programs.

GRiSP will participate in the proposed GCP transition toward a cross-cutting Genomics and Integrated Breeding Service (GIBS). The GCP has proposed that this GIBS be demand-driven and designed to support CRPs, NARES, and other partners in genomics research and molecular breeding. Expanding on the GCP's ongoing work on developing an integrated breeding platform (IBP; supported by a grant from the Bill & Melinda Gates Foundation until mid-2014), the GIBS will be integrated into the crop CRPs within the new CGIAR logframe. The GIBS will be a one-stop shop via a Web-based portal providing information for accessing genetic stocks and prebreeding materials, with seed maintained and distributed by crop lead centers. The portal will provide high-throughput services for genotyping and specialized physiological or metabolic measurements, informatics tools, and support services. The GIBS will support capacity and community development for genomics research and integrated molecular breeding projects. The service should be operational as an integrated pipeline by 2012, at which time it will be open to a broader set of users within and outside of the CG system. The service was designed to be sustained past GCP's "sunset." The format, as well as the operational framework, including a business plan and governance that this service is proposed to adopt after 2013, will be discussed and defined with partners during this transition phase. GRiSP lead centers will have overall responsibility for rice data management and storage, and will become major drivers of the GIBS.

Theme 1: Harnessing Genetic Diversity to Chart New Productivity, Quality, and Health horizons

Overview

Rationale and objective

Genetic diversity is the foundation of the genetic improvement of crops. Knowledge of multiple facets of rice genetic diversity from the molecular to the phenotypic is essential for effective conservation and use to meet both current and future needs. Although the genetic makeup of rice, a vast catalogue of genes, has been revealed as a result of recent advances in biotechnology, most of their functions remain largely unknown. Thousands of undiscovered genes can potentially benefit rice productivity and quality and the processes to decipher their functions are complex—requiring cutting-edge biotechnology, phenotyping methods, and bioinformatics. An individual institution can cope with only a few at a time. If we are to exploit the rice genome adequately in a timely manner to help increase the world's rice harvests, a global research effort is needed, integrating the strengths of public and private organizations and facilities from high-tech laboratories to farmers' fields. The CGIAR, through existing centers and new research networks as a basis for wider partnerships, is ideally placed to lead this effort.

Theme 1 draws together germplasm conservation, diversity analysis, gene discovery, and dissemination of advanced genetic/breeding resources, presenting a unique opportunity to maximize the use of conserved and customized germplasm. Because water is fundamental to rice productivity, traits dealing with stress related to water—too little or too much—are the core concern of this global effort to reduce risks to farmers and to mitigate the effects of a changing climate. Research will also include a wide spectrum of genes for other traits that have high impact in the various rice production environments.

Research approach

The basic approach is to improve the conservation, characterization, and use of the world's rice gene pool for varietal development by joining the resources of organizations across the globe. This will mean joint management of the world's rice genetic resources both in genebanks and in research, development, and extension institutions. The theme will capitalize on the rapid advances in DNA sequencing technologies to reveal rice diversity in a comprehensive manner. We will also learn from plant species with better photosynthetic efficiency (Box 8) to redesign the rice plant for greater productivity for the future. Theme 1 will also provide capacity building for many NARS collaborators in new molecular biology approaches.

Box 8. C4 rice—re-engineering photosynthesis
Construction of C_4 rice, in which the 3-carbon metabolic pathway of photosynthesis in present rice plants is converted into a 4-carbon one, is a revolutionary, elegant concept and a grand challenge to be addressed in GRiSP. C_4 rice would increase rice yields dramatically, by up to 50%, independently of the rice-growing environment (unlike all other interventions), while using water and fertilizer up to 30% more efficiently. The metabolic components already exist in C_3 rice plants. However, the anatomical and biochemical features of C_4 plants must be understood and transferred to rice plants. A technological innovation of this magnitude requires the skills and technologies of a global alliance of multidisciplinary partners. In GRiSP theme 1, this is being pursued by a group of scientists and their resources from advanced institutions around the world in the international C_4 Rice Consortium. The aim is to construct a functioning C_4 rice plant within the next 20 years. Success would mean a quantum leap in securing the world's future rice supply.

R&D product lines and outputs

1.1. *Ex situ* conservation and dissemination of rice germplasm

1.2. Characterizing genetic diversity and creating novel gene pools
1.3. Genes and allelic diversity conferring stress tolerance and enhanced nutrition
1.4. C_4 rice

These product lines will provide the foundation for new international rice breeding programs, leading to new and improved rice varieties (addressed in theme 1) and cropping systems (theme 3). They will also improve both *in situ* and *ex situ* conservation of the world's rice genetic resources. Broadened access to genetic resources and tools by breeders, researchers, and plant biologists is expected to improve the efficiency of rice breeding and gene discovery activities among partners, enable precision breeding, and accelerate the achievement of breeding targets in theme 2. The research products will all be international public goods to be used by the global rice research and breeding communities. This outcome requires an open environment for germplasm exchange and sharing.

Innovative contributions

The collective research capacity under theme 1 provides opportunities for innovation not possible in individual institutions. Key innovations of significant scale and scope include

- integrating management of the world's largest collection of rice genetic resources;
- a new, global public genetic diversity research and gene discovery platform;
- modernizing trait evaluation using high-throughput precise phenotyping;
- designing a plant ideotype for climate-change scenarios; and
- producing a more efficient rice plant (C_4) for the future.

Partnerships

Leading rice genetic resources centers and research groups worldwide will become fully aligned under this theme, in which IRRI, AfricaRice, and CIAT will join forces with Cirad, IRD, JIRCAS, leading research institutions and universities from many countries, NARES, and private companies. Strong NARES systems such as those in China, India, and Brazil are expected to also make significant contributions to theme 1. The partners in theme 1 will share collections of genetic stocks and databases, take part in a global genotyping and phenotyping network, and exchange staff. Importantly, there will be close liaison between research under this theme and similar programs in the CGIAR on other crops, as is currently the case with the Generation Challenge Program (GCP). Partnership with the GCP is particularly important to theme 1 given the shared objective of building an efficient gene discovery platform. Solid links with theme 2 efforts will ensure that outputs are picked up in the rice breeding process and feedback is obtained from farmers and other rice development stakeholders.

Impact pathways

To date, only a small fraction of the rice genetic resources has been used in breeding. Sustained access to, exchange of, and use of these materials are essential because demand for them to solve production and environmental problems will increase in the future. This means greater demand for the genetic knowledge and tools needed to identify and use them.

The product lines of theme 1 are closely aligned with theme 2 by providing a comprehensive, well-documented germplasm and breeding resource base and a genetic diversity platform to enable the identification of gene combinations important for varietal development. The expected immediate users are scientists involved in genetic improvement efforts within and beyond the GRiSP in NARES, advanced research institutes, and the private sector. In relation to other Mega-Programs, rice as a genetic model has much to offer to other crop species. Gene discovery in rice will directly benefit genetic research on other commodities in TA 3 (Thematic Area 3 of the CGIAR Strategy and Results Framework). Comparative biology using plant systems other than rice will enable re-designing of the rice plant with a huge potential impact on production. At the level of discovery science, theme 1 can play an important role in leveraging the plant science community to apply genetic knowledge to reach new frontiers, as illustrated by the C_4 project, which will engage a broad community of researchers around the world.

Product Line 1.1. Ex situ conservation and dissemination of rice germplasm

Rationale

The rice gene pool encompasses a huge wealth of potentially valuable genes to support sustainable development and to improve livelihoods by addressing the problems of climate change, evolving pests and pathogens, problem soils, better nutrition, novel agricultural technologies, and improved yield potential. The gene pool is represented in the genebanks of the CGIAR by more than 130,000 accessions. Outside the CGIAR, the BRIC countries hold another 170,000 accessions, mostly in India and China, including many accessions not duplicated in the CGIAR. Four other countries (Japan, Korea, Thailand, and the U.S.) hold well-secured national collections with more than 20,000 accessions each. Together, these comprise some 80% of the known world holdings of rice. An additional 120,000 accessions are scattered among around 40 genebanks worldwide with varying degrees of security. The extent of duplication of accessions among genebanks is largely unknown.

This product line addresses the first step toward realizing the potential value of this diversity: keeping it securely, effectively, and efficiently maintained and readily available for distribution to users as required to meet user-defined targets. It ensures the sustainability of developments in rice agriculture[15] by conserving the full range of rice diversity, including genes with unknown function and genes that may serve unknown development targets as well as current priorities. It includes the basic operations involved in maintaining and disseminating germplasm conserved in the CGIAR collections. It also includes activities required to improve the efficiency and effectiveness of conservation, at the level of individual genebanks and globally, and to fill global gaps in the conserved gene pool.

All aspects of germplasm conservation and dissemination are critically dependent on high-quality integrated data management. Workflow management systems that ensure adherence to best practices are essential for quality control and quality assurance in the laboratory. Appropriate data validation procedures are essential to ensure accurate data. Integration of data from different stakeholders involved in germplasm management is essential for rational joint management decisions in a global system. This includes cross-referencing of accessions from different genebanks, and linking genebank accessions to the research and breeding programs that use them. Through the International Crop Information System (ICIS), IRRI has developed the world's first information management system with the capacity to provide all this functionality in one integrated system, setting the scene for raising efficiency and effectiveness of conservation and use to unprecedented levels. Essential developments in the system are included within the product line.

Activities

At the most basic level (product 1.1.1), the genebanks of the CGIAR must be maintained and coordinated. Currently, each CGIAR center has a mandate to conserve and manage its own germplasm collection. The GRC is recognized as a flagship crop genebank. It operates a

[15] Brundtland Commission 1987: Sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs."

continuous program of registering, duplication, characterization, testing, regeneration, documentation, and distribution of its germplasm, and must be maintained to serve the needs of rice researchers. Similarly, the AfricaRice Genebank must maintain and distribute its rice germplasm. CIAT needs to upgrade its seed processing and storage facilities for maintaining its working collections. These collections will be duplicated for conservation in the GRC and fully documented in the International Rice Information System (IRIS) Genetic Resources Information Management System (GRIMS). The basic operations of the three CGIAR genebanks will be critically analyzed to identify and cost the operations that could benefit from coordination or centralization (such as long-term conservation), and those that must remain separate within each institute (such as distribution to local users). Based on this analysis, a plan will be developed and implemented for efficient conservation and use of accessions held within the CGIAR.

Second (product 1.1.2), since the CGIAR holds only a small proportion of the total gene pool of rice, action is required to improve conservation of the global rice gene pool. This will be achieved by developing a rational, efficient, and effective global system for the conservation of rice diversity, in partnership with other rice genebanks and the Global Crop Diversity Trust. A key target will be to improve coordination among genebanks, thus avoiding unnecessary duplication of efforts and sharing responsibilities when appropriate. This in turn will require a mechanism to facilitate joint decisions, based on a global database of rice accessions cross-referenced to show the correspondence between accessions in different genebanks. Through a concerted program coordinated by the Trust, unique accessions will be rescued in genebanks where secure conservation is threatened by inadequate capacity. Investment in identifying and filling gaps in collections will be undertaken only in the context of the global strategy.

Third (product 1.1.3), in response to the growing evidence that current best practices for germplasm conservation are not optimal, conservation research will be undertaken. There is an urgent need to conduct novel research on the consequences of applying different regeneration, postharvest, and management procedures on the genetic integrity of conserved germplasm and on the physiological quality of conserved seed. The research results will be used to devise and test improved procedures for germplasm tracking and for handling plots and seeds to improve the quality of conservation.

Finally (product 1.1.4), an integrated rice germplasm documentation and sourcing system will be deployed, initially covering the genebanks of the key GRiSP institutions.We have adapted the germplasm documentation facilities of ICIS by augmenting its schema and engineering specialized data entry and validation tools to create the GRIMS. Its development is well advanced but still requires further development of tools for sample tracking, data quality assurance, and intellectual property rights for seed distribution under the Standard Material Transfer Agreement (SMTA) of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). GRIMS will be improved to accommodate the needs of other GRiSP partners, to be linked to the GCP Integrated Breeding Platform being developed in theme 2 that includes GCDT, GRIN-Global, and GENESYS collaborations.

Products

1.1.1. Sustained and enhanced management of the rice collections of the CGIAR
1.1.2. Enhanced conservation of the global rice gene pool
1.1.3. Improved conservation of rice in genebanks
1.1.4. Data management for quality assurance

Partnerships

For the overall management and operation of the rice genebanks at IRRI, AfricaRice, and CIAT, our primary partners are the Global Crop Diversity Trust (GCDT), Inter-Center Working Group on Genetic Resources (ICWG-GR), FAO-Commission for Genetic Resources for Food and

Agriculture (CGRFA), Central Advisory Service for Intellectual Property (CAS-IP), ITPGRFA, and Svalbard Global Seed Vault. The ICWG-GR plays the role of setting up the operational basis and mechanisms for coordination among the genebanks of the CGIAR. For enhancing and improving conservation of the global rice gene pool, our primary partners are curators of genebanks of national programs. The list of research partners includes those currently active in activities under the global system for rice conservation. Participation is dynamic and is expected to increase.

For data management, our partners are the ICWG-GR, ITPGRFA, Generation Challenge Program, United States Department of Agriculture, and Bioversity International. A large majority of local adapters/users are within GRiSP. This reflects the fact that this product line provides the starting point for all germplasm-related research in GRiSP, and emphasizes the need for close coordination with other product lines to ensure effective progression along the value chain to achieve impact

Uptake and impact pathway

This product line provides the starting point for addressing all development objectives based on using and improving rice germplasm, in all themes of GRiSP and in all other rice research and development projects even outside the formal GRiSP partnership. To solve a substantial share of these problems, it is necessary that relevant germplasm be made readily available to any and all projects; and that the relevant germplasm for each project be readily identified. It is assumed that each project has the competence to exploit germplasm provided under this product line.

The immediate users are GRiSP researchers and the global community that use rice genetic resources. These include advanced research institutes, the private sector, NARES, NGOs, and farmers. All organizations and individuals are accepted and encouraged as users. There is only one restriction: users must comply with the terms of the Standard Material Transfer Agreement, a contract that encourages the fair use of genetic resources for research, breeding, and training for food and agriculture, while preventing their misappropriation and misuse.

Effective delivery of the right germplasm to the right user requires close interaction between this product line and users. As new knowledge is generated through other research in GRiSP, the knowledge fed back will enable this product line to target more effective use of germplasm for specific development objectives. Sequence information will be an increasingly important component of the genebank database and is expected to grow dramatically over the next 5 years. Theme 2 research will provide trait evaluation data from breeding lines and theme 4 research on quality and specialty rice varieties. Theme 3 research will provide information on the match required between a variety and the farming system used for its production.

The final users—farmers—will adopt improved rice germplasm and provide important feedback to breeders through participatory varietal selection work in theme 2. Diffusion on a large scale will be achieved through linkages with development and private-sector partners (theme 6).

Financing strategy

It is assumed that the basic operating costs of the CGIAR genebanks (product 1.1.1) will be financed through a system-wide genebank maintenance window coordinated by the Consortium and the Global Crop Diversity Trust. Product 1.1.1 is included within the scientific and operational framework of GRiSP to ensure effective delivery, but its costs are excluded from GRiSP budget calculations.

The GCDT has played a key role in the development of the global system of rice conservation (product 1.1.2). The framework for the global system has been established with financial support from a grant from the GCDT, but practical mechanisms need to be established for its continued operation, especially to facilitate the participation of stakeholders that will not receive GCDT grants. This is beyond the current budget and will require additional resources.

A conservation research laboratory (product 1.1.3) has been set up at IRRI. Additional sources of funding will need to be identified to undertake the research identified as necessary to achieve the proposed milestones.

Basic capacity has been established for data management, both for high-quality curation and for the development of required new software applications. However, the team is significantly underresourced and can make only slow progress relative to the magnitude of the task at hand. Additional programmers and data curators are required at all three CGIAR centers to complete the world-leading system envisioned.

Product Line 1.2. Characterizing genetic diversity and creating novel gene pools

Rationale

Rice diversity is the foundation for rice improvement programs. Intelligent use of this diversity can both help solve current production problems and create opportunities for future rice production and respond to climate change. To use fully the wealth of rice diversity, two essential ingredients are needed: we need to have the genetic blueprints of diverse rice germplasm accessions and varieties in use, and we need to generate plant populations with numerous recombined genotypes to allow full expression of phenotypic variation in order to discover new genes or QTLs for use in breeding programs. Rapid advances in DNA sequencingwith declining costs will allow us to decode the genomes of a large number of rice accessions. This product line capitalizes on new sequencing, SNP genotyping, and phenotyping technologies to fully explore rice diversity while also creating populations suitable for trait dissection and the discovery of gene functions.

Activities

Two approaches will be taken to enable the efficient use of rice diversity: (1) develop a genetic diversity platform to predict gene-phenotype relationships, and (2) generate genetic stocks for trait dissection. First, we will create a SNP haplotype map to decode molecular variation. With public- and private-sector partners in the Rice SNP Consortium, 2,500 diverse accessions from Asia, Africa, and Latin America will be genotyped by a high-density SNP detection platform (600K Affymetrix chip) at a resolution of 1 SNP/kb of the rice genome. Purified seed stocks will be available to trait-expert partners in a Global Phenotyping Network who will apply lab and field-based methodologies for large-scale trait evaluation relevant to yield and climate-change-related stresses. We will capitalize on Cirad's expertise and the investment made on developing methods, modeling tools, and high-throughput precision phenotyping for association genetics. Investments will be made to upgrade phenotyping capacity and develop high-throughput screening procedures for selected traits. The large data sets from genotyping and phenotypic evaluation will enable inference of important genotype-phenotype relationships by association genetics.

We will establish high-throughput SNP marker platforms at IRRI and CIAT to provide SNP marker development and genotyping services to GRiSP researchers and public- and private-sector partners. These facilities will greatly accelerate the application of SNPs to genetic research and breeding, including DNA fingerprinting, mapping, and marker-assisted selection. Low-cost SNP fingerprints for INGER nominations, breeding lines, and released varieties will enable quality control, seed purity testing, and tracking adoption rates.

While the initial haplotype map will employ SNP chips, a longer-term goal is to sequence most of the rice germplasm collection once sequencing technologies deliver a low enough cost per accession. We will begin preparing a comprehensive DNA bank for at least 100,000 rice accessions using a high-throughput pipeline (2011-14). Low-cost sequencing techniques will be tested and optimized to determine the cost per accession (2012-13), followed by sequencing of 100,000 accessions (from 2014 onward). This comprehensive sequence information, together with geographical data on their origins and the trait associations detected in the initial set of 2,500 lines, will allow us to select specific accessions for evaluation of traits and isolation of novel genes.

For the second approach, we will produce specialized genetic stocks and populations that are rich in allelic diversity and genotypic combinations. We will generate diversity panels that include mutants of specific genotypic backgrounds, recombinant inbred lines (RILs), chromosomal segment substitution lines (CSSLs), and near-isogenic lines (NILs). Special emphasis will be given to the multiparent advanced generation intercrossed (MAGIC) technique with which repeated genetic recombination among multiple parents breaks down linkages to create novel genotypic combinations. RILs, MAGIC, and CSSLs will be developed with diverse indica, japonica, aus, aromatic, and Asian and African/Latin American AA-genome types that exhibit abiotic/biotic stress tolerance, wide adaptation, high yield potential, and good grain quality for use in breeding. Special efforts for the African rice, *Oryza glaberrima,* will include the development of intraspecific and interspecific materials and deep sequencing of the parental set used to construct CSSLs and iBridges lines. These multipurpose populations will enable precise QTL estimation and gene identification for both the cultivated and wild rice gene pools.

Because of the large amount of data produced, a bioinformatics pipeline for data analysis and documentation is essential. We will create a database to manage and visualize rice genetic and phenotypic data from thousands of genomes that are linked to IRIS GRIMS along with a toolkit to analyze these data. Existing technology and information from public open-source databases and software solutions will be adapted, and then deployed to meet the specific needs of rice. This will be done in partnership with ARI partners that have expertise in high-throughput data analysis and management, and comparative biology, so that existing tools and resources are effectively cross-linked to those developed by GRiSP. For instance, we will build on the database architecture analysis tool developed by Cirad for functional analysis (OryGenesDB and OryzaTagLine), for comparative genomics between *Arabidopsis thaliana* and rice genomes (GreenPhylDB). User-centric workbenches that merge gene function evidence from heterogeneous distributed rice resources will be developed.

Products

1.2.1. High-resolution SNP genotypes of diverse accessions and a high-throughput SNP genotyping platform (Rice SNP Consortium)
1.2.2. A global phenotyping network for key agronomic traits and responses to major stresses, including climate-change traits
1.2.3. Whole-genome sequencing of all unique germplasm accessions held in the genebanks at IRRI, AfricaRice, and CIAT and other genetic stocks
1.2.4. Specialized genetic stocks and novel populations through enhanced recombination of cultivated and wild rice gene pools

Partnerships

Product 1.2.1 is primarily developed by the Rice SNP Consortium, which currently includes Cornell University, IRRI, Cirad, AfricaRice, CIAT, USDA, Syngenta, Bayer CropScience, and the Taiwan Agricultural Research Institute. We expect additional partners to join this consortium in the next two years. The consortium will be responsible for the production of high-density genotypes for a large collection of germplasm nominated by members. Product 1.2.2 on a global phenotyping network will include most of the members of the Rice SNP Consortium but also additional partners with specialized expertise in phenotyping. These include Colorado State

University, JIRCAS, the China National Rice Research Institute (CNRRI), and interested NARES partners in IRRI breeding networks. Because of the diverse needs in trait evaluation, we expect that the phenotyping network will continue to grow over the course of the project. Product 1.2.3 on genebank sequencing will involve the best technology providers for low-cost sequencing. Currently, we are in discussion with the Beijing Genomics Institute (BGI).

For product 1.2.4 on the development of specialized genetic stocks, our partners include IRD, IRRI, AfricaRice, Cirad, CIAT, USDA, Cornell University, and selected NARES. These institutions have a long history of producing novel genetic resources and disseminating them for public use.

Uptake and impact pathway

New genes and alleles for adaptive traits, including traits related to climate change, identified through association analysis are the main deliverables resulting from the various activities in this product line. These products are of a global nature with tremendous scientific and practical significance. The immediate users will be rice breeders and geneticists in advanced research institutes, NARES, and the private sector. The knowledge and novel genetic resources produced will accelerate the varietal development objectives in theme 2, thus delivering improved varieties to farmers and consumers at a faster pace throughout the world. In the near term, applications of the genetic diversity platform will concentrate on traits that are particularly relevant to expected changes associated with global climate change such as the occurrence of extreme weather and extreme temperatures, with too much or too little water, and more severe epidemics of diseases and insect pests. For the long term, the genetic diversity platform will have broad applications to infer relationships between genomic variation and phenotypic diversity of rice in multiple traits. Across MPs, the data sets on genotype and phenotype will be closely linked to the Genomic Integrated Breeding Service coordinated by the Generation Challenge Program.

Financing strategy

Because of the broad interest in the use of rice biodiversity for impact, this project will involve extensive international collaboration and it has attracted considerable interest from partners and donors. Under the Rice SNP Consortium, funds have been raised from multiple sources, including public agencies (primarily the Japan Rice Breeding Project), research institutions, and the private sector, but additional resources are still needed. A one-time investment is immediately required to develop the facilities for high-throughput SNP genotyping. Similarly, a one-time investment in modern, high-throughput phenotyping facilities is needed for the rapid evaluation of multiple traits. Ongoing funds will be needed to support large-scale trait evaluation for the phenotyping network. The genebank sequencing project will require major funding, especially from 2013 to 2015.

For bioinformatics support between 2010 and 2015, a minimum investment of $1,000,000 per year will be required. Fresh donor commitment to informatics for genetic resources is required, since designated funding is not currently in place. The genotype-phenotype data analysis is supported in part by the Japan Rice Breeding Project. Staff who are dedicated to software engineering are partially covered by the BMGF GCP "Molecular Breeding Platform" grant. However, to meet the challenges presented by rapidly expanding genotypic and genomic data sets, this activity will require additional funds above the baseline. Activities for comparative genomics analysis have begun in part through the C_4 rice project. Extension of the concept to other research projects and engagement of ARI partners in a global network for comparative plant biology will require investment above the baseline. Long-term development of this resource may be considered for funding by the GIBS-GCP component of TA 3.

Product Line 1.3. Genes and allelic diversity conferring stress tolerance and enhanced nutrition

Rationale

Tolerance of environmental stresses and enhanced nutritional value are priority traits for rice in multiple environments. In some instances, QTLs with large effects can offer solutions to major constraints. Examples of such high-value genes include some disease-resistance genes or the *SUB1* gene that offers a solution to flash-flooding. With genome sequencing, mapping of QTLs for specific traits can be achieved in a relatively short time if suitable mapping populations and robust phenotyping systems are available. The question is, Which of these QTLs or major genes are worthy of investment for molecular cloning and functional validation?

We have identified a set of genes that (1) show evidence of having large effects on the phenotypes, (2) are needed to solve a major constraint, and (3) can be deployed over a large area with potentially high impact. In some cases, markers flanking the QTL can be used directly in marker-assisted selection. However, for the potentially high-impact traits, knowing exactly which genes are responsible for the traits has multiple benefits from a breeding standpoint. First, it allows the development of functional markers that have perfect prediction of phenotypes and performance. Second, knowledge of the specific function of a gene reveals the mechanisms conferring the phenotype and possible interactions with other genes and biochemical pathways. Third, perhaps the most important benefit, is the ability to identify and deploy allelic diversity of the gene that may function in different genetic backgrounds or environments.

This product line is designed to focus on high-value genes with a clear pathway for impact. It has three objectives: (1) isolate genes conferring phenotypes that have a large impact for breeding programs, (2) identify allelic diversity of the high-value genes, and (3) establish an efficient pipeline to validate gene function with the expectation that increasingly more large-effect genes will become available in the near future.

Activities

Our current product portfolio includes genes for abiotic stresses (drought, flooding, nutrient deficiencies, extreme temperatures, and traits of grain quality that are affected by temperature extremes) and for biotic stresses (fungal, bacterial, and viral diseases, and insects). Besides stress tolerance, research efforts will be devoted to understanding root and panicle development for yield potential and nutrient uptake.

While the evaluation of phenotypes and genetic mapping are specific to traits, many approaches of gene isolation and functional validation are in common. By housing the gene isolation and functional validation activities under one product line, we can share resources and create synergy to support different activities. To fast-track cloning of current and future QTLs, we will establish a pipeline with technical and infrastructure support for isolating QTLs and validating functions of candidate genes. This pipeline will have the following features:

- Technical staff support for QTL sequencing, gene cloning, and transformation
- Optimized transformation systems (vector and promoter construction and design, targeted transgene integration, tissue-specific transgene expression)
- High-throughput production of transgenic products
- Genomic and molecular data sets for predicting candidate gene functions

Products

1.3.1 Genes for drought-tolerant and aerobic rice
1.3.2 Genes for flood-prone environments
1.3.3 Genes for nutrient-deficient and problem soils

1.3.4 Genes for temperature extremes and grain quality
1.3.5 Genes for disease and insect resistance
1.3.6 Genes for improving the architecture of rice roots and panicles
1.3.7 Transgenic prebreeding events for stress-response genes
1.3.8 Gene identification and validation pipeline

Partnerships

The diversity of the traits that will be addressed in this product line will require a large number of partners with specialized expertise. For each product, a unique composition of partners will be formed depending on the traits and target genes. All collaborative projects involve multiple CG centers, NARES, and ARIs that together have the needed expertise at different levels and enable the best use of available infrastructure. Whereas ARIs contribute the highest level of expertise in specialized research areas supported by up-to-date technologies, CG centers and NARES provide strengths in genetic analysis of germplasm, QTL identification, and field evaluation capacity to ensure that the selected genes are of high value and relevant to farmers. Below, we provide several illustrative examples of this collaboration model.

Research on drought-tolerance genes will involve IRRI, AfricaRice, Cirad, CIAT, and NIAS-Japan, in which field-proven, drought-tolerant breeding materials will be used for gene discovery to ensure agronomic relevance of the target genes. For analysis of genes for flood-prone environments, our key partners are UC-Riverside and UC-Davis, which provide the expertise in molecular biology and physiology. Molecular work on genes with tolerance of flood-prone areas will be channeled to breeding programs in theme 2. For example, submergence-tolerant (Sub1) varieties are being tested in farmers' fields in collaboration with AfricaRice and NARES. The upstream work on the phosphorus uptake gene (*Pup1)* is mainly conducted in a collaborative project between IRRI and JIRCAS, with contributions from MPI-Golm. In parallel, *Pup1* breeding lines are being developed at ICABIOGRAD in Indonesia. A similar project is being pursued by Embrapa to isolate the *Pup1* gene in sorghum. Further out-scaling of *Pup1* breeding now involves AfricaRice and various NARES in Asia.

The identification of novel genes and processes leading to improved roots and panicles (1.3.6) will be approached using different strategies and starting materials depending on the partner institute. For instance, Cirad and IRD in collaboration with CIAT and other partners will mine and characterize transcription factors and miRNAs through forward and reverse genetic approaches using expression arrays and insertion mutants. Other partners will contribute in proteomics (UWA and NIPGR), metabolomics (IPK and MFU), and glycomics (NU) analyses to identify genes for improved root traits under drought and genes for spikelet development to increase yield potential. At IRRI, genetic diversity in root development will be explored to identify novel QTLs and processes that enhance stress tolerance. Detailed biochemical analyses will be conducted at MPI-Golm. For work on disease and insect resistance, we will engage partners with traditional strengths in research on host-plant resistance. These include Kyushu University, Ohio State University, and Colorado State University for their expertise in molecular cloning of host resistance genes.

For producing transgenic prebreeding events for stress-response genes, IRRI in collaboration with CIAT, JIRCAS, and RIKEN (Japan) has formed a collaborative network for high-throughput transgene production to evaluate candidate genes for tolerance of abiotic stresses. JIRCAS and RIKEN provide gene constructs, whereas IRRI incorporates the genes into lowland indica lines and CIAT incorporates the genes into upland rice. Lead transgenic events will be evaluated under stress conditions and promising materials will be transferred to NARES and FLAR for further evaluation.

To establish an efficient gene validation platform, we will engage laboratories with strong expertise in vector construction and chromosome engineering. IRRI has developed a high-throughput transformation system to overexpress and down-regulate gene expression in indica rice. Partners such as the University of Minnesota, Meijo University, University of Arkansas, University of Wisconsin, Cirad, and IRD will provide state-of-the-art technology for multigene transformation and gene targeting using zinc finger nuclease, homologous recombination, and *cre/lox* recombinase. In parallel, the University of Düsseldorf and other partners will work toward identifying tissue-specific, inducible, and developmental stage-specific promoters. This technology development will be crucial for studying and incorporating high-value genes for yield, quality, and biotic stresses, and engineering metabolic pathways in rice.

Uptake and impact pathway

The immediate users of the products will be national system and private-sector breeders with responsibility for incorporating target traits in their breeding programs. The eventual users will be farmers using improved varieties. For effective uptake, there must be close interaction among molecular biologists, physiologists, breeders, and agronomists to ensure that the criteria of high-value genes are met and that there is good integration of molecular data and tools into breeding projects to ensure that the cloned genes are agronomically relevant.

Product Line 1.3 is the logical extension of Product Line 1.2; large-scale genetic characterization of germplasm will lead to the prediction of QTLs and gene-phenotype relationships. Investments made in sequencing the genebanks (Product 1.2.3) will directly benefit the search for allelic diversity of the target genes. This product line will receive analytical support from the bioinformatics team established under Product Line 1.2.

Linkage with theme 2 will be in two ways. Functionally validated genes can be used for transgenic products and gene-based markers for marker-assisted selection in breeding programs. From theme 2, breeding lines with proven performance can be used as starting materials for QTL cloning. This approach has been exemplified by the work on large-effect QTLs for drought tolerance originally identified from drought breeding programs.

We expect strong interest in co-investment in activities under Product Line 1.3, particularly with research institutions interested in the biology of the target traits. The involvement of academic institutions to jointly investigate practical problems has yielded many successful results. A number of research projects supported by the USAID Linkage Programs exemplify this type of linkage that leads to impact.

Financing strategy

Currently, a majority of the products are supported by specific grants targeting a breeding objective. Additional investment in a gene-validation pipeline that serves multiple gene-cloning activities will improve efficiency by sharing resources for common activities. Such investment should consider both infrastructure and continuous training of technical staff.

Because of the high-impact nature of the targeted genes, the prospect of attracting new funding for Product Line 1.3 is good. Early success in any of the products in demonstrating impact will attract further funding. This is also an area of considerable interest to the private sector, which may provide funding. However, this will require careful IP management to ensure public access to the products.

Product Line 1.4. C4 rice

Rationale

In the majority of plants, including rice, CO_2 is first fixed into a compound with three carbons (C_3) by the photosynthetic enzyme ribulose bisphosphate carboxylase oxygenase (Rubisco)—this is known as C_3 photosynthesis. In contrast, the more efficient C_4 pathway involves the initial fixation of atmospheric CO_2 into C_4 acids using an enzyme that is insensitive to O_2. In the next stage of the pathway, CO_2 is released from the C_4 acids for fixation by Rubisco. The two stages are spatially separated, allowing a high concentration of CO_2 in the vicinity of Rubisco. The buildup of CO_2 by this "CO_2 pump" requires extra energy from sunlight and therefore it operates most optimally in bright warm climates.

A fully functional C_4 pathway requires a coordinated change in tissue structure and metabolic biochemistry. In nature, this has occurred more than 50 times in a wide range of flowering plants, indicating that, despite being complex, it is a relatively easy pathway to evolve. This provides hope that it is possible to replicate the process using a combination of genetic engineering and breeding. The aim of the C_4 Rice Project is to produce a large (approximately 50%) and sustainable increase in rice productivity in all ecosystems by increasing the efficiency of solar energy capture by photosynthesis. To achieve this, the C_4 photosynthetic pathway will be introduced into rice. C_4 rice will not only bring about very high productivity but also far more efficient use of limited resources, such as water and nitrogen fertilizers; thus, it is particularly relevant to solving the problems faced by resource-poor farmers in developing countries.

Activities

Specific objectives of the C4 Rice Project are to

- Discover the genes responsible for high solar energy conversion in leaf photosynthesis.
- Generate a model rice plant with increased photosynthetic efficiency by installing the cassette of genes responsible for expressing the C_4 pathway of photosynthesis.
- Introduce C_4 photosynthesis into widely used rice cultivars and test for yield, water use, and nitrogen fertilizer requirement under a range of agronomic conditions.
- Produce a toolkit for the introduction of the cassette of genes responsible for expressing C_4 photosynthesis into other important crop species growing in the tropics.

To achieve these objectives requires a sustained collaborative effort with multiple disciplines. An international team of scientists with the necessary range of skills and experience has been assembled to form a C_4 Rice Consortium (http://beta.irri.org/projects15/en/consortium-c4rice). The team is multidisciplinary and contains molecular biologists, geneticists, physiologists, breeders, biochemists, and mathematicians; all of this expertise is essential to achieve these objectives. Partners of the C_4 Rice Consortium conduct research in four areas: genetic screening for gain or loss of C_4-function, physiological phenotyping, molecular toolkit development, and dissection of biochemical pathways and Kranz anatomy through comparative genomic and molecular approaches.

In the first phase of the project, the primary focus is on understanding the genetic regulation of C_4 leaf anatomy. Large-scale screening for C_4-like characters in rice mutants and for reversion to C_3 characters in sorghum mutants is now in progress. The consortium will identify genes controlling mesophyll cell number between veins, chloroplast number, and the size and distribution of bundle sheath cells. A transgenic approach is being used to decipher the biochemical network of regulatory genes for C_4-function. Molecular toolkits are being developed to define elements that allow specific expression of transgenes in mesophyll cells and bundle sheath cells of rice.

Products
PL 1.4 has only one product: the creation of C_4 rice with improved photosynthetic efficiency and productivity. Valuable intermediate products for understanding photosynthetic efficiency are expected in the pursuit of this research agenda. In the medium term (4–11 years), we expect to have identified the genes responsible for Kranz-type C_4 anatomy and biochemistry and constructed prototypes of C_4 rice. In the long term (12–15 years), we expect to have optimized C_4 photosynthesis in cultivated rice lines and evaluated its benefits in some farmers' fields.

Partnerships
The C_4 project is conducted by a consortium of partners contributing their unique skills toward the engineering of C_4 rice. Currently, the consortium includes IRRI, the University of Cambridge, University of Oxford, Cornell University, University of Sheffield, University of Nottingham, University of Toronto, CSIRO, Washington State University, University of Düsseldorf, Kyung Hee University, Australian National University, Shanghai Institutes for Biological Sciences, Academia Sinica-Taiwan, and Simon Fraser University. These partners play distinct roles in genetic screening, the production of transgenic plants, comparative analysis of C_3/C_4 pathways, biochemical and physiological characterization of transgenes, and the development of molecular toolkits. We expect more to join over the course of the project.

Uptake and impact pathway
The next users of products from C_4 rice research will be global plant scientists interested in C_3-C_4 photosynthesis, evolution, plant development, and biochemistry, who are largely in advanced research institutes and larger national research systems. They will gain from having new technologies for screening for alterations in photosynthetic efficiency, C_4 mutants that have reverted toward C_3 in their leaf anatomy and physiology, activation-tagged rice showing C_4 characteristics, transgenic rice plants with genes associated with photosynthesis silenced in a cell-specific manner, and a molecular toolbox specific to the manipulation of the factors regulating cell-specific photosynthetic activity.

The intermediate users will be researchers and breeders in national systems and the private sector who are interested in applying genes and genetic materials generated from the C_4 Rice Project. The final users will be farmers interested in growing rice cultivars with increased photosynthetic capability and higher productivity.

Within theme 1, C_4 rice is linked to PL 1.2 (characterizing genetic diversity). Novel genotypic variation created by recombination of the cultivated and wild rice gene pools will provide new resources for screening C_4 photosynthetic properties. A new initiative on nitrogen-fixing rice under discussion has the potential to reduce the dependency on high-nitrogen input in productive C_4 rice and to enhance the use of increased photosynthetic capacity in rice. With other CRPs, C_4 rice is linked to research on the impacts of climate change on yield via high CO_2 in CRP Climate Change.

Financing strategy
Long-term sustained funding is needed to conduct very large scale experiments to recover interesting variants with altered photosynthesis and leaf anatomy. Scientific facilities and institutional infrastructure need to be available to accommodate the long-term research agenda. IRRI provided startup funds to initiate the C_4 Rice Project in 2008. The project is currently supported by the BMGF for the first 3-year phase ($11.1 million for 2009-11). New funding will be required from 2012 onward. We expect the same level of annual funding for the next phase. Discussion is ongoing to engage research organizations in China and India to leverage co-investments. Co-investments are also expected from the European Union and advanced institutions with interest in agricultural productivity in the long term. We will also explore linkages with the private sector.

Theme 2: Accelerating the Development, Delivery, and Adoption of Improved Rice Varieties

Overview

Rationale and objective

From identifying desirable rice traits to the widespread adoption of varieties incorporating them is a long and exacting process spanning up to 15 years. The need for a large and comprehensive truly global program to develop new varieties for rice production environments and bring new seeds to farmers faster is becoming more compelling and it will require the engagement of a wide range of public- and private-sector organizations and networks. New approaches, such as marker-assisted breeding, can shorten varietal development cycles by 3–5 years and allow breeders to design new varieties and improve existing rice varieties and hybrids more precisely. These new approaches must be implemented through well-designed, product-oriented, interdisciplinary, and interconnected breeding programs in the world's major rice regions. For example, great opportunities exist now to further develop and spread new rice varieties from inter- and intraspecific crosses, particularly to meet local needs in Africa. A quantum increase in yield can be made in rainfed systems by creating new varieties that tolerate abiotic stresses, such as drought, iron toxicity, submergence, salinity, and heat.

Demand is increasing from consumers for better quality rice varieties. Also, rice must become resilient to climate change. For this, we must gather better information on the spatial and temporal variability of the target production environments; preferences of farmers, processors, and consumers; new cultivation practices used by farmers; and the impact of climate change, and use it to guide rice breeding programs in a precise manner. Hence, theme 2 focuses on the transformation of global rice breeding programs toward better targeted, more precise, and more efficient development of new varieties and hybrids that meet future demand in a world of changing farming systems and climate.

Research approach

Interdisciplinary breeding teams, integrated across mainly public-sector partners—sharing critical facilities and learning from each other—will identify and define ideal rice phenotypes (ideotypes) for different production environments, adapted to future cropping systems, as well as key biophysical and socioeconomic constraints, and market demand. They will also enable better south-south transfer of germplasm, making innovations from leading NARES also available to other countries, and better linkages with the private sector. The tools for parental selection and better understanding of the genetics of agronomic traits should lead to more efficient breeding programs that make optimum use of the available resources.

Joint basic research will be carried out by program partners on varietal improvement and advanced breeding methodologies. Capacity for marker-assisted breeding will be significantly strengthened in breeding programs of developing countries. Germplasm evaluation across Africa, Asia, and Latin America will be accelerated, with a modernized International Network for the Genetic Evaluation of Rice (INGER) as an engine for germplasm exchange and variety testing in different environments.

R&D product lines and outputs

2.1 Breeding informatics and multienvironment testing
2.2 Improved donors and genes/QTLs conferring valuable traits

2.3 Rice varieties tolerant of abiotic stresses
2.4 Improved rice varieties for intensive production systems
2.5 Hybrid rice for the public and private sector
2.6 Healthier rice varieties

These products will be provided in a timely manner to breeding programs (see below) for testing and eventual use by farmers. Thus, the outcome of theme 2 is an indispensable step toward poverty reduction by improving rice productivity and hence farmers' income.

Innovative contributions

Plant breeding methods are changing rapidly, mainly through the application of molecular markers in precision breeding. Key innovations in theme 2 include

- more precise targeting of rice breeding to key environments and grain quality requirements for major market segments;
- development and use of high-throughput marker applications in rice breeding programs;
- wider use of interspecific crosses;
- breeder-friendly decision tools for the public and private sector;
- sources of improved pest resistance;
- new, global research networks (e.g., Rice Blast Research Network) as a key strategy for achieving stable disease resistance in rice;
- a new generation of "climate-change-resilient," stress-tolerant rice varieties with combined adaptive traits;
- renewed efforts to break the yield barrier in rice through a fine-tuned ideotype breeding approach, combined with advanced multienvironment testing;
- first breeding programs for direct-seeding and conservation agriculture;
- a new generation of hybrids with higher yield, better quality, and higher seed yield; and
- recurrent selection for physiological traits that confer higher yields, and attention to yield evaluation earlier in the breeding process.

Partnerships

This theme involves many partnerships among CGIAR centers, Cirad, IRD, CIAT-FLAR, JIRCAS, the Generation Challenge Program (GCP), NARES, advanced research institutes, the private sector, farmer organizations, and specialized NGOs to provide the research power needed to accelerate the development of new germplasm, and obtain critical feedback from all users in the rice value chain. One such network will be the Africa Rice Breeding Task Force (Box 9), which started in 2010.

Box 9. Africa Rice Breeding Task Force

NERICA is now a household name in Africa—a name that stands for good rice. NERICA is synonymous with the work that earned AfricaRice the King Baudouin award in 2000, Dr. Monty Jones the prestigious World Food Prize in 2004, and Dr Moussa Sié the Fukui International Koshihikari Rice Prize from Japan in 2006. More than 200 rice varieties developed by AfricaRice and partners have been released over the last 20 years in sub-Saharan Africa.

Through grants by the government of Japan, the Bill & Melinda Gates Foundation, and other donors, AfricaRice will team up with IRRI, NARES, and other partners from inside and outside Africa to develop the next generation of rice varieties in Africa. Through a task force mode of operation, efficient and effective product development pipelines focusing on clearly defined target populations of environments (TPEs) will be established. National and international rice breeders will work in interdisciplinary breeding teams, dividing responsibilities for testing of fixed lines and segregating populations according to technical capabilities and the presence of hotspots for certain stresses in their respective countries. This Africa Rice Breeding Task Force will also clearly have a capacity-building role for young aspirant breeders.

The INGER-Africa network will be responsible for multiplication and distribution of new seed for in-country hotspot testing, participatory varietal testing trials, central data acquisition, and genotype-environment analyses.

The CGIAR centers involved (IRRI, AfricaRice, CIAT) will focus on developing global and regional public goods, whereas the local breeding networks involving dozens of partners in Asia, Africa, and Latin America will focus on specific target production environments, including drought-prone, flood-prone, and salt-affected areas in South and Southeast Asia; high-yielding irrigated areas; as well as temperate rice-growing areas that are the target of the Temperate Rice Research Consortium (TRRC). New public-private partnerships will enable more rapid development of hybrid rice, which is rapidly becoming a prominent feature of Asian rice farming and becoming increasingly important in Latin America. Some existing models that will be expanded are the Hybrid Rice Development Consortium (HRDC) and FLAR.

Advanced research institutes and universities in developed and developing countries are key partners in the generation of relevant science and technologies. Linkages between ARIs and CGIAR centers and institutions in less developed countries will leverage resources and skills to speed up the development and dissemination of pertinent germplasm solutions by linking research priorities to needs and likely adoption. Through applications of cutting-edge science findings such as the discovery of traits and genes associated with biotic/abiotic stress tolerances and other valuable agronomic traits, interventions that more closely match farmers' requirements can be developed at an accelerated pace. National and regional adaptive research will involve a range of partners from the public and private sector, national agricultural research and extension systems, international NGOs (e.g., BRAC, World Vision, CARE, WHO), national NGOs (e.g., NEFORD, Shushilan, RDRS), farmers' organizations, and other civil society groups, principally for evaluation, dissemination, and out-scaling. This theme will integrate these efforts with technologies being developed through other themes of GRiSP to ensure maximum benefits.

Theme 2 will also build on the progress of the challenge programs (Climate Change, Water, and Food; the Generation Challenge Program; HarvestPlus) and work closely with relevant CRPs in TA 3 (wheat, maize, dryland cereals) to develop and deploy rice varieties that are suitable for major farming systems such as rice-wheat, rice-maize, and rice-legumes. Linkages with CRP 7 will ensure the development of germplasm and technologies that can cope with the adversities of climate change through the development of stress-tolerant varieties and varieties that permit further adjustments in farming systems as adaptation strategies. Varieties will also be designed to suit new production systems designed to mitigate the impacts of climate through a reduction in GHG emissions. Through these linkages, theme 2 will ensure the development of suitable germplasm that provides solutions to current food and environmental challenges and boosts and sustains system productivity to keep up with the increasing need for more food from diminishing resources.

Impact pathways

Products from this theme will be delivered at an accelerated pace through the establishment of a molecular rice breeding platform and integration with conventional breeding, for defining efficient breeding strategies, building on a global rice germplasm information system and well-designed networks for multilocation testing of varieties. Users of the molecular rice breeding platform, the germplasm information system, and the networks will be breeders in GRiSP, NARES, and the private sector. This work will be facilitated by involving the genomics and integrated breeding (GIB) services of the GCP. Final users of the climate-change-resilient, high-yielding varieties will be rice farmers in Africa, Asia, and Latin America and the Caribbean.

Theme 2 outputs will be linked with management practices from theme 3 to ensure that the performance of the new varieties is optimized in the appropriate growing conditions. Seed production and dissemination strategies from theme 6 will ensure efficient and widespread adoption. Linkage with nationally and internationally funded development projects will also assist with the uptake of improved varieties by farmers (theme 6).

In Asia, established consortia and major regional initiatives, such as CURE for the unfavorable rice environments of Asia, IRRC for the favorable environments in Asia, and CSISA for intensive rice-based cropping systems in South Asia, will link improved germplasm with appropriate management practices and cropping systems (theme 3). The HRDC will channel the products of IRRI's hybrid rice research to commercial seed producers in Asia.

The Africa Rice Breeding Task Force will strongly stimulate the uptake of new varieties in and beyond AfricaRice's 24 member states. New varieties will be combined with new and improved management practices (addressed in theme 3) to further close yield gaps in farmers' fields, which is especially relevant in Africa. In Latin America and the Caribbean, FLAR will be the key mechanism for implementing theme 2 research in conjunction with improvements in cropping systems management and delivery (theme 6).

Product Line 2.1. Breeding informatics and multienvironment testing

Rationale

The success of modern rice breeding depends on the use of accurate selection criteria derived from multiple sources of information. To implement marker-assisted breeding effectively, an integrated breeding platform is required that has an efficient information system for managing breeding logistics and information from different sources (phenotypic, genetic, genomic, etc.) and provides efficient analytical pipelines and decision support tools. This can lead to a shortening of the breeding cycle while minimizing resource requirements. An efficient system for genotyping markers tightly linked or diagnostic of trait-controlling genes is also needed. Phenotypic information needs to be collected from environments that are representative of the target population of environments (TPE) to reveal and explore genotype-by-environment interactions (GEI). Efficient multienvironment testing (MET) networks are needed for determining the stability and adaptability of genotypes and the discrimination power of specific environments. MET networks can also facilitate the exchange of germplasm among breeding programs, which can potentially speed up the development of new varieties while increasing genetic diversity.

Products and activities

Breeding efficiency can be increased by using more accurate selection criteria, shortening breeding duration, and minimizing resource requirements. Approaches for improving the quality of phenotyping and genotyping information are efficient management of breeding logistics, well-designed and well-managed MET networks, and an efficient genotyping system for tightly linked or functional markers of trait-controlling genes. An optimal breeding strategy in terms of duration and resource requirements can be designed using appropriate decision support tools. A suite of decision-making tools will be developed for all major breeding methods applicable to rice such as cross selection, backcrossing, gene pyramiding, and recurrent selection, including genomic selection.

2.1.1. An integrated breeding platform with rice-specific marker applications and decision tools.
IRIS content will be greatly improved through quality checks, reorganization of existing data sets, and uploading of well-curated historical data sets. Efficient analytical pipelines will be developed for predicting breeding value (genetic merit) using pedigree, marker, and phenotypic data. A suite of decision support tools will be developed to assist in the design of efficient marker-/genomics-assisted breeding strategies. An efficient genotyping platform for SNPs that are diagnostic for important traits will also be developed and diagnostic SNP markers for key traits will be validated, optimized, and made available for deployment in breeding programs.

Decision support tools will be developed through collaboration with the Integrated Plant Breeding Platform (IBP) project of the Generation Challenge Program.

2.1.2. A global rice germplasm information system to support rice breeding
A global rice information system will be developed that integrates phenotypic data with genetic, genomic, and genotypic data with breeding decision support tools to support the implementation of modern rice breeding strategies. Data integration is one of the key components in developing breeding informatics. The system includes data curation tools, a data-processing pipeline, Web visualization, and simple data-mining tools. The breeding decision support tools (2.1.1) will also be migrated into the integrated data environment. This will add critical value through Web-based data access and use to the key products of the IBP project.

2.1.3. Multienvironment testing (MET) and international germplasm evaluation (INGER)
The new MET system will be a systematic and multistage testing scheme for promising breeding lines developed by GRiSP breeding programs. To be managed by GRiSP, MET will involve public- and private-sector partners at the key locations. This will allow for products to be channeled quickly into the right target environments and markets, while generating valuable feedback from farmers, millers, consumers, and other stakeholders in the public, private, and NGO sector. Through INGER, NARES can exchange superior materials among themselves for release directly to farmers or use in hybridization. Aside from seeds, INGER will facilitate the worldwide exchange of nonseed biological materials and breeding-related information. In Africa, INGER will be embedded in the Africa Rice Breeding Task Force. This task force will be established to regroup scarce human resources devoted to rice breeding in Africa and it will aim to achieve higher rice productivity through (1) the identification of required plant types responding to farmers' needs and consumers' preferences in well-characterized target populations of environments; (2) establishment of a regional rice variety testing network using extensive METs and centralized G × E analyses; (3) development of accelerated and regionally accepted varietal release procedures; and (4) development of alternative and effective models for seed production systems.

Uptake and impact pathway
The next users of breeding informatics and germplasm are rice breeders in GRiSP, the private sector, and NARES. The final users are farmers for varieties released through the MET/INGER system and the Africa Rice Breeding Task Force. The availability of high-quality phenotypic data on key agronomic traits and access to an efficient genotyping system and computing facilities will increase breeding efficiency. The product line will have a close linkage with theme 1 activities related to databases and seed distribution. Established consortia such as CURE for the unfavorable rice environments of Asia and IRRC for the favorable environments will link improved germplasm with appropriate management practices and cropping systems. The Africa Rice Breeding Task Force will greatly stimulate the uptake of new varieties in and beyond AfricaRice's 24 member states. Germplasm from theme 1, management practices from theme 3, and seed production and dissemination strategies from theme 6 will be linked with theme 2. Linkage with nationally and internationally funded development projects will facilitate delivery of improved varieties to farmers (theme 6).

Financing strategy
The breeding informatics activities (2.1.1 and 2.1.2) are currently partially funded by the GCP/BMGF IBP project (about $700,000 for the next 2 years). Some work on trait-specific SNP marker development is funded by the Syngenta-IRRI SKEP project ($300,000 for 2010-12). The work on product 2.1.3 will be partially supported by the Japan Rice Breeding projectand BMGF-STRASA, BMGF-GSR, and BMGF/USAID-CSISA projects. This activity will require infusion of

funds to NARES partners to support the key testing sites and generate high-quality data at about $5,000 per site per season. The INGER component (nurseries and seed exchange) will be partially funded by STRASA and GSR projects. Additional funding will be required to support all three products under this product line.

Product Line 2.2. Improved donors and genes/QTLs conferring valuable traits

Rationale

Rice varieties in all environments require similar basic traits, especially good grain quality and resistance to diseases, nematodes, and insect pests. Breeding for resistance requires knowledge on resistance mechanisms, genetics, and epidemiology, to deploy efficient resistances that reduce crop losses (in yield and quality). There is an urgent need to broaden the gene pool of rice varieties through the transfer of genes from diverse sources. Advances in tissue culture, molecular markers, and genomics offer new potential to broaden the gene pool of rice by tapping the genetic variability hidden in the wild species and to further enhance the efficiency of alien gene introgression. Insect damage reduces yields in rice and causes farmers to use insecticides that are harmful to the environment and human health. For quantitative traits such as yield, many genes and many environmental factors collectively determine trait performance. Favorable alleles are likely to be spread across more than two lines, therefore requiring the assembly of alleles from different sources in a single inbred line in order to achieve significant improvement. In recurrent selection (RS), multiple genotypes are crossed and the resulting plants intercrossed to increase the chance of creating novel allelic combinations.

Products and activities

2.2.1. Novel gene sources for breeding

New genes will be introduced from *Oryza* species through hybridization and backcrossing in elite parents. The favorable genes or alleles will be tagged with molecular markers for marker-assisted selection. African (*O. glaberrima*) strains will be used to developed stress-tolerant cultivars and develop new interspecific varieties containing greater and more targeted parts of the African rice genome, following on the successful NERICA varieties in Africa. Wild species of the AA genome will be used to introduce yield-enhancing genes into elite cultivars. Specialized genetic stocks will be developed.

2.2.2. Disease-resistant rice

The focus will be on blast, bacterial blight, rice yellow mottle virus (RYMV), tungro virus, brown spot, and sheath blight diseases. New universal genomics-based tools will be developed to characterize and understand the pathogen population structure of blast and bacterial blight. Disease-resistance loci will be identified for tungro virus. Epidemiology of brown spot resistance will be studied and resistance components will be quantified. Phenotyping methods for sheath blight resistance will be developed, resistance mechanisms clarified, and QTLs identified. Strengthening of partnerships and capacity building will be high priorities. New global research networks for addressing key rice diseases will be established as an important strategy for achieving stable disease resistance in rice.

2.2.3. Insect-resistant rice

A number of resistance genes/QTLs have been identified for resistance against planthoppers and leafhoppers. Varieties with resistance to and tolerance of stem borers in Asia have been identified. Sources of durable resistance against major Asian rice pests are available.

Resistance screening (phenotyping) will need to be improved, but could also be expanded to determine broad-spectrum resistances (i.e., lepidopteran and diopsid stem borers). New knowledge-based screening methods will help devise better deployment strategies and develop pyramided product lines and seed mixes. IRRI's experience and expertise in breeding for resistance can support initiatives in Latin America and Africa. Key products would include resistant and tolerant varieties tested against a broad range of insect pests and with associated knowledge-based deployment strategies. NILs and MAS can be used to strategically deploy genes with different modes of action in a multiline approach for mega-varieties and commercial hybrids.

2.2.4. Population improvement

About 100 lines will be identified as potential parents by group discussion (expert view), and genome-wide SSR profiles will be generated. Parental lines will be selected for the development of 10-parent recurrent selection (RS) populations (high yielding, wide adaptation, physiological trait-oriented, drought-prone lowland, and upland). The recessive male-sterile gene contained in the IR36 mutant and the dominant male-sterile gene contained in PXDMS will each be transferred into five parental lines. This is to increase the genetic potential of and genetic diversity among the male-sterile lines to be used in future recurrent selection (RS). Computer simulation experiments will be designed to investigate the effects of key factors on RS efficiencies such as heritability, crossing schemes including male-sterility-facilitated and manual crossing, selection intensity, etc. The results of these simulations will then be used to design more efficient RS schemes.

Uptake and impact pathway

The next users for prebreeding products and genetic characterization are rice breeders working in GRiSP, the private sector, and NARES. Intermediate users are seed producers and marketers. Final users are farmers, who may also be next users when generated materials are released directly as varieties. There is an assumption that NARES scientists will have sufficient capacity and available resources to use new donors, breeding populations, and screening methods for new traits or resistance genes. Germplasm sources and information, as well as phenotyping methods, should be available from theme 1, and in some cases there will be linkage with management practices and epidemiology in theme 3.

Financing strategy

Currently, this research is largely funded from unrestricted sources and various restricted grants of different length, including the Japan Rice Breeding project, BMGF-CSISA, ADB-Planthoppers, and Pioneer-SKEP. Additional annual funding of $1 million is needed over 5 years to support epidemiology and crop health research (personnel and equipment, partnerships).

Product Line 2.3. Rice varieties tolerant of abiotic stresses

Rationale

Rice production in unfavorable environments is mostly constrained by abiotic stresses. These areas are commonly overpopulated, and are characterized by widespread and persistent rural poverty. About 30% of the 700 million people in absolute poverty (with income of < $1.25 per day) in Asia live in rainfed rice-growing areas in South Asia alone. The most serious abiotic stresses currently affecting rice production in Asia are drought, submergence, and salt stress, annually affecting about 23, 20, and 15 million ha, respectively. Low temperature adversely affects rice at high elevations and where rice is grown during the winter season in the subtropics, and heat stress is emerging as a serious threat to rice production as a consequence of climate change. The bulk of the rice produced in Africa is grown under rainfed conditions, accounting for more than 80% of the total rice cultivation. Stresses such as drought, salinity, submergence, low temperature, and iron toxicity are widespread in rice fields in Africa, contributing to persistent low rice yields. Iron toxicity and low soil fertility are common problems in Latin America, whereas low temperature is confined to southern Brazil, Uruguay, Argentina, and Chile. Considerable opportunities exist to at least double the yield in these areas through the use of stress-tolerant varieties.

Products and activities

2.3.1. Drought-tolerant rice

All uplands risk water deficiency, and it is also a problem in rainfed lowland ecosystems. In the last decade, short-duration interspecific (NERICA) upland varieties have been widely deployed in Africa and they now occupy more than 300,000 ha. In addition, deep-rooting varieties are being used to develop drought-tolerant varieties with potential to extract water from deeper soil layers. Recent research at IRRI demonstrated potential for achieving an increase in yield of at least 1.0–1.5 t/ha under drought stress through breeding. Progress was also made in identifying major QTLs associated with yield under stress, and their effectiveness under field conditions was validated. Phenotyping techniques will be standardized to establish platforms for large-scale, precise measurements of yield and related traits under drought. NILs possessing drought-tolerance QTLs will be analyzed physiologically to unveil the interaction between these QTLs and facilitate their effective use in breeding. A wide range of genetic resources (*O. sativa* and other *Oryza* species indigenous in Africa) will be used for the development of drought-tolerant varieties.

2.3.2. Submergence-tolerant and other flood-tolerant rice

Rice is sensitive to flooding during germination, which hinders direct seeding in rainfed areas, and also during the vegetative stage when completely submerged. Stagnant partial flooding of 20–50 cm for most of the season also affects considerable areas, estimated at more than 5 million ha in India and Bangladesh alone. The *SUB1* gene, which confers an advantage of 1–3 tons of grain yield following flooding for 10–15 days, will form the basis of tolerance of submergence in all breeding materials. This will be introduced into a wide range of genetic backgrounds to develop more tolerant varieties that are also adapted to longer-term stagnant flooding. Lines tolerant of anaerobic germination will be developed from the best sources identified, and through the use of marker-assisted selection. Tolerance traits of all submergence types will be characterized at the physiological level and the best donors for breeding will be identified and used in crosses. The *SUB1* gene that confers submergence tolerance is now being transferred into African mega-varieties, using IRRI donors. The improved mega-varieties, in terms of submergence tolerance, will be evaluated on a large scale in multilocation trials at "hotspots" in Africa.

2.3.3. Improved varieties tolerant of salt stress and other problem soils

Poor soils with excess salt or deficiency in certain plant nutrients limit rice productivity in most rainfed rice areas, and several million ha of land suited to rice production in Asia and Africa are currently unexploited because of salinity and other related soil problems. Rice is suitable for reclaiming these soils because it thrives well under flooding, and has high potential for genetic manipulation. Rice productivity in salt-affected areas is very low, <1.5 t/ha, but this can reasonably be raised by at least 2 t/ha. *Saltol* and other QTLs for seedling-stage tolerance and one for the reproductive stage will be targeted to develop varieties tolerant at both stages, and the physiology and genetics of tolerance at both stages will be advanced. Nutritional imbalances such as P and Zn deficiency and Fe and Al toxicity are widespread in most rice production areas in Asia, Latin America, and Africa. Donors for tolerance of these soil problems will be identified and physiologically and genetically characterized, and the major QTLs identified and used in breeding. Iron toxicity is a widespread growth constraint in lowland rice in Africa. Several highly tolerant varieties/lines such as Suakoko 8 (*O. sativa*) and CG 14 (*O. glaberrima*) have been identified and some improved varieties have been released by AfricaRice that are tolerant of iron toxicity, including both intra- and interspecifics. At AfricaRice, breeding is under way to validate tolerance of iron toxicity and to identify new QTLs for use in MAS.

2.3.4. Varieties tolerant of cold or hot temperatures

High temperature will become an increasing problem because of climate change. In the Sahel region of Africa, temperatures above 40 °C are experienced quite often during rice cultivation periods. Heat stress causes high sterility, leaf yellowing, and accelerated development leading to low yield potential in sensitive rice varieties. Rice plants are most sensitive at the flowering and ripening stages. Both yield and grain quality are adversely affected. Donors for tolerance of high temperature are being identified by screening improved and traditional rice varieties. *O. glaberrima* could be a useful genetic source since it has a habit of early-morning flowering and high transpiration with sufficient water, both of which are convenient traits for avoiding heat stress. These donors will be used in a crossing program to incorporate tolerance of high temperature into elite cultivars suitable for different growing environments. QTL mapping will facilitate the use of marker-assisted selection in developing improved heat-tolerant cultivars. Segregating populations from IRRI will be evaluated and selected at CIAT. Cold-tolerant cultivars are needed in both temperate regions and high-elevation tropical areas. Cold stress can be experienced during the whole crop cycle and thus tolerance is needed at both the seedling and reproductive stage. New genes and QTLs are being mapped that confer tolerance of low temperature at different growth stages. At AfricaRice, breeding for cold tolerance is being done for indica-type varieties in the Sahel zone and for japonica types in the highlands. However, for both ecologies, indica-type grain is mainly preferred by consumers and this is being integrated into the breeding objectives. In Latin America, cold-tolerant cultivars are needed both in the Southern Cone (Brazil, Uruguay, Argentina, and Chile) temperate regions and in some high-elevation tropical areas.

Uptake and impact pathway

The next users are rice breeders working in GRiSP, NARES breeding programs, and the private sector. Intermediate users are seed producers and distributors, including the public sector, private companies, and NGOs, and final users are farmers. It is assumed that there will be assured funding from donors and national governments to produce and deliver the required amount of seed to farmers. Government policies should facilitate the release of stress-tolerant cultivars. For instance, varieties released in one country in West Africa should automatically qualify for release in other ECOWAS member countries for the same ecology. For the unfavorable rice environments of Asia, CURE will play a key role to link improved germplasm with appropriate management practices and cropping systems. Germplasm sources should be available from theme 1 and management practices for unfavorable areas will be developed in theme 3, requiring close linkage. Participatory varietal selection (PVS) is a method that is necessary for the effective evaluation of improved germplasm with farmers, and participation of social scientists is essential. Seed production and dissemination will be handled by linkage with theme 6. Linkages with nationally and internationally funded development projects will facilitate the delivery of improved varieties to farmers. The Africa Rice Breeding Task Force, revitalized in 2010 with Japan's support, will greatly accelerate region-wide varietal development/evaluation, dissemination, and harmonization of varietal nomination and release systems.

Financing strategy

The research is currently funded by several restricted grants that need to continue and expand under the new funding windows of the Consortium, including BMGF-STRASA (products 2.3.1–2.3.4), USAID-CSISA (2.3.4), the Japan Rice Breeding project, and other projects from BMZ, GCP, and RISOCAS. Work on low-temperature tolerance is funded largely through a project with RDA-Korea. National partners are contributing through in-kind support and funding for seed production activities. Additional funding on climate change activities should include high-temperature stress and tolerance of stagnant flooding and salinity (delta areas). In Latin America, work on low-temperature tolerance is funded largely through FONTAGRO; new funding will be required for work on high-temperature stress and to support more work on breaking the yield barrier.

Box 10. Impact example for product 2.3.2: Submergence-tolerant rice

SUB1 is a major quantitative trait locus (QTL) that confers submergence tolerance in rice. The impact pathway of *SUB1* provides an example of how new varieties are being developed through modern breeding tools in PL 2.3, with ensuing unsurpassed impacts in farmers' fields (see table on next page). It involved the effective use of natural variation for germplasm improvement and efficient delivery methods in accelerating impacts.

Farmers in flash-flood areas have been using local landraces for decades because they mostly possess some tolerance of prevailing abiotic stresses, but with low productivity and poor quality. Collection and evaluation of this material from flood-prone areas identified FR13A from Orissa, India, as the best source of tolerance. Conventional methods to develop tolerant varieties made limited progress over a few decades. The success in genetic mapping of *SUB1* has enabled marker-assisted breeding of high-yielding rice varieties capable of enduring complete submergence for up to 2 weeks, with a yield advantage of 1–3 t/ha demonstrated in farmers' fields following complete inundation for variable durations. The triumphs of this technology prompted considerable interest and support from NARES. The first breeding line, Swarna-Sub1, was developed in 2006, and, by 2009, a few varieties were already formally commercialized in South and Southeast Asia.

Considerable efforts are still needed to transfer *SUB1* into more varieties suitable for areas prone to flash-floods in Asia, Africa, and Latin America. In Asia alone, more than 20 million ha can benefit from this technology. Further improvements are needed to develop more resilient varieties for flood-prone areas, and to cope with the changing climate. Additional QTLs need to be identified to increase tolerance to at least 20 days of complete submergence, and, in most areas, tolerance of partial stagnant flooding is needed as a water level of up to 50 cm can prevail after flash-floods. Direct seeding in flood-prone areas will be possible only pending improvements in tolerance of flooding during germination and early crop establishment. Developing more durable varieties for flood-prone areas will thus require the combination of these tolerance traits in high-yielding genotypes possessing other agronomic and quality traits desired in particular target regions. Seeds of these varieties need to be delivered to farmers via effective seed systems, together with packages of adjusted management options to fully exploit their potential for better and sustained system productivity. A concerted global effort of numerous partners such as that being built in GRiSP is needed, involving CGIAR centers (IRRI, AfricaRice, CIAT), advanced research institutes, NARES, GOs and NGOs, the private sector, and farmers.

Past and projected research to impact pathway of submergence-tolerant rice (with the SUB1 gene)

	1960-80	1985 -90	1991-95	1996-2000	2001-05	2006-10	2011-20	2021-35
Milestones	Tolerant landraces collected Gene-bank screening Donor (FR13A) identified	Breeding combining tolerance and dwarf phenotype IR49830-7 developed	*SUB1* mapped to chr. 9 (70% phenotype)	Fine-mapping advanced Markers developed for MABC	Cross of Swarna with IR49830 (2002) MABC developed for *SUB1* *SUB1-A* gene identified	Precise markers developed (2006) Swarna-Sub1 developed through MABC (2006) Six Sub1 varieties developed (2008) *SUB1* advantages quantified in farmers' fields (1–3 t/ha after submergence)	*SUB1* combined with one or more QTLs to provide protection for approx. 20 d of submergence New varieties combining *SUB1*, AG, and tolerance of stagnant flooding available	50 Sub1 varieties developed 20 varieties combining AG and tolerance of submergence and stagnant flooding developed
Research partners	IRRI, CRRI	IRRI, CRRI, NDUAT	IRRI, UCD	IRRI, UCD	IRRI, UCD, UCR	IRRI, UCD, UCR, CRRI, NDUAT, BRRI, PhilRice; other NARES from S and SE Asia	IRRI, UCD, UCR, AfricaRice, CIAT, NARES in Asia, Africa, and Latin America	IRRI, UCD, UCR, AfricaRice, CIAT, NARES in Asia, Africa, and Latin America
Delivery partners						AfricaRice, African NARES, ACIAR, CRRI, NDUAT, BRRI, PhilRice, BRAC, other NARES, GOs and NGOs in S & SE Asia	AfricaRice, CIAT, NARES, GOs and NGOs in Asia, Africa, and Latin America	AfricaRice, CIAT, NARES, GOs and NGOs in Asia, Africa, and Latin America
Delivery strategies/ milestones						Provision of seeds to NARES PVS trials and extension Facilitating release Seeds via effective seed systems (GOs, NGOs, private sector) Network efforts (INGER, shuttle breeding, CURE, STRASA, MoFA)	Provision of seeds to NARES PVS trials and extension Facilitating release Seeds via effective seed systems (GOs, NGOs, private sector)	Provision of seeds to NARES PVS trials and extension Facilitating release Seeds via effective seed systems (GOs, NGOs, private sector)
Adoption levels						Swarna-Sub1 released in India & Indonesia (2009) Other Sub1 varieties released in Bangladesh (2), Philippines (1), and Indonesia (3) in 2010 Over 200 tons of seeds of Sub1 varieties distributed Sub1 varieties cover over 0.1 million ha in Asia	Submergence-tolerant varieties released in 5 countries in Asia and 5 in Africa/Latin America Yield losses from submergence reduced by 40% on 20% of flood-prone areas in Asia	Tolerant high-yielding varieties released in flood-prone areas of all countries in Asia, Africa, and Latin America Tolerant varieties grown on 12 million ha of flood-prone areas with 40% reduction in yield losses

Partners: Details contained in the GRiSP partners database. MoFA: a project supported by the Japanese Ministry of Foreign Affairs (2007-09). AG = anaerobic germination.

Product Line 2.4. Improved rice varieties for intensive production systems

Rationale
Asian urban centers have the majority of the world's urban poor and, within the next 25 years, nearly 55% of the population of Asia will be located in these areas. Both the urban and rural poor require food at affordable prices and this must come from increased productivity in intensive rice systems, which account for 75% of total rice production. Similarly, Africa's intensive irrigation schemes and their expansion are expected to contribute greatly to enhancing rice production in Africa. Varieties that do well in Asian irrigation schemes are expected to also perform well in Africa. For example, the well-known Sahel108 variety selected by AfricaRice and now widely grown in the Senegal River Valley is originally an IRRI variety. Rice is the leading food staple in Latin America and the Caribbean (LAC), and demand for rice is growing. During 1990-2004, rice yield in LAC expanded annually at 3.5%. LAC has unique pests and diseases, as well as distinct grain types and cropping systems. Eco-efficient rice production systems, with high productivity and low impact on the environment, are critical for the future. However, considerable opportunities to increase rice production exist given LAC's abundant land and water resources.

Yield potential has not been increased substantially in the newer varieties released for irrigated conditions. An improved understanding of the genetic basis and physiological mechanisms of yield potential, pest resistance, and grain quality will allow the development of elite inbred germplasm with higher yield potential, multiple resistance to insects and diseases, and superior grain quality. Increasing water scarcity threatens agriculture and livelihoods, and this will be pronounced in many areas, thus requiring rice cultivars with better adaptation to aerobic conditions. Similarly, labor shortage would require the development of varieties specifically suited to mechanized direct seeding and other evolving conservation agriculture systems.

Products and activities
2.4.1. A new generation of elite inbreds with increased yield potential, premium quality, and resistance to key diseases and insects
Conventional transplanted systems in Asia represent the largest areas of rice cultivation. Although high-yielding varieties are grown in these areas, continual progress is necessary to incorporate disease and insect resistance and improved grain quality characters. Farmers in these areas are expected to rapidly adopt new varieties that are superior to the older varieties still in cultivation. Higher-yielding varieties will be developed by focusing on key physiological plant traits and genes expected to confer higher yield, as well as by a more systematic selection for yield in early generations and in multienvironment yield trials (Product 2.1.3). Technological development of the LAC rice sector has had a big impact on rice yields and total production but yield potential has not been increased substantially in the newer varieties released for irrigated conditions. An improved understanding of the genetic basis and physiological mechanisms of yield potential, pest resistance, and grain quality will allow the development of elite inbred germplasm with higher yield potential, multiple resistance to insects and diseases, and superior grain quality.

2.4.2. Rice varieties for dry seeding in aerobic rice and conservation agriculture systems
Water shortage is becoming an increasing problem in traditionally irrigated areas because of depleting groundwater resources and competing uses from other sectors. Likewise, particularly in systems such as rice-wheat, rice-maize, or rice-pulses, frequent tillage and removal of residues may lead to a decline in soil fertility and unsustainable production. Resource-conserving technologies, particularly water-saving irrigation, reduced or no tillage, and retention

of residues, are required to re-vitalize yield growth, improve production efficiency, and reduce the negative impact on natural resources. However, cultivating rice under such conditions requires new genotypes adapted to dry direct seeding, that is, varieties that have early vegetative vigor, are competitive with weeds, have strong root systems, and are also resistant to lodging, root pathogens, and nematodes. Genetic diversity exists for these traits, and the best donors will be crossed with high-yielding varieties to develop improved varieties for these systems. A key strategy is to select for the new traits required from early stages in the breeding cycle, under the target environments, particularly in South Asia.

2.4.3. High-yielding varieties for irrigated systems in Africa

Irrigated and favorable rainfed lowland areas in Africa are expected to expand. High-yielding Asian varieties can perform well under irrigated conditions in Africa, but they need to have resistance to the important diseases and insect pests. These will be incorporated by crossing to donors and locally adapted germplasm.

Uptake and impact pathway

The next users are rice breeders working in GRiSP, the private sector, and NARES. Intermediate users are seed producers and distributors, including the public sector, private companies, and NGOs, and final users are farmers. It is assumed that there will be assured funding from donors and national governments to produce and deliver the required amount of seed to farmers. Germplasm sources should be available from theme 1, and management practices for intensive systems will be developed in theme 3, requiring close linkage. Seed production and dissemination will be handled by linkage with theme 6. Linkage with nationally and internationally funded development projects will facilitate the delivery of improved varieties to farmers. Theme 5 will provide feedback to breeding programs on target environments, market segments, and consumer and farmer preferences. FLAR will be a key player for impact in Latin America.

Financing strategy

At present, the mainstream breeding programs of IRRI, AfricaRice, and CIAT largely depend on unrestricted funds, which have been dwindling during the past 20 years. This has been one of the major reasons for why progress in varietal improvement has been slower than expected. Likewise, efforts to increase the yield potential of irrigated rice have suffered from a lack of funding at levels required for making substantial breakthroughs through advanced physiology and breeding research. Partial restricted funding is provided by BMGF/USAID-CSISA, the Japan Rice Breeding project, and BMGF-STRASA, MAFF-IRRI, Philippines-IRRI, ICAR-IRRI, and RDA-IRRI projects. Research at CIAT is currently funded by CIDA, Agrosalud, the Ministry of Agriculture and Rural Development of Colombia, FEDEARROZ, FLAR, Peru, and other projects from GCP, and CIAT Core. Many national partners are contributing through in-kind support and research personnel. Large amounts of additional resources are urgently needed, particularly to support more work on breaking the yield barrier. National partners are contributing through in-kind support and research personnel.

Product Line 2.5. Hybrid rice for the public and private sector

Rationale

Hybrid rice generally outyields inbred rice varieties by 10–20% and has been used in commercial rice production since 1976. Currently, about 20 million hectares are grown to hybrid rice, with China having the largest share of 17 million ha. Outside China, the major hybrid rice-growing countries are India, Bangladesh, Indonesia, the Philippines, and Vietnam in Asia, and the U.S. and Brazil in the Americas. In Africa, no hybrids are in large-scale commercial rice production yet. IRRI, collaborating with public and private partners, has been playing a crucial role in hybrid rice research and development internationally for the last 30 years, with a large number of hybrid rice varieties and parental lines shared with partners and numerous varieties released for commercial production. Hybrid rice R&D has been one of the main investments at IRRI for increasing yield potential and promoting rice production. In 2008, IRRI established the Hybrid Rice Development Consortium (HRDC), a public-private partnership with the objectives of renewing and strengthening collaboration between the private and public sector, and enhancing the dissemination of hybrid rice technology. Hybrid rice R&D programs at IRRI and in other public institutes are currently shifting to a product-oriented approach, focusing more on product development with key private-sector partners, but also with NARES programs and selected NGOs.

Products and activities

2.5.1. Rice hybrids for Asia

Developing hybrids derived from male-sterile systems is currently the best and most stable approach for using heterosis in rice. Among the factors affecting hybrid rice dissemination, yield in hybrid seed production is the most critical component. The aim is to produce hybrid seeds with reduced cost and have acceptable seed prices for farmers. Recent research at IRRI and in other commercial programs showed that seed yield could be increased to 3–4 t/ha from the current 1–2 t/ha through breeding. Germplasm with high outcrossing traits will be identified from diverse sources collected or developed at IRRI, and used in developing new female parents. Higher heterosis, which is required to achieve the advantage of hybrid rice over inbred varieties, is closely related to germplasm diversity. Germplasm will be exploited and heterotic patterns will be studied for developing hybrids with higher heterosis. Good grain quality is one of the factors influencing acceptance by consumers, and the high broken rice and chalkiness that can occur with hybrids need to be overcome. Hybrid rice grain quality should be studied, and the genetic and environmental components controlling grain quality will be identified for use in improving quality. As hybrid rice is grown widely, traditional biotic stresses (diseases and insects) may change with new rice cultural practices and management. Resistance or tolerance should be introduced into hybrid rice parents for developing improved rice hybrids. Traditional breeding methods combined with new molecular technologies will be employed in hybrid rice breeding to speed up product development.

2.5.2. Rice hybrids for Africa

F_1 hybrids from Egypt, IRRI, China, and other Asian sources will be tested with parental lines in multilocation trials for evaluating their yield and resistance to abiotic and biotic stresses of Africa. Maintainer lines for developing locally adapted CMS lines will be identified.

2.5.3. Rice hybrids for Latin America

Parents of Asian and other hybrids will form the basis for identifying the best hybrids for Latin American conditions. Cirad activities include the integration of molecular markers into the reciprocal recurrent selection scheme through QTL mapping for combining ability, within the B and R breeding populations, for combining ability and pyramiding of QTLs of interest.

Uptake and impact pathway

The next users are rice breeders working in GRiSP, private enterprises, and NARES. Intermediate users are seed producers and distributors in the public and private sector, and final users are farmers. Hybrid products developed in GRiSP will be transferred to small and large private companies through appropriate licensing mechanisms that ensure wide availability, also for the public sector. Private seed companies will produce hybrid rice seeds and deliver them to farmers. Government policies should facilitate the release of commercial hybrid cultivars. For the countries in Asia, the HRDC will play a key role to link improved hybrids with appropriate product delivery systems. For Africa, hybrid rice cultivation is still only in the testing phase (varietal performance and socioeconomic feasibility studies). IRRI will provide support to AfricaRice and CIAT/FLAR for establishing hybrid rice breeding and research programs.

Financing strategy

The hybrid rice research at IRRI is currently funded by the HRDC, partially by other projects (ACIAR-Chalk, BMGF-STRASA, Pioneer-SKEP), and IRRI unrestricted funding. Income from HRDC membership fees, germplasm development fees, and hybrid licensing is expected to grow steadily so that other funding could be reduced or eliminated over time. All HRDC income will go back to supporting hybrid rice research (HRDC has established a mechanism for this). New funding will be required for work on more breeding efforts and product evaluation in multilocation environments. National partners are contributing through in-kind support and funding for product testing in local environments. The BMGF-GSR project supports work on hybrid evaluation in Asia and Africa.

Product Line 2.6. Healthier rice varieties

Rationale

Among the major micronutrient problems common in rice-consuming countries, the following are highly prevalent: iron, zinc, and vitamin A deficiencies. It is estimated that more than 3 billion people in the developing world are iron-deficient. Almost 3 million children of preschool age have visible eye damage owing to vitamin A deficiency. Estimates of subclinical prevalence of vitamin A deficiency range from 100 to 250 million people. Billions of people are at risk for zinc deficiency. The cost of these deficiencies in terms of lives and quality of life lost is enormous. Current rice varieties do not provide enough micronutrients for leading healthy productive lives. Since rice is the dominant cereal crop in most Asian countries and is the staple food for more than half of the world's population, even a small increase in micronutrient content in rice grains would have a significant impact on human health. Moreover, biofortification—breeding staples with high micronutrient content—has evolved as a new strategy to address micronutrient malnutrition. Biofortification is likely to reach rural households, as the improvements are targeted to the crops and foods that can be grown and sourced locally and they are expected to have impact in a sustainable manner.

Products and activities

Research in product line 2.6 will be done in collaboration with a wide range of partners and it includes participation of IRRI, AfricaRice, and CIAT in HarvestPlus and associated MP Health and Nutrition activities. However, since the biofortification breeding work is closely tied into mainstream gene discovery and rice breeding work, it is executed in GRiSP as its primary home. Outputs of this research may be cross-listed in GRiSP and MP Health & Nutrition.

2.6.1. Pro Vitamin A-enriched rice (Golden Rice)
The carotenoid locus from the leading GR2 event is being introgressed into mega-varieties of rice popular in South and Southeast Asia in the first phase, using modified marker-aided backcrossing. In addition, the event is also being backcrossed into germplasm preferred in areas with high incidence of vitamin A deficiency. In parallel, communication of the nutrition and health benefits of GR to farmers and consumers to drive adoption and consumption will be undertaken. The communication content will be based on known bioavailablity data and on bioefficacy datato be determined before wide-scale promotion and will be linked to consumers' understanding of nutrition and health.

2.6.2. High-Zn rice
High-yielding varieties possessing enhanced grain zinc content will be developed. Ample genetic diversity in the cultivated germplasm for grain zinc content exists, and the best donor parents will be crossed with high-yielding indica elite lines, whereas superior recombinants will be selected using newly developed high-throughput screening methods. The initial launch country will be Bangladesh, which is establishing a support network for this launch. In addition, the bioavailability study of Zn from higher-Zn rice is nearing completion; this result will be used in consumer acceptance/promotion studies.

2.6.3. High-Fe rice
High-yielding varieties possessing enhanced grain iron content will be developed. We do recognize that limited genetic diversity in the cultivated germplasm for grain iron content exists. However, the best individual donor parents, separately and together, will be crossed with high-yielding indica elite lines, whereas superior recombinants will be selected using newly developed high-throughput screening methods. The project benefits from knowledge of the bioavailability result for Fe from higher-Fe rice already determined and from synergies with the high-Zn project. Efforts will be made to evaluate the lead/gene promoter combinations from collaborators to raise grain Fe content in transgenic rice to the HarvestPlus target and above. In the following phase, the identified lead events will be transferred into mega-varieties/elite breeding lines. In parallel, high-Fe benefits will be communicated to farmers and consumers to drive adoption and consumption.

2.6.4. Rice with enhanced folic acid
Women with folate deficiency are more likely to give birth to low-birth-weight and premature infants and infants with neural tube defects. A deficiency of folate occurs when dietary intake of folate is inadequate. This is a worldwide problem and some foods are required to be fortified, such as wheat flour. Rice contains little or no folate (B9). Major breakthroughs have been made in recent years in transgenic rice expressing significant levels of folate. These laboratories in Europe and Australia would be collaborators in the project to develop high-folate rice for developing countries. Activities include evaluating existing fol+ events from ARI collaborators, optimizing gene promoter combinations to maximize folate production and retention in rice grain, and evaluating lead events across diverse genetic backgrounds.

Uptake and impact pathway
The next users are rice breeders working in GRiSP, the private sector, and NARES. Intermediate users are seed producers and distributors, including the public sector, private companies, and NGOs, and final users are farmers. It is assumed that there will be assured funding from donors and national governments to produce and deliver the required amount of

seed to farmers. Government policies should facilitate the release of nutritious rice cultivars. INGER, CSISA, and IRRC will play a key role to disseminate and link improved germplasm with appropriate management practices and cropping systems. Germplasm sources should be available from theme 1, and management practices for unfavorable and favorable areas will be developed in theme 3, requiring close linkage. Seed production and dissemination will be handled by linkage with theme 6 and the seed systems in the target countries. Linkage with nationally and internationally funded development projects will facilitate the delivery of improved varieties to farmers. This phase of the project will also benefit from the experiences from the release, production, dissemination, promotion, and uptake of “specialty” rice varieties developed under the BMGF-STRASA project and its successors.

Financing strategy

The research is currently funded by HarvestPlus, USAID, the Bill & Melinda Gates Foundation, Rockefeller Foundation, and CIDA. However, additional funding will be required, including co-investments from CRP 4 on Health & Nutrition in this product line on healthier rice varieties.

Theme 3: Ecological and Sustainable Management of Rice-based Production Systems

Overview

Rationale and objective

Irrigated rice systems account for 75% of global rice production, providing the staple food for about 2 billion people. Rainfed rice systems in lowlands and uplands, on the other hand, provide livelihoods for hundreds of millions of farmers and their families living in some of the poorest regions of the world. Theme 3 is all about accomplishing multiple goals of improving food security, incomes, and nutrition and doing it in a more environmentally friendly and sustainable manner—through innovations for more precise management of future rice-based farming systems. These production systems will be both more productive and more eco-efficient, but also more resilient to climatic extremes and other drivers of change.

Three millennia of continuous production of irrigated rice in Asia, either as a monocrop or in rotation with other crops, demonstrates the inherent sustainability of the system. This historic sustainability is now threatened, however, by recent rapid population growth that leads to a declining share of land, water, labor, and energy resources. Inefficient use or overuse of production inputs may also lead to pollution, environmental degradation, and declining ecosystem services. Nitrogen-use efficiency in most intensive rice systems remains below 40% and unbalanced nutrient applications are still common. By 2025, 15–20 million ha of irrigated rice will suffer some degree of water scarcity, which results from competing water uses and climate change, and requires rethinking of current management paradigms. In northwestern India, declining groundwater levels pose a serious threat to one of the world's most important grain baskets. In fact, rice systems draw much of their ecological resilience from intensive water use (e.g., weed control, control of soil salinity and pH, heat avoidance through thermal cooling), and new solutions need to be found for water-scarce conditions.

In many areas, the ecological resilience of rice ecosystems and their capacity for natural control of rice pests are weakened by the overuse of pesticides and breakdown of rice host-plant resistance. Animal pests, diseases, and weeds are responsible for a 25–45% loss of rice production in tropical and subtropical Asia. Market-driven diversification of rice-based cropping systems, while offering potential for increasing farm income, also presents new challenges for sustainable management. If done wrong, it may lead to a decline in soil health and productivity. Overarching these issues are the threats of—and opportunities from—climate change. Besides increased temperatures, stresses such as flooding, drought, and salinity, which are widespread in rainfed environments, now encroach on irrigated environments as well.

In Latin America, irrigated rice monoculture is the most common system in the tropics, while monocropping and crop rotations are predominant in the southern temperate regions.Yield gaps are high throughout the region. In Africa, lowland rice is cultivated along an intensification gradient, ranging from practically undisturbed inland valleys to intensively cropped irrigation systems. Fertilizer use is generally very low, mainly because of high prices and poor distribution networks. Gaps between attainable and actual yields are high, even in input-intensive systems. Because most rice is grown under rainfed conditions, drought is a major determinant of yield, often in combination with phosphorus deficiency. Even in Asia, about half of the rice area is affected by drought, uncontrolled submergence, or salinity. Yields in these stressed environments are typically low, in the range of 1–2 tons per hectare, and poverty is extreme and widespread. Moreover, climate change is expected to exacerbate the frequency, severity, and extent of these stresses. In Asia, Africa, and Latin America, rice is also cultivated in upland ecosystems (about 40% of the rice-growing areas in sub-Saharan Africa and LAC). Uplands are extremely diverse and fragile, and deep poverty is found among upland farming communities where socioeconomic constraints hamper intensification and the development of more profitable farming systems.

There is still large scope for significant and sustainable increases in rice productivity globally through improved agronomic practices. Water-saving technologies such as safe alternate wetting and drying (AWD) and dry seeding not only offer hope for rice farmers affected by water scarcity but also can free up water from rice-growing areas for other economic or environmental purposes. The novel system of aerobic rice, in which rice is cultivated in nonpuddled and nonflooded soil just like wheat and maize, drastically reduces water requirements and allows cropping of rice where a lack of water has made this impossible till now. Site-specific nutrient management (SSNM) greatly increases the use efficiency of applied fertilizers and can increase yields, reduce losses to the environment, and increase the profitability of farming. Through the development of new machinery and resource-conserving technologies (RCT), principles and practices of conservation agriculture (CA), which hitherto have mostly been used in dryland crops, now have scope for application in both single-rice and diversified rice-based cropping systems. Landscape management by ecological engineering can increase ecological resilience against invasive pests such as brown planthoppers and thus reduce the need for application of pesticides. Regional strategies for the deployment of resistance genes against pests and diseases can increase the durability of varietal resistance. New rice varieties with increased tolerance of drought, submergence, and salinity are becoming available and targeted management technologies help exploit the genetic potential of these varieties in farmers' fields. Emissions of greenhouse gases can be reduced by modified water and nutrient management, such as AWD and timely tillage and residue management. Altogether, new crop and resource management technologies offer tremendous scope for reducing yield gaps, increasing rice production, and protecting the environment, with positive benefits for both rice farmers and society at large.

Research approach

In theme 3, we focus on further developing the scientific basis for so-called "component technologies" (such as AWD, SSNM, CA) and integrating them into holistic and pro-poor farming-system solutions. We will increase our understanding of crop-soil-water interactions through long-term field experiments established at "experimental platforms" in key rice ecologies. At these platforms, a range of rice-based cropping systems are established based on principles of ecological intensification (Box 11) and resource-conserving technologies, and they are geared toward the future in terms of major drivers of change. We will study interactions among animal pests, diseases, and weeds on the one hand and soil, nutrient, and water management on the other. At selected sites, we will study fluxes of energy, water, and greenhouse gases to determine the impact on global warming potential. Existing knowledge and new process-based insight will be used to design best-bet cropping systems for participatory on-farm testing and site-specific adaptation to local conditions.

New farm implements, machinery, and equipment to practice conservation agriculture are compared, tested, and improved. Farmer participation and the use of learning alliances among key stakeholders (farmers, extensionists, scientists, NGO agents, etc.) will ensure the inclusion and use of local and third-party knowledge and bring to the forefront gender issues and perspectives. Taking into account socioeconomic resource endowments and boundary constraints, whole-farm and cropping-system solutions will be pro-poor and adoptable.

In intensive rice production systems, we will focus on opportunities for, and challenges to, ecological intensification and crop diversification (e.g., rice-wheat/maize/pulses/potato). In major stress-prone environments (such as drought, submergence, and salinity), new varieties with increased tolerance will be incorporated into the cropping systems.

Box 11. Ecological and sustainable intensification, a road map forward

Ecological and sustainable intensification (ESI) aims at increasing the efficiency with which inputs are used based on scientific agroecological principles. With increased input-use efficiencies, yields can be increased, losses to the environment reduced, costs of production lowered, and profitability of farming increased. ESI combines component technologies to increase the efficiency of single input use, such as fertilizer or water, with technologies to reduce the use of pesticides and herbicides, and technologies to reduce emissions of greenhouse gases.

We will establish medium- to long-term field experiments in which component technologies are integrated into various rice-based cropping systems. Measurements will be made of system performance in terms of yield, input-use efficiencies, nutrient flows and loads to the environment, and greenhouse gas emissions. Process-based knowledge will be integrated into so-called field calculators or technical coefficient generators for rice life-cycle analysis and quantification of input-output relationships. These tools will subsequently be validated in farmers' fields and used to explore options for ESI under a wide range of environmental conditions. Eventually, at scale levels beyond the field/farm, tools to increase ecological resilience of landscapes will be included.

Across agroecosystems, we will develop management technologies that reduce emissions of greenhouse gases and design new cropping systems that are adapted to climate change. At the landscape level, we will apply principles of ecological engineering to manipulate landscape components such as bunds, dikes, and other noncropped areas, to increase biological diversity and increase resilience against pests and diseases.

Epidemiological research will be conducted on major rice pests and diseases by elucidating relationships among rice plants, diseases and their vectors, crop management practices, and the natural environment. In addition to experimentation, we will develop and use simulation modeling tools (for crops, water, and pest and disease epidemics) to scale-up site-specific experimental results, to assess the impacts of climate change and major drivers of change such as water scarcity, and to explore options of management interventions.

R&D product lines and outputs

3.1 Future management systems for efficient rice monoculture
3.2 Resource-conserving technologies for diversified farming systems
3.3 Management innovations for poor farmers in rainfed and stress-prone areas
3.4 Increasing resilience to climate change and reducing global warming potential

Innovative contributions

- New experimental platforms linked to adaptive research in key regions for designing and studying future rice-based systems in response to major drivers of change, including climate change.
- Detailed understanding of energy balances and fluxes of water and greenhouse gasses to design mitigation options and adaptation strategies for climate change.
- Integrated, science-based management principles for increasing the efficiency of rice production systems, closing yield gaps, and reducing negative externalities.
- Water-saving irrigation technologies to respond to water scarcity and free up water from rice areas for other users.
- New tools and technologies for site-specific nutrient management.
- Conservation agriculture and resource-conserving technology solutions for diversified lowland rice systems of South and Southeast Asia and Latin America, and for upland rice systems in Africa.
- New approaches for weed management in direct-seeded rice.
- Dry-seeded and aerobic rice systems for water-short and labor-scarce environments.
- Small-scale mechanization of rice production systems in Africa.
- Ecological engineering approaches for pest management.

- New modeling tools to design cropping system interventions that reconcile multiple objectives (e.g., reduce global warming potential, adapt to major drivers of change, minimize environmental footprints, and increase productivity and profitability).

Partnerships

In general, GRiSP CGIAR centers (IRRI, AfricaRice, and CIAT) focus on developing generic international and global/regional public goods, whereas regional, national, and local partners play a key role in adaptive research and diffusion/dissemination of technologies. Advanced research institutes and universities, especially from India, China, and Brazil, are frontier partners in the research on and development of new management technologies and the underlying science. By linking these partners with those in less-developed target countries, south-south technology transfer and adaptation of technologies are facilitated. Local adaptive research and dissemination/diffusion involve an array of public- and private-sector partners.

Theme 3 interacts closely with theme 6 and boundary partners for further uptake and widespread diffusion include formal public-sector extension agencies, NGOs (e.g., World Vision in Vietnam and CRS in Africa), civil society groups, farmer groups, irrigation system managers, and the private sector, such as fertilizer and agricultural equipment companies. Partnerships with leading institutions in developed and BRIC countries are also forged on advanced and upstream science and R&D topics such as simulation modeling, for which we partner with WUR in the Netherlands, CSIRO in Australia, NIAES in Japan, and Cirad in France. Innovation partnerships on participatory and adaptive research and development will ensure that indigenous and local knowledge are captured and that gender-specific issues are explored in the design of new management technologies. Cirad co-leads a number of product developments, especially on crop modeling, land and water management, and upland production systems.

Through creating and fostering innovative public-/private-sector partnerships in key regions, work under this theme will boost the deployment of well-adapted germplasm × management solutions for the world's primary irrigated and rainfed rice-based cropping systems, including new ones for the future, such as resource-conserving technologies for conservation agriculture.

Impact pathways

Products from this theme will reach farmers at an accelerated pace through regional networks for crop and resource management research and delivery, such as IRRC, CURE, and CSISA in Asia; IVC and the new Task Force Mechanism led by AfricaRice in Africa; and FLAR in Latin America. These networks help to channel management innovations into adaptive efforts by NARES, NGOs, agricultural development initiatives, and extension efforts. A concrete example of an impact pathway is given for the technology of site-specific nutrient management in PL 3.1. Theme 3 activities will be closely linked with variety development in GRiSP theme 2 to ensure that the performance of new varieties is optimized for appropriate growing conditions. Theme 3 products mainly feed into GRiSP Theme 6 for accelerated and large-scale delivery. This will also involve engagement with other CGIAR research programs and centers working in the target regions.

Product Line 3.1. Future management systems for efficient rice monoculture

Rationale

Double- and triple-crop rice monoculture systems occupy a land area of 24 million hectares in tropical and humid subtropical Asia, accounting for 40% of global rice production. In Southeast and East Asia, double cropping of rice occurs on large inland plains and in major river deltas where irrigation allows for rice cropping in the dry season (e.g., the "rice bowls" in deltas of the Mekong, Red, Ayeyarwady, Ganges-Brahmaputra, Cauvery, Yangtze, and Chao Phraya rivers). Intensification of lowland cropping systems in Asia since the mid-1960s has increased the number of crops grown per year and the yield per crop cycle. Triple cropping of rice occurs in the Mekong Delta of Vietnam and in parts of other countries. It is increasingly proposed as a response to reduced food security by several nations (e.g., Indonesia, Philippines). These intensive rice production systems are the main economic activity in many rural areas, they provide the staple food for hundreds of millions of people, and they greatly affect the livelihoods and health of the urban and rural poor.

To be sustainable, however, such intensive rice monocropping systems must be managed well. Overuse and losses of agro-chemicals (pesticides, fertilizers) may pollute the environment and diminish the capacity to deliver of other ecosystem services, while consumption of limited resources (e.g., water, phosphorus) depletes precious natural resources. Farmers urgently need new water management options to alleviate increasing water scarcity. Ecological resilience of monocropped rice ecosystems and their capacity for natural control of rice pests are weakened by overuse of pesticides and the breakdown of rice host-plant resistance. Animal pests (insects, rodents, nematodes, birds), diseases, and weeds are responsible for a combined loss of rice production of 25–45% in tropical and subtropical Asia. Recently, acute outbreaks of planthoppers and rodents have occurred in intensive monocropped rice areas in Asia. Planthoppers damage rice crops directly, and indirectly by transmitting devastating virus diseases. The spread of new viral diseases is being observed alongside planthopper outbreaks in East and Southeast Asia. Water scarcity leads to less flooding of rice fields, which induces weed species shifts and enhances weed growth. Weed resistance to several herbicides is already confirmed in several countries. In the end, component technologies such as water, nutrient, pest, and disease management need to be integrated as they often interact; thus, holistic approaches are needed.

In Africa, fully or partially irrigated rice is grown on about 1.7 million ha in countries such as Egypt, Mali, Senegal, Côte d'Ivoire, Guinea, Madagascar, Nigeria, and Tanzania. About 1 million ha of that are under intensive management. With an average yield of 10 t/ha, productivity in Egypt can be considered the highest in the world. Enhanced rice production in Africa will depend to a large extent on enhancing cropping intensity in irrigated systems as well as expanding irrigation areas. A major issue for the near future will be to introduce water-saving measures in such systems, in farmers' fields as well as in delivery systems, to maintain the natural resource base and enhance rice production. In Latin America, irrigated rice accounts for nearly 60% of rice production, with the largest irrigated rice systems found on 1.3 million ha in the Southern Cone region (southern Brazil, Uruguay, Argentina).

This product line includes management technologies and their underpinning science to enhance the profitability and productivity of rice monocropping systems while at the same time reducing negative externalities. It delivers integrated management options and their underpinning science to improve water-use and nutrient-use efficiencies, and protect rice from animal pests, diseases, and weeds. Potential impact is improved food security, enhanced livelihoods, and a clean environment, which are derived from profitable, sustainable, environment-friendly, and resilient rice cropping systems that are ready for the future. The key research question is how the profitability and productivity of rice-based cropping systems can be increased while simultaneously reducing negative externalities.

Activities
Activities combine long-term and on-station field experimentation at so-called "experimental platforms" with adaptive and participatory crop, water, crop health, and soil management research. At the experimental platforms, cropping systems "of the future" that respond to major drivers of change are designed and tested. Detailed process-based science is developed to support the optimization of these cropping systems. Adaptive research trials will be established in farmers' fields with our research and extension partners, and will deliver concrete site-specific management recommendations for rapid out-scaling. Site-specific nutrient management and water-saving technologies will be developed. Pest and disease management guidelines will be integrated with water, nutrient, and crop management practices to arrive at best-bet integrated management recommendations. Innovation partnerships and learning alliances will ensure that indigenous and local knowledge are captured and that gender-specific issues are examined in the design of new management technologies.

Products
3.1.1 Strategies to improve water-use efficiency
3.1.2 Principles and tools for site-specific nutrient management
3.1.3 Management options for pests, weeds, and diseases
3.1.4 Integrated good agricultural practices (GAP)

Partnerships
Advanced research institutes and universities, especially those in BRIC countries, are partners in the research on and development of new technologies and the underlying science. For example, CAU, WU, and HZAU in China and IARI in India are long-standing partners in the development of water-saving technologies such as alternate wetting and drying and the aerobic rice production system. Local adaptive research and dissemination/diffusion involve an array of public- and private-sector partners. For example, adaptive research and development of site-specific implementation of water-saving technologies and aerobic rice in other target countries in Asia are done in collaboration with local and national R&D institutions such as PhilRice, CLSU, and BSWM in the Philippines; and DPP, CLRRI, NOMAFSI, and FCRI in Vietnam. Boundary partners for further uptake and widespread diffusion include formal public-sector extension agencies, NGOs (e.g., World Vision in Vietnam), civil society groups, farmer groups, irrigation system managers (for water-saving technologies), and the private sector such as fertilizer companies (for SSNM) and Syngenta (for AWD). For Africa, expertise from Asia will be mobilized and enhanced collaboration will be established with research institutes in Egypt.

Uptake and impact pathway
Products feed into GRiSP theme 6 and other national and regional co-investment programs for accelerated and large-scale delivery. The IRRC is a major mechanism to link the development of management technologies with local partners for adaptive research and to accelerate diffusion through fostering and promoting innovation partnerships. It also plays a pivotal role in linking the development of the new products of this product line with large-scale diffusion efforts to support the growth of the rice sector (theme 6). Regional and global public goods are taken up and site-specifically adapted by local R&D partners whereas extension and boundary partners adapt and diffuse technologies to farmers and farmer groups. This PL will also closely collaborate with the CRP on land and water, in which field-/farm-level rice technologies are placed in a larger regional context. A concrete example of an impact pathway is given below for site-specific nutrient management.

Financing strategy

The IRRC, several projects funded by ACIAR, ADB, and MAFF (Japan), private-sector grants, and new projects focusing on future systems (the Ecological Intensification project) are the current major funding mechanisms for this product line. Extra funds need to be raised to ramp up the development of tools to quantify the biophysical and economic footprints of rice production and to develop management technologies that will reduce these footprints. Substantial continued funding of 3.1.4 is of high priority. There is a need to invest in capacity building on ecological intensification concepts. Activities in Africa focusing on water savings will need to source additional funding.

Box 12. Impact example for product 3.1.2: Site-specific nutrient management (SSNM)

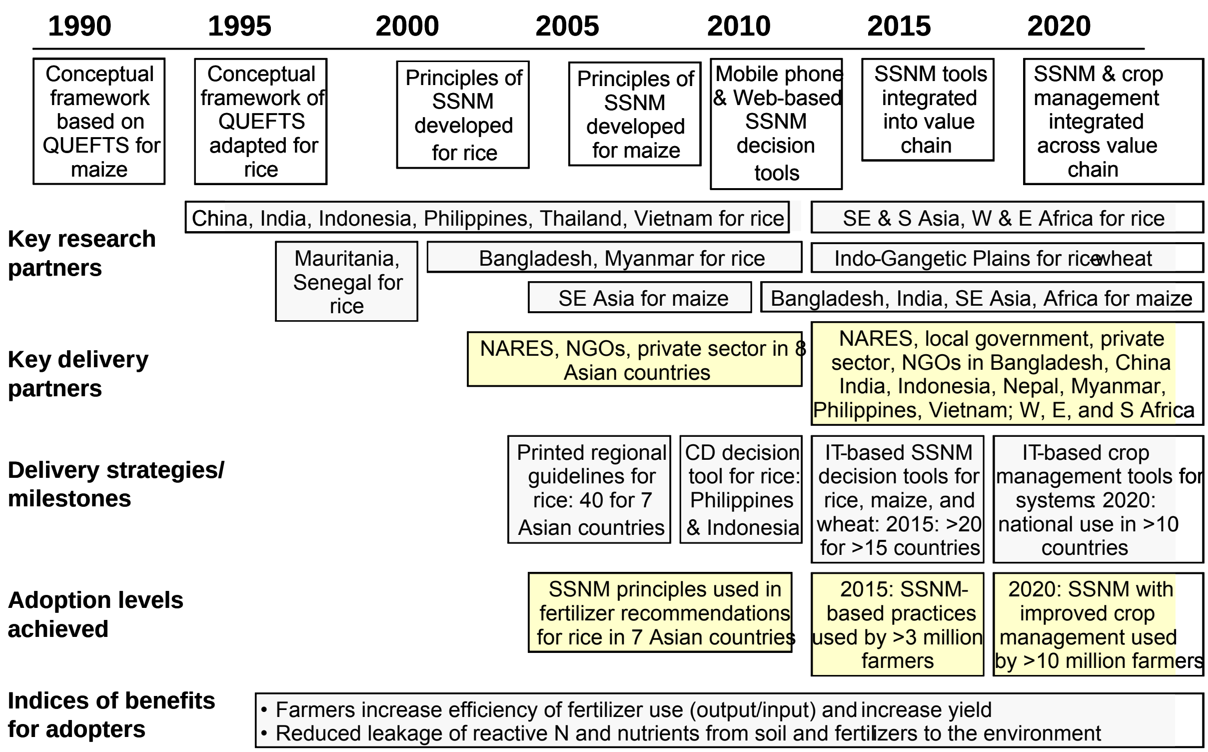
Site-specific nutrient management provides research-based principles for guiding the judicious and efficient use of nutrients as and when needed by crops. Locally adapted decision tools based on SSNM principles enable farmers to implement best practices for their specific fields.

SSNM principles were developed for rice through more than a decade of research beginning in the mid-1990s and involving countries across Asia and in Africa. The experiences with rice were subsequently used to develop SSNM principles for maize and wheat, which were ready for delivery by 2010.

Delivery of SSNM for rice from 2002 to 2008 focused on developing and promoting printed guidelines for large rice-growing regions. Uptake by farmers was limited due to the knowledge intensity required in the use of printed materials to develop a guideline for farmers' field-specific conditions.

From 2008, delivery focused on using computer-based decision tools consisting of 10 to 15 questions easily answered within 15 minutes by an extension worker and farmer. Based on responses to the questions, a field-specific guideline with amounts of fertilizer by crop growth stage is provided. The *Nutrient Manager for Rice* decision tool was released nationally on CD in the Philippines and Indonesia in 2008. A Web-based and mobile phone-based application was released in the Philippines in 2010.

The experience in the Philippines now provides a delivery model to be replicated across at least 15 countries in Asia and Africa by 2015. This will result in wide-scale exposure through IT tools for farmers in Asia and Africa to improve practices for their specific field conditions. This is projected to result in the uptake of improve nutrient management practices by more than 3 million farmers, leading to higher profits and yields and reduced leakage of reactive N and nutrients to the environment. By 2020, SSNM-based principles will be fully integrated with other best management practices across the value chain in more than 10 countries.



Product Line 3.2. Resource-conserving technologies for diversified farming systems

Rationale

Intensive, diversified rice-based production systems are a main economic activity in many rural areas and they provide the staple food for hundreds of millions of people, and greatly affect the livelihoods and health of the urban and rural poor. Intensive cereal cropping systems that include rice, wheat, and/or maize are widespread throughout South Asia (India, Pakistan, Bangladesh), providing the bulk of the regional food supply there. Rice-wheat cropping is also important in China and rice-maize systems are gaining importance in Southeast and South Asia. Rice-wheat occupies 13.5 million hectares in the Indo-Gangetic Plains of South Asia and another 3.5 million ha in China. More recently, increasing demand for maize in many countries of Asia has resulted in the diversification of rice-rice or rice-wheat systems to rice-maize systems, which probably occupy up to 3 million ha at present. In Africa, diversified cropping systems occur in inland valleys with good market connections. More profitable crop rotations with high yields, including higher-value crops, legumes, and fodder crops, have good market potential and are a promise for generating employment and income.

Market forces are driving further intensification and diversification of rice-based cropping systems in irrigated and so-called favorable (sufficient rainfall, good soils, good market access) areas in Asia and Africa. To be sustainable, however, such intensive "future" cereal systems must use resources efficiently and management must focus on sustaining soil health and productivity. Overuse and losses of agro-chemicals (pesticides, fertilizers) and consumption of limited resources (water, phosphorus) degrade the environment, deplete precious resources, and diminish the capacity of rice ecosystems to sustain rice productivity and deliver other ecosystem services. Resource-conserving technologies and principles of conservation agriculture are therefore vital components of managing whole cropping systems in these environments. Labor is increasingly scarce and expensive, and options for mechanization and direct seeding (instead of the traditional method of transplanting) are increasingly important. Persistent yield losses to diseases, animal pests, and weeds remain a major concern.

This product line includes the development of resource-conserving management technologies and their underpinning science to enhance the profitability and productivity of diversified rice-based cropping systems while at the same time reducing the negative externalities. Potential impact is improved food security, enhanced livelihoods, and a clean environment, which are derived from profitable, sustainable, and environment-friendly rice-based cropping systems that are ready for the future.

Activities

Activities combine long-term and on-station field experimentation at so-called "experimental platforms" with adaptive and participatory research on integrated crop management, mechanization, and resource-conserving technologies and conservation agriculture. At the experimental platforms, cropping systems "of the future" that respond to major drivers of change are designed and tested. Detailed process-based science, supported by simulation modeling, is developed to support the optimization of these cropping systems. Adaptive research trials will be established in farmers' fields with our research and extension partners, and will deliver concrete site-specific management recommendations for rapid out-scaling. To ensure linkages between the adaptive research and the more detailed experimental platforms, the latter will be located in key target domains where the adaptive research is conducted. Site-specific nutrient management and irrigation water-saving technologies will be developed for whole cropping systems (rotations). Innovation partnerships will ensure that indigenous and local knowledge are captured and that gender-specific issues are examined in the design of new management technologies.

Products

3.2.1. Diversified cropping systems in Asia
3.2.2. Mechanization and conservation agriculture

Partnerships

Particularly through CSISA, this product line involves collaboration with many other CGIAR research programs and centers (e.g., CIMMYT, ILRI, IFPRI, ICARDA, ICRISAT, IWMI, WorldFish) working in the target regions, particularly CRP 3 (wheat, maize, pulses, livestock), CRP 1 (aquatic systems/coastal zones), CRP 4 (nutrition), CRP 5 (land, water, ecosystem services), and CRP 7 (climate change). More collaboration will also be sought with AVRDC on the inclusion of vegetables in such systems. Research institutions and universities in India, Bangladesh, Nepal, Pakistan, and other countries are key partners in the research on and development of new technologies and the underlying science. For example, Punjab Agricultural University, ICAR (Indian Council of Agricultural Research) Research Complex for the Eastern Region, Haryana Agricultural University, and the Directorate of Wheat Research in India are long-standing partners in the development of mechanization options for conservation agriculture in rice-wheat systems. Advanced research institutes in South Asia host new experimental platforms that cater to the more process-based and in-depth research. Local adaptive research and dissemination/diffusion involve an array of public- and private-sector partners. For example, the following partners are involved in adaptive development of farm machinery for mechanized seeding and conservation agriculture in India: John Deere Equipment Pty. Ltd. (Patna), Farmer Association (Begusarai), Department of Agriculture (Haryana), Dasmesh Mechanical Works (Punjab), Amar Agricultural Implements Work (Punjab), and Preet Combines (Punjab) Boundary partners for further uptake and widespread diffusion of developed products include the formal public-sector agencies with an extension mandate (e.g., KVKs in Jamui, Pipra Kotha, E. Champaran, Sarghatia, Kushinagar, Sasuli, Maharajganj, Sasuli, and Maharajganj), NGOs (BRAC, CARE, Save the Children), civil society groups (e.g., Gorakhpur Environmental Action Group, Gorakhpur), farmer groups (e.g., Kishamot Bhuipara ICM farmers' club), and the private sector (e.g., Bayer CropScience, Syngenta, Devgen, Pepsico). In Africa, advanced research institutes, such as WUR and Cirad, are partners in research and development for new technologies at research platforms hosted by NARES partners.

Uptake and impact pathway

Regional and global public goods are taken up and site-specifically adapted by local R&D partners, whereas extension and boundary partners adapt and diffuse technologies to farmers and farmer groups. The next users for integrated cropping system options are scientists from ARIs and NARES partners who will adapt the options to local conditions and validate performance. Intermediate users are extension agents and agricultural experts of NGOs and the private sector (see above on Partnerships). Final users are farmers.

Products from PL 3.2 feed into GRiSP theme 6 and other national and regional co-investment programs for accelerated and large-scale delivery. CSISA and a number of specially funded projects in the target area are major mechanisms to link the development of management technologies with local partners through adaptive research and to accelerate diffusion through fostering and promoting innovation partnerships. CSISA also plays a pivotal role in linking the development of the new products of this product line with large-scale diffusion efforts to support the growth of the rice sector (Theme 6).

Financing strategy

The BMGF/USAID-CSISA project, several projects funded by ACIAR, IFAD, and MAFF (Japan), private-sector grants, and new projects focusing on future systems (DFG-ICON, Ecological Intensification) are the major funding mechanisms for this product line. CSISA is expected to last 10–15 years and its continuity is required to guarantee ultimate impact among rice farmers and consumers. CSISA co-invests in several CRPs under TA 3 of the CGIAR. Significant co-investments are provided by numerous local partners involved. Besides the current investments through unrestricted and restricted mechanisms, there is a need for a rapid buildup of investments to increase the capacity to quantify and reduce the footprints of rice production.

Product Line 3.3. Management innovations for poor farmers in rainfed and stress-prone areas

Rationale

About half of Asia's rice area is affected by drought, uncontrolled submergence, or salinity. Yields in these areas are typically low, in the range of 1–2 t/ha, and poverty is extreme and widespread. Moreover, climate change is expected to exacerbate the frequency, severity, and extent of these stresses. Gene discovery and new breeding tools are leading to the development of new rice varieties with increased tolerance of drought, submergence, and salinity. However, to fully benefit from the genetic potential of these new varieties, new and adapted management strategies need to accompany their introduction in the target regions. In contrast to Asia, rice in Africa is mostly grown under rainfed conditions and drought is a major determinant of crop yields, often in combination with phosphorus deficiency. In addition, low-lying areas can be affected by iron toxicity in inland valleys, by salinity in coastal zones and river deltas, and by alkalinity in inland irrigation systems. There is large potential to intensify rice production by introducing mechanization. Recently, acute outbreaks of African rice gall midge in Africa have ravaged rice crops. Rice is produced in Latin America across a number of different environments, cropping systems, land and water availability, and farm sizes and socioeconomic characteristics. New fungus and bacterial disease problems are emerging, notably *Burkholderia glumae.* In Africa, rice yellow mottle virus can devastate farmers' crops, whereas, in Latin America, the hoja blanca virus transmitted by *Sogata* planthoppers and rice blast continue to be a main threat.

Uplands worldwide are home to extremely poor farmers who rely on their rice crop for food self-sufficiency. In Africa and LAC, approximately 40% of all rice is cultivated in upland ecosystems, usually still based on slash-and-burn practices. Yields are constrained by frequent drought, low soil fertility, and soil acidity. Rice production is further hampered by biotic stresses such as blast disease, stem borers, termites, and weeds. It is important to introduce crop rotations and conservation agriculture practices that help build soil fertility and stabilize these slash-and-burn systems. Upland rice areas in Asia are highly heterogeneous in terms of climate, soil, and topography. Options exist for rice intensification as a stepping stone out of poverty by introducing lowland paddy rice or aerobic rice systems on terraces and in river valleys.

Activities

Activities include adaptive and participatory crop, water, and soil management research to accompany the introduction of stress-tolerant varieties in well-defined target areas that specifically suffer from drought, submergence, iron toxicity, or salinity. Pest, weed, and disease management guidelines will be developed that are appropriate for rainfed conditions. Options for increasing mechanization and introducing conservation agriculture will be explored in the rainfed lowlands, while new cover crops, aerobic rice, and crop rotations will be introduced and tested in the uplands. Activities will focus on farm-level improvement because rice is rarely the only crop farmers grow under rainfed lowland or upland conditions. Because of the extreme poverty found in many rainfed and stress-prone environments, special care is taken that developed management options are pro-poor.

Relying on the long-term experimental platform and partnership model developed by Cirad in Madagascar, systems research approaches will be used to (1) understand the interactions between environmental conditions and cropping systems, and (2) develop diverse and innovative upland cropping systems suited to the local rice commodity chain. Knowledge is integrated in the field around perennial but adaptive experiments conducted by researchers and around farmers' field networks. Based on the Madagascar experience, a new long-term experimental platform will be established in West Africa for the development of conservation agriculture–based upland rice-cropping systems for this region.

Products

3.3.1 Management options for drought, submergence, and salinity
3.3.2 Management options for pests, diseases, and weeds
3.3.3 Mechanization and conservation agriculture for low-input and upland systems
3.3.4 Land and water development options for inland valleys

Partnerships

Research in this product line is conducted in collaboration with a range of advanced research institutes and universities from various countries. For example, work in the drought-prone lowland and upland environments in Laos is conducted together with ACIAR, Charles Sturt University, the University of Queensland, JIRCAS, CIAT, NAFRI, and the National University of Laos. Local adaptive research and dissemination/diffusion are targeted with national and regional NARES partners (NAFRI, NAFREC, the National Rice Research Program, the Department of Agricultural Research, the Champassak Provincial Agriculture and Forestry Office, and the Savannakhet Provincial Agriculture and Forestry Office), a large IFAD investment project (IFAD RLIP—Rural Livelihood Improvement Program), the Oudomxay Community Initiative Support Project, and World Vision. Similar mixtures of partners are used or targeted in all other countries this product line is working in. Also, a new strategy to achieve better technology out- and up-scaling is followed in two recently accepted CURE projects. In both, adaptive research partners (NARES and IRRI) will provide "technical innovation services" (TIS) to IFAD-funded investment projects and, where present, NGOs involved in technology dissemination. The TIS mechanism will provide linkages and feedback between research and development activities at the international and national level, thus helping the CURE network and collaborating development projects to improve technology targeting, delivery, and larger outreach. Partnerships with private-sector partners are still rare, mostly because many fewer such potential partners are operating in rainfed environments, but, hopefully, more collaboration can begin in the near future.

A good example of south-south collaboration is the involvement of the Japanese universities of Hitotsubashi, Tsukuba, and Kinki as well as IWMI in the development of African inland valleys, notably on the environmental and economic aspects of small-scale water management. The social settings and subsequent negotiations through stakeholder platforms are undertaken with Cirad, ICRA, WUR, and IITA. New initiatives for investigating combined biophysical and social interactions for inland valley improvement are being discussed with the University of Bonn. Specific partners in Madagascar include Cirad, the University of Madagascar, School of Agronomy, National Agronomic Research Institute Fofifa, Association for the Development of Conservation Agriculture in Madagascar (GSDT), and the NGO TAFA

Uptake and impact pathway
The next users are scientists from ARIs and NARES partners, who will perform adaptive work on the management systems. The Inland Valley Consortium and AfricaRice-NARES Task Force mechanisms are major means to link the development of management technologies with local partners through adaptive research and to accelerate diffusion through fostering and promoting innovation partnerships. In Africa, Cirad will play a lead role in developing farm management innovations through their collaborative upland rice-based systems research platform in Madagascar. Likewise, Cirad and WUR will lead R&D actions for integrated crop and resource management for inland valleys in the framework of the activities of the Inland Valley Consortium. In Asia, CURE is a major mechanism to link the development of management technologies with local partners through adaptive research and to accelerate diffusion through fostering and promoting innovation partnerships. In LAC, CIAT-FLAR will play a lead role in the transfer of crop management innovations through their public-private partnership to accelerate the diffusion of improved varieties and technologies to farmer groups. Once these technologies and varieties are validated, intermediate users are extension agents and agricultural experts of NGOs and the private sector. Final users are farmers. Products feed into GRiSP theme 6 and other national and regional co-investment programs for accelerated and large-scale delivery. Rice varieties developed in GRiSP theme 2 are critical inputs into product line 3.3. Products feed into GRiSP theme 6 for accelerated and large-scale delivery and linkage with other co-investments at the national or regional level.

Financing strategy
The BMGF-STRASA project and the IFAD-funded CURE are major current funding mechanisms for this product line. STRASA is expected to last 10–15 years and its continuity is required to guarantee ultimate impact among poor farmers. STRASA focuses mainly on varietal improvement. Research on the development of low-cost water control options, multistakeholder platforms, and intensification and diversification of inland valley lowlands is funded through grants from Japan and the European Union. In Africa, existing co-investments by Cirad will be a key contribution to this product line. In Asia, CURE plays a pivotal role in linking the development of new varieties in Theme 2 with the products of this product line. In LAC, CIAT-FLAR co-investments are supporting this PL.

Product Line 3.4. Increasing resilience to climate change and reducing global warming potential

Rationale
Rice production simultaneously contributes to global climate change and is affected by it. Currently, irrigated double- and triple-cropping rice systems are a significant source of methane and a small source of nitrous oxide. But, flooded rice fields also sequester and store large amounts of soil carbon, which would be emitted as atmospheric CO_2 in case of an unsustainable conversion to upland systems. Management of water, soil organic matter, and nutrients can be changed to minimize these contributions to global warming. Reduced soil tillage not only affects organic matter or water availability but also can further reduce fossil fuel consumption. Global climate change will have profound effects on the livelihood of rice farmers as well as on rice production. Crop yield losses may increase because of rising air temperature or more frequent occurrence of extreme heat, drought, or storms. Because of these drivers of change, farm management practices will change. Already, two major trends are emerging rapidly in the intensive rice systems of Asia: (1) changes in management of the rice crop and (2) changes in cropping systems, particularly diversification from double or triple rice monoculture to rice–

upland crop systems such as rice-maize, rice-wheat, and rice-wheat-legumes. Systems that traditionally have been flooded for long periods of the year will be exposed to greater soil aeration. These trends will occur simultaneously and they will lead to significant changes in the cycling of energy, water, carbon, nitrogen, and other elements of paddy fields. There will be impacts on C and N budgets through changes in net fluxes of greenhouse gases (CO_2, N_2O, CH_4) and reactive nitrogen compounds, on local and regional water budgets, on the sustainability of rice production systems over the long run (e.g., conservation vs. loss of soil organic matter), and on heat fluxes and associated climate-change processes (systems that use less water are likely to have increased soil and canopy temperatures).

The flora and fauna and behavior of weeds, insects, and plant diseases will change in direct response to changing climate and in indirect response to changes in management practices. The resilience of rice ecosystems, which is threatened in some intensive rice production systems already, will be further affected by these changes. For example, massive outbreaks of planthoppers have been reported in intensive rice areas in Thailand, Vietnam, Indonesia, and China, with associated increases in hopper-transmitted viral diseases. In Africa, the major challenge will be maintaining high production with less available water and selecting varieties that can cope with extreme temperatures. Other challenges are the effects of climate change on the distribution, virulence, and socioeconomic impact of pests, weeds, and diseases. The underlying processes of climate change and its induced short- and long-term impacts must be understood to formulate appropriate mitigation and adaptive strategies and policies. Governments need to develop policies to respond to climate change and transform the agricultural sector to protect farmers, consumers, agri-businesses, and natural resources.

The key question is how rice systems should be managed to be resilient and less vulnerable to high temperature and water shortages, to take advantage of rising atmospheric CO_2 levels, and, at the same time, to emit fewer harmful greenhouse gases and remain profitable for farmers.

Activities

At new interdisciplinary "experimental platforms," cropping systems "of the future" that respond to major drivers of change will be designed and tested. Detailed process-based science will quantify the fluxes and budgets of energy, greenhouse gases, and water in an unprecedented level of detail, for current and future scenarios. Models will be used to predict the trade-offs associated with crop/system improvements, and to design appropriate combinations of component technologies. For example, increasing water scarcity may increase crop temperature and thermal stress, further exacerbated by rising atmospheric CO_2. Integrated solutions thus need to be targeted at specific climatic conditions and they will be different in semi-arid and humid tropical irrigated systems.

We will analyze and model crop microclimate and carbon and water balances in the rice canopy with respect to changing weather and soil water conditions. Upstream research will fill in knowledge gaps and weaknesses in current models, especially on (1) microclimate as influenced by the crop and plant-avoidance mechanisms of thermal stresses (e.g., thermal cooling and its trade-offs with water use), (2) the determinants of phenology, (3) temperature-induced respiration losses, and (4) the interaction of external factors such as temperature, CO_2 concentration, and soil water content with crop growth and performance. Insights gained will be used to adapt management practices to mitigate global warming potential.

Adaptive research trials will be established in farmers' fields with our research and extension partners, and will deliver concrete management recommendations and cropping system practices that both mitigate global warming and adapt to the impacts of climate change. We will investigate whether seasonal weather predictions can be generated and used through decision support systems to enable farmers to make strategic and tactical decisions about cropping system management. Epidemiological research will be conducted on major rice pests and diseases by elucidating the relationships among rice plants, diseases and their vectors, crop management practices, and the natural environment as determined by weather and hydrology. A global network for assessing crop health will be established with key partners. Weed species shifts in response to changes in hydrology (as induced by water scarcity) and crop management (e.g., shifts from transplanting to direct seeding) will be studied to identify intervention points for weed control. Principles to enhance ecological resilience against insect pests will be developed through ecological engineering and regionally targeted deployment of resistance genes in rice varieties.

Products

3.4.1 Assessment tools (ecological resilience, impact of climate change, adaptive value of response options)
3.4.2 Field management technologies to reduce greenhouse gas emissions
3.4.3 Strategies to adapt to climate change and increase resilience

Partnerships

Advanced research institutes and universities are partners in the research on and development of new technologies and the underlying science. For example, a consortium of German institutions (from the Universities of Giessen, Bonn, and Bremen as well as Karlsruhe Institute of Technology, IMK-IFU, and Max Planck Institute, Marburg) are partners in the process-based research to measure and model the turnover and fluxes of carbon, nitrogen, and water in rice systems and to design mitigation options. We also closely collaborate with a range of international networks dealing with atmospheric processes, for example, FluxNet and AsiaFlux. JIRCAS and JAMSTEC in Japan will collaborate in the development of seasonal weather forecast models and integrate these into decision support systems for rainfed rice farming. Local adaptive research and dissemination/diffusion involve mainly research institutes and universities in the target countries, such as NAFRI in Laos; PhilRice in the Philippines; Can Tho University, Southern Institute for Water Resource Planning, and Cuu Long Rice Research Institute in Vietnam; and BARC, BARI, and BRRI in Bangladesh. At the same time, we perceive an increasing interest coming from the private sector (e.g., Bayer CropScience) to work jointly on adaptation and mitigation technologies.

Upstream science partners in the development of global health monitoring and ecological engineering tools to increase ecosystem resilience include other CGIAR centers, Charles Sturt University, University of Wisconsin, University of California-Davis, Embrapa and University of of Viçosa (Brazil), and ICAR institutes in India. A private-sector organization, Syngenta, is involved in management tool evaluation coordination, problem definition, and field surveys in target countries in Asia. Sites for experimental ecological engineering are established and maintained by the Chainat Rice Seed Center, Chainat (Thailand), Southern Regional Plant Protection Center and Plant Protection Department (Vietnam), and Zhejiang University and the Plant Protection Station, Jinhua, Zhejiang, China. In the area of systems approaches to adaptation to climate change, an informal consortium of crop scientists and modelers, operating since 2007, is intensifying its work at the interface of CRP 7 and GRiSP. Leading this consortium are scientists from IRRI, AfricaRice, Cirad, WUR, and NIAES.

Research into strategies to cope with less available irrigation water includes IWMI and Agrymet. The effects of extreme temperatures are being evaluated with the help ofCirad and the University of Hohenheim, while the effects of climate change on the virulence of rice pests in Africa are being analyzed with the aid of the University of Gottingen. With IITA, ICIPE, and the CGIAR Systemwide Program on IPM, Gottingen is also a partner in the proposal to use sustainable pest management strategies for mitigating the effects of climate change. The effects of climate change on the economic impact of parasitic weeds are being studied in close collaboration with WUR.

Uptake and impact pathway

Users of information, tools, and mitigation and adaptive technologies will essentially include stakeholders (farmers, scientists, extension personnel, and policymakers) and the scientific community. Communication with farmers will engage a variety of means, including farmers' direct involvement in field testing of technologies and participation in field days, farmers' fairs, and on-site workshops. We will also target local media that are accessible to farmers. Research outputs will be developed into simple extension materials and advisory notes that are culturally sensitive and easy to understand and these will be distributed through channels accessible to farmers.

We will take a multitiered approach to communication and dissemination, using different approaches to target different audiences. In the extension domain, including the relevant departments of extension (e.g., Cambodia, Laos) or appropriate NGOs (e.g., Bangladesh) in projects as core partners will be the general pathway by which technical guidelines and adaptation options will be mainstreamed into public- and private-sector extension services (e.g., the model being trialed by IDE in Cambodia) and thus channeled to farmers beyond those involved with the projects. This will require significant training activites to foster outreach to more extensionists within extension departments. Different training activities will be tailored toward the needs of immediate project partners, complemented by "training the trainer" approaches to reach out beyond the immediate extensionists involved in the projects. In countries such as Bangladesh, it is envisaged to involve various NGOs in annual technical workshops. In the policy domain, we intend to conduct routine briefings with key government stakeholders and implementation agencies, as well as with other donor organizations.

Financing strategy

In Asia, two ACIAR-funded projects, the MAFF-funded CCARA, the GTZ-funded ICON (in preparation), BMZ-funded activities, and USAID-funded activities under the CSISA umbrella are the main funding mechanisms for this product line. NOW/WOTRO is funding the study on the effects of climate change on parasitic weeds. GTZ is funding two climate-change projects in Africa: RISOCAS in Senegal, Mali, and Madagascar, and MICCORDEA in Tanzania, Rwanda, and Uganda. A proposal for a third GTZ-funded project called CC&SPM in Benin, Ghana, Nigeria, Mozambique, and Tanzania has been submitted. A concept note for CC studies in the Niger River and Senegal River basins is currently being discussed with UEMOA. Additional funds are needed to finance experimental platforms in Egypt, Senegal, and possibly Mali and Nigeria. In LAC, CIAT-FLAR co-investments are supporting this PL.

Theme 4: Extracting More Value from Rice Harvests Through Improved Quality, Processing, Market Systems and New Products

Overview

Rationale and objective

Theme 4 links strongly to Themes 1, 2, and 5 to develop ways to add economic, nutritional, and environmental value to the crop through (i) a reduction in postharvest losses; (ii) improved grain quality of new rice varieties, including access to and supply of quality and specialty products to current and emerging markets; (iii) improved value-chain linkages and efficiencies; and (iv) innovative uses of husks and straw to produce bioenergy, cut carbon emissions, and increase carbon sequestration.

Present processing practices in the developing world cause around 15–25% physical loss and, because of poor quality, financial loss at the market of 10–20%. Improvement to both loss and quality is hampered by the separation of the three segments of the sector—production, processing, and marketing. Farmers would benefit from better information flows and linkages with processors and retailers on general and emerging market trends and opportunities that could influence their choice of varieties, as well as a better understanding of the causes of and solutions to postharvest losses.

Each year, hundreds of millions of tons of rice straw and husks are produced. These are commonly disposed of by burning, thus emitting greenhouse gases. Innovative uses, such as bioenergy and biochar, of husks and straw will provide local business opportunities and extra income sources for farmers, and simultaneously mitigate, instead of accelerate, climate change. Another mitigating option is improving the digestibility of the straw so that it can be used as livestock feed.

Traditional varieties, grown for their quality, still occupy much of the world's rice-growing land. They have not been replaced by higher-yielding versions because current evaluation tools do not discriminate sufficiently. Recent technological triumphs suggest that investment into developing accurate phenotyping and genotyping tools for quality is timely. Combining quality with high yield will increase food security and decrease the environmental footprint of rice by harvesting more grain from less land. Demand for specialty products is increasing globally. Capacity to measure quality will ensure that it is maintained in new products. Other opportunities to add value to broken rice are products such as high-value oil from bran, and high-energy biscuits for malnourished children. Supplying rice varieties for these high-value markets will increase economic benefits to farmers and nutritional benefits to consumers.

Research approach

Postharvest technologies will be identified and verified with end-users, and the technologies adapted to suit varied local conditions. This has commenced in Benin, Cambodia, Nigeria, the Philippines, and Vietnam, and in GRiSP will be extended to other Asian, Latin American, and African countries. Research to upgrade the postharvest value chain includes tools and methodologies for analysis, improved market information systems, assessment of consumer needs, linkages, and other proposed interventions, such as the adoption of business models. Research on husks and straw will determine the variability in digestibility of the straw, and identify and address the main constraints to using straw as livestock feed. Concepts for decentralized bioenergy and uses of biochar in carbon sequestration will be developed using

‘’green chemistry’’ approaches. Ways to select for quality and specialty traits will be determined using newly developed techniques for identifying compounds that contribute to taste, flavor, and texture, and identifying the components of the grain that determine specialty, sensory, and cooking properties. A phenotyping platform for quality will be developed and used to develop low-cost, high-throughput tools, and in collaboration with themes 1 and 2, to associate with genetic maps of particular populations to identify genes, allelic variation, and molecular markers.

R&D product lines and outputs

4.1. Technologies and business models to improve rice postharvest practices, processing, and marketing
4.2. Innovative uses of rice straw and rice husks
4.3. High-quality rice and innovative rice-based food products

A variety of new products and technologies that add economic, environmental, and nutritional value to rice harvests and by-products will be the main outputs in this theme. The other major outputs are mechanisms for integrating the different parts of the rice sector to improve information flows among them, thus improving the overall efficiency of the sector. Widespread adoption of the products of this theme can lead to more stable rice prices, increased income for farmers, and healthier consumers, which will increase labor productivity and decrease the cost to poor families and national health budgets. Better use of the large volume of by-products of rice cultivation can result in significant mitigation of climate change as well as increased income for farmers.

Innovative contributions

- Adaptations of improved postharvest technologies to highly variable or local conditions.
- Entrepreneurial business models for sustainable adoption of postharvest technologies and management options.
- Innovative management of market information systems and linkages between cross-sector actors.
- Establishment of multistakeholder platforms (e.g., learning alliances) for capturing new knowledge and disseminating new information on postharvest technologies and new phenotyping tools to evaluate the quality of breeding lines.
- Options to reverse carbon emissions from burning of straw and hulls to sequestration and value-added uses.
- Production and use of rice biofuels to generate electricity for small enterprises.
- New varieties with improved straw digestibility for livestock feed.
- Improved nutritional and health value of rice to help reduce disease and malnutrition.
- New traits of quality and a new-generation phenotyping platform to break through the quality plateau and allow high quality to be combined with high yield and specialty traits without penalty.
- Innovative ways to process broken grain to add value and generate employment opportunities, especially for women farmers and food processors in Africa.

Partnerships

Work under this theme will rely heavily on public-private partnerships and multistakeholder platforms appropriate to each product line to take advantage of new rice varieties and production technologies under GRiSP on the one hand and private-industry experience in postharvest, marketing, and distributing new rice varieties and other rice-based foods on the other. Links are strong with themes 1, 2, and 3, with theme 5 regarding information dissemination and knowledge of consumer preferences, and with theme 6 for widespread distribution and out-scaling of the products and technologies. Collaboration in PL 4.2 will be strong with ILRI (straw traits for livestock feeding, link with CRP 2).

Impact pathways
Products developed in this theme address the major opportunities to add value to the crop, improve food security by reducing postharvest losses, mitigate climate change by new, green options for husks and straw, and help meet nutritional and health needs of consumers through higher-quality varieties. Uptake of the technologies and products requires networks of multiple stakeholders to ensure that (i) appropriate end-users and consumers are aware of the products and their benefits, (ii) technologies are out-scaled and products distributed through appropriate business models, (iii) and improved flows of information and learning are developed among cross-sector actors. Key intermediaries and disseminators for generating awareness, communicating information, and providing support for the adoption of these products include in-country learning alliances, NARES networks, NGOs, farmer groups, processors, technology and service providers, retailers, health organizations, and climate change scientists and carbon traders.

Product line 4.1. Technologies and business models to improve rice postharvest practices, processing, and marketing

Rationale
Modernization of the postharvest sector has not kept pace with increased production and new problems caused by additional harvests during the wet season. Postharvest losses in Asia, Latin America and the Caribbean, and Africa of up to 30% are caused by spillage and grain loss in all postharvest processes, losses to animals and pests, contamination (for example, by mycotoxins), and inefficient rice mills. In addition to physical loss, inappropriate postharvest management practices, delays caused by labor shortage, outdated postharvest equipment, and low operator skills lead to losses in quality, thus reducing the market price of milled rice by 10–30%. In all regions, farmers are often forced to sell immediately after harvest because of indebtedness, inability to dry, or poor on-farm storage. At harvest time, freshly harvested paddy swamps the markets, driving down prices so that farmers cannot maximize their returns by timing their sales. Moreover, limited market information prevents market-oriented production. Previous interventions in postharvest often focused on component technology development and did not consider nontechnical support service needs for adoption and uptake by farmers and rural processors such as extension, financing, marketing assistance, etc. These groups lack the necessary knowledge, entrepreneurial skills, and resources to source and apply technologies to improve income by reducing losses and increase income by adding value. Business models for farmers can enable farmers and processors to link to these resources and apply postharvest technologies as small entrepreneurs.

Activities
(1) Initiation of sustainable postharvest networks embracing key postharvest stakeholders for identifying national impact pathways, establishing baselines, planning and implementing interventions, studying adoption and impact, and engaging policy. (2) Development, adaptation, optimization and participatory verification of harvesters, dryers, threshers, mills, storage systems, village-level quality assessment tools, and postharvest management options. (3) Development of business models, market information systems (MIS), and networks for exchanging and disseminating market information more efficiently. (4) Piloting linking farmers to

markets and to micro-finance through NGO and private-sector channels. (5) Developing and verifying low-cost mycotoxin detection technology. (6) Development and testing of training packages for postharvest technologies and business models.

Products

4.1.1 Improved technologies and management options to increase postharvest yield

4.1.2 Business models for postharvest technologies and tools for improved rice market information systems

4.1.3 Postharvest practices for reduced mycotoxin contamination of milled rice

4.1.4 Institutional and organizational innovations enabling greater access to output markets for smallholder farmers

Partnerships

4.1.1. Partners for research on and developing new and improved postharvest management options and technologies include advanced research institutes, national research institutions, and national universities, and, in some cases, private manufacturers. The technology verification and adaptation to local conditions are done in partnerships with key users through participatory research trials supported by the same national research institutions and universities that are engaged in the development. Some NGOs and private-sector entities such as local manufacturers also engage in adaptive R&D. Since multiple channels are used for dissemination of the research results, the partners for out-scaling include national extension systems, private-sector extension agents, final users' associations, and NGOs with their grass-roots networks. Out-scaling is supported by working with policy institutions to generate favorable frameworks, and by linking with financing institutions such as banks and micro-credit schemes, stakeholders can have better access to markets.

4.1.2. The development and upgrading of business models for piloting and sustained adoption of postharvest technologies will involve a wide range of cross-sector actors. Research partners from government institutes and universities will assist in identifying appropriate technologies and piloting, as well as monitoring and feedback. Other partners, such as local technology producers, retailers, and after-sales service providers with necessary linkages to postharvest chain actors, including farmer organizations, processors, and trading intermediaries, will be fostered. Partnerships with disseminators of market information, training, and additional support services delivered by public and private extension networks, NGOs, and local civil society organizations (CSOs) will also be leveraged, including the development of innovative tools and methods for improving market information systems.

4.1.3 Surveys of postharvest management practices in the field and gathering of samples are facilitated in partnership with farmers' organizations, local government units, and agricultural and extension agencies. Research partners will analyze gathered samples for mycotoxin content. New management options and validated technologies for minimizing mycotoxin contamination will be disseminated through learning alliance networks and local adapters

4.1.4 Information and learning materials will be developed in partnership with Regional Economic Communities and NARES partners and disseminated to farmers, processors, and agents of agricultural extension services and CSOs. Participatory learning and action research (PLAR) methods will be applied with partners to facilitate institutional and organizational innovations enabling greater access to output markets for smallholder farmers and for reaching larger domestic urban markets with higher-quality local rice. Cooperation and collective action between and among local rice farmers, parboilers, millers, and traders will be stimulated, and partnerships will be forged with regional institutions across sub-Saharan Africa to establish a framework to develop and improve regional rice policy and outreach.

Uptake and impact pathway

The products will be developed and out-scaled through a rice postharvest, processing, and marketing task force in Africa and outreach programs of IRRI in Asia (IRRC, CURE, CSISA) that involve national postharvest networks with stakeholders from the private and public sector (e.g., traders' and millers' associations, NGOs, farmers' organizations), but also support for postharvest programs of other investors (e.g., the World Bank-funded Agricultural Competitiveness Project in Vietnam). Partnerships with NGOs will be strengthened for linking farmers to markets and micro-finance. The next users, who conduct local adaptation work, are in national research systems, while important intermediate users include NGOs and private-sector producers of postharvest equipment. The final users of that equipment are processors. Through theme 6, co-investments will be explored to out-scale innovations in collaboration with development partners (e.g., ADB, AfDB, IFAD, CARD).

Financing strategy

Current investments include bilateral grants from ADB (US$0.6 million/year until mid-2011) and SDC-IRRC ($40,000/year until 2012). Reaching $2 million/year within 2 years is necessary to have significant impact. Initial funding for the work in Africa has been sought from CIDA.

Box 13. Impact example for product 4.3.1. Rice dryers in SE-Asia

Impact pathways of the dryers in SE Asia have not been linear and have involved many actors at different points of time as the case of Vietnam shows. Interactions between countries were very important for incremental innovations in the dryer development and therefore it is difficult to look at only national impact pathways. Vietnam is far ahead with dryer usage with dryer capacity in the Mekong Delta installed for drying around 30% of the crop. In Cambodia, Lao and Myanmar dryers were introduced in 2005 and with more favorable markets for better quality, already proven technical solutions and improved delivery platforms we can expect an accelerated introduction compared to the process that started in the 1980s in Vietnam and is still ongoing there.

International research contributed initial prototypes (mid 1970s), new concepts such as the automatic rice husk furnace (1997), and drying principles like low temperature drying when these were needed to further develop the technology based on users needs and more recently facilitation of the transfer of proven technologies from Vietnam to neighboring countries. National research institutions carried out most of the adaptive research, often in close collaboration with selected manufacturers. NLU also played an important role in the IRRI facilitated technology and know-how transfer. Since 2004 private sector actors like the MRPTA in Myanmar, rice millers associations and other market actors play an increasing role in the promotion of dryers and in providing drying services to farmers.

Future international R&D will still be needed to increase input use efficiency of dryers and quality of dried rice. In addition international institutions play an important role as an honest broker in facilitating technology transfer processes and bringing the multiple stakeholders from different sectors required for out-scaling of drying technologies together, e.g. though platforms like the learning alliances. Selected final users of dryers, in most cases drying contract service providers for farmers, millers and traders, will contribute to the adaptation and also to dissemination of the technology through their networks and associations. Since most dryers are locally produced local manufacturers are key players in the adaptive R&D but they are usually lacking know how and capacity to do the adaptive research, e.g. to adapt a fan performance to an up-sized drying bin, therefore public sector R&D and support remains essential. Private players in the marketing chain will play an increasingly important role since they can open up marketing channels for high quality rice products including specialty rice, branded rice and certified rice with labels like GAP or resource efficiency eco-labeling, which would require the use of dryers to guarantee consistently high quality. Policy is needed to pave the way for trading better quality by e.g. removing red tape in export in countries like Myanmar and Cambodia.

Year	1970s	1980s	1990-1997	1998-2003	2004-2005	2006-2009	2010	2035
Key research milestone, internat. research	Flatbed dryer (FBD) developed at UPLB (2t), adapted to rice at IRRI (1t)	FBD introduced to VTN	RHF designs evaluated at IRRI, Development of automatic RHF, in-store drying	No R&D on drying	Adaptation of automatic RHF for FBD Technology transfer	Support to NARES and private sector for adaptive R&D	Support to NARES and private sector in optimization (e.g. fan testing)	Reduction of energy and labor use and residues, paddy quality improvement,
Key adaptive research milestone	Dryer tested in national programs	VTN: Pilot tested with initial users	VTN: FBD fan optimized for 4t dryer, improved manual RHF introduced, low-cost dryer for farm level	VTN: Optimize fan performance, Increase of capacity to 6-10t, Fan for 10 t dryer	IRRI facilitation of technology transfer to LAO, MMR, CAM, PHI VTN: 3rd generation FBD with reversible airflow for better quality	VTN: piloting of automatic RHF INO: fan improvements, FBD with 3.3-10t	Local production of FBD established in INO, CAM, MMR, LAO. Initial units installed in Africa	Locally adapted technologies (next generation) locally produced, Integration in value chain, linkages with quality markets
Key research partner	UPLB, IRRI NARS country programs	VTH: NLU	Hohenheim University, NLU	VTN: NLU, DANIDA, local manufacturers	NLU, MRPTA, NAFRI, CARDI	NLU, MRPTA, NAFRI, MAFF,	R&D institutes, extension, manufacturers	ARS, local research institutions
Key delivery partners	National gov. programs in key IRRI partner countries	VTN: Large state owned manufacturers	VTN: NLU, local manufacturers	VTNL NLU, DARD, national research institutions	VTN: NLU, manufacturers, gov. extension. MMR: MRPTA	Increasingly private sector partners	Extension, manufacturers	Manufacturers, market actors, extension, finance institutions
Delivery strategies, milestones	Provision of dryers to government institutes	VTN: Mostly driven by private sector, up-scaled to 4t	VTN: R&D program with extension component	DANIDA funded extension/credit program	VTN: little support from public sector.	Demonstrations, multi stakeholder platforms, inclusion of market players	Learning alliances, public private partnerships	Public private partnerships, business models for dryer usage
Adoption level achieved	Few hundred units, little usage due to high fuel cost	VTN: Limited adoption by farmers and drying service providers	VTN: few hundred units of mainly 4t dryer, mostly drying contract service providers	VTN: farmers increasingly buy low cost dryer. More millers discover advantages of drying		VTN: 1,400 low cost dryers by farmers, 6,200 FBD MMR: 50 FDB, CAM: 12 FBD, INO 100	7,000 FBD in VTN, Capacity: 30% of production in Mekong Delta	VTN: 90% of Mekong Delta production, CAM: 30%, LAO, MMR, INO: 15%

Countries: CAM – Cambodia; INO – Indonesia; LAO – Lao PDR; MMR – Myanmar; PHI – Philippines
Technology: FBD - Flat bed dryer; RHF - Rice husk furnace
Partners: DARD - Provincial Department of Agriculture and Rural Development, Vietnam; MAFF -; Ministry of Agriculture Forestry and Fisheries, Cambodia; MRPTA - Myanmar Rice and Paddy Traders Association; NLU - Nong Lam University, Vietnam; UPLB - University of the Philippines Los Baños, Philippines.

Product line 4.2. Innovative uses of rice straw and rice husks

Rationale

Each year, about 550 million tons of rice straw and about 5 and 110 million tons of husks are produced in Africa and Asia, respectively. Although rice residues are major by-products of rice production, they generally have little or no commercial value. In intensive systems, where two or three crops are grown each year, the time for incorporated residues to decompose is very short and the remaining residues may disrupt soil preparation, crop establishment, and early crop growth. Although residue retention is essential for sustainable management of more diversified (rice-upland crops) systems, long-term research has shown that residue removal has no negative consequences for the productivity, sustainability, and soil health of intensive double- and triple-cropping rice monoculture systems. However, where practiced, burning of rice residues causes severe air pollution in some regions, but, the alternative, incorporation into the soil, is a major source of methane emissions from rice fields. Therefore, in this product line, research will be conducted on innovative uses of rice straw and husks, including modifications of the rice plant. This will generate new income opportunities for the rice-farming sector and help to mitigate the effects of climate change.

Activities

(1) Develop tools to select for high digestibility of rice straw through understanding the chemical composition and then incorporate selection tools for highly digestible straw into breeding programs. This work will be carried out by ILRI in South Asia, under CSISA. (2) Activities include an inventory of existing bioenergy technology designs; evaluation of a range of concepts for bioenergy production using rice husks or rice straw; adaptation of promising concepts to local conditions and rice straw, and verification on a pilot basis; characterization and management options for biochar usage for carbon sequestration, nutrient recycling, and increased soil fertility and soil health; energy balance, life-cycle analysis, and the carbon footprint for selected bioenergy/biochar systems established; and development of a road map for participation in clean development mechanism (CDM)/carbon trading. (3) Improve rice mils to obtain better separation of husk and bran during milling. (4) Evaluate (i) a range of concepts for the production of biomaterials using rice husks and/or straw and (ii) the commercial viability of these products in sub-Saharan Africa.

Products

4.2.1 Rice straw with increased digestibility for feeding to livestock
4.2.2 Climate change mitigation through renewable, profitable, and sustainable energy production and carbon sequestration options based on rice residues
4.2.3 Innovative, profitable, and sustainable processing options for rice husks and rice straw

Partnerships

4.2.1 ILRI and IRRI scientists will collaborate with farmers in South Asia to determine indicators for suitable rice straw quality for use as a fodder. Both partners will then screen a range of cultivars for the desired traits, and provide rice breeders with a tool to select for these traits. Promising lines will then be recommended to NARES partners in South Asia for further evaluation and use.

4.2.2 IRRI and Cirad will conduct an initial desk study on available bioenergy technologies for crop/rice residues. Together with AfricaRice, AIT, and suitable NGOs or private-sector partners, the most suitable system(s) will be analyzed in detail on a pilot basis. IRRI in collaboration with

NARES and an ARI will analyze the integration of bioenergy/biochar systems in rice-based cropping systems. Life-cycle assessment, carbon footprint analysis, and concepts for carbon trading will be developed with Cirad and other suitable partners.

4.2.3 AfricaRice and Cirad will determine the feasibility of developing commercially viable products from rice husks and rice straw in partnership with the private sector.

Uptake and impact pathway
Tools for selecting for improved digestibility will be used in the rice breeding process of theme 2, as well as for public- and private-sector breeding efforts, so that the trait is mainstreamed into South Asian varieties. The product of those efforts, rice straw with improved digestibility, will be an attractive, self-spreading technology because many smallholder farmers in South Asia are already using straw for feeding livestock. However, competing demands for its use as feed or concerns about soil health may limit adoption in some areas.

The principal audience for feasibility work on bioenergy will be agencies involved in setting standards for carbon finance, so that appropriate standards can be developed for markets for averted emissions. Uptake of bioenergy/biochar technologies requires that the price of the energy produced is competitive on the local market, that the emissions and by-products do not harm the environment, and that by-products from bioenergy production can have additional value such as for carbon sequestration or nutrient recycling. There will be close linkages with product line 4.1. Accelerated impact requires linkages with investments in clean energy. Uptake will be driven by the private sector and NGOs with expertise in that area. For new uses of rice milling by-products, the next users, who conduct local adaptation work, are in national research systems, whereas important intermediate users include private-sector producers of postharvest equipment. The final users of that equipment are processors and small enterprises that will use by-products as inputs.

Financing strategy

PL 4.2 currently receives little funding. It is an area in GRiSP in which we gradually wish to build up more expertise and thus also invest more, but also seek substantial co-investments from partners. Product 4.2.1 is currently funded by CSISA; annual investments of $0.5 million are required to support 4.2.2. Product 4.2.3 in Africa is expected to be funded by CIDA.

Product line 4.3. High-quality rice and innovative rice-based food products

Rationale
Traits of grain quality strongly influence the adoption of new varieties. Examples of traditional varieties that continue to be widely grown, despite efforts to replace them with higher-yielding lines, are Basmati 370, selected in 1920; Domsiah and Khao Dawk Mali 105, selected in 1958; and Koshihikari, selected in 1960. However, current quality evaluation tools cannot distinguish the variety from the breeding line even though consumers can readily do so. A major constraint to combining high yield with desired quality is the absence of appropriate phenotyping tools to evaluate eating quality. Enhancing knowledge on grain quality will enable informed targeting of the products developed in themes 1 and 2. Specialty products that add value to grains by meeting the increasing demand for products that are minimally processed, nutritionally beneficial, or environmentally friendly further illustrate the need for new phenotyping tools for quality. Specialty traits could penalize eating quality; thus, understanding the basis of different

eating qualities will ensure that the right traits are combined with specialty traits so that eating quality is maintained, thus facilitating adoption by high-value markets. Our second approach to increasing income, especially for women farmers and processors, is to determine innovative uses of low-value broken grains. Even with the best postharvest management, some grains will always break during milling. Innovative ways to use these in rice-based products will add more value to milled rice. The proportion of broken grains decreases the price of rice, so, providing a market for those will increase the value and quality of the rice. Specialty traits and innovative rice products that increase the nutritional and commercial value of the crop will be prioritized on the basis of consumer studies (theme 5).

Activities

A phenotyping platform will be developed for eating quality and specialty traits. Structures and compounds in the grain will be analyzed for development of the platform. Trait-relevant phenotyping data will be associated with genetic maps of existing populations to identify the genes underlying the traits in collaboration with theme 1. Specialty traits such as slow digestibility, high dietary fiber, longer shelf-life, and faster cooking will be prioritized in collaboration with the INQR and theme 5. Grain quality specialists will contribute to regional interdisciplinary task forces in collaboration with theme 2 for the development of varieties for specific end-users, including high-value specialty markets. Broken and chalky grains that fetch a low value in the market will be ground into flour and different applications for the flour developed that include weaning foods, high-energy biscuits for malnourished children, and extruded and bakery products. Women food processors will be trained in making and marketing these products.

Products

4.3.1 A phenotyping platform and tools for evaluating quality and specialty traits of grains and rice products
4.3.2 Specialty rice with good eating quality for high-value markets
4.3.3 Processing techniques that add value to low-grade rice
4.3.4 Market analysis and information for developing and targeting specialty rice and rice products

Partnerships

4.3.1: This work is being carried out by IRRI and a number of research partners for defining sensory products, and identifying structures and metabolites in the grain. Samples of rice differing in eating quality are provided by members of the International Network for Quality Rice (INQR). As new phenotyping methods are developed, they are tested by members of the INQR, and disseminated by the International Standards Organization (ISO) and the members of the INQR. Genotyping methods, high-throughput methods, and germplasm panels of allelic series of fragrance and chalk genes will be developed at IRRI and delivered to local adapters and disseminators in the INQR. New QTLs/markers for grain quality traits will be developed together with the breeding programs in theme 2.

4.3.2: A number of specialty traits have been prioritized in consultation with members of the INQR. Germplasm and mutants carrying these traits will be developed at IRRI in collaboration with one research partner. Once germplasm and markers are developed, they will be delivered to the members of the INQR to adapt and disseminate them. Specific specialty rice and rice products will be developed in collaboration with food producers.

4.3.3: This work was initiated by AfricaRice in collaboration with the CSIR-Food Research Institute in Ghana. Trials were conducted based on the preferences of consumers in Ghana and a draft recipe book was produced. The recipe book will be updated and the number of products and processing methods, such as parboiling, increased for Ghana and subsequently out-scaled to other countries in sub-Saharan Africa through the rice postharvest, processing, and marketing task force in Africa.

4.3.4: Market analysis and information about demand for specialty rice and rice products will be conducted by partners that include public and private research organizations, consumer advocacy groups, public health organizations, and industry associations, as well as rice value-chain actors. Product development partners will include public- and private-sector researchers, food producers, and rice growers. Other dissemination partners will include links to members of the INQR, rice consumers, wholesale and retail networks, and nutritional service providers.

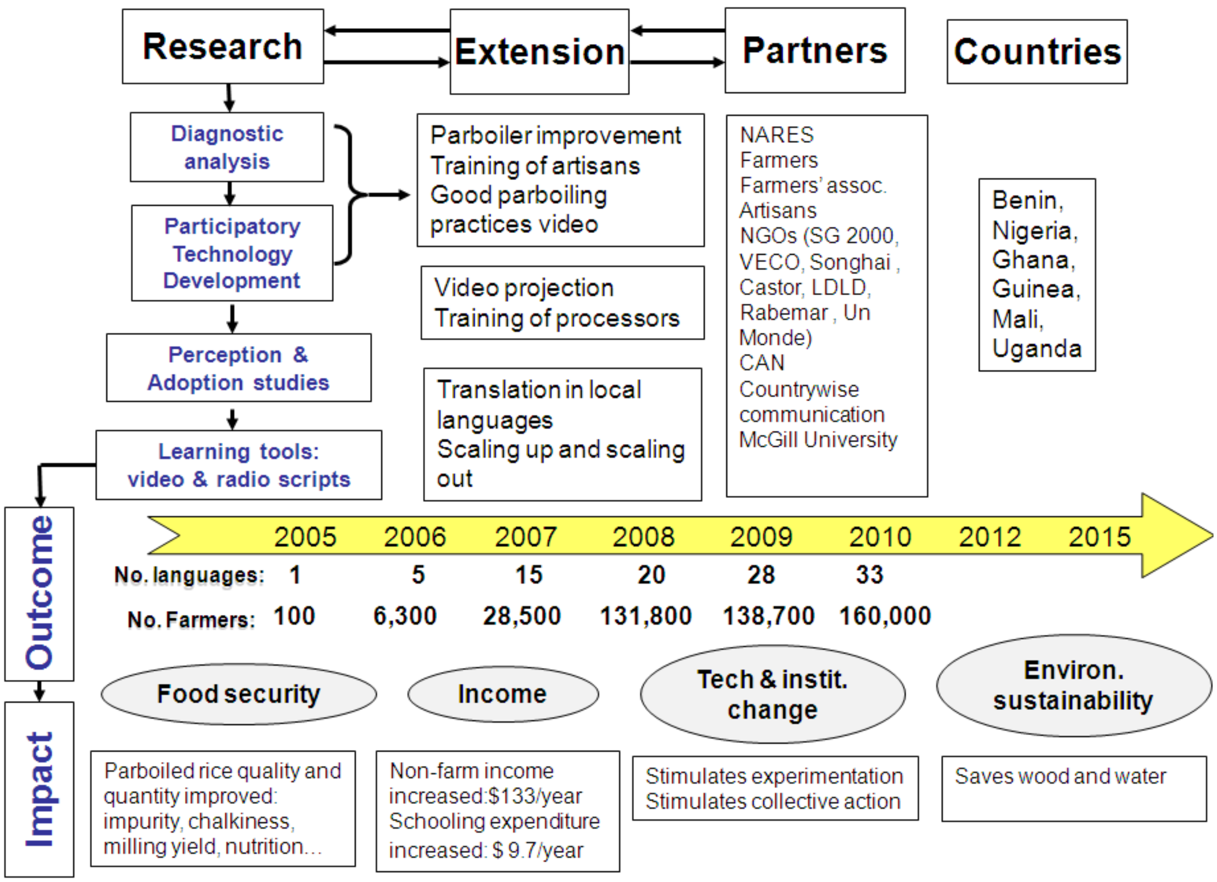
Uptake and impact pathway

Phenotyping tools developed in this theme for evaluating quality, specialty, and processing traits will be used in themes 1, 2, and 4, as well as for public- and private-sector breeding efforts, so as to enable the development of high-value varieties. Market analysis will also feed into the same users to help direct varietal development efforts. The products will be locally adapted specialty rice, from which farmers can derive a premium. For value-adding processing techniques, the next users are millers, processors, and marketers, and the final users are consumers. Evidence from the uptake of other specialty cereals, and products from them, indicates that these products will be popular in the global market.

Financing strategy

Initial funds are available for developing new phenotyping tools for current and new traits of quality until 2014 from ACIAR and the Japan Rice Breeding project, but not for specialty traits. Developing specialty rice and processing methods is a new area of work and additional funding of $3 million is needed to finance this product line from 2010 until 2013. In Africa, support is anticipated from CIDA for products 4.3.3 and 4.3.4.

Box 14. Impact example for product 4.3.3: Developing and scaling-up improved parboiling technology



Parboiling is an important step in rice processing, potentially enhancing the quality of milled rice in physical appearance and nutritional quality. Since 2005, AfricaRice has worked to develop prototypes of improved energy-efficient parboilers and strategies to scale-up good practices related to parboiling, especially aimed at women processors. The parboiling project started with a diagnostic study during which feedback was collected from women rice processors on a parboiler prototype introduced in Benin by INRAB. Through a participatory technology development process and in collaboration with Sasakawa Global 2000, INRAB, and local artisans, an improved parboiler was developed. A video was produced on good parboiling practices. Local artisans were also trained in the fabrication of the improved parboiler to enable women processors to have easy access. The video was used by NGOs and extension services to train women in 80 villages in Benin.

Through a partnership with the Faculty of Agriculture of the University of Abomey-Calavi, the determinants of the adoption of improved parboilers by rice processors were identified. To enable large-scale diffusion of good parboiling practices, the video was translated into more than 30 languages and it reached almost 160,000 farmers by 2010. Impact studies showed that the improved technology enhanced the income and food security of women processors and helped to sustain the environment. The video stimulated experimentation and collective action among rice processors.

Theme 5: Technology Evaluations, Targeting and Policy Options for Enhanced Impact

Overview

Rationale and objective

Rice research is largely the remit of the public sector of the developing world. Therefore, governments have to be at the forefront of any concerted effort to improve the rice sector in their countries, to create the enabling environment and resources for the many public and private stakeholders to carry out the required research, development, and extension. However, in many rice-producing countries, the fragmented nature of the rice sector—production, processing, and marketing systems—has resulted in a dearth of effective policies to improve and make more equitable the functioning of the sector. Rice is, in general, a highly regulated crop and very much affected by policies related to inputs and outputs. Developing countries in particular have had large welfare losses caused by inappropriate policies. For example, during the 2008 rice price crisis, major exporting countries, such as India and Vietnam, imposed export restrictions to protect domestic consumers, but the effect was to further raise world market prices, already high as the world market shrank.

In no small part, such inappropriate policies and measures to implement them are due to the lack of good-quality information at high spatial and temporal resolution on farmers' technology needs, rice ecosystems, yields, input use, rice markets, and prices. Accurate and timely information on the global rice situation can have a strong impact on rice market prices and influence policies. Indeed, better and more easily available information can help to fine-tune national and regional rice development strategies and guide priority setting for public- and private-sector investments. Further, it can lead to harmonization of policies at the regional level.

Policymakers, donors, research managers, and others also need more accurate evidence-based information on specific constraints and research needs and the impact of research and development investments to date, so as to generate political support and target continued investment in rice research. In addition, in the absence of market feedback, publicly funded rice research requires systematic analysis of expected impacts on the poor to target future investments, and establish metrics for monitoring and evaluation. This theme seeks to redress the situation described above through a much-expanded effort to provide the necessary information using new technologies.

Research approach

Knowledge and information related to the technology needs of poor farmers (both male and female) and the identification of institutional and policy options for rapid adoption and diffusion of improved technologies will be generated by conducting farm-level studies at various locations. This involves collection and analyses of cross-sectional and panel data on household and farm characteristics, the resource base of households, labor use, income levels, farmers' perceptions on technology needs, technology adoption patterns and constraints, and farm-level effects of technologies on representative households. Such micro-level data will be further disaggregated by gender to identify the varying gender roles in rice farming and assess the consequences of technologies for women farmers. The data generated will be geo-referenced and will be analyzed through various qualitative and quantitative tools to derive the required feedback for researchers, research managers, and policymakers.

A comprehensive rice information gateway will be created that synthesizes and makes available rice knowledge worldwide and provides accurate science-based information to policymakers, donors, scientists, agricultural professionals, farmers, and the general public. The information gateway will also include general information on all aspects of rice production; policies; statistics; studies and projects; global market information, such as on seed, fertilizer, and equipment; best management practices; and even prominent persons in the sector.

The data will feed into new predictive tools to identify what research opportunities offer the greatest expected benefits to the poor and the environment. On-the-ground economic, environmental, and social impacts of technology adoption will be assessed when research products are near their peak level of adoption, while more immediate feedback to scientists will be provided through qualitative evaluation approaches focused on early adoption.

R&D product lines and outputs

- 5.1 Socioeconomic and gender analyses for technology evaluation
- 5.2 Spatial analysis for effective technology targeting
- 5.3 A global rice information gateway
- 5.4 Strategic foresight, priority setting, and impact assessment for rice research

Theme 5 provides critical feedback to all other GRiSP themes, allowing them to develop well-targeted, demand-driven products and delivery approaches toward technologies, management systems, and information that farmers and other users really need. Policymakers and research managers will use household-level and spatial information to guide technology development, rural-investment portfolios, and policies. An increased understanding of livelihood strategies will help the intended users develop and implement research projects and agricultural policies that will increase the likelihood of achieving their development goals. The main product, the information gateway, will provide critically needed detailed information and expertise for broader policy research. Some information will be used for advocacy purposes toward better rice-sector policies; other information will provide the basis for gender-responsive agricultural policies.

Innovative contributions

The much-improved household-level data, agroecological information, and information gateway will provide unprecedented availability of information on all aspects of the rice sector worldwide. This will allow many previously impossible analyses to be made, from local to global scales. Real-time crop monitoring and forecasting will become possible.

The CGIAR has a mixed record of priority-setting performance to date, and has rarely employed systematic forward-looking impact analysis to inform resource allocation. Thus, dedicated attention to this area and the methodologies developed in GRiSP will be a substantial innovation, not only in terms of analytical methods but also in terms of institutional culture.

Partnerships

Work in theme 5 will involve numerous partners and policymakers in the target countries of GRiSP, but also scientists working in other GRiSP themes. GRiSP work at the country level will be implemented through and by NARES partner institutes. Annual GRiSP regional and national work plans will be developed jointly by CGIAR, ARI, and NARES researchers. NARES researchers will be given responsibility at the national level for all the studies in their respective countries, including data collection and analysis, report writing and publications, and dissemination of results in national scientific and policy forums. CGIAR and ARI researchers will backstop their NARES collaborators and, whenever necessary, provide them with training in the use of data management and analysis tools needed to implement the agreed-upon work plans. In addition, CGIAR and ARI researchers will be responsible for harmonizing research methods and tools across countries, conducting regional and global aggregated and cross-country analyses and syntheses, and publishing with NARES results in policy briefs and international journals.

The training provided to NARES researchers will be through targeted short-term group training workshops, visiting scientist schemes at CGIAR and advanced research institutes, and degree training at local universities or abroad and in relation to GRISP projects. CGIAR and ARI researchers will also mentor NARES junior researchers to help them grow professionally through training and co-publication. Collaboration with ARIs and service providers will be required for the spatial characterization and global information gateway work. The information gateway work will be conducted in conjunction with public and private organizations, including IFPRI; regional and national policy institutions; United Nations organizations (FAO, United Nations Development Programme, World Food Programme); regional rice development organizations—such as the Coalition for African Rice Development (CARD) and FLAR—and major regional political organizations such as ASEAN, South Asian Regional Cooperation (SARC), Economic Community of West African States (ECOWAS), Economic Community of Central African States (CEMAC), and East African Community (EAC); and farmer organizations such as the Network of Farmers' and Agricultural Producers' Organizations of West Africa (ROPPA) and the Eastern Africa Farmers' Federation (EAFF). The information generated in this theme will also feed into CGIAR TA 2 (Policy).

Impact pathways

Research priority setting and targeting derived from the gateway are intended to be used by GRiSP research managers and partners to help focus research portfolios on areas that offer the greatest impact potential, thereby improving long-term flows of benefits to the poor and the environment from research investments. In addition, this evidence should help to bring other supporting actors in local research and extension systems into alignment with global and regional priority areas, thus creating further synergies that improve impacts for target beneficiaries. Adoption studies play a similar role, and help to offer feedback to improve the focus of research and dissemination efforts by actors in the global rice research system.

Ex post impact assessment has three sets of target users: (i) those conducting priority-setting exercises, so as to improve the prediction of adoption and impact trends; (ii) donors, who often require evidence of impact so as to sustain and improve research funding flows; and (iii) analysts concerned with development issues, to better understand the relative efficacy of alternative development investments. With better ex post impact assessment results, each of these intermediate audiences can help to foster more effective development investment policies on the part of implementing and donor agencies.

Real-time data on the rice market and instruments to contain rice price volatility can help national policymakers to forecast and mitigate problems in the sector effectively. In particular, costly policies with high deadweight losses, such as expensive government procurements or export bans, are often unnecessary and costly, and can be avoided without detriment to national food security. Moreover, these responses can come with real harm to the poor—for example, inappropriate rice market responses contributed significantly to the global rice price spike in 2008. This research will help to avoid this pattern in the future by engaging rice traders and government agencies to advocate more appropriate market responses to GRiSP forecasts.

Product Line 5.1. Socioeconomic and gender analyses for technology evaluation

Rationale

Technology needs of farmers and the potential impact of technologies on poverty reduction depend on farmers' livelihood strategies. Poor farmers are mostly engaged in a number of livelihood activities that include crop production, livestock rearing, and wage employment, which may be on the farm or outside the farm. Livelihood strategies differ among farmers depending on their farm size, family labor resources, human capital, financial capital, and access to markets, information, and technologies. They also differ by gender. Livelihood strategies are not static but dynamic and they evolve according to changes in the broader economic, institutional, and social contexts of farming. It is the interaction among these various drivers of changes in the livelihood of farmers that determines the suitability of various interventions (technology and policy) in generating the desired impact. Similarly, long-term observation and analyses of changes in institutions and social contexts of rice farming are needed as such changes are generally gradual and slow. A good understanding of farmers' livelihood strategies and how various factors such as policy, infrastructure, and institutions influence changes in livelihood strategies is essential for underpinning technology development.

Analysis of technology adoption patterns and constraints to adoption is similarly essential for providing feedback to researchers and policymakers for improvements in technology characteristics and policy setting to promote a rapid diffusion of technologies. Technology adoption levels tend to vary among farmers depending on socioeconomic and biophysical characteristics. Adoption is a dynamic process in which farmers adopt technologies incrementally over time as they learn more about them. Adoption levels may also differ between male and female farmers of different socioeconomic categories and are conditioned by institutional and policy contexts that determine land tenure and the working of input markets.

Activities

This product line will generate the knowledge and information, primarily based on farm-level studies, for designing technologies and sustainable crop management and diversification options suited to the needs of poor farmers, both male and female, and for identifying institutional and policy options to promote rapid adoption and diffusion of improved technologies and cropping systems. Cross-sectional and panel data on household and farm characteristics, the resource base of households, labor use, income levels, farmers' perceptions on technology needs, technology adoption patterns and constraints, and farm-level effects of technologies and management practices in rice-based cropping systems will be collected and analyzed. Such micro-level data will be disaggregated by gender for identifying the varying gender roles in rice-based farming systems and assessing the consequences of technologies and crop management and diversification options for women farmers. The data generated will be geo-referenced and will be analyzed through various qualitative and quantitative tools to derive the required feedback for researchers, research managers, and policymakers.

Products

- 5.1.1 Knowledge of farmer technology needs, adoption patterns, and constraints to adoption by male and female farmers
- 5.1.2 Knowledge of poverty dynamics, livelihood strategies, and gender roles in rice-based farming systems
- 5.1.3 Gender-disaggregated analysis of consumption preferences, including quality traits, for targeted product development

Partnerships
All research will be conducted in collaboration with partners involving other CGIAR centers, agricultural universities, and public- and private-sector research organizations. Household surveys will be conducted with the help of state agricultural universities, national and regional agricultural research centers, government bodies and local agricultural universities, and NGOs. The Indian Agricultural Research Institute (IARI) will help coordinate some of the major activities at the national level. Analytical work will be conducted by IRRI scientists jointly with key members of the national teams involved in data collection. The Hellen Keller Institute will be a key partner on some activities related to gender analysis. Similarly, Humboldt University will be involved in some work in Bangladesh.

In the case of Africa, GRiSP work at the country level will be implemented through and by the NARES partner institutes. NARES researchers will be given responsibility at the national level for all the studies in their respective countries, including data collection and analysis, report writing and publications, and dissemination of results in national scientific and policy forums. AfricaRice will backstop its NARES collaborators and, whenever necessary, provide them with training in the use of data management and analysis tools needed to implement the agreed-upon work plans.

Key CGIAR centers involved are IFPRI, CIMMYT, ILRI, AfricaRice, ICRISAT, and CIAT. More local-level partners will be identified during the course of implementation.

Uptake and impact pathway
The feedback on technology needs and insights into the evolution of target farming systems generated in this product line will be used by NARES, agricultural development policymakers, GRiSP themes 1–4 and 6, and, more broadly, in CGIAR TA2 (Policy). Policymakers and research managers will use this information to help guide technology development and rural investment portfolios, and to address policy constraints to technology adoption. An increased understanding of livelihood strategies and gender roles will help better target technologies, and improve the on- farm performance of technologies, technology adoption rates, sustainability of cropping systems, and the distributional effects of specific interventions.

Financing strategy
Several ongoing grants, including STRASA, CSISA, GSR, IFAD facility grant, VDSA, Rice policy and technology impact on food security and poverty reduction (EURO3B), Enhancing smallholder access to NERICA for alleviating rural poverty in West and Central Africa (IFAD4), Diffusion of Improved Varieties in Africa (DIVA), Tracking Improved Varieties in South Asia (TRIVSA), and Assessing impact of public-private partnerships (CIAT-FLAR), provide current support for many activities in this product line. However, this level of funding needs to be extended and sustained. Gaps particularly exist with regard to household-level data for the LAC region.

Product Line 5.2. Spatial analysis for effective technology targeting

Rationale
In recent years, remote-sensing (RS) technology and geographic information systems (GIS) for spatial analysis have become widespread due to the improved availability of computing hardware and software at lower costs as well as improved access to spatial data due to rapid developments on the Internet and in spatial data infrastructure (SDI). These technologies can be used to monitor and evaluate agricultural systems to determine where and when (spatial and temporal) rice is grown and where crops are performing well or where they are not. The causes

for these variations can be analyzed within GIS by combining RS-derived information with thematic layers on the socioeconomic and biophysical characteristics that are obtained from other sources.

Such mapping and monitoring of the biophysical and socioeconomic characteristics of rice-producing areas is key for developing effective targeting strategies for the dissemination of new technologies and sustainable crop management and diversification options. Modeling of the target domains and mega-environments of rice production/consumption and understanding their resilience under economic, demographic, and climate change scenarios will help to guide limited resources to achieve the greatest potential benefits.

Similarly, the identification of regions where there is an opportunity to expand the area of rice production is necessary as an input for policies that will deal with the growing demand for rice. Moreover, by placing agricultural systems in the context of a river basin or at a national or regional level, the impact of existing and potential rice production areas on the environment, such as degrading water quality or water availability, can be assessed.

The key message for this product line is the supportive role of GIS and RS activities to "provide actionable information to decision makers."

Activities

Mapping and characterizing rice-growing areas. A principal activity in the spatial analysis of rice systems is to map them. On a regional or global scale, RS techniques using high-frequency MODIS imagery will allow rice areas and changes in rice areas to be mapped from year 2000 to now. Components of this analysis include (i) ground-truth surveys, (ii) the generation of "ideal" spectral and temporal signatures of rice cultivation under different conditions, (iii) supervised and unsupervised classification of MODIS time series, and (iv) validation against plot-level data and subnational statistics. Semi-automated classification techniques will be developed and run on high-performance computing (HPC) facilities such as the Amazon Elastic Computing Cloud (EC2) service to ensure timely provision of rice area maps across Africa and Asia at high spatial resolution.

Knowledge on rice phenology provides key information for integrated pest and invasive species management. Moreover, it can be used in crop modeling in a move toward spatially variable crop calendars that can vary from year to year instead of static country-level crop calendars. Rice phenology information can be derived from remotely sensed imagery once the imagery has been smoothed to remove artifacts and noise caused by pervasive cloud cover and atmospheric effects. Time-series smoothing and curve-fitting algorithms will be developed to derive these smooth temporal signals. The results will include (i) a library of rice signatures, (ii) key phenological information at high spatial resolution for Africa and Asia for use in crop and pest and disease models, and (iii) relevant syntheses of climate data from key phenological dates. Furthermore, failed seasons or changes in cropping intensity due to climate shocks or policy changes may be identified from this information and, in the longer term, climate change effects may also be observed.

Abiotic and biotic stresses. Monitoring and mapping drought and flood events—that have high spatial and temporal variability—requires a remote-sensing approach that can identify the onset and duration of stress-causing events and validate them against daily weather station data. RS methods to detect surface water at vulnerable stages of rice growth and vegetation stress from drought conditions will be improved and calibrated against subnational time series of rice statistics to develop a spatial database of the frequency, duration, and extent of drought and submergence to permit spatial targeting of new stress-tolerant varieties. The best available information on soil constraints (e.g., iron toxicity, salinity, and sodicity) will be compiled and standardized to assess the extent of these stresses on rice production.

The potential and actual impact of biotic stresses on rice yield will be assessed using a spatial model of potential epidemics in conjunction with existing and proposed pest and disease surveys.

Yield and yield gaps. Spatial crop modeling using daily climate data within a GIS environment is a strong tool for analyzing where crop production is close to its potential and where a significant yield gap exists. By combining these results with subnational yield statistics and the previously mentioned outputs on rice areas and their biotic and abiotic stresses, targeted locally adapted interventions can be formulated to close the yield gap.

Recommendation domains for technology targeting and delivery. A comprehensive database of relevant spatial layers and survey data for South Asia, Southeast Asia, and sub-Saharan Africa will be developed and will form the basis of an agroecological zoning model for rice cultivation and the multiscale modeling of target domains and rice mega-environments based on socioeconomic and biophysical factors and constraints. The resilience of these mega-environments under global change scenarios will be assessed and the results fed back into the decision process for future rice research investments and targeting of new technologies.

An inventory of potentially suitable rice ecologies in Africa will be completed. Activities will include ground-truth surveys, the development of a rice detection algorithm suited to African rice-growing environments, and adaptation of an existing model for mapping potential suitable areas for rice cultivation. Current activities on mapping biotic and abiotic stresses will continue.

Products

5.2.1. Seasonally updated information on rice agroecologies (cultivated areas, phenological stages, etc.) using RS and GIS technology and subnational statistics
5.2.2. Maps of major rice-growing rice areas suffering from abiotic and biotic stresses
5.2.3. Identification and characterization of rice mega-environments for effective technology targeting

Partnerships

A strong network exists from partners in both the public and private sector. Most importantly, researchers from IRRI, AfricaRice, and CIAT will team up to combine their knowledge and develop innovative methodologies that are applicable on the three target continents. The seasonally updated information on rice agroecologies will be gathered in collaboration with partners involving other CGIAR centers, regional and national research centers, agricultural universities, and public- and private-sector research organizations. The research partners for the characterization of abiotic and biotic stresses are IRRI, AfricaRice, and regional centers. Results will be developed by IRRI and AfricaRice, while some of the secondary data collection will be conducted in collaboration with regional partners. The results will be shared with regional partners to identify or target stress-prone areas. Recommendation domains for technology targeting and delivery will be a joint research activity between IRRI and AfricaRice. Examples of national partners include Institut d'Economie Rural (Mali) and Université de Abomey-Calavi (Benin), etc. International partners include Wageningen University (The Netherlands), Cirad (France), FutureWater (The Netherlands), International Water Management Institute (CGIAR), etc. Private-sector partners include HPC providers Amazon and RADAR, and remote-sensing specialist Sarmap.

Uptake and impact pathway

The short-term outcome is the use of results by GRiSP partners, NARES, ARIs, and donors to enable more effective targeting of rice technologies. The long-term outcome is increased benefits for the poor and the environment from more targeted and better funded investments in production and processing infrastructure and research. Results must be validated and demonstrated to add value over existing similar products. This requires an effective delivery and communication mechanism for these large data sets. This product line provides baseline data to themes 3, 5, and 6 in GRiSP. It will benefit from collaboration with HPC providers (e.g., Amazon) and key satellite imagery providers (ESA or JAXA).

Financing strategy
Current funding comes from BMGF-GSR (2009-11), BMGF-STRASA (2008-10), Philippines RSSP (2009-11), and the Japan Rice Breeding project (2010-14). Approximately $600,000 of additional annual investment is needed, starting in 2011.

Product Line 5.3. A global rice information gateway

Rationale
The global rice information gateway aims to provide real-time crop information, medium-term supply and demand outlook, policy briefs, and comprehensive rice data sets at the national, subnational, and household level. The real-time crop monitoring and forecasting would become a vital backbone for improving planning and policy decisions as well as for strategically deploying resources and new technologies to the right areas. This information is also essential for the smooth functioning of the global rice market. The recent rice crisis is an example in which inaccurate information on the global food situation led to an export ban by major rice-exporting countries and panic by importing countries to stockpile rice to avert any possible shortage. The end result was the tripling of rice prices between November 2007 and May 2008 and an additional 100 million people falling back below the poverty level.

In addition, policymakers, commodity groups, and agribusiness organizations are increasingly interested in having a medium-term supply and demand outlook and knowing the impacts of expected or potential economic/trade, technological, and policy factors/trends for future policy planning and domestic food security. The quantitative assessment of domestic and trade policy reforms will also aid in harmonizing rice policies regionally and globally. These projections are expected to support government agencies, agribusiness, commodity groups, and others for their medium- to long-term planning.

The leading centers in GRiSP are uniquely positioned to provide unbiased policy solutions to national policymakers for sustainable rice production and accurate information on the current and future conditions of the global rice market. Apart from a multidisciplinary setting, an absolute requirement for developing a rice monitoring and forecasting system, we also have an added advantage of having field-level data and information on current crop conditions, disease problems, and other issues affecting the rice crop in various Asian and African countries that have implications for global rice production. More importantly, our constant awareness of ongoing technological and varietal developments and their possible effects on future rice yield growth makes us a leader in this area. Development of this gateway will supplement information published from FAO and IFPRI related to rice market and policy.

Activities
The rice monitoring and forecasting system for each country will be developed by combining modern techniques such as satellite-based remote sensing with weather and crop modeling, and econometric modeling. Real-time information on rice production will be estimated using an Internet-based rice information system developed by Sarmap, a Swiss company engaged in providing and processing high-resolution radar imagery for rice crop monitoring, that would provide more timely and objective data on area and yield. This system consists of two

components that make use of geospatial tools, including remote sensing, GIS, and GPS technologies. The remote-sensing component comprises a largely automated protocol using multidate radar imagery for mapping and estimating rice area and planting dates.

For medium-term market outlook and policy analysis, a comprehensive, state-of-the-art structural econometric model describing the behavior of the world rice market and its linkage with other agricultural and nonagricultural inputs and products will be developed to analyze national and regional policy impacts on production, consumption, trade, and prices. The econometric model will be developed using a theoretically consistent framework that captures product differentiation of rice both at the origin and with end uses and identifies spatial trade flows for a few major exporters and importers. For the major rice-producing countries in the region, rice production will be estimated in a regional framework to capture climatic differences and regional heterogeneity in availability of water and other natural resources that influence the mix of crops in various parts of a country. For the major rice-consuming countries, demand will be further disaggregated into population groups according to socioeconomic and demographic groupings. In this way, we can provide possible outcomes that are based on solid, accurate data from an individual developing country to predict how specific population groups will be affected by changes nationally or internationally. This model will also be used for ex ante and ex post impact assessment of technology interventions. Other quantitative approaches, including spatial econometrics and time-series analysis, will be used in assessing the effects of policies.

For the world rice statistics database, national and subnational data will be updated on a regular basis and all existing household data sets will be digitized and uploaded on the Web for public access.

Products

5.3.1 A rice monitoring and forecasting system
5.3.2 Rice databases to support rice policy, technology targeting, and impact assessment
5.3.3 Medium-term outlook and quantitative assessment of domestic and trade policies
5.3.4 Opportunities identified for regional integration of rice policies

Partnerships

Partners involved in PL 5.3 include CGIAR centers (IFPRI), agricultural universities, and public- and private-sector research organizations. The rice monitoring and forecasting system will be developed jointly with Sarmap. Currently, we are working together on developing a real-time monitoring system for the Philippines with active collaboration from PhilRice. Sarmap is responsible for providing the necessary technical expertise, training, and facilitation of the acquisition of high-resolution radar images from ESA. IRRI and PhilRice scientists will jointly conduct data processing, testing, and validation of the products generated. The national network of PhilRice will be used as test sites. We are also in the process of establishing partnership with National Taiwan University to expand the monitoring system to East Asian countries. More partnerships will be forged in the future as we keep expanding the system to include other major rice-growing regions in Asia.

The research partners for the econometric model of the global rice market include the Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri-Columbia, IFPRI, and the Global Rice Marketing and Policy Research Center at the University of Arkansas. FAPRI's expertise in stochastic modeling will be used for adding a stochastic component to our global rice model. Research collaboration will also be developed with national agricultural policy research centers for gathering subnational/regional data on area, yield, use, cost of production, and prices, and jointly developing country models. These partners will have access to a version of the global rice model that includes a full-blown country model and a reduced-form rest-of-the-world model for conducting their own market outlook and policy analyses. Some of these national partners are the National Center for Agricultural Economics and Policy, India; National

Taiwan University; Department of Agricultural Planning, Myanmar; PhilRice, Philippines; and Center for Policy Dialogue, Bangladesh. These national partners will also be used for disseminating policy results to national and local policymakers.

The development of the rice databases, particularly the subnational data of world rice statistics, needs the collaboration and timely provision of data by our national partners in charge of collecting and compiling rice and related statistics in their respective countries. Collection, validation, and processing of farm household data sets that will eventually be included in the household survey database are also done in collaboration with our national partners. We are still in the process of establishing a network among Asian rice-producing countries to facilitate the timely acquisition of secondary rice statistics at the subnational level. Our current national partners include PhilRice and the Bureau of Agricultural Statistics, Philippines; the Office of Agricultural Economics, Ministry of Agriculture, Thailand; and BRAC and BRRI, Bangladesh.

Uptake and impact pathway

In this era of low buffer stocks, policy choices by agencies involved in agricultural trade and the information they rely upon will continue to play a vital role in the volatility of price responses. For rice, a staple source of nutrition for more than half of the world's population and a source of livelihood for two billion people, the wild swing in prices is a matter of serious concern for policymakers in developing countries. A regular update on global rice production can be particularly useful for rice importers in Africa and Asia in accurately sourcing and timing their import needs rather than stockpiling from the beginning of the crop marketing year with proper knowledge of their requirements and availability elsewhere. Accurate and real-time information will help stabilize the global market with lower price volatility. In the long run, such a system will benefit the poor and reduce resource misallocation.

In addition, timely availability of information on the effects of trade and price policies will help to identify deadweight losses, resource inefficiencies, and sources of price volatility, which will help advocates to influence policymakers for appropriate reforms. In the long run, accurate policy assessments and policy dialogue will lead to a harmonization of regional rice policies, thus facilitating greater stabilization of the global rice market. Reduced price volatility, as a result, should help to save expenditures for poor rice consumers and to reduce price risks to producers. To backstop this evolution, capacity building for NARES partners in quantitative policy analysis will complement efforts to disseminate analytical results. The information generated in this product line will be used in CGIAR TA2 (Policy) and GRiSP themes 4 and 6.

Financing strategy

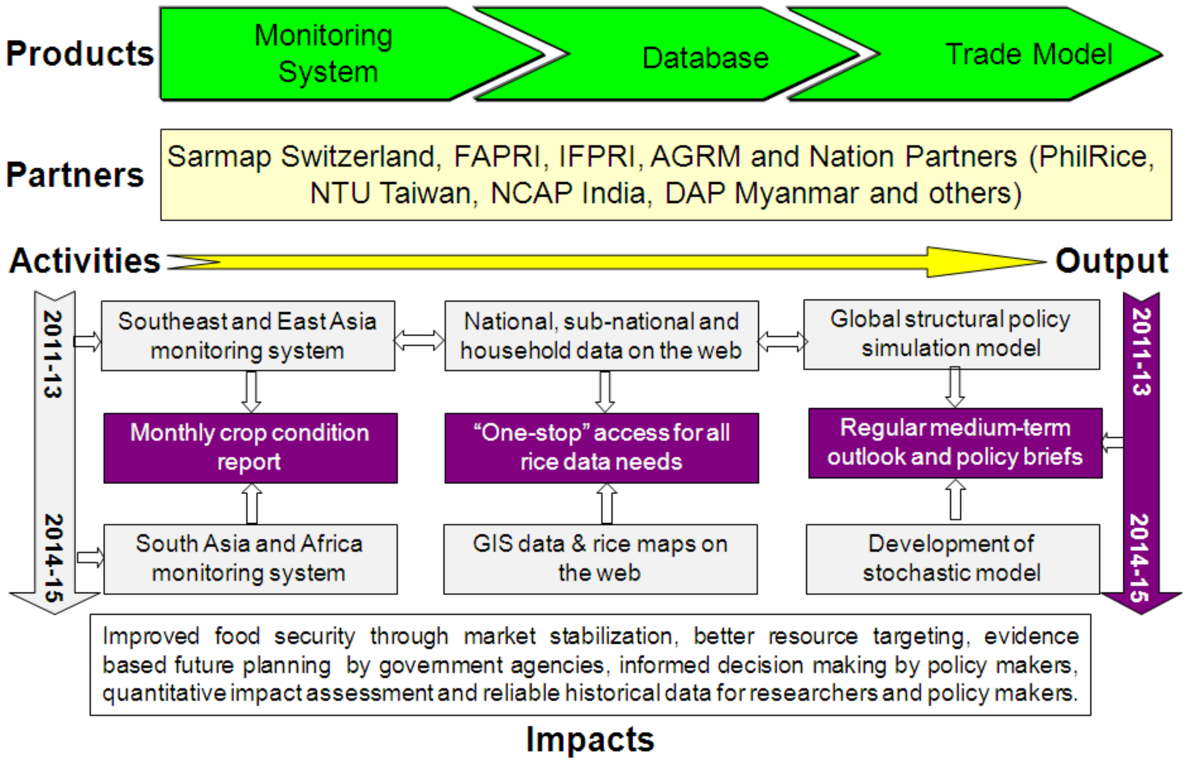
Annual investment of $1,000,000 will be needed in the next five years (2011-15) for the development and validation of the monitoring system. Initially, the system will include major Asian rice-growing regions and will be expanded to Africa and Latin American countries in the next phase. Once the system is in place, the short-term market information will be provided on a subscription basis whereas long-term market outlook and rice databases will be available to the public free of cost. It is expected that the money generated from the subscription fees will be used for the maintenance and operation of the system.

Initial development of the global rice model has been started with support from IRRI. However, $100,000 of annual additional investment will be needed over the next five years to manage and update the global rice model for baseline outlook and policy simulations. The recently funded "Global Futures for Agriculture: Integrated Modeling and Scenario Assessment" (BMGF-IFPRI) provides some support for developing the partial-equilibrium global rice-modeling activities.

Box 15. Impact example for product 5.3.1: Real-time crop monitoring for the global rice information gateway

For rice, any significant swing in prices is a matter of serious concern for policymakers in developing countries. Up-to-date detailed information on, for example, crop conditions and markets is in demand by policymakers, the business community, donors, aid and health agencies, scientists, the media, and farmers. Currently, the analytical capability to provide this information does not exist.

As part of the overall global rice information gateway to be constructed in PL 5.3, a real-time crop monitoring and forecasting platform will be developed by combining modern techniques such as radar satellite-based remote sensing with weather and crop modeling, and econometric modeling. The main products will be regular updates on global rice area, production, consumption, stocks, trade, and prices; assessments of the impact of climate change on rice production in Asia, Africa, and Latin America, and the identification of principal adaptation options; biannual briefings on the state of the world's rice crop to media and policymakers; short- to medium-term market analyses and projections on global rice supply, demand, and prices; and technical and briefing reports on the impacts of various domestic and trade policies as they arise.



Product Line 5.4. Strategic foresight, priority setting, and impact assessment for rice research

Rationale

Systematic empirical analysis (priority assessment) is needed to help guide limited resources to those research areas that have the greatest potential to produce benefits in line with CGIAR goals such as productivity enhancement, poverty reduction, and environmental improvement. Dedicated work is needed to help tease out implicit assumptions about the intended use of research products, and to translate forecasted use into comparable metrics that represent contributions to different goals and objectives of a research organization. Priority assessment can also be an important "learning" tool, as the assumptions elicited regarding the future use of research products can be tested against the results of past evaluations and experience, so as to enlighten and educate scientists.

Ex post impact assessment is thus essential for following up on these projections, improving future assumptions, and demonstrating to donors and other audiences how benefits to the poor and the environment are being generated.

Activities

To conduct priority setting, participatory, structured, and quantitative approaches will be employed to obtain estimates of economic, poverty, health, and environmental benefits per dollar of investment in potential research areas. Components of this analysis include the assessment of projected yield gaps under future climatic conditions, mapping of rice agroecologies, and disaggregation of yield gaps into efficiency gaps, abiotic yield limitations, and biotic yield reductions for particular agroecologies and countries. This is complemented by assessments of quality gaps, analysis of potential improvements in yield potential, and the identification of losses due to inappropriate policies. Estimates generated will be used with data from product 5.3.2 to assess on-farm economic and social effects of technological solutions, which will be used in PL 5.3's global rice trade model to assess dynamic price and land-use consequences, which will then underpin estimates of poverty impacts. Parameters underpinning the assessment will be regularly reviewed and updated by a task force of leading GRiSP scientists, which will oversee a revision to the priority-setting study every five years. In addition, regular interaction with CRP 2's strategic foresight function will be maintained so as to build linkages with priority setting at the CGIAR system level.

Ex post impact assessment will be employed when research products are near their peak level of adoption, whereas more immediate feedback to scientists will be provided through evaluation approaches focused on early adoption (PL 5.1). The emphasis of ex post studies will be to go further "down the impact pathway" than has been the case in prior studies so as to assess how research-induced changes in production practices have led to changes in CGIAR mission-level goals related to poverty, food security, and environmental protection. Where feasible and appropriate, assessment will be differentiated by gender.

Natural resource management technologies for rice have far less documented impact to date than do improved varieties, yet it remains unclear whether this is due to achievement or measurement difficulties. To help resolve this quandary, a series of impact assessments is planned for management innovations with rapidly rising adoption—optimized crop management in sub-Saharan Africa and Latin America, water-saving technologies in Asia, site-specific nutrient management in Southeast Asia, and reduced tillage in South Asia. To enable more accurate future adoption estimates at lower cost, remote-sensing methods will be tested for tracking the diffusion of varietal and crop management practices.

To ensure that assessment of long-term impact and priority setting is adequately funded, a 1.5% impact assessment levy will be applied to restricted grant proposals under the GRiSP, where possible, rather than specific impact assessment milestones.

Products

5.4.1 Foresight and intelligence for strategic assessment of research priorities

5.4.2 Ex post assessment of aggregate technology adoption trends and associated economic, poverty, and environmental impacts

Partnerships

Ex ante and ex post impact assessment are a multidisciplinary undertaking, requiring a wide range of expertise and perspectives drawn internally from international GRiSP lead institutes, as well as other CGIAR centers, agricultural universities, and public- and private-sector research organizations. Partnerships are both direct for the conduct of household surveys, data collection, and analysis, and indirect through linkages with activities such as other GRiSP product lines and the contributions of partners there involved (such as climate change analysis, epidemiological forecasting, crop growth modeling, spatial analysis, and trade modeling). Key other partner CGIAR centers include CRP 2, IFPRI, CIMMYT, ILRI, Bioversity, and WorldFish, as well as the CGIAR Science Council Standing Panel on Impact Assessment. Additional advanced research institute partners will be engaged as appropriate to lend independence and objectivity to particular ex post studies.

Uptake and impact pathway

The short-term outcome is the use of results by the GRiSP, NARES, and donors to focus investments on research areas with the greatest potential to benefit the poor and the environment. The long-term intended outcome is increased benefits for the poor and the environment from more targeted and better funded rice research. This assumes the willingness of CGIAR managers, scientists, and donors to respond to evidence of achieved impacts and impact potential. This product line will provide feedback to all other themes in GRiSP and is linked to CGIAR TA2 (Policy).

Financing strategy

Approximately $500,000 of additional annual investment is needed, starting in 2011. A substantial amount of this funding will be provided from the M&E/strategic impact assessment/priority-setting budget line item in the global program coordination and support budget of GRiSP.

Theme 6: Supporting the Growth of the Global Rice Sector

Overview

Rationale and objective

GRiSP aims to achieve large-scale productivity increases in rice, reduce poverty, improve environmental sustainability, and make gains in global, regional, national, and household food security. Regionally, links between research and development investments are often weak. As a result, opportunities for large-scale exposure of farming and agribusiness communities to new rice technologies and management principles (such as knowledge of insect cycles, plant nutrients, weed flora, collective decision-making, seasonal work plans and budgets, etc.) are missed. The recent GCARD consultations highlighted the prevailing divide between research and extension. New technologies and principles that have met with strong farmer acceptance in participatory research networks are often not scaled up and out sufficiently to reach millions of farmers and others in the rice value chain.

Diverse learning, innovation, and dissemination approaches, through multiple actors and pathways, are imperative to cater to the varying institutional and biophysical environments and specific approaches needed for particular technologies. Actors and pathways for disseminating a new rice variety, for example, are different from those required for a water-saving technology. The diversity and complexity of rainfed environments in Africa or Asia will often require greater farmer participation in technology adaptation than in the more homogeneous irrigated systems. The best ways to reach poorer households, women, or disadvantaged groups are highly location-specific. Innovations in information and communication technologies (ICT) provide opportunities for large-scale dissemination of information to overcome prevailing weaknesses in public and private extension systems, NGOs, and farmer associations. The objective of this theme is to support the growth of the global rice sector through better linkages (feedback loops) between research networks and development initiatives in the public sector, civil society, and the private sector.

Research approach

The facilitation of large-scale testing, adaptation, and adoption by farmers of rice technologies and agroecological and socioeconomic principles requires that international and national research centers connect to a much larger number of farmers, using existing networks and new partnership models (Box 16). This type of “last-mile delivery” effort is likely to vary in form and scale according to regional, national, and local differences and it needs to be inclusive of poorer households and women. International centers will also need to build better in-house and partner capacity to link to major regional and national investment efforts that aim to boost the rice sector, and use innovative communication technologies to support and strengthen extension capacity.

The independence and interdependence of networks and individual stakeholders (comprising the private sector, public sector, and civil society) are recognized. At the same time, facilitating the establishment of learning alliances between such networks and stakeholders (within-country, regionally, and globally) will nurture innovation and provide a critical voice and momentum to efforts to increase production and productivity of the rice sector in a sustainable manner. Such learning alliances will facilitate learning across the four regions (Africa, Southeast and East Asia, South Asia, and Latin America and the Caribbean). Approaches learned in one region may have important implications in another region. An example is the FLAR Agronomy Program in LAC for FLAR—a south-south public-private partnership for irrigated rice production.

In addition, strengthening links to FAO in its global commitment to ICT for agriculture and extension capacity building will enhance the impact of GRiSP. In a similar way, CABI, with its strong commitment to plant health, will become a partner at the global level. The innovations in value-chain development and training expertise at the regional level of ICRA, in its partnership with AfricaRice, will bring lessons learned to other regions. *Learning* is expected to have a catalytic effect through more effective private-public and public–civil society partnerships. Finally, learning alliances will ensure strong inclusion of small and marginal farmers, and women, as direct beneficiaries, as illustrated, for example, by the participatory learning and action research (PLAR) approach developed by AfricaRice.

Civil society partners such as CRS with its experience in targeting poorer households, and country-specific partners such as RDRS-Bangladesh in regional forums and Li-BIRD-Nepal in village-level adaptive research, are expected to enrich out-scaling across regions. Capacity building for stakeholders that empower farm households will strengthen the voice of end-users. This is illustrated, within-country, in the partnership between IRRI and national agencies in the Poverty Elimination Through Rice Research Assistance Project.

The Emergency Rice Initiative in Africa is an example of a link between a research network and regional investments of major donors and national governments to enhance rice sector development in West Africa, with AfricaRice providing technical and planning support. The African Development Bank has supported the African Rice Initiative (ARI) in seven West African countries since 2005, which has greatly stimulated the uptake of NERICA and other improved varieties. AfricaRice is also involved in rebuilding rice research and extension capacity in postconflict countries, such as Liberia, similar to IRRI's experience in Cambodia.

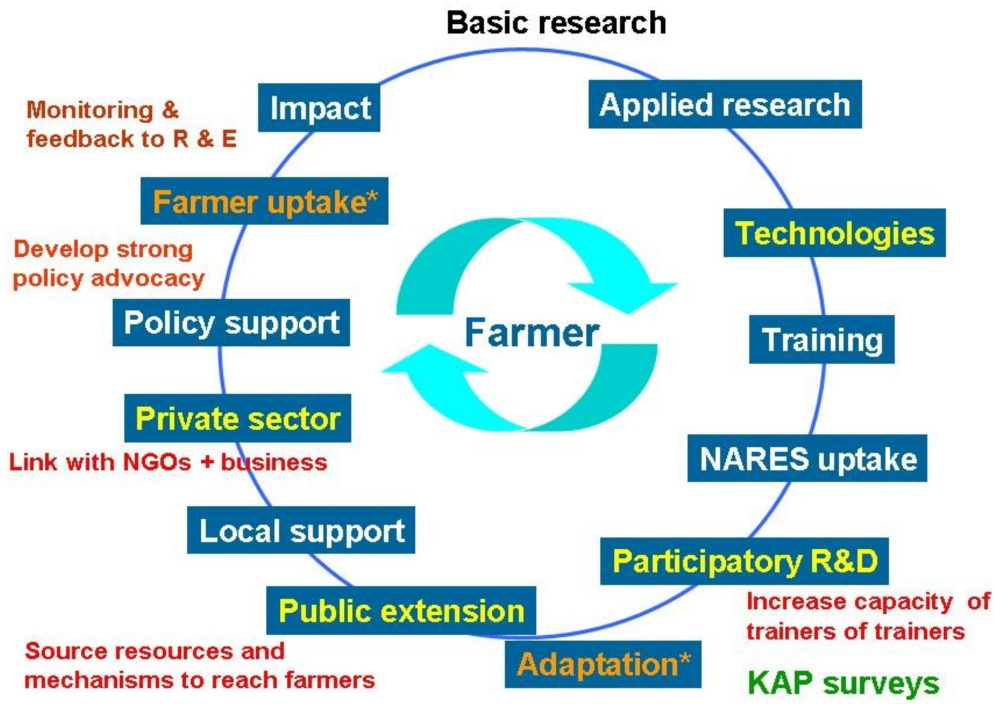
In Asia, IRRI has, for example, promoted good agricultural practices for rice in many countries or subregions within a country. At the national level, the partnership of IRRI with the Philippine government in implementing the national Rice Self-Sufficiency Program is another recent example of the role an international center can play in effectively supporting such national efforts. At a more local level, an example is the work of IRRI and its research and extension partners in An Giang Province, Vietnam, where, with support from the Swiss Agency for Development and Cooperation, the provincial government, and the World Bank, agriculture in an entire key province is being modernized. Two consortia, CURE and IRRC, provide the technical foundation for these types of activities. There are also many good examples of engagement at the grass-roots level with NGOs, private companies, national programs, and farmer-to-farmer extension in major regional initiatives. CSISA and STRASA (Stress-Tolerant Rice for Poor Farmers in Africa and South Asia) are illustrative. The respective aims are to disseminate new management options for intensive cereal systems and new varieties of stress-tolerant rice to millions of poor farmers through hundreds of partner organizations. Strong links have also been built with the International Fund for Agricultural Development (IFAD) investment projects in both Africa and Asia. In Latin America and the Caribbean, FLAR provides both seeds and technologies to member organizations, which then adapt them to local conditions and deliver them to farmers.

The technical capability of partners will be strengthened to extend the interface between demand-driven technology development at centers and their national and regional partners. Support for capacity building in the research and extension sectors is an important component. Initiatives will often be at a national level, such as the new self-sustained extension agronomist program being implemented in India. Support will extend to the grass-roots level through strengthened capacity of dealers, technicians, and multiskilled service providers. A grass-roots competitive fund for NGOs and local associations will be established to nurture innovative initiatives to disseminate technologies to poor farmers.

The provision of coherent, up-to-date information in formats suited to extension specialists and farmers will underpin delivery initiatives. This will involve innovative use of multiple ICT formats, such as video and radio, and Internet and mobile phone technology (linked to themes 2, 3, 4, and 5). The Rice Knowledge Bank (RKB) of CG centers IRRI, AfricaRice, and CIAT and national RKBs will be the principal platforms. These resources will include information on specialist topics as well as extension training materials.

Box 16. Cycling from research to impact through multiple channels and learning alliances

Large-scale dissemination of new rice technologies through multiple channels requires the association of stakeholders with complementary roles and expertise. As such, innovation can be nurtured on multiple fronts, from technology adaptation, seed systems development, and micro-credit to a positive policy environment. In Asia, the Cereal Systems Initiative for South Asia (CSISA), the Irrigated Rice Research Consortium (IRRC), and the Consortium for Unfavorable Rice Environments (CURE) provide examples of platforms with a wide range of partners involved in adaptive research and delivery—public, private, and civil society. Participatory learning and adaptive research approaches of AfricaRice and the partnership of FLAR with CIAT in Latin America are other examples of innovative and effective approaches. Progress results from an iterative process, involving different actors at each of the stages leading to successful adoption. Pathways tend to differ according to the nature of local and national conditions but local involvement is a "common thread."



New rice technologies can have a positive impact on poverty, yet poorer households and women often have very limited access to new technologies or lack either adequate knowledge or the financial capital to apply them. Pathways that are inclusive of poorer farmers and women will be required if GRiSP is to have a significant impact on poverty at scale. Civil society organizations may provide the necessary networks for local adaptation and for scaling out of new rice-based technologies to poorer households and women, and for the required development of the value chain and micro-finance linkages. Current examples of civil society–international center–national public research alliances are the Catholic Relief Services/CIAT agro-enterprise alliances in eastern Africa and Central America. In Bangladesh, IRRI built strong partnerships between government research and development institutions and NGOs, such as BRAC and RDRS. Poorer farmers and women were the particular targets of these efforts. Another avenue for moving to large-scale targeted dissemination is the formation of NGO alliances that will seek investments to support demand-led access of poorer households and women to technologies. Further, learning alliances, operating across different scales, will provide a strong reflective environment to bring together active learning from adaptive research of themes 2, 3, and 4 and the social auditing and analysis of theme 5. Through such associations, accountability will be nurtured and large-scale exposure of farmers and other rice-development stakeholders to (prototype) technologies and principles facilitated.

In summary, ***theme 6 is catalytic*** and seeks to leverage effort for the growth of the rice sector. There is a strong emphasis on mobilizing partners to use their own resources and seek their own funds, through public-sector commitment, private-sector investment, or civil society projects.

R&D product lines and outputs

- 6.1 Innovation in learning and communication tools and extension capacity development
- 6.2 Effective systems for large-scale adoption of rice technologies in South Asia
- 6.3 Effective systems for large-scale adoption of rice technologies in Southeast and East Asia
- 6.4 Effective systems for large-scale adoption of rice technologies in Africa
- 6.5 Effective systems for large-scale adoption of rice technologies in Latin America and the Caribbean

In the medium term, strong links with regional/national organizations and within-country investment programs will have been established, together with a flow of demand-driven rice technologies and agroecological principles being tested, adapted, and adopted by farmers through public, private, and civil society institutions. At the same time, a cadre of competent extension agronomists will provide leadership in demand-driven technology transfer to farmers through the wider extension community using local practices adapted from international best practice. Extension personnel will have stronger facilitation skills that empower farmers. Tools, such as PLAR, illustrate an empowerment in rice technology development. Further, all target countries will have a system of knowledge management and a national rice knowledge bank that provides effective delivery in suitable media. Innovations in ICT will be a strong driver in facilitating the widespread diffusion of new technologies. Diverse approaches will cater to regional and local differences, and encourage cross-country learning and sustained innovation. An adaptive research approach to delivery will foster achieving the desired outcomes of theme 6.

Innovative contributions

Novel communication approaches will support seed delivery systems; agronomic, postharvest, pest management, and processing innovations; and extension capacity building. The mobile phone technology for nutrient management recommendations for farmers as developed by IRRI is one such example. Alliances will be strengthened between international centers and national and local delivery agents. Public-sector research institutions will be encouraged to engage with relevant public, private, and civil society agencies and help develop closer links between research and extension. RKB development nationally and internationally will ensure the availability of up-to-date information to diverse users. Finally, to enable wider learning, the monitoring and evaluation activities (managed under theme 5 and with links to themes 2, 3, and 4) will audit the performance of the different delivery approaches, overall acceptance of technologies, and the inclusion of women, ethnic minority groups, and poorer households.

Partnerships

National development and extension systems, the private sector, farmers' organizations, and NGOs are key partners in theme 6 to provide the large-scale investments that are needed to accelerate the dissemination of new management technologies and information. For last-mile delivery and making information widely available, even in real time, theme 6 will collaborate closely with modern communication companies and organizations. Grass-roots-level NGOs are expected to play a major role in farmer-to-farmer extension, with technical and capacity-building support from GRiSP theme 6. Innovative public-private partnerships for delivery, including suitable business models and new professional certification schemes, will provide another important avenue.

To support partnerships for innovative delivery through NGOs and farmers' associations, GRiSP aims to establish a modest partnership development fund under the centrally managed Global Program Coordination and Support budget. On a regional basis, theme 6 will interact with many other CRPs, particularly Mega-Programs under TA 3 (wheat, maize, pulses, livestock) and TA 1 (dryland systems, humid zones, aquatic systems/coastal zones). Delivery approaches that cut across GRiSP and these other MPs will be addressed through joint projects, often in "hubs" that represent major target environments. An example for this is the Cereal Systems Initiative for South Asia (CSISA). Collaborating CGIAR centers are IRRI, CIMMYT, CIP, ICARDA, ICRISAT, IFPRI, IITA, ILRI, IWMI, and WorldFish, and AVRDC is a nonassociated center.

Impact pathways

Theme 6 will be closely aligned with activities in themes 2, 3, and 4 to provide feedback to product development, and with the social science research and monitoring and evaluation of theme 5. Impact pathways for large-scale dissemination will be linked to regional, national, and nongovernmental agricultural development programs and investments, particularly those related to extension. Leadership in extension will be developed through an accreditation program of extension agronomists and women's leadership development. This will be coupled with support for grass-roots extension capacity in farmer intermediary institutions and organizations. Such capacity building will be underpinned directly with the online and up-to-date technical information in RKBs and innovative communication products. The information, materials, and guidance will empower skilled extension personnel in the delivery of new rice technologies.

Product line 6.1. Innovation in learning and communication tools and extension capacity development

Rationale

The future challenge of global, national, and household food security for rice growers and consumers demands stepping out of the boxes that separate research and extension functions. The governance practice of demarcation is obsolete. It has proved particularly detrimental to small and marginal farmers and to women. Each country has a unique set of actors in dissemination comprising the public sector, private sector, and civil society. The successes within one country or region can potentially be adapted in other countries or regions. At the same time, the global ICT revolution has had an impact for the poorest and most vulnerable farm households. To improve rice production, farmers need coherent and consistent rice production and postharvest knowledge that is up-to-date and in a format that can be clearly understood.

The platform of the Rice Knowledge Bank (RKB) globally and within-country provides consistency in rice knowledge. This can be greatly strengthened by linking with the initiatives of FAO concerning ICT and food security. FAO provides an umbrella for the many public ICT efforts in agriculture. At the same time, joining with CABI and its ICT program for plant health will give added consistency to rice health messages. Already, IRRI and CIMMYT have consistent protocols for the Cereal Knowledge Bank (CKB) for rice, wheat, and maize systems, and this will be extended to Africa in collaboration with AfricaRice. AfricaRice and IRRI and LAC are working together on ICT development to build capacity in rice extension. Lessons learned may be of benefit to other CGIAR Research programs in the future. ICT innovations provide an opportunity to go to scale within-country and across regions. The mobile phone technology for nutrient management recommendations as developed by IRRI is an example and it can be adapted to specific country settings. The rice seed health videos for women illustrate an ICT that has crossed cultural borders across regions (from Asia to Africa).

The public extension service is aging in many countries and often has struggled with structural readjustment, a private sector in extension is emerging in some countries, and civil society has varying capacity in agricultural extension. New models/approaches in extension capacity are needed to ensure a young cadre of competent extension professionals. Capacity building for women in extension will ensure greater extension penetration for rural women.

To take advantage of large-scale regional rice investment projects, the international centers must assemble technical expertise that can readily link the advances in rice science and production technology to avenues for large-scale delivery regionally and nationally. Environmental disasters linked to climate change and periodic country postconflict risk management require technical expert services. It is not uncommon for the international centers and disaster/postconflict civil society organizations to become engaged in disaster mitigation and institutional rebuilding. Examples have been Cambodia, Bangladesh, Myanmar, Sri Lanka, and, more recently, Liberia.

Activities

The international centers with key partners will form a global learning alliance for accelerating the scaling up of rice technologies with a particular focus on ICT for development, knowledge management, and innovative models/approaches for extension capacity development. This platform will link with the FAO ICT and Food Security group and CABI ICT Plant Health for moving forward together in practical innovations in ICT for growth of the rice sector. The link with FAO will provide an important entry to policy dialogue for extension for rice within regions and nationally. The learning will draw directly on practical experiences within each region: for example, the mobile phone technology for fertilizer application developed by IRRI or the video on dissemination of learning of AfricaRice, the agronomy extension training program of FLAR, and the accreditation program for agronomists in India. The alliance will draw on cross-country learning on projects that have been successful in reaching small and marginal farmers. Experiences will also be shared from effective private- and public-sector and civil society–public-sector partnerships. For the latter, an NGO summit will be held to frame an alliance for the large scale delivery of rice technologies, particularly to support delivery to women and poorer farm households.

Investments in technologies for mobile phones, e-learning modules, the Rice Knowledge Bank, and videos within Asia and Africa will be the basis of ICT for extension. Within Asia under CSISA, there will be multichannel approaches with telecenters, mobile phones, and community radio. An e-seed course will be released across the regions in local languages to support the private and public sector and farm-level seed production. The international centers will work closely together in the use of the Rice Knowledge Bank globally, regionally, and within-country for providing consistent extension messages for rice production and postharvest care and the centers will be the platform for multiple ICT products for dissemination.

Under a JICA project, IRRI and AfricaRice with PhilRice will release a season-long coherent training course for extension capacity building in Africa. This will be a south-south product with international center support. The PLAR adaptive and extension approach as developed by AfricaRice will be used for capacity building in ESA, WA, and Asia.

A new team of extension agronomists and business development specialists and multistakeholder facilitators will be established across South Asia and Africa. This cadre will be crucial for building awareness and linkages to national and regional investment for large-scale diffusion of new technologies and to provide a coordinated expert response to natural disasters and postconflict situations. The team will also help with the design and piloting of improved delivery systems, including business models for large-scale roll-out of technologies. AfricaRice will support rebuilding national rice research and extension capacity in postconflict countries, such as Liberia. IRRI will also seek to partner in new investments to support reconstruction in the war-torn areas of northern Sri Lanka or other countries.

Products

6.1.1 Rice knowledge management for dissemination
6.1.2 ICT for development
6.1.3 Innovative models for extension capacity building
6.1.4 Technical expert services for rice-sector investment and disaster/postconflict response

Partnerships

Products of this product line will feed into PL 6.2 to 6.5 and will rely on partnerships within and across regions. The participation of CSOs will be particularly important for rapid out-scaling of products and inclusion of poorer farming communities and women.

Rice knowledge management will be coordinated globally through the Rice Knowledge Bank at IRRI, with links to NARES partners that will develop country sites. A major effort will be undertaken in Africa to boost rice knowledge management capacity.

ICT development will require linking up with other development partners already active in this area, most notably FAO and CABI and the private sector, for example, telecommunication companies. Much is expected from mobile phone technology, providing multiple services for farmers.

Partnership for capacity building in extension will include strong NARES partners to help with or outsource technical training through a multitude of means from e-learning courses to season-long training. Collaboration with ICRA will ensure ample attention to improving skills to facilitate change and establish learning alliances across the rice value chain.

The creation of pools of rice experts (extension agronomists) in the various regions, mostly from NARES partners, but with a limited number employed by AfricaRice and IRRI, will allow improved and more sustainable linkages with major rice investment projects and rapid and focused contributions to country-led responses to natural disasters or postconflict situations.

Uptake and impact pathway

The uptake and impact pathway will vary according to national systems and the roles of public, private, and civil society organizations in various countries. It will also vary according to the nature of the technology. Nutrient management, water-saving technology, and postharvest processing technology dissemination will often require different intermediaries. CSISA and STRASA in South Asia illustrate how to effectively engage a diverse set of actors for adaptive research and dissemination. The use of mobile phone technology to disseminate rice knowledge engages the international centers, the national research and extension system, telecommunication companies, and local telecenters. For video education on rice seed health, evidence from AfricaRice shows that pathways include more than 500 organizations, with national research institutions, NGOs, universities, schools, networks, rural radio, and television participating.

Consortia such as CURE and IRRC each have more than 100 partners drawn from a wide diversity of actors in the public and private sector. These specific consortia also have socioeconomic teams in place that provide regular evaluation of extension pathways, as well as ex ante and ex post impact assessment. Knowledge from the local Bangladesh RKB fact sheets is disseminated through the public extension system, NGOs, CD shops, local mosque committees, and schools. There will be additional pathways through the networks linked to FAO and CABI for ICT extension. The video extension and the season-long training in rice production for African extension personnel illustrate a south-south impact pathway. The program for the accreditation of extension agronomists will support uptake through committed individuals, private companies, and civil society and public-sector extension. For poorer farmers and for women, the effective dissemination pathways will include specific civil society organizations and the establishment of learning alliances, which provide feedback for public- and private-sector extension. Investment projects regionally and nationally and links with regional economic communities such as ECOWAS in West Africa will provide a further opportunity for large-scale dissemination. For a coordinated response to postconflict situations or natural disasters, the pathway will be through public-sector and specialized civil society organizations such as CRS and global actors such as FAO.

There will be strong linkages to the products emerging from themes 1, 2, 3, and 4 that also link with the IRRC and CURE for IRRI, the AfricaRice Task Force initiatives, and FLAR in LAC. Impact pathway monitoring and evaluation will be linked with theme 5.

Financing strategy

The strategy for financially supporting ICT for development and rice knowledge management for dissemination is predominantly through embedding it within larger objectives. This is coupled with seeking additional in-country co-investment. The STRASA and CSISA projects illustrate this approach. The mobile phone extension technology has been initially funded for Southeast Asia through IRRC, and its development within South Asia via the CSISA project. RKB knowledge management development for ESA has been within an IFAD R&D project. At IRRI, significant input into updating the RKB is provided by the different consortia. What is apparent is the cross-linking of projects for ICT product development. JICA is committing resources to extension capacity building for Africa through AfricaRice, IRRI, and PhilRice. The accredited extension agronomist model for India is a self-funded model with local institutionalization. The financial model for technical expert resource development will be cost recovery through regional or national investment projects. Examples are the larger-scale investment opportunities with the World Bank for Vietnam, AusAID for Cambodia, and USAID for Cambodia. Funding within LAC is through farmer associations, public contributions, and as an implementer of the rice component for investment projects. Funding for Africa for learning and communication tools and rice knowledge management is expected to come partly from a new BMGF grant on integrated soil fertility management led by CABI. Extension capacity-building efforts in Africa will be supported by Japan, the African Development Bank, BADEA, ECOWAS, and BOAD, among others.

Product line 6.2. Effective systems for large-scale adoption of rice technologies in South Asia

Rationale

To achieve the outcomes in productivity gains, sustainability, and livelihoods, improved rice technologies need to be adopted by large numbers of farmers. There are several challenges to this, including poor communications in the rural sector, weak extension services, and commonly large substantial institutional "gaps" between research, extension, and farmers. Such gaps are evident in South Asia due to an aging pubic-sector extension service, an emerging private sector that is weakly connected to the public research sector, and the large number of NGOs that often lack access to information on rice production and postharvest technologies. In the case of Sri Lanka, in addition, certain regions have suffered upheaval as a result of the recent civil war.

There is a need to build cohesion in the research to farmer linkages in order to support large-scale uptake of new rice technologies. Improved linkages and communication using multiple channels will help ensure household food security and national food security through the adoption of new technologies. Enabling growth of the rice sector through supporting technology delivery requires that linkages be made with large-scale or regional investments, and that there be engagement at the local level with NGOs and with national and farmer extension programs. To achieve this, international research centers must also assemble technical expertise for supporting the planning and implementation of large-scale rice-based technology delivery and development projects.

In addition, there is a need to support extension capacity building to increase competence in rice production and postharvest management working with multiple agencies and clients, including poorer farmers and women. Wide-scale delivery of information on new technologies is necessary to underpin these efforts and this will require innovative use of multiple media formats such as video and radio, Internet and mobile phone technology, and strong feedback from end-users.

Activities

Communication materials will be developed in multiple formats for direct use for extension of technologies in the intensive cereal systems and for abiotic stresses. Within large hubs in South Asia, modern communication tools will be applied to capacity building of grass-roots-level public- and private-sector partners. IRRI and CIMMYT will work with national and local partners on localized content for the Cereal Knowledge Bank in key CSISA hubs, to support multichannel communication organizations (e.g., public and private telecenters) for last-mile delivery of information to extension and farmers. Support will be provided to develop the capacity (including monitoring systems) of public and private seed networks. An innovative accreditation scheme for certified crop advisors (CCA) will be initially developed with public- and private-sector partners and the American Society of Agronomy for several states in India, and then out-scaled to other countries in the region. Women's leadership training will be conducted and followed up with the formation of a network for women leaders that will support the enhanced capacity of grass-roots extension staff.

Through the STRASA and CSISA projects, IRRI in partnership with CIMMYT, ILRI, IFPRI, and more than 200 local partners will provide catalytic support for seed multiplication and targeted, scalable dissemination of new stress-tolerant rice varieties and management practices for resource-conserving cropping systems. Particular emphasis will be on establishing new business models for scalable, self-sustained delivery of new information and technologies, including the use of new hub communication platforms. Evidence-based information to support these activities will be made available through the private and public sector and civil society organizations for intensive cereal systems and for stress-prone environments.

Products

6.2.1 New models for seed multiplication and targeted delivery systems
6.2.2 New platforms for delivering agronomic, postharvest, and processing innovations
6.2.3 New models for jointly building extension capacity

Partnerships

Partnerships will align closely with major national initiatives, such as the National Food Security Mission (NFSM) of the government of India. For delivery of new technology, there are traditional public R&D institutions along with medium- and large-scale companies (e.g., DCM Shriram Consloidated Ltd., ITC Ltd., and Tata Chemicals Ltd. in India; and Agrimall, Fauji Fertilizer Company, and SACAN in Pakistan), farmers' organizations, NGOs (e.g., BRAC, RDRS, and Shushilan in Bangladesh; FORWARD and LI-BIRD in Nepal; and CRS and M.S. Swaminathan Foundation in India), and international companies and associations (AWhere and International Plant Nutrition Institute–IPNI, U.S.). The American Society of Agronomy will support the CCA program. For dissemination, most partners implement with their own resources but are linked for technology access and knowledge. Some strategic partnerships influence the public sector for large-scale dissemination. An example is the minikit distribution in India under NSFM, through which there is large-scale distribution of the new Sub1 varieties.

Uptake and impact pathway

Centers will support delivery according to priorities and natures of the national systems. In India, this will focus on the emerging private sector and the public extension services, and to a more limited extent NGOs. For Bangladesh and Nepal, the uptake pathway will comprise the predominant public and NGO sectors, together with a weaker private sector. In Sri Lanka, opportunities exist for partnerships to support the rehabilitation of extension services in the northern areas. Impact pathways associated with large-scale investment opportunities will involve strong links to the government. Leadership capacity in extension will be developed through support for an accreditation program of extension agronomists and women's leadership. This will be coupled with support for grass-roots extension capacity with intermediary institutions and farmers' organizations. Capacity building will link directly with the online up-to-date technical knowledge of the RKBs, the hub communication platform, and innovative communication products. These components will underpin the activities of skilled extension personnel and enable them to effectively deliver new rice technologies. In addition, a grass-roots competitive fund will support innovative delivery mechanisms for NGOs and farmer associations for poorer farmers and women.

There will be strong linkages to the products emerging from themes 1, 2, 3, and 4 that also link with the IRRC and CURE. Impact pathway monitoring and evaluation will be through theme 5.

Financing strategy

Two large regional initiatives currently provide support—CSISA and STRASA. The initial undertaking is for three years, with expected support over a 10-year period. Additional in-country funding is sought through links to the Food Security Commission in India, the NATP investment fund in Bangladesh, and large-scale national food security missions and development projects in Pakistan, Nepal, and Sri Lanka. New funding is required to build up a strong, professional extension support team at IRRI to link science with development efforts on the ground. Further support is required for the development of communication approaches and information systems

Product line 6.3. Effective systems for large-scale adoption of rice technologies in Southeast and East Asia

Rationale

Demand is strong for new rice technologies from large numbers of farmers in Southeast and East Asia. This is reflected nationally, for example, in the Philippines with the government's *Rice Self-Sufficiency Program* and provincially with the local government and IRRC investment in An Giang Province, Vietnam, which promotes good agricultural practices (GAP) for rice. Indonesia has a concerted government effort to achieve national self-sufficiency in rice. In Laos, IRRI provides support for NAFRI and is actively involved in technology development through support for delivery in the irrigated and rainfed rice ecosystems. Considerable unsatisfied demand remains, however, in Southeast and East Asia for support in the delivery of agronomic, postharvest, and processing innovations. Further, the resources, skills, and approaches required to provide such support are lacking. The development of the rice knowledge banks as a resource for extension and farmers is in its early stages, with a lack of strong links between the research scientists and communications or training personnel. The development of information resources, training materials, communication methods, and capacity building is required to facilitate the large-scale delivery of resources. To support the delivery of innovations, this product line will aim to develop the means to underpin and facilitate the large-scale dissemination of rice technologies in Vietnam, Indonesia, the Philippines, Myanmar, Cambodia, Laos, and Thailand in accordance with national priorities.

Activities

A new team of extension agronomists and business development specialists will be formed to support the design and development of improved business models for large-scale roll-out of technologies, to build awareness, and to develop links to national and regional investments. This team will support the large-scale diffusion of new technologies and provide links for investments to enhance the dissemination of improved rice systems technologies. To develop awareness of current practices and innovations, an NGO summit will be held to strengthen NGO-IRRI partnerships. Linkages will be strengthened between RKBs and consensus developed among various scientists in the respective institutions. Country RKBs will be linked to a regional network that is, in turn, supported by the IRRC and CURE consortia. Innovative communication media (e.g., mobile technology for SSNM recommendations) will be developed to incorporate emerging technologies.

Activities to support delivery of technologies will include (1) the development of innovative diffusion pathways for AWD and SSNM in the Philippines; (2) development of training and extension materials, and technical backstopping for IRRC technologies in the curriculum for 70,000 farmer field schools on integrated crop management in Indonesia; (3) an IRRC Country Outreach Program (ICOP) on NRM of rice in Myanmar in three divisions; (4) delivery of "good agricultural practices" for rice (rice GAP) through ICOP in five provinces in the Mekong Delta, Vietnam; (5) linkages established with IFAD investment programs for out-scaling of CURE technologies for upland and drought-prone areas; (6) delivery of GAP for unfavorable areas; and (7) delivery of technologies for salinity and submergence-prone conditions in the Mekong Delta along with support for capacity in seed processing.

Products

6.3.1 New models for seed multiplication and targeted delivery systems
6.3.2 New platforms for delivering agronomic, postharvest, and processing innovations
6.3.3 New models for jointly building extension capacity

Partnerships

Partnerships in Southeast Asia in research-extension are diverse. Consortia such as CURE and the IRRC have developed strong partnerships with more than 150 institutions. Examples of these partnerships in the public sector for specific countries include Indonesia (ICRR, ICATAD, Dinas Pertanian), Cambodia (three ministries associated with agriculture and water development), Laos (NAFRI, NAFREC), Myanmar (MAS), the Philippines (PhilRIce, DA, PCCARD, ITA, local government units), Thailand (Rice Department, a range of universities), and Vietnam (CLRRI, provincial DARDs, PPD, various academies of VAAS, universities). Private-sector and civil society partnerships are also many and include, for example, Syngenta, World Vision (Vietnam and Laos), CRS (Philippines), Kellogg, Myanmar Rice and Paddy Traders Association, GrainPro, and many private companies associated with the rice value chain (see theme 4). We will continue to build a platform for delivery on three pillars: adaptive research, which has active involvement of end-users (e.g., smallholder farmers, small and large millers), learning alliances, and effective partnerships with key actors in national, provincial, and local extension. Nationally, we actively work to establish effective communication with key policy advisors, and work closely with national extension partners to establish and test innovative pathways for the delivery and dissemination of technologies and processes for improving rice productivity. The establishment of learning alliances early in the development of projects has provided a highly effective pathway for the diffusion of NRM technologies. Effective environmental stewardship of rice agroecosystems for future generations is facilitated through partnerships with FAO, UNEP, local university partners, etc., and is exemplified by the project on agricultural engineering of lowland rice landscapes in Thailand and Vietnam, and our engagement with the SP-IPM program of the CGIAR. We will also work closely with national partners in fostering the development and implementation of "good agricultural practices for rice."

Uptake and impact pathway

The public sector has a dominant role in the dissemination of production technologies in Southeast and East Asia, though in postharvest options the private sector has a major role. In consequence, IRRI's support to uptake and impact pathways will be differentiated according to pre- and postharvest production technologies. In common, however, activities will provide support to planning in national and regional programs (an example, RSSP-Philippines). In the Philippines and Vietnam, accredited extension agronomists will support grass-roots extension capacity in farmer intermediary institutions and organizations.

Large-scale dissemination will build on experience derived from the IRRC's ICOP dissemination experience that provides linkages between adaptive research and extension. RKBs, along with innovative communication products, will support the capacity building of extension and resources for their training of farmers. To support innovative delivery mechanisms for NGOs, particularly for poorer farmers and women, and potentially for farmer associations to support emerging leadership, a limited grass-roots competitive fund will be established.

There will be strong linkages to product development under themes 1, 2, 3, and 4 and also with the IRRC and CURE. Impact pathway monitoring and evaluation will be linked with theme 5.

Financing strategy

Financial support is currently provided through a number of research and development initiatives—SDC, ADB, ACIAR, and private-sector grants (IFA, IPNI, IPI, Kellogg) for supporting the IRRC; an IFAD grant for CURE; and Philippine government grants for the RSSP. Co-investments are being made through national and provincial extension and development efforts in all countries to which this product line contributes. IRRI has been approached concerning larger-scale investment opportunities with the World Bank for Vietnam, AusAID for Cambodia, and USAID for Cambodia. The IRRI expert technical group will actively seek such links as a subcontractor for the rice component of larger projects. Project funds will be sought to develop the partnerships, and innovative communication and extension approaches required to support large-scale delivery. New funding is required to build up a strong, professional extension suppot team at IRRI to link science with development efforts on the ground. Further support is required to support the development of communication approaches and information systems.

Box 17. Impact example for product 6.3.2: Alternate wetting and drying irrigation (AWD)

IRRI pioneered research on water-saving technologies to cope with increasing irrigation water scarcity already in the early 1970s with experiments at the IRRI farm under nonflooded conditions to find out the sensitive stages of rice under water shortage. In the late 1980s and the 1990s, field experiments with saturated soil culture and various forms of alternate wetting and drying involved research partners in the Philippines, PhilRice and CLSU. At the same time, water-saving technologies were developed and disseminated to farmers in China, and, in 2002, IRRI started collaboration with Chinese universities (Wuhan University of Hydrology and Electrical Engineering and Huazhong Agricultural University as research partners) and irrigation system managers (dissemination partners: Zanghe Irrigation System and Liuyuankou Irrigation System). This collaboration also involved CSIRO, and was aimed at an in-depth understanding of water × nutrient interactions under AWD, optimizing AWD scenarios, impact assessment of adoption of AWD by farmers, and the role of policies and infrastructure). Learning from this collaboration in China was transferred to target developing countries through IRRI's networks and consortia.

By the early 2000s, IRRI started collaborating with R&D partners and extension partners with farmer participatory and adaptive research in target countries in Asia through the Irrigated Rice Research Consortium. New partners included the National Irrigation Administration, Bulacan Agricultural State College, and the Bureau of Soil and Water Management in the Philippines. The principle of safe AWD was developed in which 15–30% of irrigation water can be saved without significant yield loss, and farmers started adopting safe AWD in pump-irrigation systems in Central Luzon. Based on these positive results, extension and training materials were developed and tested in the Philippines. Through the IRRC, training for R&D partners, extensionists, NGOs, and other agencies was organized in various provinces and regions of the Philippines, Vietnam, Bangladesh, Laos, Indonesia, and Myanmar. Whereas some institutes in these countries started their own R&D program on AWD (such as NOMAFSI, FCRI, and CLRRI in Vietnam; Bangladesh Rice Research Institute and Rural Development Academy in Bangladesh), more and more agencies with an extension and dissemination mandate became involved. AfricaRice started research on AWD around 2005.

Throughout 2005-10, large-scale diffusion of safe AWD (along with generic sound water management practices) was increasingly facilitated by formal extension and "boundary" partners who took up the technology and incorporated it in their outreach activities:

- In Vietnam, the Department of Plant Protection and the Department of Agriculture and Rural Development of An Giang Province (DARD-AG) in the Mekong Delta adopted safe AWD: in 2009, four training courses for district extension workers were organized, 50 demonstration plots were established, and safe AWD was incorporated in the provincial "5 Reductions, One Must Do" program for farmers. By 2010, tens of thousands of farmers were estimated to have adopted the technology. It is expected to result in a 10–30% water savings and 15% yield increase, thanks to a reduction in lodging, which often occurs in direct-seeded rice.

- In Bangladesh, the Bangladesh Agricultural Development Cooperation, Barenda Multipurpose Development Authority, and Department of Agriculture Extension (DAE) established demonstration plots in farmers' fields in different ecological zones. DAE trained more than 400 of its staff members on AWD and established 460 demonstration farms in 25 districts. Practical Action, an NGO, conducted demonstrations with 400 farmers, while Syngenta-Bangladesh trained its own 1,200 employees and currently works with 50,000 farmers on AWD. The AWD work in Bangladesh culminated in a national Workshop on "Adoption and Success of AWD Technology for Rice Production" held in July 2009, in which the secretary of the Ministry of Agriculture supported AWD and directed DAE to upscale the technology nationwide. DAE and other agencies, including NGOs and Syngenta, have plans to disseminate AWD to more than 50 districts in 2010, covering more than 12,000 ha of boro rice. Tens of thousands of farmers are estimated to have adopted the technology. In-country reports mention an on-farm reduction in water use of 15–30%, which translates into a reduction in pumping cost and fuel consumption, and increased income of US$67–97 per hectare.

- In the Philippines, a highlight of AWD adoption has been the inclusion of AWD as one of the key technologies to be used in the National Rice Self-Sufficiency Program. The secretary of the Department of Agriculture has issued an Administrative Order directing all agencies concerned to adopt AWD and other water-saving technologies in all water management nationwide. Under the name "controlled irrigation," AWD has been included in the official Rice Check (Palay Check). It is estimated that, in 2010, more than 60,000 farmers have adopted safe AWD.

While safe AWD is being disseminated and adopted, IRRI continues research on water savings beyond the safe/no-yield-penalty threshold, and investigates impacts of AWD on emissions of greenhouse gases. IRRI stopped basic research on safe AWD by 2005.

Past and projected research to impact pathway of AWD in Asia.

	1970-80	1980-90	2000-05	2005-10	Beyond 2010
Milestone	First trials on nonflooded rice at IRRI farm	First field experiments on nonflooded rice with partners in Philippines	Joint field experiments in China and multidisciplinary study of water-saving technologies and their adoption	Background research on AWD beyond safe/no yield penalty and on GHG emissions begun at IRRI farm	Safe AWD extended with residue and nutrient management to reduce global warming potential
			First on-farm adaptive trials in the Philippines with training and extension partners	Widespread diffusion of safe AWD by a range of partners in the Philippines, Vietnam, and Bangladesh; training and extension activities in Myanmar and Indonesia	AWD fully mainstreamed in extension efforts by formal extension institutes, relevant NGOs, and civil society organizations in Southeast Asia; AWD tested in light soils and in rice-nonrice cropping systems by partners in South Asia; local training materials developed; AWD tested in target African countries through GRiSP
			Concept of safe AWD developed, along with prototype training and extension materials	Training and extension materials translated into Vietnamese, Burmese, various Philippine languages, and Bangladeshi; E-learning training course	Training and extension materials on AWD included in curricula of agricultural colleges, universities, and extension certification schemes
Research partners	-	CLSU, PhilRice	CLSU, PhilRice, WUHEE, WU, BSWM, BASC, CSIRO	CLSU, PhilRice, BSWM, BASC, NOMAFSI, FCRI, CLRRI, BRRI, RDA, AfricaRice	PhilRice, AfricaRice, NAFRI (Laos), CSISA-R&D partners in South Asia
Dissemination partners			BSWM, NIA, BASC, ZIS, LIS	BSWM, NIA, BASC, DPP, DARD-AG, RDA, BADE, DAE, BMDA, Syngenta, WV	BSWM, NIA, BASC, DPP, DARD-AG, RDA, BADE, DAE, BMDA, Syngenta, WV, NAFRI, CSISA-partners in South Asia

Product line 6.4. Effective systems for large-scale adoption of rice technologies in Africa

Rationale

Recent years have been characterized by a sharp decline in global rice stocks and widely fluctuating rice prices. Africa's dependence on imports is clearly not sustainable. Commitment at the national and regional level and from the donors' side is mounting to boost Africa's rice sector and invest in production, processing, storage, and distribution, and in marketing infrastructure.

Research can play an essential catalyzing role in the development of the rice sector in Africa but, in the past, links between research and development efforts have been suboptimal at best. Moreover, with few exceptions (most notably Egypt), the research and extension capacity in Africa is extremely weak. Much better coordination between research and development efforts and commitment at national and regional levels to hire, train, and retain new staff in rice reseach and extension will be needed. Research and extension efforts also need to acknowledge the importance of women in rice farming and rice value chain development.

There is therefore a strong need for a pro-active role by GRiSP partners to ensure that research products reach many more prospective users in Africa than through research networks alone. It will also be crucial to ensure that products reduce the burden of rice farming on women and make it an attractive occupation for young people.

The Africa Rice Center as an association of 24 member countries has had since its inception as the West Africa Rice Development Association a mandate to actively support the growth of the rice sector in Africa. The Center has vast experience in this domain and it created a special unit of extension agronomists in 2008 (RiceTIME, where TIME stands for training, information management, and extension linkages) to more effectively respond to the rice crisis, focusing entirely on this product line. This unit will be strengthened to include value chain development and training expertise via a partnership with ICRA (International Center for development-oriented Research in Agriculture). Small-scale mechanization of rice production will be among the key focus areas in PL 6.4.

Box 18. Transforming rice production across sub-Saharan Africa through mechanization

The annual consumption of rice in sub-Saharan Africa is increasing by 6% each year and nearly half of it is being imported to satisfy this rising demand, costing about $3.6 billion annually. The lack of labor and efficient farm implements results in late planting on poorly prepared lands that need more water and yield low harvests because of poor fertilizer efficiency, uneven ripening, weeds, and pest damage. Delays during harvesting, threshing, and drying combined with poor postharvest treatment and storage can reduce the value of milled rice by 20–50% on the market.

AfricaRice, IRRI together with CARD, national governments, NGOs, and commercial companies, will spearhead the local adaptation and development of sustainable business models for small-scale mechanization in Africa. Crop management systems will be improved and small equipment introduced to reduce labor requirements, improve timeliness, close yield gaps, reduce the risk of crop failure, and provide a power source for pumping water, crop threshing, and rice milling. These efforts will also create new business opportunities for local entrepreneurs, cooperatives, small companies, and others along the whole value chain. Training programs for specialists and farmers will be an integral part of the work.

Activities

Through this product line, GRiSP partners in Africa will link up with development partners and investment projects to ensure large-scale adoption of rice technologies and principles in Africa. A key partner will be the Coalition for African Rice Development (CARD), regrouping major rice research and extension institutions and donors (African Development Bank, AfricaRice, AGRA, FARA, FAO, International Fund for Agricultural Development, IRRI, JICA, JIRCAS, NEPAD, World Bank), which aims to double rice production between 2008 and 2018 in sub-Saharan Africa. Links will also be sought with major NGOs active in Africa, such as Africa Harvest Foundation, Catholic Relief Services (CRS), and Sasakawa Africa Association (SAA).

Activities to support the delivery of technologies and principles of rice value-chain development will include the following:

- Establishment of rice knowledge centers to stimulate farmer-to-farmer learning in investment projects of AfDB, IFAD, and other partners in both West and Central Africa and East and Southern Africa to stimulate participatory learning of rice principles and technologies and their out-scaling.
- Development of learning tools, such as training modules, rural radio scripts, video, etc., in local languages.
- Active development of rice knowledge banks and their access through innovative means, such as mobile-phone text messaging.
- Seed-sector support, building linkages between private- and public-sector partners from breeder to certified seed and seed of acceptable quality.
- Support for small-scale mechanization through developing local businesses
- Capacity building of extension agents, from both governmental and nongovernmental agencies, actively targeting women leaders to play a pro-active role in their communities.

All these activities will be implemented with partners, fully exploiting knowledge available at the NARES level in Africa to ensure easy out-scaling in all of AfricaRice's 24 member states and beyond.

Products

6.4.1 New models for seed multiplication and targeted delivery systems
6.4.2 New platforms for delivering agronomic, postharvest, and processing innovations
6.4.3 New models for jointly building extension capacity

Partnerships

Key partners involved in this product line will include grass-roots-level partners from national extension systems and NGOs, such as CRS, to stimulate farmer adoption and adaptation of agronomic, postharvest, and processing innovations and public-private partnerships for delivery of rice technologies and business models for, for example, seed or agricultural machinery suited to farmer conditions. Large investment projects will catalyze enhanced diffusion of rice knowledge and technologies through a variety of means, including capacity building and the use of ICT tools from product line 6.1.

Uptake and impact pathway

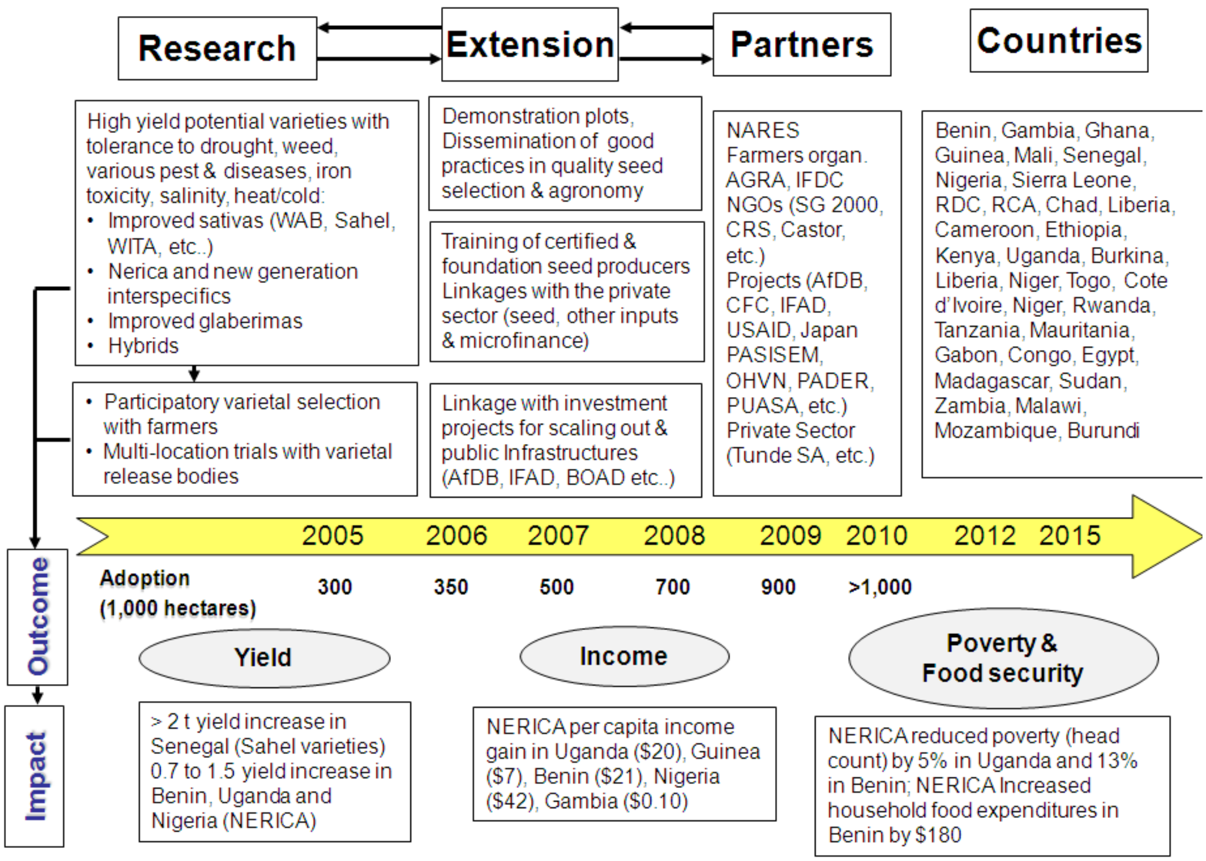
Ex ante impact analyses and technology targeting will guide out-scaling of rice knowledge and technologies from GRiSP research hubs to a much larger number of beneficiaries. Prototype technologies and rice knowledge (derived from GRiSP research or other sources) will be further tested and fine-tuned to local settings by applied research partners as needed in innovation hubs ("rice knowledge centers") covering the entire rice value chain. Ready-to-go technologies and knowledge will be out-scaled through development partners, such as investment projects (e.g., of the African Development Bank, and IFAD) and major NGOs such as CRS or BRAC, promoting large-scale adoption of agronomic, postharvest, and processing innovations. The latter will provide valuable feedback to research on the performance of the research products and local adaptations made. A special effort will be made to support the development of seed multiplication and delivery systems, linking public- and private-sector partners and civil society partners. This theme will maintain strong linkages to product development under themes 2, 3, and 4 and with research networks such as the Inland Valley Consortium and the task force mechanism, most notably the Africa Rice Breeding Task Force. Impact pathway monitoring and evaluation will be through theme 5.

Financing strategy

Financial support will come from major development partners, such as the African Development Bank through a second phase of the African Rice Initiative (ARI), from IFAD through grants to develop links with investment projects in both West and Central Africa and East and Southern Africa, and from regional economic communities, such as ECOWAS. Support to rebuild Liberia's rice research and extension capacity is expected from the World Bank and USAID. Project funds are sought to develop rice extension capacity across the continent through collaboration with strong NARES partners, such as Egypt, Ghana, and Mali. Support from the Syngenta Foundation will be targeted at postharvest and processing innovations to boost the competitiveness of locally produced rice.

Box 19. Impact example for product 6.4.1: Outscaling of new rice varieties in Africa

Rice genetic improvement efforts by AfricaRice and its NARES partners during the past two decades has led to the development and diffusion of high-yielding and short-duration rice varieties for irrigated, upland, and lowland ecologies. Three improved varieties (Sahel 108, 201, and 202) were developed in 1994 for the Sahelian irrigated environments. The Sahel varieties have rapidly gained producers' acceptance and are currently cultivated on about 70% of the rice area of the Senegal River Valley. Five new irrigated rice varieties (Sahel 134, 159, 208, 209, and 210) were released in 2007. A range of new interspecific rice varieties named NERICA (New Rice For Africa) were also developed by AfricaRice and its NARES partners in the mid-1990s for upland and lowland growing conditions. Now, 18 varieties are suited for upland growing conditions (NERICA1 to NERICA18) and 60 varieties are suited for lowland growing conditions (NERICA-L1 to NERICA-L60). AfricaRice and its partners joined forces to create a mechanism to scale up the dissemination of NERICA and other improved rice varieties throughout sub-Saharan Africa (SSA), namely, the African Rice Initiative (ARI) in March 2002. ARI uses participatory varietal selection (PVS) and community-based seed systems (CBSS) to expose farmers to improved varieties and help them access quality seed. Through PVS, 17 upland NERICA varieties are adopted/released in 19 SSA countries and 20 lowland NERICA varieties are adopted/released in 12 countries. ARI has also facilitated the production of large quantities of breeder, foundation, and certified seed of NERICA and other improved varieties. Between 2005 and 2009, 275 tons of breeder and foundation seeds were distributed. During the same period, 30 technicians were trained as trainers in seed production. These trainers have themselves trained 300 farmers in the seven ARI pilot countries. ARI has also helped open new market opportunities for women by developing a range of NERICA-based processed products such as cookies, cakes, pancakes, and bread.



NERICA varieties have affected the livelihoods of rural populations across Africa. To date, about 1,000,000 ha are under improved varieties. Partnership with NARES, NGOs, and farmers' organizations with donor support (Japan, The Rockefeller Foundation, AfDB, IFAD, UNDP, CFC, World Bank, IDRC, USAID) is the key word for ARI success. ARI has also become involved in emergency and postconflict situations to restore old varieties and expose rice farmers to new material.

Product line 6.5. Effective systems for large-scale adoption of rice technologies in Latin America and the Caribbean

Rationale

Rice production in LAC takes place across a number of different environments, crop systems, land and water availability, and farmers' size and socioeconomic characteristics. During the last 20 years, total production has been steadily increasing, driven by a fast rate of yield increase and a shift from upland and rainfed to irrigated systems. There has been an important reduction in land used for rice, although much more grain has been produced, even though yield gaps are widespread in the whole region and across production systems. The FLAR agronomy project confirmed during the last six years that yield increases could be as large as 3–4 t/ha in Central America or 1–3 t/ha in much more developed rice sectors such as the ones in southern Brazil and Argentina. These impressive yield increases are obtained with the same varieties farmers have been using for 10 to 20 years, on the same land, with the same machinery, and by reducing many chemical inputs. It is just a matter of doing the right things at the right time, focusing on a few key crop management factors.

Very good new varieties are available that could also improve yields and reduce costs but that do not reach farmers properly in several countries in LAC, due to a lack of effective seed systems. There is a range of problems such as weak seed laws and a lack of institutional support for variety maintenance, basic and certified seed production, effective certification programs, and education of farmers about the value of high-quality seed. Finally, few technological options exist to improve rainfed rice production by crop management. The lack of water control leaves farmers at risk to climatic extremes. LAC is one of the most blessed regions in the world in terms of water availability but only a tiny part of this water is properly used for production. There are good opportunities in the tropics for developing simple on-farm water-harvesting techniques that could help farmers shift to highly productive irrigated rice or to other crops. The three topics in this product line (crop management, seed systems, and water harvesting) have very well developed programs in some of the countries, thus opening excellent opportunities for within-the-region improvements, helped by institutional platforms such as FLAR. This regional expertise could also be transferred to other continents by close collaboration with other partners in GRiSP.

The key research questions are how the profitability and productivity of rice-based cropping systems can be increased by closing the yield gap through improved crop management, better seed systems, and improved water-use efficiency; reducing the costs of production; and reducing at the same time the environmental footprint of rice.

Activities

The entry point for reducing yield gaps are transfer and extension programs with direct involvement of farmers and other public or private local organizations. There is no success if these transfer programs do not rely on the institutions directly involved in each rice region; the intervention of FLAR/CIAT would be in complete alliance with them. There is clear evidence that farmer-to-farmer exchange is essential for incorporating new production strategies and so farmers' participation in designing and executing these programs is also needed. There is good experience at FLAR to implement and expand this kind of program in the whole region, starting with a diagnostic of a few key management factors to improve, identifying innovative farmers to do initial validation plots, implementing farmers' groups around these farmer-leaders, and conducting intense training of farmers and technicians involved. The same approach could be applied for implementing water-harvesting strategies, using farmers and local institutions to support the initial efforts.

Products

6.5.1 Systems for enhanced extension of improved crop management practices for closing yield gaps among farmers

6.5.2 Effective variety release mechanisms and seed systems for delivering high-quality seed of new varieties

6.5.3 Systems for enhanced adoption of water-harvesting technology in the tropics for land transformation to irrigated agriculture

Over the short term, improved crop management transfer programs will be in place and farmers will adopt best management practices in six countries. Several water-harvesting pilot farms will be running in different tropical countries and farmers and agronomists will be trained on high-yielding and highly efficient irrigated agriculture, including the use of high-quality seed. Over the longer term, wide adoption of best management practices in targeted regions will result in substantial increases in total rice production by 2015 and expansion of the program to other countries. A high percentage of farmers will use certified seed of new varieties that reach farmers in less time than previously. Small and medium rice farmers in the tropics will have changed from low-yield, low-income upland rice to high-yielding and highly efficient irrigated agriculture. Water availability allows farmers to diversify production and include maize, beans, and fish production, and obtain higher and more stable income.

Partnerships

Work in this PL will be done in close association with about 30 public- and private-sector development partners in LAC. The Latin American Fund for Irrigated Rice (FLAR), established in 1995, consists of public and private institutions—rice farmers' associations, industry groups, seed companies, and public research and extension institutions—in 15 countries in the region. These institutions invest part of their resources in a joint regional rice program to support development of the rice sector in Latin America and the Caribbean. CIAT provides new germplasm and technologies; FLAR is using these in its applied research projects and passes the results on to its members; and national public and private institutions adapt and adopt them. FLAR is a model for other world regions, but it also wishes to expand into new technologies, particularly hybrid rice. For that, FLAR will interact with GRiSP by sharing expertise while GRiSP will provide new products such as new germplasm, personnel, and knowledge on good agronomic practices. In non-FLAR member countries, new partnerships will be sought with rice-related institutions.

Uptake and impact pathway

The next users are regional research and development organizations, NARES partners, rice farmers' and industry associations, and seed companies. Intermediate users are extension agents, and final users are farmers and policymakers. It is assumed that extra funds can be raised to expand these three components that at present have minor contributions from FLAR and its partners. FLAR is a major mechanism to link the development of management technologies with local partners through adaptive research and to accelerate diffusion through fostering and promoting innovation partnerships.

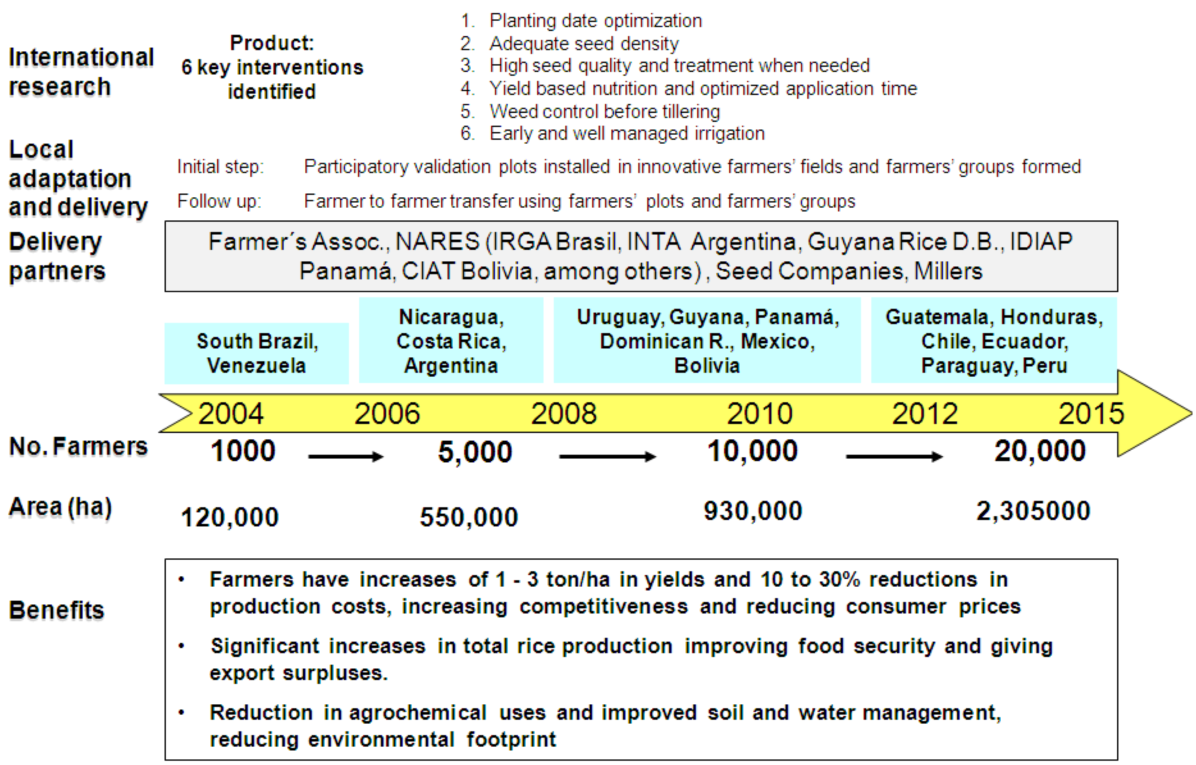
Financing strategy

Financial support is provided through a number of research and development initiatives. CIAT and FLAR developed and submitted a concept note to IDB (InterAmerican Development Bank) to propel an agronomic rice revolution in LAC in coordination with NARES and farmers' associations. The FLAR expert technical group will seek links as a subcontractor for the rice component of larger projects. Funds will be sought to develop partnerships, and innovative communication and extension approaches are required to support large-scale delivery.

Box 20. Impact example for product 6.51.: the FLAR program in LAC for closing yield gaps

FLAR is also tackling the yield gap, through a program on the transfer and extension of good management practices. This program has spread to 10 countries because of its success: yields have increased on average by 1–3 tons per hectare and costs have declined by 10–30%. FLAR is also spearheading efforts to transform drought-prone upland areas into irrigated rice systems, through water-harvesting techniques.

It is critical to involve public and/or private local and international development organizations because the full implementation of this strategy needs funds, loans, or other kinds of development assistance. To improve seed systems in selected countries, there will be an initial diagnostic assessment (variety purification, basic seed, seed industry, seed laws, etc.) and identification of improvements, development of proposals targeting the problems of each country or region, and implementation of these proposals in a joint venture with local public and private institutions. The whole process must be done in alliance with farmers' associations, NARES, and the seed industry. There will be strong linkages to product development under themes 1, 2, 3, and 4. Impact pathway monitoring and evaluation will be through theme 5.



Program Management

Oversight, planning, and management

The Global Rice Science Partnership (GRiSP) is contracted by the Consortium Board to the lead center, IRRI, which is executing it together with AfricaRice and CIAT as the primary CGIAR research partners, and with other research and development partners. Among these partners, some may through their mission and resources contribute significantly to GRiSP research at an international level, thus enhancing its progress and impact across several themes and/or regions. Such institutions may thus also have status as a primary research partner, including greater involvement in strategic planning and implementation of GRiSP. At present, only Cirad, IRD, and JIRCAS belong to that category. Each of these institutions has an explicit international research for development mandate and very strong rice research activities that have been operating for decades in Asia, Africa, and Latin America and the Caribbean. They have also agreed to strategically align their future rice research activities and resources with GRiSP in order to achieve greater synergies.

In establishing the GRiSP, all three CGIAR member centers (AfricaRice, CIAT, IRRI) accept that all of their rice research agendas and financial obligations will be reported under GRiSP, except for certain activities that are reported under other CGIAR Research Programs (CRPs). IRRI, as the lead center of GRiSP, has the capabilities and is willing to assume the financial obligations and reputational risks involved in leading GRiSP. The following criteria were taken into account in the development of the oversight, planning, and management and implementation structures of GRiSP:

1. Low transaction costs – free up more time for scientists to do science
2. Transparency
3. High involvement of stakeholders
4. Avoidance of bureaucracy
5. Fiscal protection of the lead center and other centers
6. High-quality scientific oversight

The GRiSP oversight, management, and implementation structures, flow of funds, and relationships among GRiSP members and partners are shown in Figure 14. The director general (DG) and the board chair of IRRI will have the overall responsibility for GRiSP, including technical and financial reporting to the Consortium. GRiSP strategic guidance will be provided by an Oversight Committee (OC); research planning and management will be coordinated by a Program Planning and Management Team (PPMT) and a program director (PD) with a small Program Management Unit (PMU). Implementation will be through global and regional research teams. Research management structures and processes in the three CGIAR centers will be changed to fully align with the thematic and product-oriented management structure of GRiSP. Current research leaders will thus take on new responsibilities to reflect the global programmatic approach in GRiSP. The OC is designed to replace major current Board Program Committee functions at the center level. With the exception of the new external members of the OC, the PD, and the small PMU, GRiSP will be largely managed through existing staff. Additional administrative transaction costs for implementing GRiSP will therefore be only about 1% of the total program budget.

Role of the lead center. The DG of IRRI and its Board of Trustees are accountable to the Consortium Board for the successful execution of GRiSP, for effective engagement of the OC and the PPMT, and for fulfilling the lead center's own contractual obligations to GRiSP. The IRRI board chair and DG will report to the Consortium Board on GRiSP as a whole, including an annual financial and progress report in relation to the performance contract signed between the

Consortium Board and the lead center (IRRI). The lead center DG will also work closely with the Consortium CEO on matters related to GRISP and liaise with leaders of research partners in case conflict resolution cannot be achieved by the OC or PPMT, before bringing the matter to the attention of the Consortium CEO and board.

Role of center boards. All CGIAR centers involved in GRiSP will maintain their own legal status and boards, and authority over all center management policies. GRiSP activities will be reported by the respective centers in their audited financial statements. The PMU will prepare consolidated financial statements for GRiSP for review by the PPMT and the OC. IRRI will coordinate the audit and other due diligence and oversight responsibilities required by the performance agreement with the Consortium. Center boards will ensure that the centers assume their leadership role at the continental level within GRiSP (Africa: AfricaRice; Asia: IRRI; Latin America: CIAT). That is, AfricaRice will coordinate and report on activities by all GRiSP partners operating in Africa, IRRI will report on Asia, and CIAT on Latin America. In addition, IRRI will report on all cross-cutting global research done within GRiSP, including bilateral grants that may cut across several world regions.

The center board members on the OC (see below) will report to the center boards on scientific progress in GRiSP. As the new OC becomes operational, the boards of IRRI and AfricaRice will decide how current Board Program Committee functions can be handed over to the GRiSP OC to further reduce transaction costs.

Oversight Committee (OC). Scientific oversight of GRiSP will be undertaken by an Oversight Committee representing the principal CGIAR centers in GRiSP and key stakeholder groups. The OC acts as an advisory body to GRiSP and reports to the board chairs of IRRI, AfricaRice, and CIAT.

The composition of the OC is two board members from IRRI (including the current Board Program Committee chair), two board members from AfricaRice (including the current Board Program Committee chair), one board member from CIAT (the current Board Program Committee chair or member), at least four independent world-class thinkers from different regions that represent key stakeholders and have an excellent understanding of science and development issues, and the DGs of IRRI and AfricaRice as ex officio members.The four external OC members will be selected from eminent scientists nominated by, and representing the perspectives of, each forum where rice is important (i.e., FARA, APAARI, and FORAGRO). The OC will also be composed so as to ensure representation of all major scientific disciplines, regions, and partner sectors in GRiSP. Members of the OC are also expected to have good knowledge of gender issues in agricultural research and development. One of the four external experts will be elected by the OC to serve as the chair of the OC. The four external members of the OC will be elected initially by the boards of IRRI, AfricaRice, and CIAT. Subsequently, the OC will form a nomination and election committee to screen and recommend new members, with approval by a single majority vote of the whole OC. Representatives of the boards of IRRI, AfricaRice, and CIAT will be selected by the boards of these centers. Members of the OC will be appointed for 3 years, but terms of 2–4 years may be used initially to ensure a staggered turnover of members or continuity of the chair's position. The OC may renew the appointment of an OC member once, at the end of his or her term.

The main functions of the OC will be to (i) monitor and review progress in science and its development relevance in relation to the agreed criteria in the performance contract; (ii) provide recommendations regarding strategic directions at the global level, new opportunities for investment, and enhanced performance; (iii) advise on the management and organization of GRiSP, including appointing new primary research partners to the PPMT; (iv) approve the annual GRiSP budget proposal prepared by the PD and PPMT; (v) provide input into center policies that impact directly on science; and (vi) propose and review GRiSP-commissioned external reviews on specific areas of research.

The OC will meet once a year during a 2–3-day Annual Science Forum (ASF) of GRiSP held prior to a board meeting by either IRRI or AfricaRice boards. The OC will meet at least once in every five years in Latin America, in coordination with a board meeting by CIAT. The OC may choose to hold a second meeting in certain years to examine specific issues of high priority. Topics for the Annual Science Forum can be proposed by the OC and the PPMT. The members of the PPMT may attend meetings of the OC as resource persons. Once annually, the OC will prepare a written report, which the chair of the OC will present in person or via video conference to the boards of the three major centers. This will constitute the technical report that will go to the Consortium board following incorporation of center boards' comments and its approval by the IRRI board.

The OC will be informed about scientific progress made in the three regions through a brief mid-year update, which will also be part of the overall GRiSP communication and public awareness strategy. It will receive annual progress reports from the GRiSP program director on behalf of the PPMT and review those before submission to the Consortium CEO and board.

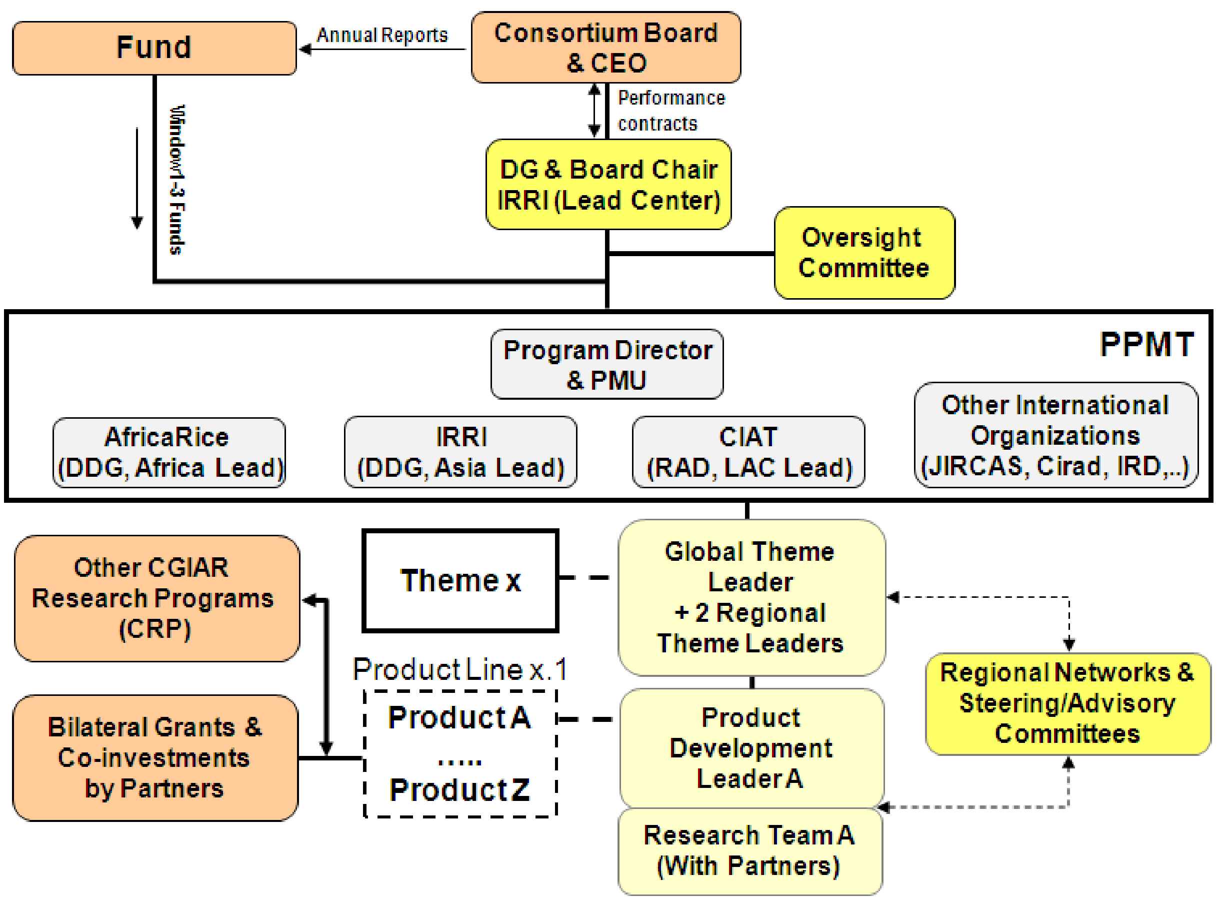


Fig. 14. GRiSP governance and management structure.

Program Director (PD) and Program Management Unit (PMU). GRiSP will largely be implemented through existing research management and administrative support systems of IRRI, AfricaRice, CIAT, and other partners in their respective target regions. However, to provide global leadership and coordination, GRiSP will be led by the program director (PD) and supported by a small Program Management Unit (PMU) composed of two assistant managers. The PMU will coordinate administrative support for GRiSP, drawing upon additional administrative support resources of the three CGIAR centers. The PD and PMU staff will be recruited and evaluated by the IRRI DG, who will also monitor the performance of the PD and the PMU and report on that to the OC.

The PD acts on behalf of all participating centers and partners in GRiSP. She or he will be responsible for

- Coordinating, with the PPMT and theme leaders, strategic foresight, planning, and reporting at the GRiSP level
- Preparing, with the PPMT and theme leaders, the 5-year and annual work plans and budgets
- Communicating with the Consortium office and CEO on GRiSP-specific matters
- Communicating with the leaders of other CRPs on coordinating linkages
- Coordinating contracts with AfricaRice, CIAT and other strategic partners; centers will continue handling all other subcontracts with their respective partners
- Monitoring and evaluation of progress against agreed milestones
- Representing GRiSP at major events of the global/regional research and development communities
- Fund raising for new global initiatives (together with the centers and other partners in GRiSP)
- Managing the PMU, including the global program support and coordination budget, as approved by the PPMT.
- Preparing and conducting meetings of the OC, PPMT, and research leaders on GRiSP themes, and other small workshops with the research and development community worldwide
- Implementing an effective internal and external communication strategy

While the PD represents GRiSP at public events, the DGs and DDGs of the three lead CGIAR centers and of strategic GRiSP partners will play commensurate roles. Key administrative support will be provided by the IRRI management system and the relevant management systems in AfricaRice and CIAT, particularly for managing finances, grants, reports, etc. Resources for this are included in the GRiSP budget.

Program Planning and Management Team (PPMT). Initially, the PPMT will be composed of senior representatives of the institutional architects of GRiSP: the DDG (R) of IRRI, the DDG of AfricaRice, the research area director (RAD) of CIAT, the rice research leaders of Cirad, IRD, and JIRCAS, and the GRiSP program director (PD). For greater efficiency and alignment, Cirad and IRD may choose to have one representative for both organizations.

The DDGs and RAD of IRRI, AfricaRice, and CIAT have the primarily responsibility for implementing all GRiSP activities in their region and they will therefore play a major role in strategic planning and resource allocation within the PPMT. In addition to that, they have numerous other center-specific functions, including ensuring high quality of science in their center, research activities in other CRPs or other areas that are outside GRiSP, management of staff, etc.

Positions for other global rice research leaders will be available on the PPMT for countries/institutions with major international research for development agendas provided that these institutions wish to integrate their research programs with the GRiSP strategic and work plan and they are willing to co-invest significant financial and human resources. Countries with multiple institutions interested in participating in GRiSP will select a national representative, which may also rotate among different institutions from that country. The OC will consider such applications and appoint representation accordingly.

Specific guidelines for PPMT membership and the roles, responsibilities, and accountabilities of these additional members will be developed by the OC in the first half of 2011. Applications for membership in the PPMT will be reviewed and approved by the OC, upon recommendation from the PPMT. Considering the heavy involvement of Cirad, IRD, and JIRCAS in international rice research and the development of GRiSP, an application from one of the French institutions to represent the French rice science community would likely be favorably considered, as would an application from Japan.

The PPMT will be responsible for the establishment, execution, and monitoring of the full GRiSP research portfolio, including the development of GRiSP strategic and work plans and business plans and regular revisions of research priorities. Full PPMT meetings will be held at least once a year, typically in conjunction with the Annual Science Forum. PPMT members will also meet monthly via video/phone conferencing and maintain frequent communication through other means.

Led by the PD, the PPMT will develop the annual GRiSP budget for approval by the OC. Annual budget proposals will be developed by the PPMT based on evidence derived from regular strategic priority assessments (see below) and agreed work plans submitted by the participating centers and their strategic partners. In the event that the resources coming from the Fund are not sufficient to cover the full range of proposed GRiSP activities, the PPMT will decide on budget adjustments and inform the theme leaders, who will then implement budget adjustments based on priorities within their themes. Key decisions will be made in a consultative and subsidiary manner among PPMT members. If the PPMT is not able to come to agreement on the allocation of Fund resources (primarily windows 1 and 2), the OC will be the final authority. Funds channeled directly to centers under Fund window 3 will be managed by the DDG/RAD of that center, as part of the overall GRiSP budget. The main recommendations of the PPMT will be presented by the GRiSP program director to the GRiSP Oversight Committee.

The PPMT will establish reporting regimes and develop mechanisms for tracking progress against milestones and budget use. In addition to external reviews commissioned by the OC, the PPMT will organize periodic research reviews to be held in conjunction with existing periodic scientific conferences organized by the two rice centers. The PPMT will implement changes in the program as indicated by these reviews. In cases of significant deviations from commitments by participants, the PPMT will recommend action to be taken by the OC.

The individual centers will be responsible for obtaining and maintaining any bilateral grants, including technical and financial reporting. However, to ensure a coherent research strategy in GRiSP, the PPMT will review all major bilateral grants proposed by the primary research centers in GRiSP with regard to research priorities and gaps in GRiSP.

The DDGs of IRRI and AfricaRice and the RAD of CIAT will report back to the PPMT on GRiSP research activities in their respective regions and involve all relevant partners to prepare such reports beforehand, for example, through the involvement of GRiSP partners in annual research days organized for Africa, Asia, and Latin America, respectively. Each DDG (or RAD for CIAT) will therefore talk on behalf of the region and not on behalf of his or her center. These technical reports will cover all aspects of GRiSP activities and will be mapped against milestones.

***Regional oversight and linkages with stakeholders*.** The three principal CGIAR centers in GRiSP will continue to seek advice on regional priorities and implementation strategies through interaction with existing regional bodies and partners representing the agricultural, environmental, and health research and development sectors.

In Asia, IRRI will interact closely with the Asia Pacific Association of Agricultural Research Institutes (APAARI) and seek specific advice from the Council for Partnerships on Rice Research in Asia (CORRA), representing the leaders of the rice-sector NARES in 10 Asian countries. IRRI also interacts with the various regional fora under the GCARD process, the Association of Southeast Asian Nations (ASEAN; IRRI has observer status), APEC, and the South Asian Association for Regional Cooperation (SAARC), and actively participates in regional and national investment fora and agricultural development initiatives.

In Africa, AfricaRice and IRRI are active members of the Coalition for African Rice Development (CARD, www.riceforafrica.org), a consultative group of bilateral donors and regional and international organizations working in collaboration with rice-producing African countries. CARD is a rice-specific response to the NEPAD/CAAD process, led by JICA and AGRA, and GRiSP will therefore be well linked with this major economic development initiative. The goal of CARD is to support the efforts of African countries to double rice production on the continent within 10 years. AfricaRice will also seek guidance from its Council of Ministers (COM, ministers of agriculture of 24 countries) and the National Experts Committee (NEC, NARES leaders of AfricaRice member countries) and by interacting with the Forum for Agricultural Research in Africa (FARA), subregional research organizations (CORAF, ASARECA, CARDESA, NASRO), and regional economic communities (ECOWAS, CEMAC, COMESA, SADC) in Africa. In Latin America, CIAT will seek guidance from FORAGRO and the 15 members of FLAR, who represent a wide range of public- and private-sector institutions.

In addition to these higher-level stakeholder interactions, numerous products in GRiSP will be implemented through specific regional consortia, networks, or task forces, most of which have steering committees with wide representation of stakeholders (see the Partnerships section). They play an important role in setting priorities, overseeing specific GRiSP research, and linking it with national systems and investments.

Program implementation and coordination

Work and business plan. GRiSP will be implemented through a 5-year rolling work and business plan addressing the six research and development themes described herein. Annual updates will be made for milestones and resource allocation. Annual financing plans will be developed by the PPMT with support from the PD/PMU and submitted to the OC for approval. GRiSP work plans will integrate milestones from major bilateral grants in a transparent manner to ensure a coherent research agenda financed through CGIAR Fund windows 1–3 as well as bilateral grants. Every 5 years, a full work and business plan review will be conducted in conjunction with the recurring strategic assessment of research priorities for international rice research (see chapter on strategic planning and impact assessment). Outcomes of the strategic assessment will provide the basis for developing a new 5-year work plan, and for major revisions in resource allocations. In the initial transitions of GRiSP (2011-12), more significant adjustments of the work plan may already be made on an annual basis, pending the outcomes of the first strategic assessment in 2010-11.

The research in each of the six GRiSP themes will be implemented through a limited number of R&D product lines (families of demand-driven R&D products; between 3 and 6 product lines per theme). Product lines are functional aggregations of products, not managerial subunits. Detailed planning of activities and measurable milestones and resource allocations will be done at the product level, integrating the different funding sources (CGIAR Fund, other sources at the center level, co-investments by partners and other CRPs). Each product line will have a set of activities contributing to a maximum of five distinct R&D products, each with an annual investment value of $0.5 million to, in some cases, more than $3 million per year. Products can be global or regional. Each product line has a detailed logframe specifying products, the key activities, concrete measurable milestones, and outcomes over 5 years along a general 10-year roadmap. Milestones are always defined for rolling 5-year periods. Short-term outcomes refer to 5 years whereas long-term outcomes refer to 10 years. Clear responsibilities will be assigned to each milestone.

Theme leaders. Each GRiSP theme will have a global theme leader (TL), who is also responsible for one of the three regions. Initially, the six TLs will be appointed by the lead center, IRRI, because it accounts for the largest research input and funding attribution in GRiSP. In addition to providing the overall theme leadership, the six TLs will therefore also lead the activities in Asia. AfricaRice and CIAT will appoint regional theme leaders to coordinate the theme-related research in their respective target region. The global TL will interact with these regional TLs to facilitate collaboration and synergies among the three regions for a specific theme and across themes in GRiSP. Similarly, leaders of the six themes within a region will interact on a regular basis to facilitate collaboration and synergies among themes at the regional, subregional, national, or local level. Theme leaders will interact closely with product development leaders and partners to plan, execute, and monitor the research on the different product lines.

All participating CGIAR centers will change their current research management structures to fully align with the new GRiSP themes and products. This will take place in late 2010 as part of the implementation plan. Hence, GRiSP theme leaders will also be the leaders of the respective research units or programs in their institutions. In the case of AfricaRice, the current research program structure is already largely aligned with the GRiSP themes. IRRI will shift from its current research matrix to a new structure based on GRiSP themes to ensure greater management efficiency.

Product development teams and leaders. The product level is where activities for product development take place, executed by global or regional research teams composed of the primary research centers in GRiSP and their direct research partners. Product development teams also interact with numerous boundary partners interested in further adaptation or uptake of research outputs. The product level is also where resources will be connected in terms of the different funding sources for it (Windows 1–3, bilateral grants, co-investments by strategic GRiSP partners).

Each product in GRiSP will have a product development leader (PDL), that is, a scientist from IRRI, AfricaRice, CIAT, or another strategic partner with a comparative leadership advantage for this product. The PDLs will be appointed by the PPMT in consultation with the TLs. Typically, scientists who are already coordinators of major bilateral grants will also assume this new role of PDLs in GRiSP, ensuring coherence, low transaction costs, and synergies between different grants and other sources. In many cases, a PDL will lead several products.

Product development leaders will facilitate the development of annual work plans, spelling out major activities, responsibilities, budgets, and funding gaps for product development. Product development may be at the global or regional level, depending on the nature of the product. Within each product, leadership for specific milestones will be assigned to the institution with the major accountability for it. Each institution involved in a particular R&D product may assign an institutional lead scientist for that product, as part of the overall product development team and with responsibilities for specific milestones. Planning and reporting on progress will be done at the product level and aggregated up to the product line and GRiSP theme by the TL, allowing for a transparent investment and monitoring mechanism.

The six themes (and products in them) will be well connected with each other and also with other CRPs of the Consortium through joint research projects that focus on cross-cutting, rice ecosystem–specific, or regional management solutions. Funding for these problem-oriented, interdisciplinary projects will initially come from bilateral grants and gradually evolve toward more funding from the overall GRiSP level. The TLs and PDLs will develop an efficient communication strategy among the scientists and key partners involved.

In summary, the centers will align their management structures under GRiSP. A theme leader will primarily interact with (i) the PPMT, (ii) the two other regional focal points for that theme, (iii) TLs of other themes, and (iv) about 10 PDLs. The PDLs are the key action points for implementing GRiSP, with transparent, decentralized accountability for critical resources at that level. They represent primarily active scientists who already have much experience in leading research at that level. We will also seek appropriate gender equality at this research management level.

Stimulating new research and partnerships. GRiSP will use two mechanisms to explore new frontiers in research and catalyze new partnerships in research or delivery. In addition to resource allocations to themes and their products in the 5-year work plan, a flexible research fund for New Frontiers Research will be created and managed by the PPMT as part of the overall GRiSP budget. This mechanism will be used, in a nonbureaucratic manner, to issue seed grants for "blue sky" research in promising, cutting-edge research areas, which may later evolve to become full new R&D products in GRiSP. The PPMT, as part of the annual work and business planning process, may commission such specific research to strategic partners on a competitive and noncompetitive basis.

Moreover, under the centrally managed Global Program Support budget of GRiSP, a partnership development fund will be created to (i) initialize collaboration between GRiSP scientists and new research partners (e.g., travel grants, staff exchange, small research support grants) and (ii) provide small initial support to grass-roots-level extension work of NGOs, farmers' organizations, and other groups that wish to collaborate with GRiSP, particularly in Theme 6. The PPMT will be responsible for developing simple, transparent mechanisms for approving such grants, which will then be facilitated by the PMU. Funds for these activities will have to be provided by the new CGIAR Fund and in addition to current levels of unrestricted and restricted funding to the CGIAR centers in GRiSP. This is vital for enabling a wider range of new partnerships right from the beginning of GRiSP. Although the funds initially available for this may be only modest, we hope to gradually grow the volume of these two mechanisms to about 10% of the annual GRiSP budget in order to have a vital, sustainable mechanism for innovation and partnership development.

Gender strategy. The DGs of IRRI, AfricaRice, and CIAT will each assign a senior gender equality specialist for implementing the gender strategy in GRiSP, which will aim to enhance the efficiency and impact of GRiSP by considering gender issues in implementing the six global R&D themes. This gender leadership team will guide scientists in incorporating the gender dimension in their research. The team will also provide expertise in ensuring that surveys and studies are appropriately designed with a gender perspective. It will also disseminate findings, strengthen networking/collaboration with gender researchers in partner organizations within the sector, and identify tools, methods, and resources for capacity building.

The gender focal points will participate in GRiSP gender activities and provide the necessary specific feedback on gender-sensitive issues addressed by GRiSP. The gender impact will be a collective responsibility of GRiSP and the gender focal points will help the system achieve this. GRiSP's gender specialists will collaborate with participatory research and gender specialists in other CRPs. Strategic research on thematic gender issues in the region and worldwide will be conducted in collaboration with IFPRI. In Africa, links will be established with the African Women in Agricultural Research and Development (AWARD) program. In Latin America, links will be established with the Program on Participatory Research and Gender Analysis (PRGA).

Gender activities not embedded in the GRiSP themes will require human and financial resources. Financial resources will be provided to the gender leadership team for organizing meetings and participating in gender-related programs in other forums, and in system-wide or intercenter activities, hiring additional gender experts, supporting new projects, and developing training modules and materials that highlight best practices of addressing gender issues in rice research for development, and conducting training of GRiSP researchers on gender issues. To meet these needs, GRiSP, as part of the global program coordination budget, will create a central fund for umbrella gender activities, to be managed by the PD under the direction of the PPMT.

Capacity-building strategy. Most science and extension capacity-building activities will be embedded under the GRiSP research themes and funded there, and also through bilateral grants. The shortage of rice research capacity in Africa will be addressed through the establishment of research task forces, pooling scarce resources and building new capacity. GRiSP theme 6 focuses on rice extension capacity building on all three continents, with special emphasis on sub-Saharan Africa. To address global science capacity needs through new initiatives (see the section on capacity building under Program Design), GRiSP, as part of the global program coordination budget, will create a central fund for umbrella science capacity-building support, to be managed by the PD under the direction of the PPMT.

Communication. The PD and PMU will be responsible for all internal communication in GRiSP. The PMU will manage and maintain a simple GRiSP Web communication platform for researchers involved in GRiSP, focusing on making key information quickly and widely available, maintaining an effective repository of key documents and information, interactive communication tools for product teams, shared calendars, and online monitoring of program progress. The PMU will also (i) develop and implement an effective electronic information distribution system to ensure that all GRiSP scientists and partners have equal access to key information and (ii) organize regular phone/video conferences of the PPMT, among TLs, and for product development teams to enable better teamwork through a high level of direct interaction. Reports will be sent by the regional theme leaders to the PMU, which will compile them for review by the PPMT. Reviewed and approved reports will then be forwarded by the program director to the Consortium Board/CEO and the Fund Council. Technical reports on all aspects of GRiSP activities, regardless of funding source, will be mapped against milestones. The PMU will prepare a brief annual report to supplement the annual reports of the participating centers and partners.

The DGs of IRRI, AfricaRice, and CIAT will each assign a senior communications specialist for implementing the external communication strategy in GRiSP. Other primary research partners may also appoint communications experts to join this GRiSP communications and media relations team. IRRI as the lead center will lead and coordinate the external communication strategy developed by this team. An annual budget will be provided from the global program coordination budget of GRiSP for supporting external communication activities.

GRiSP's general communication strategy will follow the pathways to research uptake guidelines on maximizing dissemination of communication products, as stated in the international initiative on Coherence in Information for Agricultural Research and Development (CIARD, www.ciard.net). The vision of CIARD is to *"make public domain agricultural research information and knowledge truly accessible to all."* Together with the PD and the TLs, the GRiSP communications team will develop and implement an efficient process for the synthesis of key GRiSP outputs in high-quality public information and media materials. The main external communication vehicles for GRiSP will be

(i) Knowledge and communication products (text, image, video, and audio outputs) aimed at specific stakeholder groups in the research and development sector, but also for the general public.
(ii) The well-established and widely circulated *Rice Today* magazine (quarterly) as a re-focused flagship magazine for GRiSP.
(iii) A public GRiSP Web site (linked with the sites of the participating centers and those of strategic partners).
(iv) New social media, particularly using Internet 2 technologies, to connect people and to bring the GRiSP mission, vision, objectives, and progress to the attention of the general public.
(v) Specific media releases, white papers, and media events on food security, climate change, and other subjects, targeting national, regional, and global political bodies.

The CGIAR centers in GRiSP will release their information products (scientific, popular, and promotional publications; Web pages; photographs, videos, and other multimedia presentations) as much as possible under a suitable open-content license, such as Creative Commons.

Intellectual property management. GRiSP will produce a large amount of intellectual property (IP)—materials, technologies, and tools ranging from new traits, varieties, and management technologies to information databases and publications. The current IP policies of the centers and donors involved in GRiSP will be applied to managing this IP within the context of international public goods. Our aim is to harmonize the IP policies and IP management procedures within GRiSP over time. Generally, GRiSP's products will be widely available to all countries and users, that is, intellectual property developed by a center will be made available to any public- and private-sector entity. When appropriate and fully consistent with its mandate, international agreements on genetic resources, and IP policies of its donors and partners, an institution in GRiSP may seek protection of its intellectual property. The following general principles will guide IP management in GRiSP:

- The primary beneficiaries of GRiSP research and training activities are rice farmers and consumers, especially in the developing countries.
- GRiSP centers and their partners are committed to keeping intellectual assets developed by GRiSP, including germplasm, inventions, improvements, data, processes, technologies, software, trademarks, and publications, as freely available as possible to any public- or private-sector entity.
- To the extent possible and when appropriate, publication or contractual provisions will be used to ensure that such information, innovation, or material remains available for use by the public and private sector.
- Provided it is fully consistent with their mandate, international agreements on genetic resources, and IP policies of their donors and partners, centers participating in GRiSP may, in exceptional cases, such as when it is necessary to prevent misappropriation or to ensure wider dissemination of their research products, seek protection of their intellectual assets or impose restrictions on their use by others.
- Any revenue generated from management of IP, including royalties and licensing fees, will be used to support research and capacity-building programs and those of its national partners.
- Centers participating in GRiSP shall ensure proper stewardship of their intellectual property as well as that belonging to other parties for which permission to use has been granted.

Monitoring and evaluation

The PD and the PPMT have the primary responsibility for monitoring progress, with support by the PMU. A workshop will be held in 2011 to define the specific monitoring and evaluation framework for GRiSP, including definition of the key indicators to use, and to establish the modalities for collecting and analyzing the necessary information. Our goal is to establish sets of meaningful, measurable performance indicators that can be assessed on a regular basis at the product level, but also be aggregated for monitoring overall GRiSP progress and impact. These indicators will focus on the key elements of the GRiSP vision of success, that is, improving food security and nutrition, alleviating poverty, protecting the environment, and achieving more social impact, with emphasis on gender equality. Once the final GRiSP structure is approved, research to impact pathways for each GRiSP product will be explored in detail early on to establish a successive set of intermediate indicators, and progress along impact pathways will be assessed. This product pathway analysis is expected to be completed by June 2011.

Project success will be assessed on the basis of achievement of milestones and outcomes defined in the logframe. Product-specific measurable milestones, with clearly assigned roles and responsibilities of lead and partner institutions, will form the basisfor all monitoring and reporting. Reporting on progress by measurable indicators will thus be done at the product level and aggregated up to product lines and GRiSP themes, which also form the major budget elements. This will allow for a transparent investment and monitoring mechanism; investors in GRiSP will be able to see clearly how their funds contribute to specific product lines or products, and, through the milestones and outcomes in those, to the actual progress made.

Each center will organize annual research planning and review meetings to discuss the progress made within each of the six themes in the region of interest and plan for the next year's activities. GRiSP progress will be reviewed during the Annual Science Forum and larger regional and global rice congresses taking place in cycles of 4 years (International Rice Congress, Africa Rice Congress, Latin America Rice Congress). These opportunities will be used to set new research priorities in consultation with key partners and stakeholders (see also the section on Strategic Planning and Impact Assessment under Program Design).

As a complement to ex ante and ex post impact assessment, a system of process evaluation will be embedded within the GRiSP. The intent of the system is to provide a basis for appraisal and incentives for program performance, as well as a systematic foundation for adjustments to research plans and foci. In so doing, the system is intended to be flexible enough to accommodate differences in disciplines and activities, while providing a consistent basis for continual improvement. This will be composed of five principal components:

1. Product/output monitoring
2. Performance management
3. Peer product or product line evaluation through external reviews
4. Partner feedback
5. GRiSP external reviews

Product/output monitoring. On an annual basis, progress against milestones will be reviewed and reported. Internal participatory discussions within products will be conducted to review the implications of progress against milestones, the likely pace of progress and implications for future milestones, as well as intended research directions. These changes will be reflected in an annual GRiSP logframe update.

Performance management. Within each product and in consultation with theme leadership, indicators of research performance will be identified, and will be allocated to the performance assessments of individual scientists. These indicators will capture the quality and quantity of outputs within the product as well as indices of initial use of research products (outcomes). Appraisal will be annual, and will include a combination of self, peer, and supervisory input. Aggregate indices of product performance will be submitted to the theme leader, who will review performance across the products. She or he will then submit a brief appraisal of product performance to the PPMT, which will appraise performance across the themes.

Peer product or product line evaluation through external reviews. For each product, scientific assumptions associated with specific milestones will be identified, along with associated critical junctures at which strategic decisions need to be made about future research directions (such as an intermediate finding that will determine the viability of the chosen research approach). Two or three external panel reviews will be commissioned for high-priority products (or product lines) by the Oversight Committee each year to coincide with these junctures and provide input into future research directions. Recommendations will be considered as part of a process of self-reflection by scientists within the assessed product line, and responses will be overseen by the PPMT.

Partner feedback. Frequent partner and stakeholder feedback at the product level will be provided by the steering/advisory committees of numerous regional or global consortia and networks that are part of GRiSP (see the Partnerships chapter). The GRiSP PD or other members of the PPMT will also provide annual updates on GRiSP to major regional forums such as APAARI, FARA, FORAGRO, and others. Every three to four years, GRiSP progress will be reviewed in open sessions with partners during regional and global rice congresses (International Rice Congress, Africa Rice Congress, Latin America Rice Congress). These opportunities will be used to obtain stakeholder feedback on self-assessment of research progress, achievements, and intended future directions.

GRiSP external reviews. At 5-year intervals, external reviews of the entire GRiSP will be commissioned by the Independent Evaluation Arrangement of the CGIAR on behalf of the Fund Council. These independent evaluations will provide an external perspective on research relevance and performance, and will serve as an important input into the revision of the GRiSP structure and approach every 5 years. They should be timed in conjunction with the recurring strategic assessments of research priorities so that, in intervals of 5 years, the recommendations from both the external review and the strategic assessment will form the basis for developing a new 5-year GRiSP work plan. Writing of a new 5-year GRiSP work plan should also solicit input from stakeholders during the regional and global rice congresses.

Managing potential risks

IRRI, AfricaRice, CIAT, Cirad, IRD, and JIRCAS—the leading international research organizations in GRiSP—have excellent records over several decades of being able to establish and maintain effective partnerships in the target regions of GRiSP. Such partnerships will be central to the success of GRiSP and thus also reduce the risk of failure to deliver the products and catalyze their wide-scale adaptation and adoption according to the time lines set in the work plan. Risk varies by GRiSP themes, and also by regions. Below we provide a brief overview of some potential risks.

Theme 1 includes a substantial amount of basic research, particularly on gene discovery and C_4-rice, but also needs to be connected well with theme 2 research to which its products will be fed. Inherent in theme 1 are risks such as insufficient research capacities in CGIAR centers for gene discovery, lack of access to state-of-the-art technologies and IP, insufficient phenotyping systems for gene discovery, inadequate bioinformatics support for handling massive amounts of new genome/phenome information, or changes in international guidelines for germplasm conservation and distribution. A key risk mitigation strategy is therefore to partner with the best scientists in the world for tapping scientific expertise that will be needed to make groundbreaking discoveries. GRiSP will establish mechanisms that follow the model of already existing consortia on SNPs and C_4-rice, partnering with numerous advanced research institutions worldwide. A key measure will also be to develop new mechanisms for public-/private-sector partnership in that area, particularly with regard to gaining access to advanced transgenic traits and methodologies for public-sector use.

Theme 2 bears the major risk of failing to develop new varieties and hybrids that meet the demands of farmers and consumers in a rapidly changing natural and social environment. Another risk in theme 2 is a potential disconnect of the breeding work with research in themes 3, 4, and 5. Uncertainties also prevail about regulatory policies that could affect the release and adoption of transgenic rice, including Golden Rice (PL 2.6). Among breeding goals and traits, the biggest risk remains the inability to maintain or enhance yield potential because it has been difficult to break through the yield barrier. Likewise, risks exist with regard to the ability to breed new varieties with higher levels of more durable resistance to diseases and insect pests, but also heat and drought as affected by climate change. Theme 2 will reach its targets only if (i) the right traits are prioritized, (ii) highly effective links are established between gene discovery in theme 1 and gene application in theme 2, and (iii) global rice breeding programs are transformed into effective product-oriented breeding pipelines in the public sector, linked also to the needs of the emerging private sector in rice breeding. The latter requires detailed understanding of target environments and markets, and of research to delivery pathways. Hence, risk mitigation measures in theme 2 will focus on evidence-based priority setting, rapid transformation of breeding programs toward target molecular breeding programs, fostering interdisciplinary work, and excellent partnership models.

Theme 3 embodies major opportunities for impact through better management of rice-based cropping systems, but also major challenges. Past experience has shown that it is much easier to reach high adoption rates for new germplasm than it is to bring more knowledge-intensive technologies to wider-scale adoption. Hence, nonadoption by farmers is the greatest risk for theme 3, but there are also major risks in terms of potential negative impacts that some new technologies may have on humans or on the sustainability of cropping and the environment. There is a risk that the required increases in rice production ofroughly 100 million tons more rice for each extra one billion people could lead to a large negative impact on the environment because of further depletion of soil and water resources, increased greenhouse gas emissions, increased release of reactive nitrogen into biogeochemical cycles, pesticide impacts on biodiversity and human health, and other processes. Diversification of cropping systems, if not done in a sustainable manner, can lead to a degradation of natural resources. The introduction of water-saving irrigation technologies may increase yield variability or even the risk of yield failure due to soil health constraints. Labor-saving crop establishment technologies may require more hand weeding and thus increase drudgery for women doing such work. Climate change mitigation measures could result in yield and income losses for farmers. Hence, theme 3 plays a key role in understanding these potential risks and developing new, integrated solutions for an ecological intensification and diversification of rice-based farming systems that avoid such risks. In fact, the innovations proposed in theme 3 are designed to reduce negative environmental impact, with an emphasis on greater use efficiencies of water, energy, fertilizer, and other inputs. The key mitigation measure in theme 3 is to ensure that research is participatory and demand-driven, not supply-driven, and is grounded in solid science as the basis for deriving new management recommendations. Experimental approaches and sites must be carefully selected, taking into account the potential for rapid out-scaling, for example, through links with investment programs of major development partners in theme 6. GRiSP partners have established mechanisms for that in recent years, but more resources will be needed to make the work in theme 3 fully effective.

Theme 4 needs to address the key challenge of how postharvest technologies can be out-scaled more rapidly, which requires not only more investments but also country strategies, suitable public-private partnerships, and conducive policy environments. Without those, the risk of nonadoption or slow adoption of new postharvest solutions remains high, and thus also the risk of not being able to extract more value from rice harvests is quite high. There is also a potential risk in a sense that the private sector may be a better provider in the future for the postharvest technologies developed and promoted in GRiSP. The quality and timeliness of crop management before and at harvest will determine to a large extent the opportunities for adding value after harvest. Connecting theme 3 and theme 4 experimental sites and networks will therefore be critical, too. Work on new rice products, including straw for livestock, bioenergy, or specialty rice, bears the risk that these products may not be feasible, or they may not be adopted by farmers or others in the value chain. Hence, theme 4 requires strong interactions with new grass-roots and business partners that can provide critical expertise for providing farmer, processor, and consumer feedback for developing new products from rice. Grain quality research (PL 4.3) needs to be fully integrated in the breeding programs under theme 2 in order to minimize the risk of low grain quality of new varieties being developed.

Theme 5 will depend heavily on the quality of new data and information becoming available, ranging from household-level studies all the way to global remote sensing for tracking rice growth. Technical challenges must be overcome and procedures for collecting, processing, storing, and analyzing data need to be standardized and well documented. A major risk for PL 5.2 is the poor quality or geographical coverage of currently available spatial data layers for some important indicators, particularly information on soils and pests. In PL 5.3, the major risk is that the proposed real-time monitoring and forecasting system may not succeed because of unreliable access to or the predictive value of remote-sensing information, insufficient computing power, or crop and econometric prediction models that are unable to capture the breadth and depth of environmental and market situations. As for other themes, too, key mitigation measures include close collaboration with leading experts worldwide; capacity building among NARES and other partners, with special emphasis on Africa, where risks are especially high; and excellent communication infrastructure.

Theme 6 primarily depends on maintaining policy and institutional environments favorable to technical change in agriculture through private- and public-sector partnerships. Political uncertainties exist nationally and can affect progress negatively, particularly with regard to technology adoption and reaching the anticipated impact. The risk for this is greatest in theme 6 because stable, fast growth of the rice sector requires the right technologies that fit into farmers' production and value systems, a suitable political environment, and a policy framework that enables development. Theme 6 relies on being able to leverage large co-investments or feed well into the delivery mechanisms of numerous development partners. Hence, without establishing excellent partnership mechanisms with a wide range of these "boundary partners," out-scaling of technologies developed by GRiSP will not happen. On the other hand, the potential is great that GRiSP can indeed leverage such large co-investments and thus also greatly enhance the rate of return for the R&D investments made. GRiSP has an advocacy role for shaping policies and, through policy analysis (theme 5) and links with senior policymakers, GRiSP will inform policy decisions that affect these environments.

Other risks cut across themes, among which are insufficient co-investment from partners, lack of qualified human resources at the partner level because of decades of neglect of rice research and extension capacities (especially in Africa), insufficient consideration of gender issues, and poor communication. GRiSP has defined a gender strategy, and its performance will be reviewed at least yearly by the Program Planning and Management Team. Capacity building is a cornerstone of GRiSP, weaving through all themes. A capacity-building fund managed by the PPMT will allow addressing severely underfunded science capacities that block progress and training new leaders in rice research and development. Rice extension capacity of governmental and nongovernmental organizations will be built up under theme 6, with special emphasis on Africa. Risk of insufficient co-investment will be addressed by the very nature of GRiSP itself, effectively doing away with fragmented and disconnected research efforts and linking up with major rice-sector development efforts. Regular information updates on progress and active engagement of all partners in setting priorities and research agendas in GRiSP will further reduce this risk.

Program Budget

Budgeting approach and assumptions

General considerations. Financing strategies for each PL are described in the product line descriptions. GRiSP, like most other CRPs, will start from a basis of current research, which is to 80% locked into existing restricted (bilateral) grants. These activities resulted from strategic planning and priority setting done in recent years, including a wide range of stakeholder consultations. Hence, up to 80% of the initial proposed allocation of funds is based on ongoing research, plus a number of new priorities that were identified during the CRP development process. Over time, as current restricted grants run out or are replaced by Fund Window 1-3 funding or new bilateral grants, more flexibility in resource allocation according to new priorities will emerge. The results of the first strategic assessment for research prioritization will become available for Asia in late 2010 and for Africa and LAC in 2011 (see PL. 5.4. in GRiSP). Hence, some re-allocation of resources is expected to happen as soon as in 2011 with further adjustments in subsequent years. Product-based adjustment will be done annually in subsequent years, based on evidence for high priority, opportunity, progress made, and available funds. The Program Planning and Management Team (PPMT) will make these strategic choices based on regular prioritization exercises done in consultation with stakeholders. The OC will approve the annual budget. This will ensure a consistent, transparent approach for linking resource allocation to priorities in terms of technology potential and comparative advantage of GRiSP.

Scenarios. Developing the tentative budget for the first 5-yr work and business plan of GRiSP was faced with a number of uncertainties, including:

- Unknown overall funding volume available for new activities
- Unknown donor intentions with regard to shifting funds to the new Fund windows 1-3
- Unknown approach for charging CGIAR system cost to CRPs
- Unknown approach and funding model for system-wide capacity building and gender activities

Considering this, we followed a bottom-up budget development process that was based on current and needed future expenditures by GRiSP R&D products. It included nine steps:

1. Assess cost of the CGIAR rice genebanks and remove this from the GRiSP budget.
2. Calculate key institutional infrastructure costs (see description below).
3. Define global GRiSP coordination and program support needs (PMU and administration, communication, M&E, gender and capacity building, new partnerships, new frontiers research).
4. Map all current (2010) bilateral grants and unrestricted funds into the new GRiSP PL structure (done for each CGIAR center in GRiSP).
5. Adjust future needs by priorities (gaps in PLs, new research needs, budget for new frontiers research).
6. Apply inflation adjustment (3%/yr).
7. Add CGIAR system levy to all new funds. The Consortium Board and Fund Council have proposed a levy on grants to the new CGIAR to fund system costs such as the operations of these two bodies. At the time of writing, the levy under consideration is 2% but that is not yet confirmed. However, for purposes of the GRiSP budgets, we have assumed 2% and this has been applied to all contributions to GRiSP (both Fund and bilateral) except those related to restricted grant contracts which are already signed, or at advanced stages of negotiation, at the time of this GRiSP proposal. These contracts do

not contain provisions for this levy and it does not seem appropriate to renegotiate these contracts at this point. The system levy has also not been applied to GRiSP expenses funded by center reserves or on other center generated income such as interest earned.

8. Estimate donors intentions for funding through windows 1-3 vs. bilateral. Donor intentions in terms of preferred funding windows were not well understood at the time of developing the GRiSP, making it difficult to estimate how much funds will, in the future, come through Fund windows 1-3 vs. funding for bilateral grants. To estimate the proportion of funds required from Fund windows 1-3, we made assumptions for each donor, which are shown in table B6 (Appendix 3).
9. Estimate how much needs to come from Fund windows 1-3 vs continued bilateral fundraising (= difference between bottom-up developed total budget needs and the remaining projected bilateral funding).

Using this approach, we developed three scenarios for GRiSP funding:

Scenario A is termed "**2009 base**" and adopts, as originally requested by the Consortium Board, the audited financial statements of the GRiSP centres for 2009 as the baseline year, and then adds inflation only of 3% for 2010 and through the GRiSP period. It should be noted that the projected 2010 expenditures by GRiSP centres will be already 4.1% above the Scenario A which means this scenario equates to a reduced level of activity. It should also be noted that the requirement to provide some global coordination and fund the CGIAR System levy would further erode the level of research compared to 2010. The funding for new frontier research, development of new partnerships, capacity building, and gender activities would be severely constrained in Scenario A. Hence, this scenario is only shown as a summary for reference and not discussed in more detail.

Scenario B is termed "**Steady State**" and uses the projected 2010 unrestricted and restricted (secured grants) as the base. It assumes inflation of 3% per annum through the planning period on the Research Themes and Institutional Capacity in order to maintain purchasing power. Funding for developing some new frontier research has been included in Scenario B. The Program Coordination and Capacity Building line includes those new costs essential for implementing a successful, globally integrated research program as well as increased spending in key success areas such as gender, scientific capacity building, and new partnership development. The CGIAR system cost levy is included (see comments below).

Scenario C is termed "**Growth**" and is the Steady State scenario plus real growth of 5% per annum on the Research Themes only. The amounts allocated to Program Coordination and Capacity Building, and to Institutional Capacity are the same under Scenarios B and C.

The budget narrative and detailed tables describe GRiSP allocations by centers and partners, by year, by region, and according to themes. Each cell in the budget tables is fully costed and thus includes direct research costs, the applicable share of the indirect costs and the administrative cost of handling partner funds. The indirect costs can be seen on Table B3 which recasts the budget by natural classification. Tables for each of the three budget scenarios are structured as follows:

Table B1. Projected expenditures by themes and years
Table B2. Projected expenditures by regions
Table B3. Projected expenditures by natural classification and projected funding sources
Table B4. Program coordination and capacity building
Table B5. Institutional capacity funds

The following supplementary budget tables are included in Appendix 3:

Table B6. Donor funding assumptions

Table B7. 21st Century research facilities

Table B8. Rice Genebanks

GRiSP budgets: three investment scenarios

We present three budget scenarios for the first five year planning period (2011 to 2015). In Tables B1a-c, the actual results for 2009 and the most recent estimates of the 2010 results are shown for comparison. It should be noted that the GRiSP log frame is linked directly to the steady state Scenario B described below and the programmatic implications of growth under Scenario C are indicated in the log frame as additional milestones that can only be achieved with the extra resources made available under Scenario C.

Scenario A (2009 Base) summary. If GRiSP was build around the assumption of a slow growth from the 2009 audited financial statements, annual funding would be only USD 85.8 million in 2010, rising to USD 97.9 million by 2015, for a total 5-yr volume of USD 459.5 million Table B1a). However, this scenario is flawed for several reasons:

- Secured funding for 2010 is already USD 86.3 million. This includes about 80% bilateral funds (restricted projects) funded by CGIAR and non-CGIAR donors. Hence, actual growth from 2009 to 2010 has been over 7%, exceeding the assumed 3% growth from the 2009 base (inflation adjustment).
- Scenario A would not allow initializing new activities, including research, partnerships, capacity building and gender.
- Net investment in research would actually decrease because of the need to also absorb the costs for program coordination and CGIAR system.

Hence, although we show Scenario A for comparison, we do not view it as a feasible option for implementing GRiSP and achieving its vision of success.

Scenario B (Steady State) summary. The steady state Scenario B GRiSP budget (including expenditures by all CGIAR and non-CGIAR sources of the participating CGIAR Centers) for 2011 through 2015 is USD 519.7 million (Table B1b). Scenario B includes USD 463.2 million (89%) for the 6 research themes and new frontier research, USD 26.8 million (5%) for investments in core institutional capacity of CIAT, AfricaRice and IRRI, USD 22.05 million (4%) for program coordination and capacity building, and, USD7.6 million (2%) for CGIAR System costs. Rice research in Asia would be allocated 62% of the GRiSP resources with 29% in Africa, 9% in Latin America (Table B2b).

In terms of natural expense classification, the allocation in the GRiSP budget is (Table B3b):

Personnel cost	34%
Supplies and services	26%
Travel	6%
Partners/ collaborators	13%
Depreciation	8%
Institutional overhead	11%
CGIAR System cost	2%

GRiSP involves many participants including CGIAR centers and partners. IRRI, AfricaRice and CIAT will directly require 388.3 million 84% of the Research Theme budget. Other CGIAR centers will be allocated USD 23.8 million (5%) mostly for collaborative research and regional initiatives in GRiSP themes 2, 3, 5 and 6, connecting those also with other CRPs. Non CGIAR partners such as NARES, NGOs and ARIs will receive USD 51.1 million (11%) with significant resources for work on genetic resources (theme 1), new varieties (theme 2), production systems (theme 3), policy (theme 5) and delivery (theme 6). The funds, and accountability, for other CGIAR centers and partners will flow through the GRiSP centers. It should be noted that GRiSP partners will make significant co-investments (see financing of GRiSP section).

Under the steady state Scenario B, GRiSP is expected to grow from an annual budget ofUSD 95.4 million in 2011 to USD 112.6 million in 2015, which is a 30% increase over the comparable 2010 level. The steady state scenario B is the basis of the GRiSP log frame. Although this represents a significant increase in funding over time, it would not allow investing in new priority areas or filling critical gaps. Scenario B also falls far short of the stated CGIAR goal to double funding for agricultural research and development.

Scenario C (Growth) summary**.** Under this scenario, the total GRiSP program expenditures would be USD 594.4 million for 2011 through 2015. The annual budget is USD 99.8 million in 2011, increasing to USD 139.2 by 2015, which represents an increase of 61% over the comparable 2010 figures. As noted previously, the growth would be allocated strategically to the Research Themes with the implications described in the log frame. The proportion or resources allocated to the Research Themes would therefore increase slightly and the allocation by natural classification would remain approximately the same as Scenario B. Subject to further prioritization, initial investment proportions by GRiSP themes in Scenario C are approximately:

Theme 1	18%
Theme 2	30%
Theme 3	20%
Theme 4	5%
Theme 5	9%
Theme 6	15%
New frontiers research	3%

Scenario C would provide greater opportunities for tackling new research priorities. The log frame indicates in *red italics* those milestones that can only be achieved with the additional investments identified in scenario C. Additional research resources would be invested, for example, in strengthening a number of high priority product lines, including 1.2. (phenotyping and bioinformatics for gene discovery), 1.3 (traits), 2.1. (breeding informatics and testing), 2.2. (emerging diseases; host plant interactions), 2.4. (yield potential, direct-seeded rice), 3.1 (ecological intensification & diversification), 3.4 (climate change), 4.1 (expansion of postharvest work), 4.3 (grain quality), 5.3. (rice information gateway) and 6.1. (cross-cutting extension resources). In this scenario, we would also be able to invest in gradually building up several new areas of work that currently do not have significant funding (e.g., PL. 4.2 on new products from straw and husks). Likewise, Scenario C would provide more opportunities for exploratory research (see the section on new frontiers research for examples) and more support for capacity building.

Program coordination and capacity building. Global program support and coordination consists of those functions necessary for the success of a global research initiative (Table B4). These include the management and governance structure (OC, PPMT, Program Director and the PMU), workshops, administrative support, the GRiSP external communications platform, the monitoring and evaluation components including impact assessment and priority setting mechanisms.

The budget includes centrally managed funds to support monitoring, evaluation, strategic foresight, priority setting and impact assessment work at the global program level (center staff and external resources). Additional, larger investments in strategic foresight, priority setting, and impact assessment are made through the activities in theme. In the future, GRiSP aims to move to a levy approach instead of specific short term deliverables in restricted grants in order to have sustained, longer-term funding for monitoring, evaluation, strategic foresight, priority setting and impact assessment. This will require moving towards 1% - the level recommended by the development evaluation community.

The communication budget is intended to ensure that research results are effectively communicated to the global scientific community but with special emphasis to scientists in our beneficiary countries, policy makers, and others. The communications line contains funding to further develop the quarterly GRiSP flagship publication, Rice Today, which will be a key communications vehicle, and to support new Web based communication tools.

Science capacity building and gender are areas that have suffered much from declining funding over the past two decades. Raising more funds for these activities is of high priority in GRiSP to overcome the existing severe gaps, which, without major interventions, will soon lead to a lack of qualified agricultural researchers in developing countries, men and women. As a starting point, during 2011-2015 in both budget Scenarios B and C, GRiSP aims to allocate USD 5.0 million to additional science capacity building activities in our beneficiary countries, and an additional USD 1.85 million specifically to support women in rice science leadership programs. Moreover, if such additional funds can be provided from the new Fund, GRiSP will establish a flexible partnership development under the direction of the PPMT. It will provide support for fostering new ideas and partnerships in research or for grass-roots-level delivery work with development partners, particularly CSOs (see Program Management chapter). For this period GRiSP plans to invest at least USD 2.9 million in such activities (Table 4).

Institutional capacity. The GRiSP budget identifies a suite of functions that represent the unique institutional capacity that needs to be maintained in order to support world class research operations (Table B5). The most notable elements are the long term trials at IRRI and AfricaRice, and the libraries which provide valuable support to CGIAR and partner scientists. This line also includes funding for staff development (USD2.08 million) which is an area of chronic underfunding within CGIAR centers.

The GRiSP institutional budget also includes capital funding to maintain the existing infrastructure and fixed asset base – a relatively steady state scenario – to support the GRiSP research. Specific items included are the normal array of computers, vehicles, equipment for existing labs, etc. Costs to maintain the Bouaké headquarters of AfricaRice are included. This capital budget is additional to the funds currently held in the capital funds of IRRI, AfricaRice and CIAT. It should be noted that these current capital funds held by centers are inadequate to adequately replace fixed assets as they are funded by depreciation on assets accounted for on a historical cost basis and not replacement cost.

Financing GRiSP

IRRI will be the lead GRiSP center and thus will enter into the overall performance agreement with the Consortium Board, and the necessary implementing agreements with AfricaRice, CIAT and the other partners. The actual funds flows will need to be agreed within the construct of the overall Consortium/Fund Council/Trustee discussions but IRRI is able to manage the GRiSP funds flows.

The GRiSP centers were asked to indicate how much funding will be expected from the Fund Council and how much would be sourced bilaterally. It should be noted that donor intentions regarding the Fund are not known to the GRiSP centers at this time. For example, we do not know if a particular donor will channel its contributions through the Fund, and if yes, to what extent and when it would take effect. Therefore, table B6 (Appendix 3) was developed which lists each of the current 2010 donors to the GRiSP proponent centers and states an assumption regarding those donors' contributions to the new CGIAR i.e. channeled through the Fund (window 1, 2 or 3) or bilateral. Input on the assumptions was sought from the Fund Council office. These assumptions form the basis for the Projected Funding Sources section of Table B3 for each scenario.

The following table summarizes the indicative financing of GRiSP under each of the three budget scenarios and assuming that the donor intentions listed in Table B6 are valid and take place in 2011.

	Scenario A	**Scenario B**	**Scenario C**
Funding			
CGIAR Fund	312.91	365.81	417.50
Bilateral CGIAR Members	93.24	97.66	112.92
Total CGIAR Members	**406.15**	**463.48**	**530.42**
Bilateral Non-CGIAR Members	47.24	50.17	57.85
Other Income	6.10	6.09	6.09
Total GRiSP Funding	**459.49**	**519.74**	**594.37**

Co-investment by partners. GRiSP will be a global partnership with many non-CGIAR partners participating and contributing resources. Co-investments in GRiSP have two major roles:

- Strengthen research through resources provided by partners
- Enable large-scale dissemination of new technologies by linking GRiSP with large investments in the agricultural sector. The latter will be required for GRiSP to meet its vision of success. Theme 6 in GRiSP provides the mechanism for such linkages, and clear regional entry points for such co-investments

It is not feasible to calculate those investments in the shared agenda at this time but they are expected to be significant. Contributions may include not only in-kind provision of facilities but also scientists and other direct research costs.

The GRiSP agenda will be supported by important research for development participants. For example, CIRAD and IRD, together with associated research institutions and facilities in France, expect to allocate resources (scientific time, operational expenses and access to their scientific platforms) exceeding USD 18 million per year over the initial planning period (Appendix 4). Likewise, current GRiSP-related activities of JIRCAS amount to approximately USD 4 million per year (excluding salaries, Appendix 4). Many other partners also contribute significant resources to GRiSP. It is expected, for example, the GRiSP investments in adaptation and dissemination of new technologies and information will leverage co-investments that are at least 10-fold those made by GRiSP.

Other financial needs

21st-century research facilities. The GRiSP budgets under each Scenario exclude any large institutional infrastructure needs that exceed the typical annual capital investments for maintenance and replacement on the understanding that these costs will be funded through separate fundraising. Table B7 (Appendix 3) reports these costs for information only.

In the case of IRRI, many important facilities (laboratories, training centre, conference facilities, and experimental station) date from the 1960s and 70s and are now showing their age. One sees a similar situation at CIAT. High-priority areas for IRRI include new plant growth facilities (i.e. phytotron, glasshouses) as the current units are difficult to maintain, are not energy efficient and are not the facilities required for 21st-century research methods. Similarly, CIAT needs to upgrade its phenomic transgenic and marker assisted selection facility, irrigation and machinery systems for confined biosafety trials at Santa Rosa station, and upgrade and renovation of Training Center. For AfricaRice, a well-equipped rice agronomy and post-harvest training center is urgently needed in Senegal to contribute to enhancement of the competitiveness of rice produced in the ECOWAS member states. The Center's focus on biotic stresses in rice at its station in Benin requires expansion of the current very basic phenotyping and genotyping facilities. There is also a need to expand and upgrade the long term storage facility for its genetic resources unit

These improved facilities will be essential for attracting and retaining world class scientists (either as staff, visiting scientists or partner) needed to meet the GRiSP mandate, and for conducting the high quality research expected by stakeholders. GRiSP centers understand that such investments could be funded through Window 3 in the shorter term and by Window 1 in the longer term.

Genebanks. Although genebank functions are fully integrated in the GRiSP work plan (PL 1.1), the GRiSP budgets under each Scenario also exclude the genebank costs on the understanding that these costs will be funded through a separate mechanism now being studied by the Consortium Board. Table B8 (Appendix 3) reports these costs for information only. They will be further evaluated during the ongoing genebank costing exercise.

Summary budget tables

Table B1a. Scenario A: Projected GRiSP expenditures by theme and year using 2009 actual as base, adjusted for 3% annual inflation from 2010 onwards (USD million)

Description	Actual	Current	+3% annual increase based on 2009 Actual						
		Estimate		GRiSP					
	2009	2010	2010	2011	2012	2013	2014	2015	Total
T1-Genetic Resources	14.33	15.50	14.76	14.73	15.15	15.48	15.89	16.33	77.58
T2-New Varieties	21.96	25.37	22.62	22.56	23.20	23.72	24.35	25.02	118.85
T3-Production Systems	13.50	16.94	13.91	13.87	14.27	14.58	14.97	15.38	73.08
T4-Value Chains	3.39	3.78	3.50	3.49	3.59	3.67	3.76	3.87	18.37
T5-Technology Targeting & Policy	9.34	7.96	9.62	9.60	9.87	10.09	10.36	10.64	50.57
T6-Delivery	13.96	12.32	14.38	14.35	14.76	15.08	15.48	15.91	75.59
New Frontier Research				-	-	0.50	0.75	1.00	2.25
Total Research Themes	**76.49**	**81.88**	**78.79**	**78.61**	**80.83**	**83.13**	**85.57**	**88.15**	**416.29**
Institutional Capacity	3.94	4.40	4.06	4.18	4.31	4.44	4.57	4.71	22.21
Total Center level	**80.43**	**86.27**	**82.85**	**82.79**	**85.14**	**87.57**	**90.14**	**92.86**	**438.49**
Program coordination and capacity building				2.54	2.75	2.96	3.11	3.19	14.55
Total	**80.43**	**86.27**	**82.85**	**85.33**	**87.89**	**90.53**	**93.25**	**96.04**	**453.05**
CGIAR Systems Costs (2%)	-		-	0.50	1.12	1.38	1.60	1.84	6.44
Total	**80.43**	**86.27**	**82.85**	**85.84**	**89.02**	**91.91**	**94.85**	**97.88**	**459.49**

Table B1b. Scenario B: Projected GRiSP expenditures by theme and year, Steady State (USD million)

Description	Actual	Current		GRiSP					
		Estimate							
	2009	2010		2011	2012	2013	2014	2015	Total
T1-Genetic Resources	14.33	15.50		15.97	16.45	16.94	17.45	17.97	84.78
T2-New Varieties	21.96	25.37		26.13	26.91	27.72	28.55	29.41	138.73
T3-Production Systems	13.50	16.94		17.45	17.97	18.51	19.07	19.64	92.65
T4-Value Chains	3.39	3.78		3.89	4.01	4.13	4.25	4.38	20.67
T5-Technology Targeting & Policy	9.34	7.96		8.20	8.45	8.70	8.96	9.23	43.54
T6-Delivery	13.96	12.32		12.69	13.07	13.46	13.87	14.28	67.38
New Frontier Research	-	-		1.50	2.00	3.00	4.00	5.00	15.50
Total Research Theme	**76.49**	**81.88**		**85.83**	**88.86**	**92.47**	**96.15**	**99.92**	**463.24**
Institutional Capacity	3.94	4.40		5.05	5.20	5.36	5.52	5.69	26.82
Total Center Level	**80.43**	**86.27**		**90.89**	**94.07**	**97.83**	**101.67**	**105.60**	**490.06**
Program Coordination & Capacity Building	-	-		3.85	4.17	4.49	4.71	4.83	22.05
Total GRiSP	**80.43**	**86.27**		**94.74**	**98.24**	**102.32**	**106.38**	**110.43**	**512.11**
CGIAR System Costs (2%)	-	-		0.69	1.33	1.61	1.87	2.13	7.63
Total	**80.43**	**86.27**		**95.43**	**99.57**	**103.93**	**108.25**	**112.56**	**519.74**

Table B1c. Scenario C: Projected GRiSP expenditures by theme and year, Growth (USD million)

Description	Actual	Current		GRiSP					
		Estimate							
	2009	2010		2011	2012	2013	2014	2015	Total
T1-Genetic Resources	14.33	15.50		16.77	18.13	19.61	21.21	22.94	98.66
T2-New Varieties	21.96	25.37		27.44	29.67	32.09	34.71	37.53	161.44
T3-Production Systems	13.50	16.94		18.32	19.82	21.43	23.18	25.07	107.82
T4-Value Chains	3.39	3.78		4.09	4.42	4.78	5.17	5.59	24.06
T5-Technology Targeting & Policy	9.34	7.96		8.61	9.31	10.07	10.89	11.78	50.66
T6-Delivery	13.96	12.32		13.32	14.41	15.59	16.86	18.23	78.41
New Frontier Research	-	-		1.58	2.10	3.15	4.20	5.25	16.28
Total Research Theme	**76.49**	**81.88**		**90.12**	**97.87**	**106.72**	**116.21**	**126.39**	**537.32**
Institutional Capacity	3.94	4.40		5.05	5.20	5.36	5.52	5.69	26.82
Total Center Level	**80.43**	**86.27**		**95.18**	**103.07**	**112.08**	**121.73**	**132.08**	**564.14**
Program Coordination & Capacity Building	-	-		3.85	4.17	4.49	4.71	4.83	22.05
Total GRiSP	**80.43**	**86.27**		**99.03**	**107.24**	**116.57**	**126.44**	**136.91**	**586.19**
CGIAR System Costs (2%)	-	-		0.78	1.40	1.71	2.00	2.30	8.18
Total	**80.43**	**86.27**		**99.80**	**108.64**	**118.28**	**128.44**	**139.21**	**594.37**

Table B2a. Scenario A: GRiSP expenditures by region; total for 2011-2015, using 2009 actual as base adjusted for 3% annual inflation (USD million)

Description	Asia	Africa	LAC	Total
T1-Genetic Resources	50.28	14.70	12.60	77.58
T2-New Varieties	73.50	24.94	20.40	118.85
T3-Production Systems	43.81	27.22	2.05	73.08
T4-Value Chains	9.33	8.50	0.55	18.37
T5-Technology Targeting & Policy	27.10	22.43	1.04	50.57
T6-Delivery	39.98	35.06	0.55	75.59
New Frontier Research	1.58	0.52	0.15	2.25
Total Research Themes	**245.59**	**133.37**	**37.33**	**416.29**
Institutional Capacity	12.88	7.55	1.78	22.21
Total Center level	**258.47**	**140.91**	**39.11**	**438.49**
Program coordination and capacity building	10.19	3.35	1.02	14.55
Subtotal	**268.66**	**144.26**	**40.13**	**453.05**
CGIAR Systems Costs (2%)	3.82	2.05	0.57	6.44
Total	**272.48**	**146.31**	**40.70**	**459.49**
Percentage	**59%**	**32%**	**9%**	**100%**

Table B2b. Scenario B: GRiSP expenditures by region; total for 2011-2015, Steady State (USD million)

Description	Asia	Africa	LAC	Total
T1-Genetic Resources	55.63	16.43	12.72	84.78
T2-New Varieties	88.03	30.19	20.50	138.73
T3-Production Systems	50.71	39.88	2.05	92.65
T4-Value Chains	9.38	10.75	0.55	20.67
T5-Technology Targeting & Policy	28.83	13.69	1.01	43.54
T6-Delivery	43.80	22.66	0.92	67.38
New Frontier Research	10.85	3.57	1.09	15.50
Total Research Theme	**287.23**	**137.18**	**38.84**	**463.24**
Institutional Capacity	14.51	8.27	4.04	26.82
Total Center Level	**301.73**	**145.45**	**42.88**	**490.06**
Program Coordination & Capacity Building	15.44	5.07	1.54	22.05
Total GRiSP	**317.17**	**150.52**	**44.42**	**512.11**
CGIAR System Costs (2%)	4.48	2.34	0.82	7.63
Total	**321.64**	**152.86**	**45.24**	**519.74**
Percentage	**62%**	**29%**	**9%**	**100%**

Table B2c. Scenario C: GRiSP expenditures by region; total for 2011-2015, Growth (USD million)

Description	Asia	Africa	LAC	Total
T1-Genetic Resources	64.73	19.12	14.81	98.65
T2-New Varieties	102.44	35.14	23.86	161.44
T3-Production Systems	59.02	46.41	2.39	107.82
T4-Value Chains	10.91	12.51	0.64	24.06
T5-Technology Targeting & Policy	33.56	15.94	1.17	50.66
T6-Delivery	50.97	26.37	1.07	78.41
New Frontier Research	11.39	3.74	1.14	16.28
Total Research Theme	**333.01**	**159.23**	**45.07**	**537.32**
Institutional Capacity	14.51	8.27	4.04	26.82
Total Center Level	**347.52**	**167.50**	**49.11**	**564.13**
Program Coordination & Capacity Building	15.44	5.07	1.54	22.05
Total GRiSP	**362.95**	**172.57**	**50.66**	**586.19**
CGIAR System Costs (2%)	4.54	2.71	0.93	8.18
Total	**367.49**	**175.29**	**51.59**	**594.37**
Percentage	**62%**	**29%**	**9%**	**100%**

Table B3a. Scenario A: Projected GRiSP expenditures by natural classification and projected funding sources using 2009 actual as base, adjusted for 3% annual inflation (USD million)

Cost group	Description	GRiSP					
		2011	**2012**	**2013**	**2014**	**2015**	**Total**
1	Personnel Costs	29.19	30.14	31.36	32.46	33.55	156.70
2	Supplies and Services	21.41	21.96	22.21	22.66	23.18	111.42
3	Operational Travel	5.40	5.57	5.80	6.00	6.20	28.97
4	Collaborators/Partnership Costs	15.80	16.27	16.76	17.26	17.78	83.87
	CG Centers	*4.24*	*4.36*	*4.49*	*4.63*	*4.77*	*22.49*
	NARES, NGO, ARI	*11.56*	*11.91*	*12.26*	*12.63*	*13.01*	*61.38*
5	Depreciation	3.85	3.97	4.13	4.28	4.42	20.66
	Subtotal	**75.64**	**77.92**	**80.25**	**82.66**	**85.14**	**401.61**
6	Institutional Overhead (% of direct cost)	9.69	9.98	10.28	10.59	10.90	51.44
	Total	**85.33**	**87.90**	**90.53**	**93.25**	**96.04**	**453.05**
7	CGIAR Systems Costs (2%)	0.50	1.12	1.38	1.60	1.84	6.44
	Total Projected Costs	**85.84**	**89.02**	**91.91**	**94.85**	**97.88**	**459.49**

Projected Funding Sources

Description	GRiSP					
	2011	**2012**	**2013**	**2014**	**2015**	**Total**
Funding						
CGIAR Fund	58.22	60.40	62.61	64.76	66.93	312.91
Bilateral CGIAR Members	17.52	18.19	18.64	19.16	19.72	93.24
Total CGIAR Members	**75.75**	**78.59**	**81.24**	**83.92**	**86.65**	**406.15**
Bilateral Non-CGIAR Members	8.89	9.22	9.44	9.70	9.98	47.24
Other Income	1.20	1.21	1.22	1.23	1.24	6.10
Total GRiSP Funding	**85.84**	**89.02**	**91.91**	**94.85**	**97.88**	**459.49**

Table B3b. Scenario B: Projected GRiSP expenditures by natural classification and projected funding sources, Steady State (USD million)

Cost group	Description	GRiSP 2011	2012	2013	2014	2015	Total
1	Personnel Costs	32.95	34.21	35.71	37.19	38.65	178.71
2	Supplies and Services	24.96	25.91	27.04	28.16	29.27	135.33
3	Operational Travel	6.00	6.23	6.50	6.77	7.04	32.54
4	Collaborators/Partnership Costs	12.91	13.30	13.70	14.11	14.54	68.57
	CG Centers	*4.01*	*4.13*	*4.26*	*4.39*	*4.52*	*21.31*
	NARES, NGO, ARI	*8.90*	*9.17*	*9.44*	*9.73*	*10.02*	*47.26*
5	Depreciation	7.61	7.90	8.24	8.58	8.92	41.25
	Subtotal	**84.43**	**87.55**	**91.19**	**94.81**	**98.42**	**456.40**
6	Institutional Overhead (% of direct cost)	10.31	10.69	11.13	11.57	12.01	55.71
	Total	**94.74**	**98.24**	**102.32**	**106.38**	**110.44**	**512.11**
7	CGIAR System Costs (2%)	0.69	1.33	1.61	1.87	2.13	7.63
	Total Projected Costs	**95.43**	**99.57**	**103.93**	**108.25**	**112.56**	**519.74**

Projected Funding Sources

Description	GRiSP 2011	2012	2013	2014	2015	Total
Funding						
CGIAR Fund	66.63	69.69	73.13	76.51	79.85	365.81
Bilateral CGIAR Members	18.22	18.94	19.54	20.16	20.80	97.66
Total CGIAR Members	**84.85**	**88.63**	**92.67**	**96.67**	**100.65**	**463.48**
Bilateral Non-CGIAR Members	9.37	9.73	10.04	10.35	10.67	50.17
Other Income	1.20	1.21	1.22	1.23	1.24	6.09
Total GRiSP Funding	**95.43**	**99.57**	**103.93**	**108.25**	**112.56**	**519.74**

Table B3c. Scenario C: Projected GRiSP expenditures by natural classification and projected funding sources, Growth (USD million)

Cost group	Description	GRiSP 2011	2012	2013	2014	2015	Total
1	Personnel Costs	34.51	37.48	40.88	44.46	48.26	205.60
2	Supplies and Services	26.01	28.12	30.53	33.07	35.76	153.48
3	Operational Travel	6.29	6.83	7.45	8.10	8.80	37.46
4	Collaborators/Partnership Costs	13.56	14.67	15.86	17.15	18.55	79.79
	CG Centers	*4.21*	*4.56*	*4.93*	*5.33*	*5.77*	*24.80*
	NARES, NGO, ARI	*9.35*	*10.11*	*10.93*	*11.82*	*12.79*	*54.99*
5	Depreciation	7.88	8.46	9.13	9.84	10.58	45.89
	Subtotal	**88.24**	**95.55**	**103.85**	**112.63**	**121.94**	**522.22**
6	Institutional Overhead (% of direct cost)	10.78	11.69	12.72	13.81	14.97	63.97
	Total	**99.03**	**107.25**	**116.57**	**126.45**	**136.91**	**586.19**
7	CGIAR System Costs (2%)	0.77	1.39	1.71	2.00	2.30	8.18
	Total Projected Costs	**99.80**	**108.64**	**118.28**	**128.44**	**139.21**	**594.37**

Projected Funding Sources

Description	GRiSP 2011	2012	2013	2014	2015	Total
Funding						
CGIAR Fund	69.68	75.97	83.07	90.49	98.30	417.50
Bilateral CGIAR Members	19.11	20.79	22.48	24.29	26.25	112.92
Total CGIAR Members	**88.78**	**96.76**	**105.54**	**114.78**	**124.55**	**530.42**
Bilateral Non-CGIAR Members	9.82	10.67	11.52	12.43	13.42	57.85
Other Income	1.20	1.21	1.22	1.23	1.24	6.09
Total GRiSP Funding	**99.80**	**108.64**	**118.28**	**128.44**	**139.21**	**594.37**

Table B4a. Scenario A: Program coordination and capacity building (USD million)

Description	GRiSP					
	2011	**2012**	**2013**	**2014**	**2015**	**Total**
Program Management Unit staff	0.20	0.21	0.22	0.24	0.25	1.12
PMU operations (travel, office, consultants)	0.17	0.17	0.17	0.17	0.17	0.83
General administrative support (grants, finance, reporting)	0.26	0.26	0.26	0.26	0.26	1.32
Partnership development	0.26	0.33	0.40	0.46	0.46	1.91
Workshops, reviews	0.33	0.33	0.33	0.33	0.33	1.65
Advisory Panel	0.07	0.07	0.07	0.07	0.07	0.33
Communication (Rice Today, website, newsletter, reports)	0.26	0.26	0.26	0.26	0.26	1.32
M&E/strategic impact assessment/priority setting	0.26	0.30	0.33	0.33	0.33	1.55
Gender studies and capacity building	0.20	0.23	0.26	0.26	0.26	1.22
Science capacity building	0.53	0.59	0.66	0.73	0.79	3.30
Total	**2.54**	**2.75**	**2.96**	**3.11**	**3.19**	**14.55**

Tables B4b&c. Scenarios B and C: Program coordination and capacity building (USD million)

Description	GRiSP					
	2011	**2012**	**2013**	**2014**	**2015**	**Total**
Program Management Unit staff	0.30	0.32	0.34	0.36	0.38	1.70
PMU operations (travel, office, consultants)	0.25	0.25	0.25	0.25	0.25	1.25
General administrative support (grants, finance, reporting)	0.40	0.40	0.40	0.40	0.40	2.00
Partnership development	0.40	0.50	0.60	0.70	0.70	2.90
Workshops, reviews	0.50	0.50	0.50	0.50	0.50	2.50
Advisory Panel	0.10	0.10	0.10	0.10	0.10	0.50
Communication (Rice Today, website, newsletter, reports)	0.40	0.40	0.40	0.40	0.40	2.00
M&E/strategic impact assessment/priority setting	0.40	0.45	0.50	0.50	0.50	2.35
Gender studies and capacity building	0.30	0.35	0.40	0.40	0.40	1.85
Science capacity building	0.80	0.90	1.00	1.10	1.20	5.00
Total	**3.85**	**4.17**	**4.49**	**4.71**	**4.83**	**22.05**

Table B5a. Scenario A: Institutional capacity funds using 2009 as the base (USD million)

Description	Actual 2009	Current Estimate 2010	GRiSP 2011	2012	2013	2014	2015	Total
Long term trials	0.10	0.10	0.11	0.11	0.11	0.11	0.12	0.56
Library	0.49	0.51	0.52	0.54	0.55	0.57	0.59	2.76
Capital	2.65	2.73	2.81	2.90	2.98	3.07	3.16	14.93
Mbe Station, Bouake	0.63	0.65	0.67	0.69	0.71	0.73	0.75	3.55
Staff Development	0.07	0.08	0.08	0.08	0.08	0.08	0.09	0.41
Total	**3.94**	**4.06**	**4.18**	**4.31**	**4.44**	**4.57**	**4.71**	**22.21**

Tables B5b&c. Scenarios B and C: Institutional capacity funds, Steady State and Growth (USD million)

Description	Actual 2009	Current Estimate 2010	GRiSP 2011	2012	2013	2014	2015	Total
Long term trials	0.10	0.23	0.27	0.28	0.29	0.29	0.30	1.43
Library	0.49	0.60	0.64	0.66	0.68	0.70	0.72	3.39
Capital *	2.65	2.76	3.08	3.18	3.27	3.37	3.47	16.38
Mbe Station, Bouake	0.63	0.65	0.67	0.69	0.71	0.73	0.75	3.55
Staff Development	0.07	0.17	0.39	0.40	0.42	0.43	0.44	2.08
Total	**3.94**	**4.40**	**5.05**	**5.20**	**5.36**	**5.52**	**5.69**	**26.82**

* Only includes capital required to maintain steady scenario. Major upgrades (e.g. plant growth facilities) will be presented through Funding Window 3 and referenced to the GRiSP proposal.

Appendix 1. Ex ante Assessment of the Potential Impact of GRiSP

The strategic assessment team in GRiSP is currently conducting a systematic, quantitative analysis of production constraints, impact of technology options, and R&D priorities for rice. As an example, we show preliminary results of parts of this exercise for South Asia and sub-Saharan Africa to illustrate the approach and to give an evidence-based indication of the overall impact potential of GRiSP. This chapter provides supplementary information to Boxes 1 and 2 in the chapter on *Assessing the expected benefits of GRiSP for the poor and food-insecure*.

Ex ante assessment of potential GRiSP solutions and impact in South Asia

Methods. This analysis for South Asia includes India, Pakistan, Bangladesh, Nepal, Bhutan, Myanmar, and Sri Lanka. The total rice harvest area is about 34.3 million ha of irrigated rice and 28.5 million ha of rainfed rice (including lowland, upland, and deepwater rice). The assessment was performed for two sets of technologies:

- Those that close yield gaps caused by specific abiotic and biotic stresses
- Those that increase yield potential (inbreds, hybrids, C_4 rice)

Using experimental data and literature sources, GRiSP scientists compiled estimates of the effects of yield-reducing and yield-limiting factors on the irrigated, rainfed lowland, upland, and deepwater environments of South Asia, and these were translated into a set of standardized yield loss parameters for specific areas affected within each environment. For each constraint, a research product solution was identified, along with the expected portion of the losses to be averted in the affected areas, and on-farm costs associated with adoption. The nature of each solution (management recommendations, policy changes, improved germplasm, or combinations of germplasm and management) was noted, along with the year of expected research product availability.

For technologies that improve yield potential, the following assumptions have been applied. The use of new plant architectures is forecast to eventually improve inbred yield potential by 10%. Hybrids have been continually documented to have a 15% advantage in yield potential over the best inbreds. Thus, a long-term 25% yield potential improvement is forecast, so as to maintain the 15% advantage over future inbreds. The revolutionary change of rice to a C4 photosynthetic pathway should break the yield potential barrier for inbreds. This could dramatically improve yield under irrigated conditions, but should have an even bigger effect in rainfed environments, as the C4 photosynthetic pathway will also dramatically improve water-use efficiency. As a result, projected yield potential gains are a 40% improvement in irrigated environments and a 50% improvement in rainfed environments. It is assumed that the proportional increase in yield potential transfers to the same proportional increase in actual yield.

Adoption was projected for the period of 2011-35 on the basis of assumptions reflecting research product availability, the nature of the technology, and the target environment. Adoption is assumed to start the year after initial research product availability, following an exponential curve during the period. Modest growth presumptions in line with previous adoption studies on rice technologies were applied, and these assume the fastest rates of diffusion for improved varieties (2–2.5% per year), whereas management solutions had the slowest diffusion (1–1.5% per year). Lower rates refer to rainfed environments, given that they often receive poorer extension and service provision.

Potential annual research benefits per hectare were calculated by multiplying the conditional yield gain per hectare, a technology efficiency estimate, and the unit price of paddy (fixed at a nominal $250 per ton), and then subtracting adoption-associated costs. To obtain gross annual research benefits, these gains per hectare were multiplied by the area affected by the constraint/opportunity and the adoption rate was estimated in a particular year. These calculations were performed separately for irrigated and rainfed environments.

The resulting estimates reflect total benefits from development, adaptation, testing, and extension of technologies that GRiSP will spearhead. They reflect more than impact attributable to GRiSP alone, as there are many partners in the research and extension system that need to make complementary investments to realize these impacts. Moreover, in the absence of GRiSP, other rice research actors would remain in place, and technology development would occur, albeit at a slower and less coordinated pace.

To reflect the attributable contribution of GRiSP to these benefits, this analysis made the conservative assumption that all GRiSP research products would be available eventually even in the absence of international rice research efforts. However, in GRiSP's absence, these products would be available later. In irrigated environments, it is assumed that, without GRiSP, research product availability will be delayed by 5 years. In rainfed environments, the delay is assumed to be longer, at 8 years, due to lower research, extension, and service intensities by others for those areas. GRiSP-attributable benefits are calculated by taking the difference between gross annual research benefit flows and scenarios in which those flows are delayed by the periods noted above.

This analysis represents an initial attempt to analyze expected benefits. Key limitations include that

- Not all technologies are included (e.g., postharvest, biofortification, quality improvement, etc.).
- Estimates of rice area affected by and yield losses for various abiotic and biotic constraints often rely on older data, and do not have adjustments for future changes.
- Adoption curves could be further refined with additional partner input.
- Geographic disaggregation is limited.
- Calculations focus on gross annual research benefits using a fixed rice price, rather than economic surplus effects.

Results. In terms of yield reducers and limiters, the analysis finds that current average exploitable yield gaps are about 2 t/ha in irrigated systems (the difference between attainable yield and current average yield) and 1 t/ha in rainfed systems. Nutrients, water, diseases, and weeds play a large role in current yield gaps in both environments relative to specific abiotic stresses, such as submergence, salinity, heat, or Fe toxicity (details on the estimated relative contributions of each of those can be provided upon request). In later years, after C4 rice is developed, increasing yield potential offers more economic benefits than does closing yield gaps.

The analysis finds that the development, adaptation, and dissemination of GRiSP technologies has the potential to generate a total of $58 billion of discounted gross benefits by 2035, with $5.0 billion of discounted annual benefits and 67 million net additional tons of production in that year alone, as a result. By 2020, $6.13 billion of discounted gross benefits, $1.54 billion of discounted annual benefits, and 10.0 million net additional tons of annual production will result.

Assuming that GRiSP technologies would become available, but would be moderately delayed in GRiSP's absence, GRiSP is attributable for $32.4 billion of these discounted gross benefits and 30.7 million net additional tons of production by 2035. Set against $1.0 billion of South Asian investment over the period, this translates into a 32.4:1 benefit-cost ratio under a 5% discount rate. By 2020, $5.14 billion of discounted gross benefits and 9.6 million net additional tons of annual production would be specifically attributable to GRiSP, with a benefit-cost ratio of 12.9:1.

Ex ante assessment of potential GRiSP solutions and impact in sub -Saharan Africa

Methods. The potential impact of GRISP research on poverty in Africa was assessed separately for the populations of rice-producing farmers and rice consumers (excluding rice producers) in 31 rice-producing countries in sub-Saharan Africa (Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Comoros, Dem. Rep. of Congo, Rep. of Congo, Côte d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Swaziland, Tanzania, Togo, Uganda). The total rice area harvested in these countries in 2009 was about 9.9 million ha, which represents 99.3% of the total harvested area of SSA countries. Their total paddy rice production for the same year was 19.1 million t, with a share of 99.1% of SSA total production. Thus, the results of this analysis can be considered applicable for all of SSA.

Methods for assessment at the rice farmer's level. For rice farmers, we have used data from farm household surveys conducted in 2007 and 2008 in 12 countries (Benin, Burkina Faso, Cameroon, Central African Republic, Democratic Republic of Congo, Mali, Nigeria, Rwanda, Senegal, Sierra Leone, Chad, and Uganda). The major stresses found across the countries surveyed were rats/rodents, diseases, insects, weeds, nutrients/soil, flooding, drought, and birds. These constraints were reported by more than 90% of the surveyed farmers as major stresses they have experienced in the past 4 to 5 years at the time of the survey. These stresses cause yield losses of up to 35% when they are experienced by farmers. The empirical models used to assess gross annual research benefits and the number of poor lifted above the poverty line among rice farmers are both autoregressive models of total household annual income and village-level poverty headcount index, with the contemporaneous yield losses caused by the eight major stresses as additional explanatory variabl es:

$$Y_{t,h} = \alpha Y_{t-1,h} + \beta I_{t,h} + \gamma X_{t,h}$$

where $Y_{t,h}$ is the total income of household *h* in year *t* (in the case of the model used to assess impact on total household income) or the headcount poverty index of village *h* (in the case of the model used to assess impact on poverty), $I_{t,h}$ is the percentage yield loss caused by a given stress experienced by household (resp village) *h* in year *t* with a value of zero if the household (resp village) does not experience the stress that year, and $X_{t,h}$ is a set of other factors that also determine household income or poverty. We assume that the occurrence of stresses and the yield losses they cause to farm households are exogenous to their decisions so that estimation of the AR1 model by ordinary least squares yields consistent estimates of the parameters a and ß. In general, the level of $Y_{t,h}$ depends on its past values up to a certain period, *k*. But, because of the limited data we have on past income, we restricted this dependence to just one period, which gives us a first-order autoregressive (AR1) model. The AR1 model is reasonably realistic in most economic settings and is enough to allow us to forecast the mean impact of a constant annual reduction in yield loss caused by one of the eight stresses starting in a given year, t_0, on household income or poverty in that same year and in any subsequent year, $t_0 + k$, in the future as

$$E\Delta Y_{t_0+k,h} = \beta \sum_{j=0}^{k-1} \alpha^j E\left(\Delta I_{t_0+k-j,h}\right) = \beta r \frac{1-\alpha^k}{1-\alpha} \quad k = 1,2,\ldots$$

where r is the constant annual average yield loss reduction for a given stress when holding all other variables (including the yield loss for the other stresses) constant.

After estimating and validating the equation for each stress, we used the estimated parameters and the formula above to forecast the average impact of an r% yield loss reduction on household income and poverty for each stress from 2015 to 2035. The assumed reduction in the percentage yield loss is, respectively, 0% for rats/rodents, 5% for diseases, 3% for insects, 6% for weeds, 7% for nutrients/soil, 8% for flooding, 7% for drought, and 4% for birds. We assume that GRiSP research products targeted to the eight stresses will be available to African rice farmers starting in 2015 (i.e., t_0 = 2014 in the above formula).

Estimation of aggregate economic benefits from GRiSP research. The AR1 model is estimated separately for each stress using household-level data on total household annual net income in 2007 (including crop and noncrop income), yield loss for each stress, and household socio-demographic and economic variables. The total income is converted to U.S. dollars using the exchange rate of each currency as found in the World Development Indicators database. The annual expected benefits are then forecast as described above. These benefits are average benefits for the whole population of rice farmers (across adopting and nonadopting farmers). These average benefits are then multiplied by the total estimated annual population of adopting rice farming households in each country. Adoption of GRiSP research products is assumed to follow a logistic diffusion curve with different parameters for the eight stresses, with peak adoption rates ranging from 5% for rats/rodents to 45% for diseases (details can be provided upon request). The total number of rice-farming households in each of the 31 countries included in our analysis was estimated by taking the ratio of the country's total rice harvested area (obtained from FAOSTAT) and the average rice area per household (estimated from the farm household surveys) and multiplying it by the country's average annual rural population growth (from the World Development Indicators). We then aggregated across the 31 countries and used a 5% discount rate to discount the annual nominal benefits before summing across years to get the net present value of the aggregated economic benefit in 2010.

Estimation of the reduction in the number of poor rice farmers. This analysis is done at the village level because poverty is a community outcome. We compute each village poverty headcount by using household per capita income and the poverty line used is the $1.25 per day multiplied by each country's PPP value (obtained from the African Development Bank). This village poverty headcount is the dependent variable in the AR1 model estimated. The additional explanatory variables used are the village average yield loss for each stress for the year 2007 and other village-level data on access to extension services and to various types of infrastructure (tarred roads, markets, health centers, etc.). The impact estimated from the AR1 model is the average annual reduction in the village-level poverty headcount, which was multiplied by the number of rice farmers in the country, the latter estimated by multiplying the total number of farming households (as estimated above) by the average household size (estimated from the eight countries' survey data).[16]

[16] To see that this provides a consistent estimate of the reduction in the total number of poor rice farmers at the national level, let p_v represent the reduction in the average village poverty headcount and N_v the average population size of rice farmers in a village so that the average number of rice farmers in a village lifted out of poverty is $Q_v = N_v{*}P_v$. Now, if Q is the total number of rice farmers lifted out of poverty in the whole country, N the total number of rice farmers in the country, N_a the total number of adopting rice farmers, and K the total number of rice-farming villages with adopters, then we have $N = K{*}N_v$, so that $Q = K{*}Q_v = N{*}P_v$.

Results. The results show that if GRiSP research products that reduce the yield loss from each one of the eight major stresses are available to African rice farmers in 2015, then the aggregate discounted gross annual benefit for the adopting rice farmers in the 31 countries would reach $159 million by 2020 and $2.6 billion by 2035. This corresponds to an aggregate average annual nominal income gain of about $256.4 million per year from 2015 to 2035. The highest impacts are observed for research that addresses yield loss caused by weeds, birds, rats, insects, and lack of nutrients. In terms of impact on poor rice producers, it is projected that, within 5 years of availability of GRiSP research products in Africa (i.e., in 2020), 6.16 million African rice farmers under the $1.25 poverty line would be lifted out of poverty. This number would reach 14.75 million in 2035.[17]

[17] These numbers are reductions in the number of poor achieved with the reduction in yield loss due to birds, which gives the maximum reduction in poverty across all the major stresses (followed by weeds).

Appendix 2: Logframes of Products, Milestones, Outcomes

Theme 1: Harnessing genetic diversity to chart new productivity, quality, and health horizons

R&D Product Line: 1.1. Ex situu conservation and dissemination of ricegermplasm

Research Partners	Rice genebanks (international, regional, national, community) and other stakeholders contributing policy and technical expertise in the development and implementation of a rational, efficient, effective global system for the conservation and dissemination of rice germplasm
Local adapters:	Geneticists, conservation biologists, molecular biologists, breeders and farmers needing access to rice germplasm to meet their development objectives
Disseminators:	Public and private sector breeders and seed producers using rice germplasm
Expected impact:	Agricultural development enhanced and made sustainable through delivering the germplasm users need to adapt to any current or f future challenge
Key current projects:	Global Crop Diversity Trust, Generation Challenge Programme, GTZ

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
1.1.1 Sustained management of the CGIAR rice collections	**M1.1.1.1 (On-going)** Existing accessions conserved (regenerated and safeguarded) according to best practices to ensure their viability and availability.	Global	IRRI, AfricaRice, CIAT	**Short- and long-term:** Farmers, scientists and rice breeders better able to respond to current and future challenges by using rice germplasm conserved in the CGIAR genebanks.
	M1.1.1.2 (On-going) Accessions distributed as requested in compliance with ITPGRFA**.**	Global	IRRI, AfricaRice, CIAT	
	M1.1.1.3 (2012) Plan for rationalized conservation and maintenance of the IRRI, AfricaRice and CIAT collections established and implemented.	Global	IRRI, AfricaRice, CIAT	
	M1.1.1.4 (2013) Duplication of all CIAT accessions to the GRC at IRRI, as part of the Global system (1.1.2).	Global	CIAT	
1.1.2 Enhanced conservation of the global rice gene-pool	**M1.1.2.1 (2012)** Coherent strategy for maintenance and supply of rice genetic resources, including mutants, DNA and other genetic stocks and breeding materials.	Global	IRRI, AfricaRice, CIAT	**Short- and long-term:** Farmers, scientists and rice breeders better able to respond to current and future challenges by using rice germplasm conserved by partners in the global system.
	M1.1.2.2 (2013) Coherent strategy for the conservation of rice accessions in all major participating national, regional and international genebanks	Global	IRRI	
	M1.1.2.3 (2015) Relationships between accessions in the major collections documented to facilitate rational decisions	Global	IRRI, AfricaRice, CIAT	
	M1.1.2.4 (2015) *Gaps in collections through geographic, trait and molecular characterization identified, and 4 collection missions conducted in partnership with NARES.*	Global	IRRI, AfricaRice, CIAT	

1.1.3 Improved conservation or rice in genebanks	**M1.1.3.1 (2011**) Installation of the barcode system completed.	Global	AfricaRice	**Short- and long-term:** Rice genetic resources conserved more efficiently and effectively with minimum loss of genetic and physiological quality
	M1.1.3.2 (2012) Upgraded facilities for maintenance of CIAT working collection of germplasm, CSSL and mutants	Latin America	CIAT	
	M1.1.3.3 (2013) Seed physiology and genetic studies carried out to define best practice.	Global	IRRI	
	M.1.1.3.4 (2014) Revised procedures devised and implemented for improved seed multiplication	Global	IRRI	
	M1.1.3.5 (2015) Storage maturity and seed longevity characteristics for 12 wild species determined.	Global	IRRI	
	M.1.1.3.6 (2015) Revised procedures devised and implemented for improved seed processing and storing	Global	IRRI	
	M.1.1.3.7 (2015) *Revised procedures devised and implemented for improved germplasm tracking*	*Global*	*IRRI*	
1.1.4. Data management for quality assurance	**M1.1.4.1 (2012)** All available information on genebank accessions (passport, characterization, maintenance, distribution, and IPR) documented in IRIS.	Global	IRRI, AfricaRice, CIAT	**Short-term**: All information of the current genebank collections available to and widely accessed by users. Screening of *O. glaberrima* for new characteristics by breeders accelerated. **Long-term:** Enhanced use of genetic variability and accelerated breeding activities in national and international breeding programs. Core collections available for use by breeders.
	M1.1.4.2 (2013) Improved quality assurance and workflow management system implemented through upgraded GRIMS (Genetic Resources Information Management System)**.**	Global	IRRI	
	M1.1.4.3 (2014) Online genetic resources seed request processing system with enhanced SMTA support to comply with developing requirements of the Treaty**.**	Global	IRRI	
	M1.1.4.4 (2015) Cross-linkage of genetic resources information system with Integrated Breeding Platform (Global Crop Diversity Trust/GRIN-Global/GENESYS collaboration).	Global	IRRI	
	M1.1.4.5 (2015) AfricaRice germplasm management system integrated with IRIS	Global	AfricaRice	
	M1.1.4.6 (2015) *CIAT germplasm management system integrated with IRIS*	*Global*	*CIAT*	

R&D Product Line: 1.2. Characterizing genetic diversity and creating novel gene pools

Intermediate users: Geneticists, breeders, global plant scientists
Final users: Public and private sector breeders and seed producers using rice germplasm
Expected impact: Rice global genetic resources conserved, documented and characterized for added value for their utilization.
Key current projects: Japan Rice Breeding, Bayer-SKEP, Syngenta-SKEP, GCP, BMGF-GSR, USDA

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
1.2.1. High resolution SNP genotypes of diverse accessions and high-throughput SNP genotyping platform (Rice SNP Consortium)	**M1.2.1.1 (2011)** Facility for high-throughput DNA extraction, sample tracking, and SNP genotyping set up at in GAMMA Lab at IRRI and made available for AfricaRice researchers.	Global	IRRI, AfricaRice,	**Short-term:** New insight into the structure of genomic diversity in rice. The SNP Lab infrastructure will enable rapid, cost-effective, and precise DNA fingerprinting and varietal identification, and tracking. Rice breeders in at least 30 countries will utilize genetic characterization information for elite breeding lines in the release pipeline. **Long-term:** The SNP haplotype map together with phenotype data will provide a powerful association genetics platform to identify key SNPs associated with desirable alleles for traits of interest. The SNP labs will greatly increase the speed and efficiency of diversity analysis, genetic mapping, variety tracking, and MAS.
	M1.2.1.2 (2012) Genotype data from 600K SNP chip on 2,500 accessions acquired and loaded into a database with web visualization.	Global	Cornell University, IRRI, Cirad	
	M1.2.1.3 (2013) Genotype data analyzed to review genetic structure in the *O. sativa* genepool and identify definitive diagnostic markers for variety-type classification and pedigree analyses.	Global	IRRI	
	M1.2.1.4 (2014) *Variety deployment and adoption tracked in farmer's fields in selected regions in South Asia and Sub-Sahara Africa using SNP fingerprints*	*Global*	*IRRI, AfricaRice*	
	M1.2.1.5 (2015) 2500 *O. glaberrima* lines analyzed for SNP variation	Africa	AfricaRice, IRD	
1.2.2. Global phenotyping network for key agronomic traits and responses to major stresses, including climate change traits	**M1.2.2.1 (2012)** New large scale infrastructure for precision high-throughput screening for abiotic stresses (climate change-related stresses).	Global	IRRI, Cirad, CIAT AfricaRice	**Short-term:** Efficient high throughput phenotyping techniques for climate change related stresses developed and adopted across research agencies **Long-term:** Improved phenotyping protocols and tools enable faster varietal
	M1.2.2.2 (2012) High throughput digital system for yield and related traits.	Global	IRRI	
	M1.2.2.3 (2014) Non-invasive controlled environment and field-based phenotyping tools for assessing stress responses.	Global	IRRI, AfricaRice	
	M1.2.2.4 (2015) Effective protocols for quantifying stress responses for current and emerging biotic and abiotic challenges.	Global	IRRI, CIAT, AfricaRice	

	M1.2.2.5 (2013) Three sub-samples of 200 accessions, each representative of the diversity of the indica, tropical japonica or temperate japonica phenotyped for one or more climate change related traits	Global	IRRI, CIAT, Cirad	development
1.2.3. Whole genome sequencing of all unique germplasm accessions held in the genebanks at IRRI, CIAT, AfricaRice, and other global genetic stocks	**M1.2.3.1 (2013)** Low cost sequencing methods tested and optimized on a subset of accessions as a proof-of-concept.	Global	IRRI CIAT Cornell University University of Arizona CAAS Beijing Genomics Institute and other institutes	**Short-term:** De novo sequencing of the genebanks and other materials such as advanced varieties will establish a reverse genetics system employed in genebanks worldwide for management of conserved germplasm, revealing rare alleles, enabling targeted phenotyping, and gene discovery. **Long-term:** Sequencing the rice gene pool(s) will profoundly impact the rate of genetic discovery in rice and provides the ultimate resource for allele mining for the next generation of useful genes for breeding applications.
	M1.2.3.2 (2014) DNA bank containing 100,000 rice accessions completed and made available for sequencing.	Global	IRRI	
	M1.2.3.3 (2015) Whole genome sequence data obtained for 10,000 rice accessions and loaded into a database with web visualization (at an estimated cost of sequencing and support of $10 million for 100,000 accessions).	*Global*	*IRRI*	
1.2.4. Specialized genetic stocks and novel populations through enhanced recombination of cultivated and wild gene pools	**M1.2.4.1. (2013)** 1000 indica and japonica MAGIC lines and 5 RIL populations phenotyped for abiotic and abiotic stresses and/or biomass, grain quality, and nutritional components.	Global	IRRI, AfricaRice, CIAT	**Short-term:** Rice breeders and geneticist in at least 10 countries regularly access to diverse highly recombined populations for use in QTL analysis and breeding; Diverse MAGIC lines among AA-genome species/ accessions will facilitate gene discovery for a wide-range of traits. 10-20 varieties, including 5 glaberrima varieties, released in 10 countries. **Long-term:** New QTLs for biotic and abiotic stresses are used routinely in breeding rice in at least 15 countries. Novel genes and QTLs from the secondary gene pool for biotic and abiotic stress
	M1.2.4.2. (2014) CSSLs, iBridges, and AA-genome MAGIC populations established and genotyped by SNP markers.	Global	IRRI, IRD, CIAT AfricaRice	
	M1.2.4.3. (2014) A synthetic population derived from recombining 50 indica and japonica elite accessions developed.	Global	Cirad	
	M1.2.4.4. (2015) Fixed interspecific lines (*O. sativa* x *O. glaberrima*) for rainfed and lowland ecosystems; improved populations of *O. glaberrima* obtained with new variation in resistance to lodging and grain shattering;	Global	AfricaRice, IRD	
	M.1.2.4.5. (2015) Description and mapping of interspecific sterility genes between the two cultivated species**.**	Global	IRD, AfricaRice	

				tolerances and other traits are used routinely in breeding rice in at least 15 countries. Rice breeders are provided with populations for harnessing indica x japonica complementarities and heterosis. By 2020, 1,200,000 ha under varieties possessing genetic portion of indigenous *Oryza* species in Africa. 0.1 million ha under *O. glaberrima* varieties in rainfed ecosystems of Africa.

R&D Product Line: 1.3. Genes and allelic diversity conferring stress tolerance and enhanced nutrition

Intermediate users:	Geneticists, molecular biologists, global plant scientists
Final users:	Public and private sector breeders and seed producers using rice germplasm
Expected impact:	Large-effect genes available for precision rice breeding leads to enhanced, targeted varietal development
Key current projects:	MAFF-IRRI, GCP, BMGF-,STRASA, BMZ, BMGF/CAAS-GSR, BMGF/USAID-CSISA, RDA-IRRI, Fontagro-CIAT, ACIAR-Chalk, USAID, RDA-TRRC, VLIR (Belgium)

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
1.3.1. Genes for drought tolerance	**M1.3.1.1 (2014)** At least two drought QTLs sequenced, candidate genes short-listed, and gene-based markers available to breeders	South and Southeast Asia, South America, Africa	IRRI	**Short-term:** Transgenic and MABC-derived rice cultivars with enhanced drought tolerance are used by breeders worldwide. **Long-term:** Major genes for drought tolerance routinely used in breeding programs and drought-tolerant rice widely adopted
	M1.3.1.2. (2012) Candidate genes and alleles for drought adaptation identified by whole-genome association study based on phenotyping network	South and Southeast Asia, South America, Africa	Cirad, AfricaRice	
	M1.3.1.3 (2015) Major drought tolerance genes validated and function determined	South and Southeast Asia, South America, Africa	IRRI, AfricaRice	
1.3.2. Genes for flood-prone environments	**M1.3.2.1 (2013)** Molecular mechanism of Sub1-related tolerance mechanism understood and relevant genes identified. **M1.3.2.2 (2014)** Major gene(s) for anaerobic germination validated and their function understood.	Myanmar, Cambodia, Vietnam, Philippines, Indonesia, Bangladesh, India, Sierra Leone, Guinea, Liberia Myanmar, Cambodia, Vietnam, Philippines, Indonesia, Bangladesh, India, Sierra Leone, Guinea, Liberia	IRRI IRRI	**Short-term:** Molecular basis of submergence tolerance and anaerobic germination understood and gene-based markers are used by breeders world wide **Long-term:** Major genes for submergence tolerance and anaerobic germination tolerance present in mega-varieties and rice for direct seeded system, reduces submergence losses
	M1.3.2.3 (2015) Major gene(s) for enhanced tolerance of submergence from non-Sub1 sources validated and their function understood.	Myanmar, Cambodia, Vietnam, Philippines, Indonesia, Bangladesh, India, Sierra Leone, Guinea, Liberia	IRRI	
1.3.3. Genes for nutrient deficiency and problem soils	**M1.3.3.1 (2013)** Major gene(s) for P-deficiency tolerance identified, function understood, and applied in MABC breeding	South Asia, Southeast Asia, Africa, South America	IRRI, JIRCAS, AfricaRice	**Short-term:** At least two major genes for soil-related stresses and gene-based markers used for

	M1.3.3.2 (2014) Major gene(s) for salinity tolerance at the Saltol locus identified, function understood, and gene-based markers developed for breeding.	South Asia, Southeast Asia, Africa, South America	IRRI, AfricaRice	breeding rice with enhanced yield in problem soils. Phenotyping platform established and QTL genes identified for NUE including BNI trait. Superior germplasm used by NARES breeders of 8 NARES countries. **Long-term:** Five high yielding rice varieties adapted to problem soils and low-input systems grown by farmers in Asia and Africa; MAS for NUE used by breeders on low N environment in at least 4 countries to reduce N-cost to farmers and environment; gene markers associated NUE NUE; NUE efficient genotypes/ varieties for Africa, LAC with 10-15% increase in NUE.
	M1.3.3.3 (2013) Major association QTLs for salinity tolerance within the temperate japonica group identified and fine mapped.	South Asia, Southeast Asia, Africa, South America	Cirad	
	M1.3.3.4 (2015) Major genes for salinity tolerance at two other major loci identified, precise markers developed, and function understood.	South Asia, Southeast Asia, Africa, South America	IRRI, AfricaRice	
	M1.3.3.5 (2015) At least two sets of populations for NUE and BNI traits developed and two major QTL identified for NUE.	South Asia, Southeast Asia, Africa, South America	CIAT	
1.3.4. Genes for temperature extremes and grain quality	**M1.3.4.1. (2012)** At least 10 genes and alleles for chilling and heat tolerance identified by whole-genome association study based on phenotyping network	South and SE-Asia, Africa, South and Central America, Chile, Brazil, Uruguay	Cirad, AfricaRice	**Short term:** Major new genes conferring tolerance of extreme low or high temperature during vegetative and reproductive growth identified and markers used by NARES breeders. **Long-term:** Major genes introgressed into mega varieties that are adopted to stabilize yield and maintain high grain quality in a future warmer climate or extremes.
	M1.3.4.2 (2014) Major gene(s) for tolerance of heat at flowering identified, function understood, and used in MABC breeding.	South and SE-Asia, Africa, South and Central America, Chile, Brazil, Uruguay	IRRI	
	M1.3.4.3 (2015) Major gene(s) for tolerance of cold stress at seedling and reproductive stages identified and function understood.	South and SE-Asia, Africa, South and Central America, Chile, Brazil, Uruguay	AfricaRice, RDA-Korea	
	M1.3.4.4 (2015) Major gene(s) important for yield and grain quality in a warmer climate identified, function understood, and markers available for breeding.	South and SE-Asia, Africa, South and Central America, Chile, Brazil, Uruguay	IRRI	

1.3.5. Genes for disease and insect resistance	**M1.3.5.1 (2012)** RYMV2 resistance gene cloned from *O. glaberrima* and gene-based markers available	Africa	IRD	**Short term:** At least 3 major resistance genes validated and 5 popular varieties with resistance to major pests and diseases released and promoted by national systems **Long-term:** Reduction in pest and disease outbreaks in target regions by deployment of validated resistance genes
	M1.3.5.2 (2013) New resistance genes to African Gall midge identified.	Africa	AfricaRice	
	M1.3.5.3 (2014) Genes involved in resistance to rice tungro spherical and bacilliform viruses validated.	Tropical Asia	IRRI	
	M1.3.5.4 (2015) Broad-spectrum blast resistance (*Pi*) genes, and bacterial blight genes (*Xa*) validated, recessive resistance gene against African *Xoo* strains cloned, and markers available to breeders	Global	IRRI, IRD, CIAT	
	M1.3.5.5 Genetic basis and regulatory network of defense mechanisms in rice cultivars with durable resistance elucidated	Global	Cirad, INRA, IRD	
1.3.6. Genes for improving the architecture and function of rice roots and panicles	**M1.3.6.1 (2013)** Key traits and processes identified that are important for root development and function through comparative analyses of specialized genetic stocks	Global	Cirad, IRRI, CIAT	**Short term:** Superior alleles and molecular markers for favorable root and panicle traits available and used in breeding applications; QTLs for panicle architecture and grain filling identified **Long-term:** High yielding rice cultivars with enhanced drought tolerance and nutrient-uptake capacity widely grown in stress target environments.
	M1.3.6.2 (2013) At least 3 genes identified that improve root architecture and function	Global	Cirad, IRD, IRRI	
	M1.3.6.3 (2013) At least 3 genes identified that affect panicle structure (branching) and number of spikelets	Global	CIAT, IRD, IRRI	
	M1.3.6.4 (2013) At least 2 root QTLs identified that improve water and nutrient uptake under stress conditions	Global	Cirad, IRRI	
	M1.3.6.5 (2015) At least 2 large-effect genes for panicle and root architecture validated in different genetic backgrounds and stress environments	Global	Cirad, IRD, IRRI	

1.3.7. Transgenic pre-breeding events for stress response genes	**M1.3.7.1 (2015)** Identification of lead promoter-gene combination and at least 10 lead events for drought tolerance tested through multiple contained trials.	Global	IRRI, CIAT, JIRCAS	**Short term:** Trait genes validated for drought, extreme temperature and disease resistance, leading to pre breeding materials that are widely used by NARES and the private sector. **Long-term:** Stress resilient varieties widely adopted by farmers to mitigate risk.
	M1.3.7.2 (2015) *At least 10 lead events for disease resistance identified through field evaluation*	*Latin America*	*CIAT, NIAS*	
	M1.3.7.3 (2015) At least 10 lead events for extreme temperature resistance identified through field evaluation	Latin America	CIAT, NIAS	
1.3.8. Gene identification and validation pipeline	**M1.3.8.1 (2015)** Gene-validation pipeline and facilities upgraded and available for molecular characterization and validation of high value genes	Global	IRRI	**Short term:** Research and service hub and molecular characterization pipeline for high-value genes backstops the development of transgenic rice in Asia **Long-term:** High-value genes present and functional in most widely adopted mega-varieties
	M1.3.8.2 (2015) *Novel transformation system with site-specific integration, and temporal and spatial control of transgene expression established.*	*Global*	*IRRI, Cirad, CIAT*	
	M1.3.8.3 (2015) Bioinformatics platform established for the integrated analysis of genetic and genomic datasets, and continuous training provided to end users.	Global	IRRI	

R&D Product Line: 1.4. C4 Rice

Intermediate users: Global plant scientists
Final users: Rice farmers worldwide
Expected impact: Quantum leap in rice productivity across all environments; reduced nutrient and water use, hence minimize environmental impact.
Key current projects: BMGF- C_4 rice consortium

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
1.4.1. C_4 rice with improved photosynthetic efficiency and productivity	**M1.4.1.1 (2012)** Different mutant phenotypes with altered leaf anatomy & C4 biochemistry identified from activation tagged rice mutants and sorghum revertants.	Global	IRRI	**Short-term:** Improved understanding of the genetic prerequisites for C_4-ness, including leaf anatomy and biochemical pathways enables rice genotypes with C_4-like characters which are adapted into local varieties by NARES **Long-term:** Large increases in productivity and resource-use efficiency as a result of adoption of C_4 mega varieties.
	M1.4.1.2 (2012) Kranz anatomy regulators and transcriptome atlas of mesophyll cell and bundle sheath cell in sorghum determined.	Global	IRRI	
	M1.4.1.3 (2012) A collection of rice genes relevant to C_4 pathways established based on bioinformatic search and comparative genomic analysis among C_3 and C_4 grasses.	Global	IRRI	
	M1.4.1.4 (2012) Wild rice accessions showing C_4-ness characters identified.	Global	IRRI	
	M1.4.1.5 (2012) Molecular toolbox developed to isolate promoters that drive mesophyll cells and bundle sheath cell-specific gene expression in rice.	Global	IRRI	

Theme 2: Accelerating the development, delivery, and adoption of improved rice varieties

R&D Product Line: 2.1. Breeding informatics and multi-environment testing

Intermediate users: GRiSP breeders
Final users: Public and private sector breeders worldwide
Expected impact: More efficient breeding programs lead to accelerated and more precise development of new varieties
Key current projects: BMGF-STRASA, BMGF-GSR, Japan Rice Breeding, GCP-IBP, GTZ,

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
2.1.1. Integrated breeding platform with rice-specific marker applications and decision tools	**M2.1.1.1 (2012)** Efficient analytical pipelines for breeding value prediction developed; ICIS with all functions needed for the management of rice breeding logistics released; Datasets in current IRIS reorganized and historical datasets from AfricaRice and CIAT uploaded	Global	IRRI	**Short-term:** Rice breeders in GRiSP adopt IRIS for managing breeding logistics and data and the decision supporting tools for crossing design, marker-assisted backcrossing and gene pyramiding **Long-term:** Rice breeders routinely use IRIS to access information on rice germplasm and the decision supporting tools to design their marker-assisted breeding programs, with better tailored varieties, as a result.
	M2.1.1.2 (2012) R package for analyzing breeding trials deployed.	Global	IRRI;	
	M2.1.1.3. (2013) Genotyping system for SNPs that are diagnostic for important traits developed and diagnostic SNP markers for key traits (including grain quality, BLB, blast and tungro resistance) validated, optimized, and made available for deployment in breeding programs	Global	IRRI; CIAT, AfricaRice	
	M2.1.1.4 (2014) Breeding decision supporting tools for cross selection, marker-assisted backcrossing and gene pyramiding developed.	Global	IRRI; CIAT	
	M2.1.1.5 (2015) Simulation system for optimizing marker-assisted recurrent selection developed.	Global	IRRI, CIAT-Cirad	
2.1.2. Global rice germplasm information system to support rice breeding	**M2.1.2.1 (2011)** User friendly web access to germplasm data with associated phenotypic information.	Global	IRRI; AfricaRice; CIAT	**Short-term:** Rice breeders are able to manage and visualize their own data in the context of integrated public data, with preliminary breeding decision support tools **Long-term:** Rice breeders are able to manage and visualize their data in a fully integrated system with complete breeding decision support tools.
	M2.1.2.2 (2012) Integrated genomic, high throughput genotyping and phenotyping data with visualization tools.	Global	IRRI; AfricaRice; CIAT	
	M2.1.2.3 (2013) Integrated database with breeding workflow and preliminary breeding support tools.	Global	IRRI; AfricaRice; CIAT	
	***M2.1.2.4 (2015)** Fully integrated information system to support rice breeding with visualization, analysis and decision-making tools.*	*Global*	*IRRI*	

2.1.3. Multi-environment testing and international germplasm evaluation (INGER)	**M2.1.3.1 (2011)** Design of new, multi-stage regional MET networks, including participatory variety selection and analytical pipeline for processing data	Global	IRRI (Asia), AfricaRice & IRRI (Africa), CIAT (LAC)	**Short-term:** Improved performance data and feedback from local breeders, farmers, extension workers, millers and consumers allows rice breeders to improve targeting of rice breeding programs to environments and markets **Long term:** Enhanced genetic gain (yield, stress tolerance) and faster release of new varieties with specific adaptation to local environments and market segments; rice breeding capacity built in Africa
	M2.1.3.2 (2012) Three regional MET networks (Rice Breeding Task Forces) established to test breeding lines from breeding programs of IRRI, AfricaRice, CIAT, and key partners, and to build capacity in rice breeding (especially in Africa)	Global	IRRI (Asia), AfricaRice & IRRI (Africa), CIAT (LAC)	
	M2.1.3.3 (2013) At least 1000 unique and advanced breeding lines from IRRI, AfricaRice, CIAT and NARES evaluated and disseminated in at least 15 Asian, 15 African, and 5 Latin American countries thru INGER nurseries	Global	IRRI, AfricaRice, CIAT-FLAR	
	M2.1.3.4 (2014) Comprehensive global and regional analysis of GxE of key traits	Global	IRRI, AfricaRice, CIAT	
	M2.1.3.5 (2015) At least 250 INGER nursery entries utilized in hybridization and at least 20 elite and multiple stress tolerant lines selected by at least 20 NARES for national testing and possible varietal release	Global	IRRI, Africa Rice, CIAT	

R&D Product Line: 2.2. Improved donors and genes/QTLs conferring valuable traits

Intermediate users:	GRiSP breeders
Final users:	Public and private sector breeders worldwide
Expected impact:	More efficient breeding programs lead to accelerated and more precise development of new varieties
Key current projects:	BMGF-CSISA, BMGF-GSR, GTZ, Pioneer-SKEP; ADB-Planthoppers, Japan Rice Breeding

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
2.2.1. Novel gene sources for breeding	**M2.2.1.1 (2012)** 10 high yielding indica lines developed by introducing valuable traits (drought tolerance, resistance to blast, bacterial blight, or nematodes) from wild species and *O. glaberrima*	Global	IRRI, AfricaRice, CIAT, IRD	**Short-term:** NARES partners using new genes/QTLs/ pyramided lines in stress tolerance breeding programs **Long-term:** Varieties with wild species genes having broad spectrum resistance cultivated by farmers. Yield of rice varieties increased with introgression of yield enhancing loci from wild species
	M2.2.1.2 (2013) 3 new genes pyramided for resistance to BPH from 2 wild species and 3 QTLs introgressed for drought tolerance from *O. glaberrrima*	Global	AfricaRice, IRRI,	
	M2.2.1.3 (2015) *Yield enhancing loci "wild species alleles" introgressed from O. rufipogon into 5 elite breeding lines with 10% increase in yield over recurrent parent*	*Global*	*IRRI, CIAT*	
2.2.2. Disease-resistant rice	**M2.2.2.1 (2012)** 5 pyramided lines for blast resistance and 10 for bacterial blight resistance developed and distributed	Global	IRRI; CIAT; Cirad	**Short-term:** Release of 5 varieties with multiple resistance in target rice production environments **Long-term:** Reduction in disease outbreaks and crop losses (yield, quality) across different rice production environments, globally.
	M2.2.2.2 (2013) Gene-based markers for two new genes for resistance to each of bacterial blight, blast and tungro virus utilized and pathogenicity and molecular diversity studies conducted for RGSV and RRSV	Global	IRRI, IRD	
	M2.2.2.3 (2013) Phenotyping methods developed and strategies designed for breeding for host plant resistance to sheath blight.	Asia	IRRI	
	M2.2.2.4 (2014) Five components of brown spot resistance quantified; At least 2 resistance sources identified; QTLs accounting for at least 40% of PVE identified.	Asia	IRRI	

	M2.2.2.5 (2015) Two lines for blast resistance for LAC	LAC	CIAT	
	M2.2.2.6 (2015) Broad spectrum resistance against blast based on knowledge of the pathogen population structure	Global	JIRCAS, AfricaRice	
2.2.3. Insect-resistant rice	**M2.2.3.1. (2012)** At least 3 genes/QTLs for BPH pyramided.	Asia	IRRI	**Short-term:** New pyramided lines with 3 genes for BPH resistance developed and disseminated to NARES, durable resistances to major hopper pests identified and agronomic/management for resistance maintenance devised. **Long-term:** Farmers deploy resistant and tolerant lines in South and South East Asia.
	M2.2.3.2 (2013) 2 promising sources of stem borer resistance/tolerance identified, and mechanisms of resistance to BPH and stem borer determined in 2 genotypes.	Asia, Africa	IRRI. AfricaRice	
	M2.2.3.3 (2014) Improved screening techniques for resistance to BPH and stem borer developed in Africa and LAC Laboratory hopper strains from NILs/ pyramided lines produced for determination of gene compatibility.	Global	AfricaRice, CIAT, IRRI	
2.2.4 Population improvement	**M2.2.4.1 (2012)** Four 10-parent recurrent selection populations (high yielding, wide-adaptation, stable yield, physiological trait-oriented, and drought tolerant) developed based on agronomic, morpho-physiological and genome SSR information of parental lines.	Asia, LAC	IRRI; CIAT	**Short-term:** Three 10-parent RS populations developed and new male-sterile lines used in breeding programs. **Long-term:** At least 60 elite breeding lines (20 per population) from advanced cycles developed and used in pedigree breeding programs to improve the quality of NARES varieties. New varieties breaking the yield barrier of irrigated rice in Asia and optimizing drought tolerance of upland rice in Latin America and Africa.
	M2.2.4.2 (2013) One cycle of marker assisted recurrent selection for yield potential in irrigated rice and for drought tolerance in one upland rice synthetic population achieved**.**	Asia, LAC	CIAT-Cirad, IRRI, AfricaRice	
	M2.2.4.3 (2014) The feasibility of genome-wide selection using genotypic and phenotypic information produced in Theme 1 for traits related to drought tolerance tested.	Asia, LAC	CIAT-Cirad; IRRI	
	M2.2.4.4 (2014) 5 elite male sterile lines developed.	Asia, Africa	IRRI, AfricaRice	

R&D Product Line: 2.3. Rice varieties tolerant of abiotic stresses

Intermediate users: NARES breeders and other scientists, NGOs, seed producers in Africa, Asia and Latin America
Final users: Farmers in unfavorable rice environments
Expected impact: Higher productivity and income and less risk for farmers; better protection from climatic extremes
Key current projects: BMGF-STRASA, MAFF-IRRI project, BMZ-IRRI, GCP-Rice Challenge Initiative, IRRI-RDA Collaboration, Japan Rice breeding.

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
2.3.1. Drought-tolerant rice	**M2.3.1.1 (2011)** 50 T2 lines with drought tolerance genes evaluated under confined field conditions at CIAT	LAC	CIAT	**Short-term:** Rice breeders in at least 10 countries are using new drought tolerant lines. **Long-term:** Farmers grow new drought-tolerant varieties on at least 1.5 million ha.
	M2.3.1.2 (2012) Drought phenotyping at IRRI, AfricaRice, CIAT, and 24 (7 Africa, 3 CIAT, 14 S. Asia) NARES strengthened and physiological mechanisms and interactions of at least two QTLs deciphered.	Global	IRRI, AfricaRice, CIAT	
	M2.3.1.3 (2013) At least 30 new drought tolerant donors and 10 improved pre-breeding drought tolerant QTL lines for 5 QTLs identified	Global	IRRI, AfricaRice, CIAT	
	M2.3.1.4 (2013) At least three major drought yield QTLs with multiple genetic background effects identified and characterized	Global	IRRI	
	M2.3.1.5 (2013) At least three high-yielding varieties introgressed with major QTLs for grain yield under drought	Asia, Africa	IRRI, AfricaRice	
	M2.3.1.6 (2014) Drought tolerance and submergence tolerance combined in at least two lowland varieties	Asia	IRRI	
	M2.3.1.7 (2014) 100 new promising drought tolerant breeding lines developed and distributed to NARES for PVS evaluation by male and female farmers	Global	IRRI, AfricaRice, CIAT	
	***M2.3.1.8 (2015)** 50 fixed breeding lines from GCP-MARS available for PVS in WCA and ESA.*	*Africa*	*AfricaRice, Cirad*	

2.3.2. Submergence and other flood-tolerant rice	**M2.3.2.1 (2011)** 50 promising lines with tolerance to submergence and stagnant flooding developed and disseminated to NARES for PVS evaluation by male and female farmers	Africa, Asia	IRRI, AfricaRice	**Short-term:** Rice breeders in at least 10 countries are using new submergence tolerant lines. **Long-term:** Farmers grow new submergence-tolerant varieties on at least 1 million ha.
	M2.3.2.2 (2012) 100 Advanced lines available from the new crosses made in the STRASA phase 1; varietal release (5 varieties) of materials evaluated in PVS in the STRASA phase 1	Africa	AfricaRice	
	M2.3.2.3 (2013) At least 5 new donors each for stagnant flooding and anaerobic germination tolerance identified and physiologically characterized	Asia	IRRI	
	M2.3.2.4 (2013) Performance of the five best AG lines validated in field conditions with an improved management system for direct seeding	Asia	IRRI, AfricaRice	
	M2.3.2.5 (2014) Three NILs with anaerobic germination tolerance QTLs developed; At least one NIL with non-FR13A submergence QTLs developed	Asia	IRRI	
	M2.3.2.6 (2015) QTLs for stagnant flooding tolerance identified and physiology understood	Asia	IRRI	
2.3.3. Improved varieties tolerant of salt stress and other problem soils	**M2.3.3.1 (2012)** 5 elite breeding lines tolerant of Fe toxicity identified through PVS trials	Africa	AfricaRice	**Short-term:** Rice breeders in at least 7 Asian countries using new salt tolerant lines. **Long-term:** Farmers in Asia growing new salt tolerant varieties and varieties tolerant of other soil problems on at least 2 million ha.
	M2.3.3.2 (2012) 100 new promising salt-tolerant lines developed and distributed for evaluation through PVS system by male and female farmers	Asia, Africa	IRRI, AfricaRice ,	
	M2.3.3.3. (2013) Phenotyping facilities for salt and Fe toxicity stresses upgraded and at least 5 new novel donors characterized	Asia, Africa	IRRI, AfricaRice	
	M2.3.3.4. (2013) at least 6 popular varieties introgressed with *Saltol* and at least 1 variety with 1 additional QTL for salinity tolerance developed	Asia, Africa	IRRI; AfricaRice	

	M2.3.3.5. (2013) 10 elite breeding lines combining salt stress and Zn deficiency tolerance, and 5 breeding lines combining salt stress and submergence tolerance developed	Asia, Africa	IRRI	
	M2.3.3.6 (2013) 200 salt and Fe toxicity tolerant advanced lines from the crosses made in the STRASA phase 1 available	Africa	AfricaRice	
	M2.3.3.7 (2014) At least one major QTL for P-deficiency tolerance introgressed into 5 African upland mega varieties	Africa	JIRCAS; AfricaRice	
	***M2.3.3.8 (2014)** Four QTLs associated with tolerance of nutritional problems (Fe/Al toxicity, P/Zn deficiency), targeted for use in MABC.*	*Asia, Africa*	*IRRI, AfricaRice*	
	M2.3.3.9 (2015) Physiology of tolerance of salt stress and Fe toxicity tolerance unraveled, traits associated with tolerance identified for breeding	Asia, Africa	IRRI, AfricaRice	
2.3.4. Varieties tolerant to cold and hot temperatures	**M2.3.4.1 (2012)** 100 elite heat tolerant lines selected and tested in at least 6 countries in Asia and 4 countries in LAC **M2.3.4.2 (2012)** At least one mapping population developed and QTLs for heat tolerance at flowering identified	Global Global	IRRI, CIAT IRRI, CIAT	**Short-term:** Rice breeders in at least 10 Asian, African, and LAC countries using new cold and heat tolerant lines. **Long-term:** Farmers in all regions growing new cold or heat tolerant varieties on at least 5 million ha.
	M2.3.4.3 (2013) At least two QTLs for cold tolerance identified in japonica and/or indica backgrounds	Global	AfricaRice, CIAT-FLAR	
	M2.3.4.4 (2013) at least two cold tolerant indica lines recommended for release for irrigated lowland conditions in Africa;	Africa	AfricaRice	
	M2.3.4.5 (2013) At least two cold tolerant low land and 2 cold tolerant upland lines recommended for high altitude regions in Africa	Africa	AfricaRice; Cirad	
	M.2.3.4.6 (2013) Heat tolerance phenotyping protocols established and at least 10 tolerant donors identified and validated **M2.3.4.7 (2014)** At least two QTLs for seedling cold tolerance identified and two cold tolerant breeding lines developed	Global Asia	IRRI, CIAT IRRI-RDA	
	M2.3.4.8 (2014) At least two cold tolerant elite lines recommended for south LAC	LAC	CIAT-FLAR	
	M2.3.4.9 (**2015)** A platform for breeding heat tolerant rice using MAS developed and shared	Global	IRRI	
	***M2.3.4.10 (2015)** 100 breeding lines developed from crosses with heat tolerant donors for LAC*	*LAC*	*CIAT, FLAR*	

R&D Product Line: 2.4. Improved rice varieties for intensive production systems

Intermediate users:	Public and private sector breeders
Final users:	Seed producers and farmers in intensive, irrigated rice environments of Asia and Africa
Expected impact:	Higher productivity and income of farmers due to accelerated availability of high-yielding rice varieties with multiple resistance to stresses and good grain quality, meeting the demands of processors and consumers
Key current projects:	BMGF/USAID-CSISA, RDA-IRRI, BMGF/CAAS-GSR, BMGF-STRASA, CIAT-FLAR, Japan Rice Breeding

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
2.4.1. New generation of elite inbreds with increased yield potential, premium quality, and resistance to key diseases and insects	**M2.4.1.1 (2012)** 10 donor parents with desired plant traits and predominately indica genetic background identified	Asia, LAC	IRRI, CIAT	**Short-term:** Public and private sector rice breeders in major rice growing countries are using newly developed lines in their breeding programs. **Long-term:** A new generation of high-yielding rice varieties possessing multiple resistances to pests and with acceptable grain quality become available to farmers. Farmers grow "super" rice varieties on at least 20 million ha.
	M2.4.1.2 (2012) 50 improved lines combining resistance to blast, rice hoja blanca virus, and Tagosodes developed for LAC	LAC	CIAT, FLAR	
	M2.4.1.3 (2013) Major QTLs and/or genes related to high-yielding plant traits identified. 100 promising elite breeding lines developed and distributed	Global	IRRI	
	M2.4.1.4 (2015) *Genes governing plant architecture and yield component traits pyramided*	*Global*	*IRRI, CIAT*	
	M2.4.1.5 (2015) Multi-location testing of 10 pre-release varieties by NARES at target sites in major rice growing countries	Global	IRRI, CIAT-FLAR, AfricaRice,	
	M2.4.1.6 (2015) 2 new blast resistance genes introgressed into elite cultivars in LAC	LAC	CIAT, FLAR	
	M2.4.1.7 (2015) Chinese materials adaptable to African environments identified	Africa	AfricaRice, CAAS	
2.4.2. Rice varieties for dry-seeding in aerobic rice and conservation systems	**M2.4.2.1 (2013)** 50 promising lines possessing target traits developed and distributed to national partners.	Southeast and South Asia	IRRI, Cirad-CIAT	**Short term:** New rice germplasm with enhanced genetic diversity utilized by breeders in national and private sector breeding programs. Rice breeders in at least 5 countries are using new aerobic rice lines. **Long term:** A new generation of high-yielding rice varieties for direct-seeding and well adapted to CA practices becomes widely available in Asia. Farmers grow new aerobic varieties on at least 2.0 million ha.
	M2.4.2.2 (2014) Multi-location testing of 10 pre-release varieties by NARES at target sites in major rice growing countries	Global	IRRI, NARES	
	M2.4.2.3 (2015) At least two varieties developed for target environment.	Global	NARES; IRRI	

2.4.3. High yielding varieties for irrigated systems in Africa	**M2.4.3.1 (2011)** Large scale evaluation of the selected advanced breeding lines from CAAS, IRRI, AfricaRice, CIAT and other sources with desired traits for adaptation	Africa	AfricaRice, IRRI, CAAS	**Short-term:** 5 varieties from PVS of STRASA Phase 1 released / adopted in 4 countries by 2013; another 5 varieties from crosses made in STRASA released/ adopted in 4 countries by 2015. 25 Chinese varieties released / adopted in 8 countries by 2015 **Long-term:** By 2020, 0.1 million ha covered by stress- tolerant rice varieties for irrigated systems in Africa
	M2.4.3.2 (2013) Varietal release of materials evaluated in PVS in STRASA phase 1	Africa	AfricaRice	
	M2.4.3.3 (2015) Advanced lines available from new crosses made in STRASA phase 1. IRRI materials evaluated in African environments	Africa	AfricaRice	
	M2.4.3.4 (2015) Chinese materials adaptable to African environments identified.	Africa	AfricaRice	
	M2.4.3.5 (2015) Saving pre-harvest losses by enhancing non-shattering and/or high-pre-harvest dormancy traits for Africa.	*Africa*	*AfricaRice*	

R&D Product Line: 2.5. Hybrid rice for the public and private sectors

Intermediate users:	Public and private sector breeders
Final users:	Seed producers and farmers in irrigated and favorable rainfed rice environments growing hybrid rice
Expected impact:	Higher productivity and income of farmers due to accelerated availability of high-yielding rice hybrids with multiple resistance to stresses, good grain quality, and high seed production yield
Key current projects:	Hybrid Rice Development Consortium (HRDC), BMGF-GSR, Pioneer-IRRI SKEP

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
2.5.1. Rice hybrids for Asia	**M2.5.1.1 (2011)** 50 new breeding populations developed and distributed to partners	South and Southeast Asia	IRRI	**Short-term:** Rice breeders in at least 5 countries are using new hybrid rice breeding lines. Enhanced development of the local hybrid rice seed industry in Asia. **Long-term:** Farmers grow new hybrid rice with at least 15% yield advantage and affordable seed cost
	M2.5.1.2 (2013) 5000 New hybrid parents and hybrids test-crossed and evaluated at IRRI and other locations.	South and Southeast Asia	IRRI	
	M2.5.1.3 (2015) 10 new hybrids released for commercial production by NARES or private sector partners.	South and Southeast Asia	IRRI	
2.5.2. Rice hybrids for Africa	**M2.5.2.1 (2012)** Initial multi-location evaluation of Chinese and IRRI F1 hybrids and parental lines in Africa completed	Africa	AfricaRice	**Short-term:** Performance of Asian rice hybrids evaluated and forms the basis for developing hybrid rice breeding programs in Africa. **Long-term:** Development of a local hybrid rice seed industry. At least 50,000 ha under F1 hybrids in Africa.
	M2.5.2.2 (2014) Hybrid rice with >15% yield advantage over inbred checks identified	Africa	AfricaRice	
	M2.5.2.3 (2015) GRiSP-developed hybrids evaluated in multiple locations in Africa	Africa	AfricaRice	
2.5.3. Rice hybrids for Latin America	**M2.5.3.1 (2013)** 200 New hybrid parents and hybrids test-crossed and evaluated in multi-locations in L. America (CIAT)	LAC	CIAT-FLAR	**Short-term:** Public sector rice breeders in Latin America establish and enhance hybrid breeding programs. **Long-term:** Enhanced development of the local hybrid rice seed industry. 200,000 ha under hybrids in Latin America.
	M2.5.3.2 (2013) Three hybrids yielding 15% higher than the control inbreed lines identified (Cirad)	LAC	Cirad, EMBRAPA	
	M2.5.3.3 (2015) At least 3 new hybrids released for commercial production by NARES/private partners	LAC	CIAT-FLAR	

Product Line: 2.6. Healthier rice varieties

Intermediate users: NARES breeders and national programs
Final users: Poor rice consumers that are undernourished, particularly poor women and children
Expected impact: Improved health of poor farmers and consumers that depend on rice as their main staple food
Key current projects: HarvestPlus, USAID, BMGF, Rockefeller Foundation, CIDA

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
2.6.1. Pro vitamin A-enriched rice (Golden Rice)	**M2.6.1.1 (2011)** Selection of 2-5 agronomically superior high betacarotene lines for regulatory and varietal submissions	South and SE Asia (Philippines, Indonesia, Bangladesh, India)	IRRI, PhilRice,	**Short-term:** A validated food-based approach to address VAD in rice-consuming population and strategy to increase carotenoid retention in subsequent GR2 varieties is routinely employed in varietal development **Long-term:** Adoption of biofortified varieties leads to a reduction in the prevalence and persistence of vitamin A deficiency.
	M2.6.1.2 (2013) Obtain biosafety approval in the Philippines for GR2.	South and SE Asia (Philippines, Indonesia, Bangladesh, India)	PhilRice, BRN, FNRI	
	M2.6.1.3 (2014) Bioefficacy of GR2 demonstrated in clinical and community trials in the Philippines.	South and SE Asia (Philippines, Indonesia, Bangladesh, India)	HKI, DOH, UCD, JHU	
	M2.6.1.4 (2015) Consumer marketing plans validated to support the successful adoption of GR by farmers and consumers.	South and SE Asia (Philippines, Indonesia, Bangladesh, India)	PhilRice, HKI, Commercial agencies	
	***M2.6.1.5 (2015)** Epistatic loci mapped and used to raise carotenoids levels in GR2 background*	*South and SE Asia (Philippines, Indonesia, Bangladesh, India)*	*IRRI, U Freiburg, BRRI*	
2.6.2. High-Zn rice	**M2.6.2.1 (2013)** QTLs and genes for grain Zn content identified, markers identified and used in grain zinc breeding program	South, SE Asia, Africa and LAC	IRRI, CIAT	**Short-term:** A validated food-based approach to address zinc deficiency in rice-consuming population is routinely employed in varietal development **Long-term:** Adoption of biofortified varieties leads to reduction in prevalence & persistence of Zn deficiency
	M2.6.2.2 (2013) Multi environmental testing of promising lines conducted and ten elite high-zinc lines developed for distribution to NARES partners	South, SE Asia, Africa and LAC	CIAT, BRRI, PhilRice, , AfricaRice, ICRR, DRR	
	M2.6.2.3 (2015) Two elite breeding lines possessing high grain zinc and pro-vitamin A developed	South, SE Asia, Africa and LAC	IRRI	

2.6.3. High-Fe rice	**M2.6.3.1 (2015)** Three lead transgenic events developed using 4 constructs transferred to NARES for product development.	South and SE Asia, Latin America, Africa	IRRI	**Short-term:** A new high iron breeding resource is routinely employed in varietal development **Long-term:** Adoption of biofortified varieties leads to a reduction in iron deficiency in rice-consuming population
	M2.6.3.2 (2015) High Fe varieties identified for release in at least 3 countries of LAC and Africa	LAC, Africa	CIAT, AfricaRice	
2.6.4. Rice with enhanced folic acid	**M2.6.4.1 (2013)** Optimal gene promoter combinations selected to deliver the product performance criteria	South and SE Asia	IRRI	**Short-term:** Folic acid, a novel nutritional and health trait is used for rice breeding **Long-term:** Adoption of biofortified varieties leads to reduced folate deficiency in rice-consuming population
	M2.6.4.2 (2015) Agronomically superior high folate lines selected for regulatory and varietal submissions	South and SE Asia	IRRI, NARES	

Theme 3: Ecological and sustainable management of rice-based production systems

R&D Product Line 3.1. Future management systems for efficient rice monoculture

Intermediate users:	Researchers
Final users:	Field agronomists, researchers
Expected impact:	More efficient rice management through science-based principles and tools.
Key current projects:	ACIAR-Sulawesi; BMGF-GSR; FG-ICON; SDC-IRRC; ADB-Water-saving; JICA-Bohol; Kellogg-IRRI, Japan-SMART-IV, EU RAP; Syngenta-SKEP; ADB-BPH; Anom.-Ecology; RDA-Weedy rice; ACIAR- Rodents; GTZ-MICCORDEA; EU-AfroWeeds

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
3.1.1. Strategies to increase water use efficiency	**M3.1.1.1 (2011)** Safe Alternate Wetting and Drying tools adapted for water-short areas of SE Asia.	Vietnam, Myanmar, Philippines, Indonesia (Sulawesi)	IRRI	**Short-term:** NARES partners integrate research on water saving technologies within national programs **Long-term:** Extension and development partners adopt water saving technologies
	M3.1.1.2 (2012) Knowledge about the roles of institutions and policies for equitable and efficient water use	Bohol Irrigation System (Philippines); Zanghe irrigation System (China)	IRRI	
	M3.1.1.3 (2013) Improved crop simulation model (ORYZA2000) for nutrient and water interaction validated against multilocation experimental data sets	SE Asia	IRRI	
	M3.1.1.4 (2014) *Options for sprinkler irrigation of aerobic rice evaluated at IRRI's experimental farm*	*SE Asia*	*IRRI*	
	M3.1.1.5 (2014) *Safe alternative Wetting and Drying tools tested in Africa*	*Mali, Senegal*	*AfricaRice*	
	M3.1.1.6 (2014) Options for multiple use of water along main rivers, and participatory management of land and water resources	Africa	Cirad	
3.1.2. Principles and tools for site-specific nutrient management	**M3.1.2.1 (2011)** Prototype Nutrient Manager tools for web and cell phone technology developed and tested in the Philippines	SE Asia	IRRI	**Short-term**: NARES partners integrate research on nutrient management options within national programs **Long-term:** Extension and development partners adopt nutrient management technologies
	M3.1.2.2 (2012)) Residue management strategies derived from field experiments at the IRRI farm	SE Asia	IRRI	
	M3.1.2.3 (2013) Nutrient Manager tools for web and/or cell phone technology tested in 5 countries in Asia	Asia	IRRI	

	M3.1.2.4 (2014) *Nutrient Manager tools for web and/or cell phone technology tested in 2 countries in Africa*	*Mali, Senegal*	*AfricaRice*	
	M3.1.2.5 (2015) New management strategies and DSS for integrated soil and nutrient management tested across Asia and Africa	Asia, Africa	IRRI, AfricaRice	
3.1.3. Management options for pests, weeds, and diseases	**M3.1.3.1 (2011)** Prototype strategies for sheath blight management in Asia	SE Asia	IRRI	**Short-term:** NARES partners integrate research on pests, weeds, and diseases management options within national programs **Long-term:** Extension and development partners adopt pests, weeds, and diseases management technologies
	M3.1.3.2 (2012) Prototype community-based rodent management strategies for Asia	SE Asia	IRRI	
	M3.1.3.3 (2012) CD-ROM and website on African rice weeds finalized and published	Africa	AfricaRice	
	M3.1.3.4 (2013) Management options for weed control in water-short rice systems of Asia	Asia	IRRI	
	M3.1.3.5 (2014) *Prototype epidemiological model and management strategies for viral diseases*	*SE Asia*	*IRRI*	
	M3.1.3.6 (2015) Relationship between rodents and weeds understood and novel community-based approaches tested	SE Asia	IRRI	
	M3.1.3.7 (2015) Regional strategy for deployment of resistance genes to blast	Asia, Africa	Cirad	

3.1.4. Integrated Good Agricul-tural Practices (GAP)	**M3.1.4.1 (2011)** Experimental Platform for future intensive rice monocropping operational within the Long-Term Experiments at IRRI	SE Asia	IRRI	**Short-term:** NARES partners integrate crop and natural resources management options within national programs **Long-term:** Development and extension partners adopt integrated crop and natural resources management options
	M3.1.4.2 (2012) Integrated "5-Gains One Must-Do" strategy evaluated in S Vietnam	SE Asia	IRRI	
	M3.1.4.3 (2012) *New production-scale, experimental platforms operational at key experimental sites in irrigated systems in Africa, focusing on water saving technologies*	*Egypt, Senegal, Mali*	*AfricaRice*	
	M3.1.4.4 (2013) *Adaptive on-farm trials on integrated crop and resource management technological options operational*	*Africa*	*AfricaRice*	
	M3.1.4.5 (2013) *Prototype Field Calculator for environmental footprint and economic analysis developed and tested against experimental data from IRRI farm*	*SE Asia*	*IRRI*	
	M3.1.4.6 (2013)) Improved integrated fallow, tillage, and residue management options derived from experiments at IRRI	SE Asia	IRRI	
	M3.1.4.7 (2014) *System performance (productivity, profitability, WUE, NUE and management of diseases, insects, and weeds) at experimental platforms assessed*	*Egypt, Senegal, Mali*	*AfricaRice*	
	M3.1.4.8 (2014) Prototype Rice Manager tools for web based technology tested in 3 countries in Asia	Asia	IRRI	
	M3.1.4.9 (2015) *Prototype integrated GAP aimed at water saving developed and tested by national partners*	*Africa*	*AfricaRice*	
	M3.1.4.10 (2015) Prototype integrated GAP for Thailand and Vietnam developed and tested by national partners	SE Asia	IRRI	

R&D Product Line 3.2. Resource-conserving technologies for diversified farming systems

Intermediate users: Researchers and extension workers (public sector, private sector, CSOs)
Final users: Farmers and field agronomists,
Expected impact: Farmers in intensive rice production systems in key areas in Asia and Africa adopt improved crop management practices that increase sustainable productivity, diversified cropping, and incomes, while reducing the environmental footprint.
Key current projects: ADB-Water-saving; JICA-Bohol; BMGF/USAID-CSISA; DFG-ICON; SDC-IRRC, BMGF-GSR, RDA-TRRC; ACIAR-Sulawesi; Syngenta-SKEP, ACIAR Rice-Maize; ACIAR Rice-pulses B'desh; Rice-Wheat Consortium Project, MAFF- IRRI, Kellogg-IRRI,

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
3.2.1. Diversified cropping systems in Asia	**M3.2.1.1 (2011)** Four new-generation production-scale experimental platforms operational at key sites in South Asia and at IRRI	India, Bangladesh, Philippines, Nepal, Pakistan	IRRI	**Short-term:** Strengthened R&D partnerships for adaptive research on sustainable intensification of diversified rice systems lead to locally appropriate management strategies disseminated by development partners **Long-term:** Frontier farmers adopt integrated crop management options for ecological intensification of diversified rice systems through trained extension and development agents
	M3.2.1.2 (2011) Adaptive, on-farm trials on integrated crop and resource management options operational at nine "experimental hubs" in S Asia	India, Bangladesh, Philippines, Nepal, Pakistan	IRRI	
	M3.2.1.3 (2012) SSNM principles for rice-maize systems incorporated into web-based Nutrient Manager decision tool in Bangladesh	Bangladesh	IRRI	
	M3.2.1.4 (2012) SSNM principles for rice-wheat systems incorporated into web-based Nutrient Manager decision tool in India	India, Bangladesh	IRRI	
	M3.2.1.5 (2013) Safe Alternate Wetting and Drying principles developed for medium-light textured soils in crop rotation systems in India and Bangladesh	India, Bangladesh	IRRI	
	M3.2.1.6 (2013) Sprinkler and drip irrigation for crop rotations evaluated against experimental data in India and Bangladesh	India, Bangladesh	IRRI	

	M3.2.1.7 (2013) Principles for crop health management under diversified cropping evaluated at experimental platforms	India, Bangladesh	IRRI	
	M3.2.1.8 (2014) System performance (productivity, profitability, WUE, NUE, EUE; crop health, ecological resilience) at experimental platforms quantified	India, Bangladesh, Philippines	IRRI	
	M3.2.1.9 (2014) Improved simulation models for rice and cropping systems (EcoMeristem, Samara, ORYZA2000, APSIM) to explore effects of management options	Global	Cirad, IRRI, CSIRO	
	M3.2.1.10 (2015) *Prototype Field Calculator for environmental footprint and economic analysis of diversified cropping systems validated against experimental data*	*Bangladesh, India, Philippines*	*IRRI*	
3.2.2. Mechanization and conservation agriculture	**M3.2.2.1 (2011)** New prototype tillage and crop establishment strategies for dry-seeded systems tested at experimental hubs and on-farm in India and Bangladesh	S and SE Asia (India, Bangladesh, Nepal)	IRRI	**Short-term:** NARES partners integrate mechanization and practices of Conservation Agriculture within national programs **Long-term:** Development and extension partners adopt integrated mechanization and practices of Conservation Agriculture
	M3.2.2.2 (2012) New weed control options and Decisions Support Tools for direct seeded systems tested at experimental hubs and on-farm in India and Bangladesh	S and SE Asia (India, Bangladesh, Nepal)	IRRI	
	M3.2.2.3 (2012) Residue management strategies in the fallow period tested at experimental hubs and on-farm in India and Bangladesh	S and SE Asia (India, Bangladesh, Nepal)	IRRI	
	M3.2.2.4 (2013) New generation conservation agriculture-based implements for planting cereals and other crops widely tested in farmers' fields in India and Bangladesh	S and SE Asia (India, Bangladesh, Nepal, Cambodia)		
	M3.2.2.5 (2014) Conservation agriculture-based implements for planting and fertilizing crops tested for rice-maize based systems in farmers' fields in the Philippines	SE Asia	IRRI	

R&D Product Line 3.3. Management innovations for poor farmers in rainfed and stressprone areas

Intermediate users: Researchers and extension workers (public sector, private sector, CSOs)
Final users: Farmers and field agronomists
Expected impact: Farmers in key lowland and upland areas in Asia and Africa affected by drought, submergence, or salinity adopt adapted varieties and management practices enabling increased productivity, diversified cropping, and reduced risk of crop failure
Key current projects: SDC-NURIFAR; IFAD-CURE; BMGF-STRASA, BMGF-GSR,; ACIAR-Laos; ACIAR-Cambodia agronomy; IFAD-CURE; MAFF-IRRI-JIRCAS; BMGF-STRASA, BMGF-GSR, Japan - SMART-IV, EU - RAP, GTZ-MICCORDEA, Cirad collaborative project in Madagascar (SCRID); EU - AfroWeeds, NWO/WOTRO - PARASITE

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
3.3.1. Management options for drought, submergence, and salinity	**M3.3.1.1 (2011)** Recommendations for improved seedbed management and direct seeding in flooded soils	Asia (India, Bangladesh, Myanmar, Laos, Thailand, Vietnam, Indonesia)	IRRI	**Short-term:** Strengthened R&D partnerships for adaptive research on management of drought, submergence, and salinity lead to locally appropriate control strategies disseminated by development partners. **Long-term:** Frontier farmers adopt integrated management options for drought, submergence, and salinity through trained extension and development agents
	M3.3.1.2 (2012) Crop simulation model for drought conditions (ORYZA2000) tested against experimental data sets	Global	IRRI	
	M3.3.1.3 (2013) Field management options to accompany the introduction of salt-tolerant varieties tested in S Asian and African Countries	Asia (India, Bangladesh, Myanmar, Vietnam, Indonesia), West Africa (Senegal, Mali, Guinea), Eastern & Southern Africa (selected countries)	IRRI, AfricaRice	
	M3.3.1.4 (2013) Integrated crop management options (with a special focus on establishment and nutrient management) for new drought-tolerant rice varieties developed and tested in S Asian and African Countries	Asia (India, Bangladesh, Myanmar, Laos, Cambodia, Thailand, Vietnam, Indonesia) Africa (selected countries)	IRRI, AfricaRice	
	M3.3.1.5 (2014) Integrated crop and nutrient management techniques for better crop establishment and survival after floods in flood-prone areas in Asian and African countries	Asia (India, Bangladesh, Myanmar, Laos, Thailand, Vietnam, Indonesia)); West Africa (Guinea, Sierra Leone, Liberia)		
	M3.3.1.6 (2014) Management options to prevent salinization and sodification,	Africa	Cirad	
	M3.3.1.7 (2015) Intensified and/or diversified cropping systems for drought-prone environments developed and tested in S and SE Asia	Asia (India, Bangladesh, Myanmar, Laos, Thailand, Vietnam, Indonesia)	IRRI	

	M3.3.1.8 (2014) *Crop simulation modules for saline conditions (ORYZA2000)*	*Global*	*IRRI, CSIRO*	
	M3.3.1.9 (2015) *Improved cropping systems (including rice-shrimp/fish systems) adapted to salt affected coastal zones and saline inlands*	*Asia (India, Bangladesh, Myanmar, Vietnam, Indonesia), West Africa (Senegal, Mali, Guinea), Eastern & Southern Africa (selected countries)*	*IRRI, AfricaRice*	
	M3.3.1.10 (2015) Integrated Good Agricultural Practices (GAP) for rainfed rice developed, tested, and materials available	Asia (Myanmar, Laos, Cambodia, Thailand, Indonesia), Eastern & Western Africa (selected countries)	IRRI, AfricaRice	
3.3.2. Management options for pests, diseases, and weeds	**M3.3.2.1 (2011)** Integrated management options of African rice gall midge available	Africa	AfricaRice	**Short-term:** Strengthened R&D partnerships for adaptive research on pest, diseases, and weed management lead to locally appropriate control strategies disseminated by development partners. ***Long-term:*** Frontier farmers adopt integrated pest, diseases, and weed management options through trained extension and development agents
	M3.3.2.2 (2012) CD-ROM and website on African rice weeds finalized and published	Africa	AfricaRice	
	M3.3.2.3 (2012) Integrated crop management recommendations for Burkholderia and related pest and diseases in Latin America	Latin American Countries	CIAT	
	M3.3.2.4 (2013) Management options for herbicide resistance available in Latin America	Latin American Countries	CIAT	
	M3.3.2.5 (2013) Insect pest risk monitoring and forecasting tools developed for Africa	Africa	AfricaRice	
	M3.3.2.6 (2013) Social and economic impacts of parasitic weeds on rice in Africa assessed	Africa	AfricaRice	
	M3.3.2.7 (2014) Strategies for prevention and damage control of parasitic weeds on rice in Africa developed	Africa	AfricaRice	
	M3.3.2.8 (2014) Integrated crop management recommendations for blast epidemic in upland ecosystems	Asia, Africa	IRRI, Cirad	

3.3.3. Mechanization and Conserva-tion Agriculture for low-input and upland systems	**M3.3.3.1 (2011)** Inventory of multifunctional cover crops to be used in CA upland rice cropping systems in Madagascar	Africa	Cirad	**Short-term:** Strengthened R&D partnerships for adaptive research on mechanization and Conservation Agriculture (CA) in rainfed lowland and upland rice-based systems lead to locally appropriate upland management option disseminated by development partners. **Long-term:** Frontier farmers adopt mechanization and Conservation Agriculture management options that reduce risk and enhance livelihoods through trained extension and development agents.
	M3.3.3.2 (2012) Mechanization options for rainfed lowland systems evaluated in representative farming communities in Togo and Benin	Africa	AfricaRice	
	M3.3.3.3 (2013) Set of CA cropping systems for upland rice under different conditions and constraints; Economically viable options for a better exploitation of soil water in upland rice-based systems available in Madagascar	Africa	Cirad	
	M3.3.3.4 (2013) *A long-term partnership and experimental platform on alternative upland rice production systems established*	*West Africa*	*Cirad*	
	M3.3.3.5 (2013) *Options for lowland and aerobic rice in cropping systems in uplands evaluated and ready for outscaling*	*SE and E Asia*	*IRRI*	
	M3.3.3.6 (2013) Intensified rice-livestock systems in rainfed lowlands and uplands in S Laos developed, evaluated, and ready for upscaling.	Se Asia	IRRI, CIAT	
	M3.3.3.7 (2013) New prototype tillage and crop establishment strategies for dry-seeded systems tested on-farm in Cambodia	SE Asia	IRRI	
	M3.3.3.8 (2014) Mechanization options for rainfed lowland and upland systems evaluated in farming communities in at least 4 countries in WCA	West and Central Africa	AfricaRice	
	M3.3.3.9 (2015) Tools to support innovative cropping systems based on CA and incorporating multifunctional cover crops	Africa	Cirad	
	M3.3.3.10 (2015) *Decision-making tools at the farm level to use water conservation technologies for small holder farmers*	*Africa*	*Cirad*	

3.3.4. Land and water develop-ment options for inland valleys	**M3.3.4.1 (2011)** Decision support systems tested and adapted to improve resource efficiency of rice-vegetable systems	Africa	AfricaRice, Cirad	**Short-term:** Strengthened R&D partnerships for adaptive research on land and water development options for inland valley systems lead to locally appropriate management options disseminated by development partners. **Long-term:** Frontier farmers adopt improved land and water development options that reduce risk and enhance livelihoods through trained extension and development agents.
	M3.3.4.2 (2012) PLAR adaptive and on-farm trials on integrated crop and resource management options operational	Africa	AfricaRice, Cirad	
	M3.3.4.3 (2012) Sawah system tested in Togo and Benin	Africa	AfricaRice, Cirad	
	M3.3.4.4 (2013) Prototype integrated management strategies for ecological intensification and diversification of peri-urban rice-vegetable systems	Africa	AfricaRice, Cirad	
	M3.3.4.5 (2013) Performance of multi-stakeholder platforms for sustainable development and improved market access determined	Africa	AfricaRice, Cirad	
	M3.3.4.6 (2015) Tools for outscaling Sawah systems available and disseminated	Africa	AfricaRice, Cirad	

R&D Product Line 3.4. Increasing resilience to climate change and reducing global warming potential

Intermediate users:	Researchers
Final users:	Field agronomists, researchers
Expected impact:	More efficient rice management through science-based principles and tools.
Key current projects:	ACIAR-Climate change Vietnam; ACIAR Climate Change Bangladesh; MAFF-IRRI-JIRCAS, DFG-ICON; IFAD Facility (NAIP); BMGF/USAID-CSISA; GTZ – MICCORDEA, NWO/WOTRO-PARASITE

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
3.4.1. Assessment tools (ecological resilience, impact of climate change, adaptive value of response options)	**M3.4.1.1 (2011)** Knowledge on the consequences of climate variability on resource management of men and women among rice farming households	Asia	IRRI	**Short-term:** NARES partners integrate experimental set-up and assessment tools within national programs **Long-term:** Policymakers incorporate recommendations on enhanced ecological resilience and climate change adaptation
	M3.4.1.2 (2011) Operational modeling-GIS framework to quantify and map impacts of climate change on rice	Global	IRRI	
	M3.4.1.3 (2011) Diseases, injury profiles, and situations in hot spots of Asia and Africa determined	Asia, Africa	IRRI, AfricaRice	
	M3.4.1.4 (2012) Impact of climate change on the virulence of major rice diseases in Africa assessed	Africa	AfricaRice	
	M3.4.1.5 (2013) *Impact of elevated CO_2, changes in humidity, and extreme temperature on rice and energy and greenhouse gas fluxes quantified*	*Asia*	*IRRI*	
	M3.4.1.6 (2013) Global network for crop health assessment and response to climate change	Global	IRRI	
	M3.4.1.7 (2014) Model to compute the effect of climate change on water availability for irrigation in six countries	Africa	AfricaRice	
	M3.4.1.8 (2014) Crop simulation modules for cold damage, heat stress, and CO_2 fertilization (EcoMeristem, SAMAR, ORYZA2000)	Global	IRRI, Cirad	

3.4.2. Field management technologies to reduce green-house gas emissions	**M3.4.2.1 (2011)** Prototype water and nutrient management practices to reduce Global Warming Potential (GWP) evaluated from experiments at IRRI	Asia	JIRCAS, IRRI	**Short-term:** NARES partners have integrated technologies to reduce greenhouse gas emissions from rice within national programs **Long-term**: Crop management technologies to reduce greenhouse gas emissions from rice are widely adopted
	M3.4.2.2 (2011) Simulation models to quantify effects of water and nutrient management on GWP of rice	Global	JIRCAS, IRRI	
	M3.4.2.3 (2013) On-farm effect of Alternate Wetting and Drying on greenhouse gas emissions of rice quantified in the Philippines	Philippines	IRRI	
3.4.3. Strategies to adapt to climate change and increase resilience	**M3.4.3.1 (2011)** Field sites and partnerships to design cropping systems with adaptation to climate change established in two countries in SE Asia	Asia (Vietnam, Bangladesh, Indonesia, Laos, Philippines)	IRRI	**Short-term:** NARES partners integrate experimental set-up for enhanced ecological resilience and adaptation to climate change within national programs **Long-term:** Policymakers incorporate recommendations on enhanced ecological resilience and climate change adaptation
	M3.4.3.2 (2012) Prototype system for seasonal weather prediction in rainfed rice areas in two countries in Asia	Asia (Indonesia, Laos or Philippines)	IRRI, JIRCAS	
	M3.4.3.3 (2012) Ecological engineering for insect pest control evaluated in Vietnam and China	SE and E Asia Asia	IRRI	
	M3.4.3.4 (2012) *Field sites and partnerships to design cropping systems with adaptation to climate change established in five countries in Africa*	*Egypt, Senegal, Ghana, Tanzania, Madagascar*	*AfricaRice*	
	M3.4.3.5 (2012) Country maps for improved irrigation management available for six countries	West Africa	AfricaRice	
	M3.4.3.6 (2013) Prototype crop and management systems that are adapted to increased drought and submergence	Asia (Vietnam, Bangladesh, Indonesia, Laos, Philippines)	IRRI	
	M3.4.3.7 (2014) Insect pest control strategies for preventing and mitigating climate-change induced stresses developed for Africa	Africa	AfricaRice	
	M3.4.3.8 (2014) Prototype Decision Support System for tactical decision taking in rainfed rice environments based on seasonal weather forecasts	Asia (Indonesia, Laos or Philippines)	IRRI, JIRCAS	
	M3.4.3.9 (2014) Integrated strategy to increase rice crop resilience to extreme temperatures through genetic tolerance, microclimate management, and escape (phenology)	Global	Cirad	
	M3.4.3.10 (2015) *Regional gene deployment strategy for insect pests*	*Asia*	*IRRI*	

Theme 4: Extracting more value from rice harvests through improved quality, processing, market systems and new products.

R&D Product Line: 4.1. Technologies and business models to improve rice postharvest practices, processing, and marketing

Intermediate users: Rice farmers, researchers, extension workers, agribusiness professionals
Final users: Rice farmers, seed producers, millers, traders/exporters and postharvest contract service providers
Expected impact: Increased incomes for farmers and other actors along the rice market chain.
Key current projects: ADB-Postharvest, SDC-IRRC, CFC-Central Africa, USAID, CIDA (Africa project under development).

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
4.1.1. Improved technologies and management options to increase post-harvest yield	**M4.1.1.1 Asia:** Supply chains established for hermetic storage and laser leveling technologies in 3 target countries by *2011 and in 6 countries until 2015 ;*	Regional: Southeast (Cambodia, Vietnam, Philippines, Lao PDR, Myanmar, Indonesia) and South Asia	IRRI	**Short-term:** Improved PH technologies and management options identified, adapted, and piloted by partners.
	M4.1.1.2 (2012) Africa: Adapted, locally manufactured mechanization options (mini-combine harvesters, dryers, storage systems) available in 4 target countries by 2012 *and in 8 countries by 2015*	Regional: Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)	AfricaRice	**Long-term:** Improved technologies and management options widely scaled-up and -out.
	M4.1.1.3 Asia: Dryers adapted and produced to local conditions in 3 countries by 2012; and information about locally suitable combine harvesters available to end users in 2 target countries by 2011.*and 4 by 2012*	Regional: Southeast (Cambodia, Vietnam, Philippines, Indonesia) and South Asia	AfricaRice	
	M4.1.1.4 *Technologies out-scaled throughout sustainably funded PH networks in Asia (3 by 2013)* and Africa using multi-stakeholder platforms e.g., learning alliance	Global: Southeast (Cambodia, Vietnam, Philippines) and South Asia, Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania, Uganda)	IRRI	

4.1.2. Business models for post-harvest technologies and tools for improved rice market information systems	**M4.1.2.1** Business models for postharvest technologies identified and piloted in Southeast Asia, needs and strategies for MIS identified, local postharvest value chains analyzed in initial target areas by 2011, *in two more countries in South Asia by 2013*	Regional: Southeast Asia (Cambodia, Philippines, Vietnam) and South Asia (Bangladesh, India, Nepal)	IRRI	**Short-term:** Business models piloted by partners for adoption of PH technologies and services, value chain linkages, market info flows, and efficiency improved. **Long-term:** Wide adoption of PH technologies and services as sustainable income generating business models, scaled out value chain linkages, market info networks, and interventions sustainable maintained.
	M4.1.2.2 Business models for PH technologies expanded locally, MIS networks and linkages established; local PH value chains analyzed, by 2013, *two more by 2015*	Regional: Southeast Asia (Cambodia, Philippines, Vietnam) and South Asia (Bangladesh, India, Nepal)	IRRI	
	M4.1.2.3 *Business models for PH technologies scaled out for wider adoption in all participating countries, MIS technologies and networks scaled out, PH value chains analysed in additional target locations by 2013*.	*Regional: Southeast Asia (Cambodia, Philippines, Vietnam) and South Asia (Bangladesh, India, Nepal)*	*IRRI*	
	M4.1.3.1 *Mycotoxin contamination assessed in target regions two countries by 2012, low cost mycotoxin detection methods verified by 2011*	*Regional: Southeast Asia (Cambodia, Philippines)*	*IRRI*	
4.1.3. Post-harvest practices for reduced mycotoxin contamination of milled rice	**M4.1.3.2** *Strategies and technologies for mycotoxin management developed by 2012.*	*Regional: Southeast Asia (Cambodia, Philippines)*	*IRRI*	**Short-term:** Assessed degrees of mycotoxin contamination in 3 countries with sub-optimal postharvest systems using participatory approaches creates awareness among policymakers and processors of risks. **Long-term:** Low-cost mycotoxin detection technologies used; scientists, producers, processors, policy-makers, develop and deploy best practices for minimized mycotoxin contamination.
	M4.1.3.3 *Mycotoxin minimization options out-scaled to multiple stakeholders in 1 country by 2013 and additional 2 countries by 2015)*	*Regional: Southeast Asia (Cambodia, Philippines)*	*IRRI*	
	M4.1.4.1 Institutional arrangements between (1) farmers and parboilers; (2) farmers and millers; (3) millers and traders/importers *and in 8 countries by 2015.*	Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)	AfricaRice NARES, NGOs, private sector	

4.1.4. Institutional and organizational innovations enabling greater access to output markets for smallholder farmers	**M4.1.4.2** PLAR modules and videos on good practices for linking production, processing and marketing actors *and in 8 countries by 2015.*	Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)	AfricaRice	**Short-term:** Improved access to information, methods and tools for value chain analysis enables and better informed decision-making by farmers, millers and traders. **Long-term:** Increased value chain competitiveness, improved actor incomes and smallholder farmer access to end-markets through upgraded value chains which are better tailored to end-market standards, better deployment of market knowledge and resources through improved established linkages.
	M4.1.4.3 Innovative rice labeling, branding, marketing and generic promotion strategies to catalyze RVCs *and in 8 countries by 2015.*	Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)	AfricaRice	
	M4.1.4.4 Risk management strategies and tools	Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)	AfricaRice	
	M4.1.4.5 Active rice forum re-established in WCA	Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda	AfricaRice	

R&D Product Line: 4.2. Innovative uses of rice straw and rice husks

Intermediate users: Scientists in IARCS and NARES engaged in variety development
Final users: Rice Farmers, marketers, livestock companies
Expected impact: Increased income for farmers and environmental benefits through carbon sequestration and energy production
Key current projects: BMGF/USAID-CSISA (ILRI), CIDA (Africa Project under development).

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
4.2.1. Rice straw with increased digestibility for feeding to live-stock	**M4.2.1.1 (2011)** Laboratory fodder quality traits compared with farmer perception of fodder quality for Sth Asia.	South Asia (India, Bangladesh, Nepal)	ILRI	**Short-term:** Variations in fodder quantity and quality and the potential trade-off effects between primary and straw traits are better understood and define partner breeding strategies for enhancing rice straw fodder quality.
	M4.2.1.2 (2011) Variability amongst cultivars and breeding lines in digestibility of rice straw determined.	South Asia (India, Bangladesh, Nepal)	ILRI	
	M4.2.1.3 (2012) Selection for digestible straw incorporated into breeding programs	South Asia (India, Bangladesh, Nepal)	ILRI	
	M4.2.1.4 (2012) Promising lines, varieties or hybrids with superior rice straw fodder quality identified and recommended to partners for further evaluation,	South Asia (India, Bangladesh, Nepal)	ILRI	**Long-term:** Enhanced use of rice straw to feed livestock in target regions of South Asia, in balance with conservation agriculture needs.
4.2.2. Renewable, profitable and sustainable energy product-ion and carbon sequestration based on rice residues	***M4.2.2.1 (2011)*** *Desk study of existing concepts and technologies for bioenergy from crop residues based on available information*	*Aisa (Philippines, Cambodia, Vietnam?); Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)*	*IRRI, Cirad,*	**Short-term:** Use of bioenergy and biochar outscaled to target regions in Asia and Africa **Long-term:** Biochar established as a option for carbon sequestration including access to carbon payments.
	M4.2.2.2 (2012) *Experimental analysis of bioenergy from rice husks and straw conducted, including live cycle analysis, energy balance, and environmental impact of by/waste-products;*	*Aisa (Philippines, Cambodia, Vietnam?); Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)*	*IRRI, AfricaRice,*	
	M4.2.2.3 (2013) *Use of biochar (byproduct of the bioenergy process) for soil improvement and carbon sequestration in the three most important rice-based systems evaluated;*	*Global*	*IRRI, Cirad,*	

	M4.2.2.4 (2013) *Carbon life cycle assessment conducted and carbon footprint calculated for the most promising bioenergy/biochar technology; concepts to tap carbon trading schemes developed.*	*Aisa (Philippines, Cambodia, Vietnam?); Cameroon, Ghana, Sierra Leone, Senegal, and Uganda*	*IRRI, AfricaRice, Cirad*	
4.2.3. Innovative, profitable and sustainable processing options for rice husks d rice straw	**M4.2.3.1 (2011)** Rice mills improved to obtain total separation of husk and bran during milling in 3 countries by 2011 *and in 6 countries by 2013*	Cameroon, Ghana, Sierra Leone, Senegal, and Uganda	AfricaRice, Cirad	**Short-term:** 2 mill designs promoted by partners in each of 5 African countries producing rice husk based energy and construction products. **Long-term:** Rice husk profitably used for the production of energy and construction materials in SSA
	M4.2.3.2 (2013) Concepts for the production of biomaterials using rice husks or straw	Cameroon, Ghana, Sierra Leone, Senegal, and Uganda	AfricaRice, Cirad	
	M4.2.3.3 (2014) *Commercial viability of the production of rice husk/straw-based products in Asia and SSA evaluated.*	*Philippines, Cambodia, (Vietnam), Africa (Cameroon, The Gambia, Ghana, Senegal, Sierra Leone, Nigeria, Tanzania and Uganda)*	*IRRI, Cirad, AfricaRice,*	

R&D Product Line: 4.3. High quality rices and innovative rice-based food products

Intermediate users: Quality evaluation programs and rice breeders in all rice institutes
Final users: Farmers, marketers, traders, processors
Expected impact: Increased income to farmers through uses for broken rice, and supplying niche markets, and management of non-communicable diseases
Key current projects: ACIAR, MOF Japan Rice Breeding product, CIDA (Africa project under development), CIAT-FLAR

Products	Milestones	Target region/key countries	Lead institution(s)	Outcomes
4.3.1. Phenotyping platform, and tools for evaluating quality and speciality traits of grains and rice products.	**M4.3.1.1 (2011)** Sensory profiling completed to describe eating qualities and *speciality traits* of grains and rice products.	Global	IRRI ,	**Short-term:** Phenotyping tools adapted by NARES partners to evaluate quality and speciality traits. **Long-term:** High-quality and high-yielding varieties widely adopted by farmers in Asia, Africa and LAC.
	***M4.3.1.2 (2012)** Candidate structures and compounds identified for developing phenotyping tools for the new traits.*	*Global*	*IRRI*	
	M4.3.1.3 (2013) Robust phenotyping tools developed to evaluate and quantify new traits, and associate with genetic maps.	Global	IRRI and AfricaRice, CIAT-FLAR	
	M4.3.1.4 (2015) High throughput, low cost methods, and molecular markers for eating quality delivered to INQR members, and germplasm panels carrying an allelic series for 2 quality traits, and markers to screen for the alleles, developed.	Global	IRRI and AfricaRice, CIAT-FLAR	
4.3.2. Speciality products with good eating quality for high value markets.	**M4.3.2.1 (2011)** Varieties of different qualities, and varieties and mutants carrying potential speciality traits identified.	Global	IRRI and AfricaRice	**Short-term:** Favourable alleles and speciality traits used by breeding programs. **Long-term:** Farmer incomes increased by growing and selling speciality varieties for high-value markets and nutritional markets.
	***M4.3.2.2 (2013)** Genes and allelic variation for quality and speciality traits identified.*	*Global*	*IRRI and CIAT-FLAR*	
	M4.3.2.3 (2014) Allelic combinations known for speciality products and eating quality.	Global	IRRI	
	M4.3.2.4 (2015) Speciality products with acceptable eating quality.	Global	IRRI	

4.3.3. Processing techniques that add value to low-grade rice	**M4.3.3.1 (2011)** Processing techniques for rice products tested and optimized *and in 5 countries by 2014*	Cameroon, Ghana, Sierra Leone, Senegal, and Uganda	AfricaRice and Cirad	**Short-term:** Processing technologies being promoted in 5 African countries **Long-term:** Low-grade rice profitably used for the production of higher value products across in SSA
	M4.3.3.2 (2013) Processing tools for 2 rice products developed. Techniques communicated to farmers	Cameroon, Ghana, Sierra Leone, Senegal, and Uganda	AfricaRice	
	M4.3.3.3 (2014) Women-friendly parboiling technology developed in relation with women associations managing the parboiling industry in West Africa.	Cameroon, Ghana, Sierra Leone, Senegal, and Uganda	AfricaRice	
4.3.4. Market analysis and information for developing specialty rices and rice-products	**M4.3.4.1 (2011)** *Value chain analysis and assessment for speciality rices* and products of lower -value rice by male and female farmers.	Asia and Africa	IRRI and AfricaRice	**Short-term:** Processing techniques being promoted by partners in Africa. **Long-term:** Processing technologies increasing farmers' income in Africa, Asia and LAC.
	M4.3.4.2 (2012) Innovative rice labeling, marketing and generic promotion strategies to catalyse the value chain of speciality rice and rice-based products	Africa	AfricaRice	
	M4.3.4.3 (20113) *Business models developed for linkages and resources for out-scaling specialty rices and products from them and low-value rice.*	*Asia and Africa*	*IRRI and AfricaRice*	

Theme 5: Technology evaluations, targeting and policy options for enhanced impact

R&D Product Line: 5.1. Socioeconomic and gender analyses for technology evaluation

Intermediate users:	Scientists in IARCS and NARES engaged in rice research
Final users:	Policymakers and extension agents
Expected impact:	Development of new technologies that fit farmers' needs.
Key current projects:	BMGF-CSISA, BMGF-MV Adoption, BMGF-STRASA, BMGF-VDSA, BMGF-GSR, SDC-IRRC, IFAD-Facility grant (NAIP), ICAR, CIDA, EU

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
5.1.1. Knowledge of farmer technology needs, adoption patterns and constraints to adoption by male and female farmers	**M5.1.1.1 (2011-2013)** Analysis of on farm performances, gender disaggregated constraints and social and economic effects of technologies interventions.	Asia **(**Bangladesh, India, Philippines and Nepal) and Africa,	Asia: IRRI Africa: AfricaRice	**Short-term:** Scientists use insights to develop new rice technologies that are more relevant and appropriate for farmers' needs and constraints. **Long-term:** Increased adoption of appropriate rice technologies
	M5.1.1.2 (2012) Updated database on varietal releases, research costs and protocols for collecting nationally representative data on varietal adoption in South Asia, Africa and Latin America.	Asia (Bangladesh, Bhutan, India, Nepal and Sri Lanka), Africa and Latin America (Bolivia, Nicaragua, Costa Rica, Colombia, Venezuela, Ecuador Brazil, Uruguay, Peru, Panama)	Asia: IRRI Africa: AfricaRice LAC: CIAT-FLAR	
	M5.1.1.3 (2012) Analysis of adoption patterns and constraints to adoption of rice varieties in South Asia, Latin America and Africa.	Asia (Bangladesh, India, and Nepal), Africa and Latin America (Bolivia, Nicaragua, Costa Rica, Colombia, Venezuela, Ecuador Brazil, Uruguay, Peru, Panama).	Asia and East Africa: IRRI Other Africa: AfricaRice LAC CIAT-FLAR	
	M5.1.1.4 (2013) Assessment of enablers and constraints to adoption of best management practices for natural resource management (or NRM technologies) in South and Southeast Asia, Africa and Latin America.	Asia **(**Bangladesh, Philippines and Vietnam) and Latin America (Bolivia, Nicaragua, Costa Rica, Colombia, Venezuela, Ecuador Brazil, Uruguay, Peru, Panama)	Asia: IRRI LAC: CIAT-FLAR	

	M5.1.1.5 (2012) Analysis of farmer crop diversification and livelihoods strategies for rice growing environments in South Asia and Africa.	South Asia (India, Bangladesh and Nepal) and Africa	South Asia: IRRI Africa: AfricaRice	
5.1.2. Knowledge of poverty dynamics, livelihood strategies, and gender roles in rice-based farming system	**M5.1.2.1 (2011-15)** High frequency longitudinal dataset of 12 Bangladeshi villages for understanding poverty and gender dynamics in South Asia	Bangladesh	IRRI Key Partners: SocioConsult and CPD	**Short-term:** Use of high frequency data by scientists and graduate scholars for better understanding of poverty dynamics and farmers' livelihood for targeted technology development. **Long-term:** Analysis conducted by scientists and scholars will help research managers to develop technologies that complement farmers' livelihood thereby improving adoption and potential for impact and Policymakers in formulating complementary policies to improve farmers' livelihoods..
	M5.1.2.2 (2012) Analysis of farmer crop diversification and livelihoods strategies for rice growing environments in South and Southeast Asia and Africa.	Asia (Bangladesh, Pakistan, Sri Lanka, Cambodia, Laos, Indonesia, and Vietnam) and Africa	Asia and East Africa: IRRI Other Africa: AfricaRice	
	M5.1.2.3 (2012) Analysis of changing roles of gender due to climate change, migration and widespread technological changes.	Asia (India, Nepal and Vietnam) and Africa	Asia: IRRI Africa: AfricaRice LAC: CIAT-PRGA FLAR-INIA (Peru)	
	M5.1.2.4 (2015) Assessment of farmers' coping mechanisms during monga or seasonal hunger in Northwest Bangladesh.	Bangladesh	IRRI Key partner: BRRI	
5.1.3. Gender disaggregated analysis of consumer perceptions including quality traits for targeted product development	**M5.1.3.1 (2011)** Consumer survey in the Philippines for determining perceptions and acceptability of golden rice.	Philippines	IRRI	**Short-term:** Consumer acceptance and willingness to purchase Golden Rice determined in Philippines and Bangladesh **Long-term:** Targeted release of Golden Rice in the Philippines and Bangladesh to ensure most effective delivery to vitamin A deficient populations.
	M5.1.3.2 (2014) *Consumer preferences for rice traits and for locally produced and imported rice determined for Asia and Africa (22 countries).*	*Asia, and Africa*	*Asia: IRRI* *Africa: AfricaRice*	

R&D Product Line: 5.2. Spatial analysis for effective technology targeting

Intermediate users: Scientists in IARCS and NARES engaged in rice research
Final users: Policymakers and extension agents
Expected impact: Improved strategies for technology dissemination
Key current projects: BMGF-STRASA, BMGF-GSR, EU, DOA-RSSP (Philippines), Japan-Breeding, Rice Challenge Initiative

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
5.2.1. Seasonally updated information on rice agro-ecologies (cultivated areas, phenological stages, etc.) using RS and GIS technology and sub national statistics	**M5.2.1.1 (2011-15)** Rice areas of Sub Saharan Africa, South, Southeast and East Asia and Latin America and the Caribbean mapped and classified	South, Southeast and East Asia, Sub Saharan Africa and Latin America and the Caribbean	Asia: IRRI Africa: AfricaRice/IRRI LAC: CIAT	**Short-term:** More accurate estimates of rice area, production and yield forecasts by can be generated scientists and policymakers, as a result of better underpinning data **Long-term:** Improved ability by national Policymakers in reducing production variability.
	M5.2.1.2 (2011-2015) High resolution rice area and rice planting date maps produced for major rice growing areas of SE Asia, including Philippines using RADAR data. Areas outside of the Philippines are contingent on RADAR data becoming freely available after 2012.	Southeast Asia	Philippines: PhilRice, IRRI Rest of Southeast Asia: IRRI Partners: SARMAP, European space Agency	
	M5.2.1.3 (2012) Rice phenology (start date, end date, length of season, length of fallow period, amplitude) for different agroecosystems identified.	South, Southeast and East Asia Sub Saharan Africa	Asia: IRRI Africa: AfricaRice/IRRI	
	M5.2.1.4 (2014) Annual crop calendar and fallow period database developed for Asia including climate data, actual yields, potential yield estimates and yield gaps for 2000-2013	Asia	IRRI	
5.2.2. Maps of major rice growing rice areas suffering from abiotic and biotic stresses.	**M5.2.2.1 (2012)** Areas subject to drought and submergence in South and SE Asia mapped and classified based on duration and frequency	South, Southeast Asia,	Asia: IRRI	**Short-term:** New rice technologies that are more targeted and appropriate for farmer's needs and constraints. **Long-term:** Increased adoption of
	M5.2.2.2 (2012) Areas subject to abiotic stresses in Africa mapped and classified based on duration and frequency	Africa	Africa: AfricaRice	

	M5.2.2.3 (2012) Areas subject to biotic stresses in East Africa mapped and classified based on virulence and development in a future climate	East Africa	AfricaRice/IRRI	appropriate rice technologies and availability of new drought tolerant rainfed lowland elite lines for national
	M5.2.2.4 (2012) Interactive web maps of the distribution of biotic and abiotic stresses, frequency, areas affected and yield losses for the 21 CARD countries and Niger.	Africa	Africa: AfricaRice	
	M5.2.2.5 (2013) Interactive web maps of the Participatory Varietal Selection (PVS) data	South Asia and Africa	South Asia: IRRI Africa: AfricaRice	
5.2.3. Identification and characterization of rice mega environments for effective technology targeting	**M5.2.3.1 (2013)** Characterization of target domains for new technologies based on factors such as adoption, consumer preferences, labor availability, population, poverty, purchasing power and accessibility, derived from survey and spatial data.	Southeast Asia and Sub Saharan Africa.	SE Asia: IRRI Africa: AfricaRice/IRRI	**Short-term:** New rice technologies that are more relevant and appropriate for farmer's needs and constraints as a result of better characterization of target environments. **Long-term:** Increased adoption of appropriate rice technologies.
	M5.2.3.2 (2013) A biophysical characterization based on agricultural and ecological factors such as climate, soils and growth cycles and crop duration	Southeast Asia, Sub Saharan Africa,	SE Asia and SSA: IRRI	
	M5.2.3.3 (2014) Development of a multi scale approach to link these characterizations to livelihood and production constraint information from household surveys from representative sites.	Southeast Asia, Sub Saharan Africa	SE Asia and SSA: IRRI	
	M5.2.3.4 (2015) Assessment of how markets will change under economic, demographic and climate change scenarios.	Southeast Asia, Sub Saharan Africa,	SE Asia and SSA: IRRI	

R&D Product Line: 5.3. Global Rice Information Gateway

Intermediate users: Analysts of ministry of agriculture, trade, finance, local governments, market participants, scientists and international organizations
Final users: Policymakers, commodity groups, rice traders and the ministry of agricultural trade.
Expected impact: Informed decision making by policymakers and greater stabilization of the global rice market.
Key current projects: EU, CIDA, BMGF-Global Futures (IFPRI), BMGF-CSISA; BMGF-STRASA, BMGF-GSR, Partial funding from IRRI

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
5.3.1. Global rice monitoring and forecasting system	**M5.3.1.1 (2011)** Development of monitoring and forecasting system for selected Asian countries.	Asia	IRRI	**Short-term:** Real time production information helps traders and policymakers in making timely decision on import requirements and stocks. **Long-term:** Smooth functioning of rice market by reducing price variability.
	M5.3.1.2 (2011) Establishment of the Rice Information Gateway for Africa (RIGA) portal.	Africa	AfricaRice	
	M5.3.1.3 (2012-2015) Monthly updates on rice production during cropping season	Asia	IRRI	
	M5.3.1.4 (2014) New outlets (mobile phone) for dissemination of market updates.	Asia	IRRI	
5.3.2. Rice databases to support rice policy, technology targeting and impact assessment.	**M5.3.2.1 (2011-2015)** Regular update of national rice statistics (production, consumption, trade and prices).	Global	IRRI, AfricaRice and CIAT	**Short-term:** Greater access of rice data by scientists and scholars will lead to array of analysis related to the rice sector. **Long-term:** Improved ability of policymakers to address rice related problems.
	M5.3.2.2 (2011-2015) Annual update of regional rice statistics on rice area, yield and production.	Global	IRRI: Asia AfricaRice: Africa	
	M5.3.2.3(2011) Capacity building for NARES economists and statisticians on the use of survey data management, processing, and publishing tools	Asia, and Africa	Asia: IRRI Africa: AfricaRice	
	M5.3.2.4 (2011-2015) *Information based on existing household survey datasets with gender disaggregated information, updated and made available online*	*Asia & Africa*	*IRRI: Asia* *AfricaRice: Africa*	
5.3.3. Medium-term outlook and quantitative assessment of domestic and trade policies	**M5.3.3.1 (2011-2015)** Analysis of the effects of domestic and trade policies for rice growing and importing countries at least once a year.	Global	IRRI & AfricaRice, University of Missouri, IOWA State University	**Short-term:** Timely information on policy effects helps policymakers in making accurate decision on domestic support policies. **Long-term:** Informed decision making by
	M5.3.3.2 (2011-2015) Two annual training courses in rice policy analysis for at least 20 NARES researchers	Global	IRRI, AfricaRice, Cirad and CIAT-PRGA	

	M5.3.3.3 (2011) Comprehensive database of rice policies affecting production, consumption and trade for major rice growing countries.	Global	IRRI, AfricaRice and CIAT	Policymakers in formulating appropriate policies for achieving national food security
	M5.3.3.4 (2012-13) Consultative frameworks for rice for rice policy dialogue and regional rice sector development strategies for West (2012) and Central Africa (2013).	West Africa	AfricaRice, ECOWAS, CEMAC, UEMOA, ROPPA, West Africa Women Rice Producers Association	
5.3.4. Opportunities identified for regional integration of rice policies including trade and reserve policies	**M5.3.4.1 (2012)** Evaluation of the economic cost, benefit and viability of regional rice storage systems in the ECOWAS zone and the ASEAN region.	Global	ASEAN: IRRI ECOWAS zone: AfricaRice, ASEAN Secretariat and ADB	**Short-term:** Comparative policy analysis helps with making decision on regional market integration. **Long-term:** Smooth functioning of rice market by reducing price variability.
	M5.3.4.2 (2013) Economic costs and benefits of coordinating and harmonizing rice trade policies of West Africa and ASEAN regions	West Africa, ASEAN	ASEAN:IRRI West Africa: AfricaRice	
	M5.3.4.3 (2011) Rice policy research and advocacy conference with RECs and other regional rice stakeholders	Africa	AfricaRice	
	M5.3.4.4 (2012) Assessment of the competitiveness of domestic rice production for 12 CARD countries	Africa	AfricaRice	
	M5.3.4.5 (2014) Examination of various factors affecting international/national rice price fluctuations and transmissions using time series analysis.	Global	IRRI & AfricaRice	

R&D Product Line: 5.4. Strategic foresight, priority setting, and impact assessment for rice research

Intermediate users:	Scientists in IARCS and NARES engaged in rice research and donors
Final users:	Extension agents, agricultural development agencies, farmer groups
Expected impact:	Improved economic, poverty and environmental impacts from rice research investments
Key current projects:	BMGF-STRASA, BMGF-CSISA, ADB, EU, CIDA, BMZ

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
5.4.1. Foresight and intelligence for strategic assessment of research priorities	**M5.4.1.1 (2011)** Comparative analysis of likely economic, poverty and environmental impacts expected from rice research (genetic improvement, management, policy analysis) in Asia and Africa.	Asia and Africa	IRRI: Asia AfricaRice: Africa Key partner: IFPRI	**Short-term:** Rice research portfolio of GRiSP and partners is better focused on topics with the greatest potential to benefit the poor and the environment **Long-term:** Increased benefits to the poor and the environment as a result of more relevant and effective research products that are more widely adopted
	M5.4.1.2 (2011) Detailed ex-ante assessment of the impact of improved grain quality and post-harvest research in Africa.	Africa	AfricaRice	
	M5.4.1.3 (2012) Assessment of promising crop management and diversification options.	Asia and Africa	IRRI: Asia AfricaRice: Africa	
	M5.4.1.4 (2013) *Analysis of the comparative advantages and evolving foci of different agencies in global rice research systems*	*Asia, Africa and Latin America*	*IRRI: Asia* *AfricaRice: Africa* *CIAT: Latin America*	
	M5.4.1.5 (2015) Updated comparative analysis of likely economic, poverty and environmental impacts from international rice research in Asia and Africa.	Asia and Africa	IRRI: Asia AfricaRice: Africa	
5.4.2. Ex post assessment of aggregate technology adoption trends and associated economic, poverty and environmental impacts	**M5.4.2.1 (2012-2013)** Assessment of the diffusion and adoption of modern rice varieties in Asia and Africa.	Asia and Africa	IRRI: Asia AfricaRice: Africa	**Short-term:** Enhanced ability to forecast the impact potential of alternative research investments, increased donor support to rice research for development; **Long-term:** Increased benefits for the poor and the environment from more targeted and better funded rice research
	M5.4.2.2 (2013) *Assessment of the impact of agronomic research in Latin America.*	*Latin America and the Caribbean*	*IRRI and CIAT-FLAR*	
	M5.4.2.3 (2013) Assessment of economic, environmental and poverty impacts from the adoption of efficiency enhancing NRM technologies in sub-regions of Asia, Africa, Latin America and the Caribbean.	Asia, Africa, Latin America and the Caribbean	IRRI: Asia AfricaRice: Africa LAC: CIAT-FLAR	
	M5.4.2.4 (2014) *Global analysis of the economic, poverty and environmental impact of rice genetic improvement by the IARCs.*	*Global*	*IRRI & AfricaRice*	
	M5.4.2.5 (2011-2015) One annual training course in impact assessment for at least 15 NARES researchers in Africa and one annual workshop to build partner capacity in Asia.	Asia and Africa	IRRI: Asia AfricaRice: Africa	

Theme 6: Supporting the growth of the global rice sector

Product line 6.1. Innovation in learning and communication tools and extension capacity development

Intermediate users:	Extension agents and staff from large investment projects, private sector, civil society
Final users:	Farmers and rice value chain stakeholders
Expected impact:	Effective and efficient diffusion mechanism for new rice systems technologies within country through multi-channel networks resulting in improved livelihoods for farmers and improved household and national food security
Key current projects:	BMGF/USAID-CSISA, BMGF-STRASA, IFAD-South Asia, IFAD-CURE, IRRC (SDC, ADB, ACIAR, IFA, IPNI,) ACIAR R-M, ACIAR-Cambodia & Laos, DA RSSP, IFAD-ESA, IFAD-WCA, CFC, AfDB , World Bank, USAID, Burundi HBF, Portugal Mozambique, JICA-IRRI-PhilRice, FLAR, CFC-Water harvesting

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
6.1.1. Rice knowledge management for dissemination	**M6.1.1.1 (2011)** Rice Knowledge Bank (RKB): Platform established for the RKB globally to link with FAO and CABI Bioscience knowledge management for enhanced coherence for extension	Asia, Africa;	IRRI, Africa Rice	**Short-term:** Up-to date rice knowledge is used by public and private extension and delivery systems. Teams of public and private sector professionals jointly develop local knowledge for delivery purposes. **Long-term:** Multiple stakeholders (public, private and civil society) providing up to date and consistent and timely knowledge for extension and farmers through multiple communication platforms
	M6.1.1.2 (2011) RKB: Pinoy RKB launched as principal ICT access point for rice extension for Philippines	Philippines	IRRI	
	M6.1.1.3 (2012) RKB: Research-based intensive cereal farming knowledge synthesized and uploaded on the CKB at IRRI and CIMMYT, for each country and for eight hubs in South Asia;	India, Bangladesh, Nepal, Pakistan	IRRI, CIMMYT,	
	M6.1.1.4 (2012) 3 LAC country specific knowledge banks to initiate LAC regional knowledge banks	LAC	CIAT-FLAR for LAC	
	M6.1.1.5 (2012) RKB: Rice Knowledge management portal for India shows strong links with global RKB/CKB (South Asia)	India	IRRI	
	M6.1.1.6 (2012) RKB/CKB protocol for extension knowledge established for other commodities within countries in which cross links for mega-programs (South Asia).	Asia, Africa	IRRI, Africa Rice, ILRI, World Fish	

	M6.1.1.7 (2015) RKB adapted and tested in at least 6 countries in ESA and 3 countries in WCA and used by at least three country investment projects (Africa)	Tanzania, Burundi, Mozambique, Kenya, Uganda and Ruanda in EAS and three countries in WA	AfricaRice, IRRI	
6.1.2 ICT for development	**M6.1.2.1 (2012) Mobile phone**: New products (with telecommunication company support) for widespread dissemination extension established and used; Asia (Philippines and Indonesia) with process clearly documented for cross learning with other regions.	Asia	IRRI	**Short-term:** Innovations in development and use of new ICT tools enhance dissemination of new rice technology by private, public and civil society with the outcome of enhanced dissemination **Long-term:** Farmers across the regions receive up to date knowledge on best practices in rice technology through a range of novel communication tools
	M6.1.2.2. (2012) Video: Multi-language rice DVDs distributed in at least 5 WCA and 5 ESA countries and rice production and post harvest grain quality enhanced for 200,000 farmers Africa	ESA and WA	AfricaRice	
	M6.1.2.3. (2013) Video: Public-private partnerships for large-scale video diffusion tested, documented and extended in at least three countries Africa	EAS and WA	AfricaRice	
	M6.1.2.4. (2013) Video: New series of organizational and institutional videos produced on water user groups, saving and credit groups, marketing, etc Africa with shared learning with SE and South Asia	ESA and WA	AfricaRice	
	M6.1.2.5. (2011) Hub communication platforms (HCP): established for support of delivery activities in 5 hubs for three technologies (real time information for extension and farmers)	India, Bangladesh, Nepal	IRRI	
	M6.1.1.6. (2015) Multi-channnel communication approaches for rice technology dissemination established (at least 3 telecenter networks, 2 cell phone companies, 2 TV companies and 2 community radio networks) Asia	Asia	IRRI	

6.1.3 Innovative models/ approaches for extension capacity development	**M6.1.3.1 (2011)** Joint release IRRI, AfricaRice and BRRI of e-seed training course with translation into local languages including Spanish and Portuguese at CIAT for LAC users	ESA, WA and South and South-East Asia, LAC	IRRI, Africa Rice, (NARES) BRRI and CIAT	**Short-term:** A set of training material developed for large scale capacity building of extension services. **Long-term:** Competence of extension personnel to deliver new rice technologies enhanced in Africa and Asia
	M6.1.3.2 (2013) Rice Production/ post production extension training course developed;	ESA, WA with training in Philippines	IRRI, AfricaRice	
	M6.1.3.3 (2014) Testing and documentation of learning of the agronomy extension training program of LAC in SE Asia in two countries	SE Asia	CIAT-FLAR(LAC), IRRI	
	M6.1.3.4 (2015) Review and documentation of the accreditation program for rice extension agronomists for potential use in other regions (South Asia)	India	IRRI	
	M6.1.3.5 (2015) PLAR modules on good agronomic practices used by major development projects with at least 1 t/ha yield improvement in at least 5 countries in Africa (ESA and West Africa)	ESA and WA	AfricaRice	
	M6.1.3.6 (2015) Extension methodology courses and rice production and processing training available online, on CD, and through community-based media such as radio, instructional materials for capacity building in local languages (South Asia, SE and E Asia and ESA and West Africa)	South Asia, SE and E Asia and ESA and West Africa	IRRI	
	M6.1.3.7 (2015) 138 extensionists trained with 30 percent women from 23 CARD countries (Anglophone and Francophone)	ESA, WA	IRRI, AfricaRice	
6.1.4 Technical expert services for rice sector investment and disaster / post-conflict response	**M6.1.4.1 (2012)** A new team of professional agronomists, business development specialists and multi-stakeholder facilitators is formed at AfricaRice and IRRI and CIAT-FLAR that provides technical support to large-scale development efforts in public/private or civil society and disaster/ post-conflict risk management.	Global	IRRI, AfricaRice CIAT-FLAR	**Short-term:** IRRI and AfricaRice contribute effectively to the technical components of regional and country rice investment projects. **Long-term:** Effectiveness of rice investment projects increased.
	M6.1.4.2 (2012) At least two investment fund	South Asia, SE and E	IRRI, AfricaRice,	

	partnerships implemented with IRRI or AfricaRice as key partner for rice;	Asia and ESA and WA and LAC	CIAT-FLAR	
	M6.1.4.3 (2015) For Liberia a National rice research team established, National rice research strategy adopted, national rice extension agents trained and National rice research and extension institutions fully operational	Liberia	AfricaRice	

R&D Product Line: 6.2. Effective systems for large-scale adoption of rice technologies in South Asia

Intermediate users:	Public sector research and delivery, private sector delivery agencies and civil society organizations (NGOs and peoples associations)
Final users:	Business entities, farmers (men and women)
Expected impact:	Effective and efficient diffusion mechanism for new rice systems technologies within country through multi-channel networks resulting in improved livelihoods for farmers and improved household and national food security.
Key current projects:	BMGF/USAID-CSISA (expansion Bangladesh), BMGF-STRASA Phase I and II, IFAD-South Asia, IFAD-CURE, IRRC (SDC, ADB, ACIAR, IFA, IPNI, IPI), ACIAR-R-M, FAO SAARC

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
6.2.1. New models for seed multiplication and targeted delivery systems	**M6.2.1.1 (2012)** At least 10 public and private seed companies produce and deliver high quality seed for intensive cereal systems;	India, Nepal, Bangladesh, Pakistan	IRRI	**Short-term:** Strong links established with regional/national and within country investment programs. Accelerated delivery of new stress-tolerant varieties to rice farmers in South Asia; Fast upscaling through multiple public and private sector channels; **Long-term:** Enhanced seed replacement rate and high proportion of farmers using high-quality seed.
	M6.2.1.2 (2015) Abiotic stress tolerant varieties delivered through multiple channels to 5 million farmers in South Asia resulting in 5 million tons additional rice production annually	India, Nepal, Bangladesh, Pakistan	IRRI	
6.2.2. New platforms for delivering agronomic, postharvest and processing innovations	**M6.2.2.1 (2012)** At least five private companies sign up to successful and profitable business models for out scaling intensive cereal systems technologies	India, Nepal, Bangladesh, Pakistan	IRRI, CIMMYT	**Short-term:** Strong links established between regional/national and within country investment programs and demand driven rice technologies developed in Themes 3-4. Accelerated delivery of new agronomic and postharvest technologies to rice farmers in South Asia triggers. Enhanced up- and outscaling through multiple public and private sector channels. **Long-term:** Self-sustained, multiple-channel public-private sector delivery
	M6.2.2.2 (2013) Hub Communication Platforms (HCP) established to provide seasonal monitoring information for extension service providers in five hubs (India, Nepal, Bangladesh)	India, Nepal, Bangladesh, Pakistan	IRRI, CIMMYT	
	M6.2.2.3 (2014) IRRI provides rice technical support to at least two large scale investment projects in South Asia	India, Nepal, Bangladesh, Pakistan	IRRI, CIMMYT	
	M6.2.2.4 (2015) Through improved management of intensive cereal systems at least 2 million poor rural households increased annual income by $350	India, Nepal, Bangladesh, Pakistan	IRRI, CIMMYT	

				mechanisms enable farmers to have better access to new technologies and information, thus triggering an agronomic revolution for closing yield gaps and reducing grain and grain quality losses
6.2.3. New models for jointly building extension capacity	**M6.2.3.1 (2012)** New accreditation schemes for Certified Crop Advisors (CCA) in India with at least 400 certified agronomists trained;	India, Nepal, Bangladesh, Pakistan	IRRI, Agronomy Society of America,	**Short-term:** A new model for self-sustained training, certification, and continued education of agricultural professionals enhances the knowledge and professional status of leading extension workers and service providers. **Short- and long-term:** A new cadre of professional 'extension agronomists' provides leadership in technology transfer to farmers, both in public and private sector. Grassroots trained women leaders and extension technicians through their organizations (public, private and civil) provide up to date technology and market information for farmers. A mechanism of support for partner institutions and organizations to build extension capacity.
	M6.2.3.2 (annual) Need based training of local women leaders who will provide training to women farmers on farm management, technical information and skills fro production to post harvests (25 persons per year)	India, Nepal, Bangladesh, Pakistan	IRRI with NARES and lead NGOs	
	M6.2.3.3 (2013) New retailer training and certification program for India and Bangladesh (with public and private sector)	India, Bangladesh	IRRI with NARES and private sector	
	M6.2.3.4 (2015) Trained resources of milestones 6.2.3.1-3 provide training for at least 10000 grassroots extension persons, including 30 percent women	India, Nepal, Bangladesh, Pakistan	IRRI with lead NGOs	

R&D Product Line: 6.3. Effective systems for large-scale adoption of rice technologies in Southeast and East Asia

Intermediate users:	Public sector research and delivery, private sector delivery agencies and civil society organizations (NGOs and peoples associations)
Final users:	Business entities, farmers (men and women)
Expected impact:	Effective and efficient diffusion mechanism for new rice systems technologies within country through multi-channel networks resulting in improved livelihoods for farmers and improved household and national food security
Key current projects:	CURE (IFAD, ACIAR), IRRC (SDC, ABD, ACIAR, IFA, IPNI, IPI), DA-RSSP, ACIAR-Cambodia & Laos

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
6.3.1. New models for seed multiplication and delivery systems	**M6.3.1.1 (2012)** Variety release and seed systems analyzed, including community-based seed systems; recommendations for harmonization and improvement	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	IRRI	**Short-term:** Strong links established with regional/national and within country investment programs. Accelerated delivery of new stress-tolerant varieties to rice farmers in SE Asia; Fast up-scaling through public and private sector channels. **Long-term:** Enhanced seed replacement rate and high proportion of farmers using high-quality seed.
	M6.3.1.2 (2015) Improved seed delivered through private and public sector channels	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	IRRI	
6.3.2. New platforms for delivering agronomic, post-harvest and processing innovations	**M6.3.2.1 (2012)** At least two investment fund partnerships implemented with IRRI as key partner for rice;	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand, Nepal, India	IRRI	**Short-term:** Strong links established between regional/national and within country investment programs and demand driven rice technologies developed in Themes 3-4. Accelerated delivery of new agronomic and postharvest technologies to rice farmers. Enhanced up- and out-scaling through multiple public and private sector channels. IRRC and CURE provide effective platforms for joint learning and implementation of multiple new NRM technologies.
	M6.3.2.2 (2014) Support for delivery and adoption of AWD and SSNM to at least 300,000 farmers in the Philippines	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand, Nepal, India	IRRI	
	M6.3.2.3 (2014) Support delivery and adoption of Integrated Crop Management to 1 million farmers in Indonesia	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand, Nepal, India	IRRI	
	M6.3.2.4 (2014) Stress-tolerant varieties and crop and natural resources management options delivered to 100,000 farm households in Southeast Asia	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand, Nepal, India	IRRI	
	M6.3.2.5 (2015) Novel NRM rice technologies	Vietnam, Indonesia,	IRRI	

	adopted at a national policy level strengthen delivery and adoption of Rice GAP to 400,000 farmers in the Mekong Delta, Vietnam	Myanmar, Philippines, Laos, Cambodia, Thailand, Nepal, India		**Long-term:** Self-sustained, multiple-channel public-private sector delivery mechanisms enable farmers to have better access to new technologies and information, thus triggering an agronomic revolution for closing yield gaps and reducing grain and grain quality losses.
6.3.3. New models for jointly building extension capacity	**M6.3.3.1 (2014)** New accreditation scheme for certified extension-agronomists (CCA) in one SE Asian country, with at least 400 trained professionals	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	IRRI (IRRI, NARES, private sector and civil society partners)	**Short-term:** A new model for self-sustained training, certification, and continued education of agricultural professionals enhances the knowledge and professional status of leading extension workers and service providers. **Short- and long-term:** A new cadre of professional 'extension agronomists' provides leadership in technology transfer to farmers, both in public and private sector. Grassroots trained women leaders and extension technicians through their organizations (public, private and civil) provide up to date technology and market information for farmers. A mechanism of support for partner institutions and organizations to build extension capacity.
	M6.3.3.2 (2015) Need based training of local women leaders who will provide training to women farmers on farm management, community-based organizational skills, technical information and skills from production to post harvests (25 persons per year)	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	IRRI with lead NGOs	
	M6.3.3.3 (2015) Trained resource of milestone 6.3.4.1 and 6.3.4.2 provide training for 5000 grassroots extension persons, including women	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	IRRI with lead NGOs	

R&D Product Line: 6.4. Effective systems for large-scale adoption of rice technologies in Africa

Intermediate users:	Extension agents and staff from large investment projects, private sector
Final users:	Farmers and rice value chain stakeholders
Expected impact:	Effective and efficient diffusion mechanism for new rice systems technologies within country through multi-channel networks resulting in improved livelihoods for farmers and improved household and national food security
Key current projects:	BMGF-STRASA, IFAD-ESA, IFAD-WCA, CFC-Central Africa, MOFA - Japan Emergency Initiative, AfDB – African Rice Initiative, USAID - Famine Fund project, Syngenta Foundation – rice value chain project

Products	Milestones	Target region/key countries	Lead institution in GRiSP	Outcomes
6.4.1. New models for seed multiplication and seed delivery systems	**M6.4.1.1 (2013)** At least 20 public-private partnerships established to strengthen the rice seed sector with functional seed board in 5 WCA countries	Africa	AfricaRice	**Short-term:** Strong links established between regional/national and within country investment programs and demand driven rice technologies developed in Themes 2. Accelerated delivery of new stress-tolerant varieties to rice farmers in Africa; Fast up-scaling through multiple public and private sector channels. **Long-term:** Improved on-farm conservation and high proportion of farmers using improved varieties and high-quality seed.
	M6.4.1.2 (2013) At least 10 private seed companies strengthened through supply of up to date information on farmers' needs and latest technologies	Africa	AfricaRice, IRRI	
	M6.4.1.3 (2015) Abiotic stress tolerant varieties for drought, salinity, iron toxicity, low temperature and submergence delivered to 500,000 farmers in SSA resulting in at least 500,000 tons additional rice production	Africa	AfricaRice, IRRI	
6.4.2. New platforms for delivering agronomic, post-harvest and processing innovations	**M6.4.2.1 (2011)** Major rice development projects in at least 6 African countries team up with GRiSP	Africa	AfricaRice, IRRI	**Short-term:** Strong links established between regional/national and within country investment programs and demand driven rice technologies developed in Themes 3-4. Accelerated delivery of new agronomic and postharvest technologies to rice farmers in Africa triggers. Enhanced up- and out-scaling through multiple public and private sector channels.
	M6.4.2.2 (2013) Productivity significantly enhanced in key villages (rice knowledge centers) in major rice development projects (at least 10 rice knowledge centers per country)	Africa	AfricaRice, IRRI	
	M6.4.2.3 (2015) Outscaling of innovations to second generation farming communities, reach at least 20,000 farming families per country in major rice development projects	Africa	AfricaRice, IRRI	
	M6.4.2.4 (2013) Public-private sector partnerships to stimulate mechanization of the rice sector established in at least 4 countries in SSA	Africa	AfricaRice, IRRI	

	M6.4.2.5 (2013) Multi-stakeholder and public-private sector collaborative approach to rice value chain development for irrigated and rainfed systems tested in SSA (proof of concept)	Mali, Senegal, Burkina Faso	AfricaRice	**Long-term:** Self-sustained, multiple-channel public-private sector delivery mechanisms enable farmers to have better access to new technologies and information, thus triggering an agronomic revolution for closing yield gaps and reducing grain and grain quality losses.
6.4.3. New models for jointly building extension capacity	**M6.4.3.1 (annually)** At least 60 extension agents trained in integrated rice management for lowland rice-based systems	Africa	AfricaRice	**Long-term:** A cadre of 'extension agronomists' provides leadership in technology transfer to farmers through the wider extension community using local practices adapted from international best practice. Grassroots trained women leaders and extension technicians through their organizations (public, private and civil) provide up to date technology and market information for farmers. A mechanism of support for partner institutions and organizations to build extension capacity.
	M6.4.3.2 (2014) New accreditation schemes for extension-agronomists	Africa	AfricaRice, ICRA, IRRI	
	M6.4.3.3 (2015) Trained resource of milestone 6.4.3.1 provide training to 2000 grassroots extension agents, including women	Africa	AfricaRice, ICRA, IRRI	

R&D Product Line: 6.5. Effective systems for large-scale adoption of rice technologies in Latin America and the Caribbean

Intermediate users: Agribusiness companies and organization, NARES, farmers' organizations, seed and milling industry
Final users: Farmers
Expected impact: Increase yield up to 20% by 2015 by implementation of BMP, water harvesting technologies and effective seed systems
Key current projects: FLAR, CFC-Water harvesting

Products	Milestones	Target region/ key countries	Lead institution(s)	Outcomes
6.5.1. Systems for enhanced extension of improved crop management practices for closing yield gaps among farmers	**M6.5.1.1 (2013)** Access and use of information and technology improved	Colombia, Venezuela, Guyana, Surinam, Ecuador, Peru, Bolivia, Chile, Panamá, Costa Rica, Nicaragua, Honduras, Salvador, México, Guatemala, Cuba, D.Republic	FLAR/CIAT, IRRI	**Short-term:** Improved crop management transference programs in place and farmers adopting BMP in 6 countries **Long-term:** Full adoption of BMP in targeted regions with substantial increases in total rice production by 2015 and expansion of the program to other countries
	M6.5.1.2 (2014) Best crop management practices identified for each target region, innovative farmers identified and trying BMP, groups of farmers formed, local institutions in charge of the program	Colombia, Venezuela, Guyana, Surinam, Ecuador, Peru, Bolivia, Chile, Panamá, Costa Rica, Nicaragua, Honduras, Salvador, México, Guatemala, Cuba, D.Republic	FLAR/CIAT,	
6.5.2. Effective variety release mechanisms and seed systems for delivering high quality seed of new varieties	**M6.5.2.1 (2013)** Variety release process improved and accelerated. Public breeding and certification agencies well organized and private seed industry developed.	Guatemala, Honduras, Nicaragua, Guyana, Ecuador, Bolivia	FLAR/CIAT	**Short-term:** High percentage of the farmers use certified seed of new varieties; Good quality seed reduce weed, pest and diseases problems. **Long-term:** Substantial increases in yields and in the quality of grain are obtained by farmers
	M6.5.2.2 (2014) Improved seed purification and basic seed production by partner organizations. Certified seed is produced in adequate volumes to cover demand	Guatemala, Honduras, Nicaragua, Guyana, Ecuador, Bolivia	FLAR/CIAT,	
	M6.5.2.3 (2015) Increased volume of certified seed sold to farmers	Guatemala, Honduras, Nicaragua, Guyana, Ecuador, Bolivia	FLAR/CIAT,	
6.5.3. Systems for enhanced adoption of water harvesting	**M6.5.3.1 (2011)** Sites selected and reservoir designs prepared in the target	Nicaragua, Costa Rica, Honduras, Mexico, Guatemala, Panamá, Colombia, Ecuador, Bolivia	FLAR/CIAT	**Short-term:** Small and medium rice farmers in the tropics changed from low yield low income upland rice to

technology in the tropics for land transformation to irrigated agriculture	**M6.5.3.2 (2013)** Water collecting facilities constructed. Transfer and extension programs in place in each pilot location	Nicaragua, Costa Rica, Honduras, Mexico, Guatemala, Panamá, Colombia, Ecuador, Bolivia	FLAR/CIAT	high yielding and highly efficient irrigated agriculture. Water availability allows for product diversification, including corn, beans and fish production **Long-term:** Farmers have higher and more stable income and countries improve food security
	M6.5.3.3 (2015) Financial and technical support in place to expand water harvesting to more farmers; increased number of small reservoirs constructed	Nicaragua, Costa Rica, Honduras, Mexico, Guatemala, Panamá, Colombia, Ecuador, Bolivia	FLAR/CIAT	

Appendix 3. Supplementary Budget Tables

Table B6. IRRI donor funding assumptions, 2010 Estimate (USD million)

Donor	Unrestricted	Attributed	Restricted	Challenge Programs	Total	Assumed Future Proportions %: Fund Windows 1-3	Assumed Future Proportions %: Bilateral: CGIAR Members	Assumed Future Proportions %: Bilateral: Non-CGIAR Members	Assumed Future Proportions US$: Fund Windows 1-3	Assumed Future Proportions US$: Bilateral: CGIAR Members	Assumed Future Proportions US$: Bilateral: Non-CGIAR Members
ADB	-	-	1.138	-	1.138	100%			1.138	-	-
AfricaRice	-	-	0.057	-	0.057		100%		-	0.057	-
Australia	1.282	-	-	-	1.282	100%			1.282	-	-
ACIAR	-	-	1.301	-	1.301	100%			1.301	-	-
CSIRO	-	-	0.077	-	0.077			100%	-	-	0.077
NSW I&I	-	-	0.107	-	0.107			100%	-	-	0.107
Bangladesh	0.100	-	-	-	0.100	100%			0.100	-	-
Bayer CropScience AG	-	-	0.157	-	0.157			100%	-	-	0.157
Bill and Melinda Gates Foundation	-	-	16.419	-	16.419	100%			16.419	-	-
Canada	1.172	-	-	-	1.172	100%			1.172	-	-
Challenge Programs	-	-	-	-	-				-	-	-
Generation	-	-	-	1.174	1.174	100%			1.174	-	-
HarvestPlus	-	-	-	0.954	0.954	100%			0.954	-	-
Water & Food	-	-	-	0.086	0.086	100%			0.086	-	-
China	0.140	-	-	-	0.140	100%			0.140	-	-
CAAS	-	-	1.022	-	1.022		100%		-	1.022	-
China Attribution	-	-	0.074	-	0.074	100%			0.074	-	-
SGRP, CGIAR, Bioversity	-	-	-	-	-				-	-	-
Bioversity	-	-	0.057	-	0.057	100%			0.057	-	-
SGRP, CGIAR - Bioversity	-	-	0.065	-	0.065	100%			0.065	-	-
EC	-	1.008	0.361	-	1.369		100%		-	1.369	-
FAO	-	-	0.031	-	0.031		100%		-	0.031	-
France	0.091	-	-	-	0.091	100%			0.091	-	-
CIRAD	-	-	0.095	-	0.095		100%		-	0.095	-
France Attribution	-	-	0.366	-	0.366	100%			0.366	-	-
Germany	0.569	-	-	-	0.569	100%			0.569	-	-
BMZ	-	-	0.516	-	0.516		100%		-	0.516	-
Global Challenge for Global Health	-	-	0.271	-	0.271			100%	-	-	0.271
Global Crop Diversity [b]	-	-		-	-		100%		-	-	-
HRDC	-	-	0.407	-	0.407			100%	-	-	0.407
ICARDA	-	-	0.023	-	0.023	100%			0.023	-	-
ICRISAT	-	-	0.197	-	0.197	100%			0.197	-	-
India	0.150	0.300	-	-	0.450	100%			0.450	-	-
ICAR	-	-	0.038	-	0.038	100%			0.038	-	-
IFAD	-	-	1.589	-	1.589	100%			1.589	-	-
IFA/IPNI/IPI	-	-	-	-	-				-	-	-
IFA/IPNI/IPI	-	-	0.131	-	0.131			100%	-	-	0.131
IPI	-	-	0.001	-	0.001			100%	-	-	0.001
IPNI	-	-	0.001	-	0.001			100%	-	-	0.001
IFPRI	-	-	0.094	-	0.094	100%			0.094	-	-
Iran	-	-	-	-	-				-	-	-
AREO	-	-	0.027	-	0.027	100%			0.027	-	-
Japan	0.831	0.643	-	-	1.474	100%			1.474	-	-
Go'vt of Japan	-	-	1.701	-	1.701	100%			1.701	-	-
MAFF-Japan	-	-	0.368	-	0.368		100%		-	0.368	-
NIAES-Japan	-	-	0.024	-	0.024		100%		-	0.024	-
JICA	-	-	0.293	-	0.293			100%	-	-	0.293
JIRCAS	-	-	0.479	-	0.479		100%		-	0.479	-

Table B6 (continued). IRRI donor funding assumptions, 2010 Estimate (USD million)

Donor	Unrestricted	Attributed	Restricted	Challenge Programs	Total	Assumed Future Proportions %			Assumed Future Proportions US$		
							Bilateral			Bilateral	
						Fund Windows 1-3	CGIAR Members	Non-CGIAR Members	Fund Windows 1-3	CGIAR Members	Non-CGIAR Members
Korea	0.147	0.050	-	-	0.197	100%			0.197	-	-
RDA	-	-	0.656	-	0.656		100%		-	0.656	-
Malaysia	-	-	-	-	-				-	-	-
MARDI	-	-	0.023	-	0.023	100%			0.023	-	-
Norway	0.317	-	-	-	0.317	100%			0.317	-	-
Philippines	0.100	-	-	-	0.100	100%			0.100	-	-
BAR-DA	-	-	0.046	-	0.046		100%		-	0.046	-
DA-ATI	-	-	0.020	-	0.020		100%		-	0.020	-
PhilRice	-	-	0.344	-	0.344			100%	-	-	0.344
Pioneer Hi-bred Int'l	-	-	0.171	-	0.171			100%	-	-	0.171
Portugal	-	-	-	-	-				-	-	-
IICT-Portugal	-	-	0.175	-	0.175	100%			0.175	-	-
RF	-	-	1.081	-	1.081		100%		-	1.081	-
Sweden	0.500	-	-	-	0.500	100%			0.500	-	-
Switzerland	0.932	-	-	-	0.932	100%			0.932	-	-
SDC	-	-	1.096	-	1.096		100%		-	1.096	-
Thailand	0.040	-	-	-	0.040	100%			0.040	-	-
Turkey	0.010	-	-	-	0.010	100%			0.010	-	-
GDAR	-	-	0.010	-	0.010	100%			0.010	-	-
UK	2.381	-	-	-	2.381	100%			2.381	-	-
NEFORD,DFID	-	-	0.038	-	0.038		100%		-	0.038	-
University of Aberdeen	-	-	0.009	-	0.009			100%	-	-	0.009
BBSRC, DFID	-	-	0.038	-	0.038		100%		-	0.038	-
USA	-	-	-	-	-				-	-	-
USAID "Core"	3.950	-	1.829	-	5.779	100%			5.779	-	-
USAID Missions	-	-	0.442	-	0.442		100%		-	0.442	-
USDA	-	-	0.100	-	0.100		100%		-	0.100	-
Vietnam	0.015	-	-	-	0.015	100%			0.015	-	-
AGI	-	-	0.072	-	0.072			100%	-	-	0.072
World Bank	2.410	-	0.302	-	2.712	100%			2.712	-	-
Others	-	-	-	-	-				-	-	-
Arcadia Biosciences	-	-	0.063	-	0.063			100%	-	-	0.063
The Asia Foundation	-	-	0.005	-	0.005			100%	-	-	0.005
Calvin College	-	-	0.003	-	0.003			100%	-	-	0.003
CARE International-Burundi	-	-	0.138	-	0.138			100%	-	-	0.138
Cornell University	-	-	0.161	-	0.161			100%	-	-	0.161
Charles Sturt University	-	-	0.095	-	0.095			100%	-	-	0.095
Colorado State University	-	-	0.048	-	0.048			100%	-	-	0.048
Devgen N.V.	-	-	0.049	-	0.049			100%	-	-	0.049
National Graduate Institute for Policy Studies (GRISPS)	-	-	0.011	-	0.011			100%	-	-	0.011
Hatfield Consultants Partnership	-	-	0.010	-	0.010			100%	-	-	0.010
International Institute for Environment and Development	-	-	0.046	-	0.046			100%	-	-	0.046
Anonymous	-	-	0.151	-	0.151			100%	-	-	0.151
Kellog Company	-	-	0.046	-	0.046		100%		-	0.046	-
Liang	-	-	0.020	-	0.020			100%	-	-	0.020
Nunhems BV	-	-	0.011	-	0.011			100%	-	-	0.011
Plan International	-	-	0.006	-	0.006			100%	-	-	0.006
Syngenta Asia Pacific Pte. Ltd	-	-	0.154	-	0.154		100%		-	0.154	-
The Regents of University of California	-	-	0.058	-	0.058			100%	-	-	0.058
World Vision	-	-	0.089	-	0.089			100%	-	-	0.089
Total	**15.136**	**2.001**	**35.103**	**2.214**	**54.455**				**43.773**	**7.676**	**3.005**

Table B6 (continued). AfricaRice donor funding assumptions, 2010 Estimate (USD million)

Donor	Unrestricted	Attributed	Restricted	Challenge Programs	Total	Assumed Future Proportions %			Assumed Future Proportions US$		
							Bilateral			Bilateral	
						Fund Windows 1-3	CGIAR Members	Non-CGIAR Members	Fund Windows 1-3	CGIAR Members	Non-CGIAR Members
African Development Bank (AFDB)			0.640		0.640			100%	-	-	0.640
Alliance for Green Revolution for Africa (AGRA)			0.110		0.110			100%	-	-	0.110
Banque Arabe pour le Développement Economique en Afrique (BADEA)			0.630		0.630			100%	-	-	0.630
Belgium	0.566				0.566	100%			0.566	-	-
Bioversity International			0.070		0.070	100%			0.070	-	-
Canada	0.627				0.627	100%			0.627	-	-
Canadian International Development Agency (CIDA)			0.050		0.050		100%		-	0.050	-
Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)			0.146		0.146		100%		-	0.146	-
Chinese Academy of Agricultural Sciences (CAAS)			1.130		1.130		100%		-	1.130	-
Common Fund for Commodities (CFC)			0.610		0.610			100%	-	-	0.610
Conservation, Food & Health Foundation, Inc. (CFHF)			0.006		0.006			100%	-	-	0.006
CP-Generation				0.590	0.590	100%			0.590	-	-
CP-Water and Food				0.009	0.009	100%			0.009	-	-
Esso Exploration & Production Chad Inc			0.180		0.180			100%	-	-	0.180
European Commission		1.821			1.821		100%		-	1.821	-
Food and Agriculture Organization of the United Nations (FAO)			0.200		0.200		100%		-	0.200	-
France	0.122				0.122	100%			0.122	-	-
Germany		0.231	0.740		0.971		100%		-	0.971	-
International Bank for Reconstruction and Development (IBRD/WB)	1.800		0.400		2.200	100%			2.200	-	-
International Foundation for Art Research (IFAR)			0.033		0.033			100%	-	-	0.033
International Fund for Agricultural Development (IFAD)			0.515		0.515	100%			0.515	-	-
International Rice Research Institute (IRRI)			0.874		0.874	100%			0.874	-	-
Japan - Ministry of Foreign Affairs	0.385	0.867	0.287		1.539	100%			1.539	-	-
Japan - Ministry of Finance			1.600		1.600	100%			1.600	-	-
Japan - Ministry of Agriculture, Forestry and Fisheries			0.622		0.622		100%		-	0.622	-
Japan - Others (JICA/JIRCAS)			0.200		0.200		100%		-	0.200	-
Member States	1.479				1.479		100%		-	1.479	-
Sweden	0.455				0.455	100%			0.455	-	-
Syngenta Foundation			0.077		0.077		100%		-	0.077	-
The Netherlands Organisation for Scientific Research (NOW-WOTRO)			0.104		0.104			100%	-	-	0.104
United Kingdom	0.722		0.019		0.741		100%		-	0.741	-
United Nations Development Programme (UNDP)			0.255		0.255			100%	-	-	0.255
United States	0.250				0.250	100%			0.250	-	-
United States Agency for International Development (USAID)			2.139		2.139		100%		-	2.139	-
Total	**6.406**	**2.919**	**11.637**	**0.599**	**21.561**				**9.417**	**9.576**	**2.568**

Table B6 (continued). CIAT donor funding assumptions, 2010 Estimate (USD million)

Donor	Unrestricted	Attributed	Restricted	Challenge Programs	Total	Assumed Future Proportions %			Assumed Future Proportions US$		
							Bilateral			Bilateral	
						Fund Windows 1-3	CGIAR Members	Non-CGIAR Members	Fund Windows 1-3	CGIAR Members	Non-CGIAR Members
Common Fund for Commodities (CFC)			0.470	-	0.470			100%	-	-	0.470
Canada			0.590	-	0.590	100%			0.590	-	-
FEDEARROZ			0.290	-	0.290			100%	-	-	0.290
FLAR			1.083	-	1.083			100%	-	-	1.083
FONTAGRO			0.378	-	0.378			100%	-	-	0.378
Challenge Programs											
Generation			-	0.104	0.104	100%			0.104	-	-
GEF			0.530	-	0.530			100%	-	-	0.530
Rice Tec.			0.160	-	0.160			100%	-	-	0.160
OTHERS			0.477	-	0.477	50%		50%	0.239	-	0.239
USA											
USAID OTHERS			0.350	-	0.350	100%			0.350	-	-
UNRESTRICTED	0.400				0.400	100%			0.400	-	-
Total	**0.400**	**-**	**4.328**	**0.104**	**4.832**				**1.683**	**-**	**3.150**

Table B7. 21st Century research facilities (USD million, not included in GRiSP budget)

Center	Infrastructure	Site	Cost
IRRI	New state-of the art Plant Growth Center	Los Banos, Laguna, Philippines	12.00
	Upgrade of existing plant growth facilities	Los Banos, Laguna, Philippines	5.00
	New field phenotyping facility	Los Banos, Laguna, Philippines	5.00
	Major upgrade of the Experimental Farm	Los Banos, Laguna, Philippines	5.00
	Genebank upgrade and renovation	Los Banos, Laguna, Philippines	30.00
	Upgrade and renovation of Training Center and dormitory	Los Banos, Laguna, Philippines	2.00
	Renovation of Chandler Hall Riceworld and development of conference facilities	Los Banos, Laguna, Philippines	1.00
	New physiology laboratories	Los Banos, Laguna, Philippines	5.00
	Digital campus	Los Banos, Laguna, Philippines	0.50
	Solar Energy	Los Banos, Laguna, Philippines	10.00
	Subtotal		**75.50**
Africa Rice	Rice agronomy and post-harvest training center, Senegal	Ndiaye, Senegal	1.00
	Biotic stresses phenomics and upgraded MAS facility	Cotonou, Benin	1.50
	LT storage facility GRU	Cotonou, Benin	1.00
	Subtotal		**3.50**
CIAT	Upgrade of phenomics, transgenics and marker lab facilities	Colombia	5.00
	Upgrade of irrigation and machinery systems for confined biosafety trials at Santa Rosa station	Colombia	0.50
	Upgrade and renovation of Training Center	Colombia	0.25
	Subtotal		**5.75**
Total			**84.75**

Table B8. Rice genebanks (USD million; not included in GRiSP budget)*

	Actual	Current Estimate	GRiSP					
Genebanks	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Genebank + other collections	1.11	1.44	1.49	1.53	1.58	1.63	1.67	7.90

* CGIAR-wide costing study for genebanks is ongoing to verify these numbers and define the funding mechanism.

Appendix 4. Statements of Support and Contributions to GRiSP by Partners

- Cirad and IRD, France
- JIRCAS, Japan
- New Partnership for Africa's Development (NEPAD)
- Asia-Pacific Association of Agricultural Research Institutions (APAARI)
- Coalition for African Rice Development (CARD)
- Forum for Agricultural Research in Africa (FARA)
- Catholic Relief Services (CRS), USA
- Latin American Fund for Irrigated Rice (FLAR)
- Africa Harvest, Kenya
- CABI, UK,
- ICRA, The Netherlands
- CAAS, China P.R.
- ICAR, India

cirad
LA RECHERCHE AGRONOMIQUE POUR LE DÉVELOPPEMENT

IRD
Institut de recherche pour le développement

Montpellier, September 3, 2010

Dr Achim Dobermann, DDG4R IRRI
Dr Marco Wopereis, DDG4R AfricaRice
Dr Joe Tohmé, DDG4R CIAT

Subject: update of the contribution of Cirad and IRD to the Megaprogramme *MP3: Sustainable staple food productivity increase for global food security – Rice component - GRiSP*

Dear Achim, Marco and Joe

Thank you very much for the very last version of the project document. We highly appreciate of having been closely associated in the development of the GRiSP proposal during these last five months.

With this letter we would like to reiterate the willingness of the scientific teams of CIRAD and IRD working on rice to fully participate to the implementation of GRiSP as we already expressed in a our letter of May 10th. We also really appreciate the effort made by GRiSP to involve a large number of various stakeholders from the South and from the North as well.

You will find below an updated estimate of the financial inputs linked to our foreseen contribution to GRiSP activities based on the last list of the product lines. It is however our understanding that partners (including ARIs) should have a significant access to the funding from GRiSP according to their actual involvement in its activities.

Best regards.

Bernard Dreyfus

Director Living Resources, IRD

Patrick Caron

Deputy Director General of Research and Strategy, CIRAD

Direction générale déléguée à la recherche et à la stratégie
TA 179/04 – Avenue Agropolis – 34398 Montpellier Cedex 5, France
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Forseen contribution from CIRAD & IRD to GRiSP (in US dollars)

GRiSP Themes	Contribution from **CIRAD** integrated in the GRiSP Log-frame			Contribution from **IRD** integrated in the GRiSP Log-frame			Cirad + IRD	
	Product lines	HR (FTE)	Estimated current annual investment (US $)	Product lines	HR (FTE)	Estimated current annual investment (US $)	HR (FTE)	Estimated current annual investment (US $)
1	1.1, 1.2, 1.3	20	4 160 000	1.2, 1.3	17,5	3 640 000	37,5	7 800 000
2	2.2, 2.3, 2.6	8	1 664 000	2,2	7,5	1 560 000	15,5	3 224 000
3	3.2, 3.3, 3.4, 3.5	28,5	5 928 000		0	0	28,5	5 928 000
4	4.2, 4.3	3,5	728 000		0	0	3,5	728 000
5	5.3, 5.4	1,5	312 000				1,5	312 000
6			0				0	0
Total		**61,5**	12 792 000		**25**	5 200 000	**86,5**	17 992 000

Letter of Support for Global Rice Science Partnership (GRiSP)

JIRCAS hereby describes on-going international rice research activities and estimated current annual investment, as requested.

1. Current investment by GRiSP product lines

Product line	Estimated current annual investment (US$)
Theme 1: Genetic resources and discovery	
1.3. Genes and allelic diversity conferring stress tolerance and enhanced nutrition	1,735,000
Theme 2: Accelerating the development, delivery and adoption of improved rice varieties	
2.2. Improved knowledge, donors, and genes conferring valuable traits	352,000
2.3. Stress-tolerant rice varieties for South and Southeast Asia	19,000
2.4. Stress-tolerant rice varieties for Africa	392,000
Theme 3: Increasing the productivity and sustainability of rice ecosystems (Sustainable Rice Production Systems)	
3.1. Innovative technologies for an ecological intensification of rice production systems under current and future climates	142,000
3.5. Farm management innovations for lowland rice-based systems in Africa across an intensification gradient	1,236,000
Theme 4: Adding more value from rice harvests through improved processing and market systems and new products	
4.1 Technologies and business models to improve rice postharvest practices, processing and marketing	60,000
Theme 5: Policy and Information	
5.3. Global rice information gateway for market analysis and policy planners	103,000

2. Additional rice research not included in GRiSP product lines

Capacity building for future rice science leaders 48,000

The estimated amounts given above apply only for this current financial year (2010), and do not include payment for salaries.

Sincerely yours,

Kenji Iiyama
President, JIRCAS

Date: 7th May 2010

African Union

NEPAD
A PROGRAMME OF THE AFRICAN UNION
NEPAD Planning and Coordinating Agency (NPCA)

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South Africa

Date: 28 April 2010
Ref: RM/Agric/ps

11 May 2010

Dr Papa Abdoulaye Seck
Director General
Africa Rice Center (AfricaRice)
Cotonou, Benin

Email: p.seck@cgiar.org

Dear Dr Pape Seck,

LETTER OF SUPPORT FOR THE GLOBAL RICE SCIENCE PARTNERSHIP (GRISP)

The New Partnership for Africa's Development (NEPAD) is an initiative by African Heads of State, which has the objective of pooling resources and implementing strategies to develop the African continent. We strongly believe that the Global Rice Science Partnership (GRiSP) is a novel and innovative idea and it has the full support of our organization.

NEPAD is prepared to provide the political support required for the concretization of the GRiSP because i) rice is becoming more and more an important staple food for Africans, ii) the approach being used is participatory and will benefit from the strengths of the various interveners along the rice value chain and iii) this rice science partnership can act as a bridge for South-South collaboration and exchange of useful agricultural technologies between Africa, Asia and Latin America for the benefit of African farmers in their fight against poverty and food insecurity.

In my capacity as the Head of the Comprehensive Africa Agriculture Development Programme (CAADP), I am pleased to provide the strongest support to the GRiSP.

Yours sincerely,

Head: Comprehensive African Agriculture Development Programme
NEPAD Planning and Communications Directorate

ASIA-PACIFIC ASSOCIATION OF AGRICULTURAL RESEARCH INSTITUTIONS (APAARI)

C/o ICRISAT, CG Centres Block, National Agriculture Science Center Complex
Dev Prakash Shastri Marg, Pusa Campus, New Delhi – 110 012

Ph.: 91-11-65437870; Fax: 91-11-25843243, E-mail: raj.paroda@yahoo.com

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Dr. Raj Paroda
Executive Secretary

Ref.: APAARI/2010/
Date: 04th May, 2010

Dr. Robert Zeigler
Director General
International Rice Research Institute (IRRI),
Box 933, 1099 Manila,
PHILIPPINES

Dear Dr. Zeigler,

Over the past year, IRRI has sought input from APPARI and its member institutions on the development of a Global Rice Science Partnership (GRiSP). In October, APAARI discussed the overall CGIAR change process and provided inputs into this. At that time, APAARI endorsed the concept of the GRiSP.

The Asia Pacific Association of Agricultural Research Institutions (APAARI) Executive Committee met on 24 April 2010 and discussed, among other items, the outcome of the GCARD meeting at Montpellier from 28-31 March 2010. APAARI recognizes the overwhelming importance of rice as the primary staple for most of Asia's poor, and fully supports the decision of the Board of the new CGIAR Consortium to fast track, as a Mega Program, the Global Rice Science Partnership (GRiSP) proposed by IRRI, AfricaRice, and CIAT. APAARI believes that there is an urgent need for a fully integrated global approach to tackle the main challenges of poverty, equity, food security, environmental sustainability, climate change, and policy in rice-based systems and the rice sector as a whole.

The Committee is also impressed by the broad and global partnership that GRiSP will foster. This is a strong indication that the new CGIAR is heading in the right direction to meet the needs for future staple food crop productivity growth through focused institutional collaboration. The Committee also encourages IRRI to make sure that APAARI and its members remain fully engaged in the further development and implementation of GRiSP.

APAARI is encouraged to see GRiSP emerge as a clear, identifiable Mega Program and hence would like to endorse it for funding in view of its importance for Asia-Pacific region.

With best regards,

Sincerely yours,

(Raj Paroda)

COALITION for AFRICAN
RICE DEVELOPMENT

CARD

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7th May 2010

Dr. Abdoulaye Papa Seck
Director General
Africa Rice Center
Cotonou, Benin

Dr. Robert Stewart Zeigler
Director General
International Rice Research Institute
Los Baños, Philippines

Dear Dr. Papa Seck and Dr. Zeigler,

Re: Letter of support for the Global Rice Science Partnership (GRiSP)

Firstly, the Coalition for African Rice Development (CARD) wishes to convey its utmost gratitude for the continued support by Africa Rice Center (AfricaRice) and International Rice Research Institute (IRRI) for the Initiative as Steering Committee members.

As you know the Coalition, launched by the New Partnership for African Development (NEPAD), Alliance for a Green Revolution in Africa (AGRA) and Japan International Cooperation Agency (JICA) on the occasion of the Fourth Tokyo International Conference on African Development (TICAD IV) in 2008, is an initiative to support the efforts of African countries to increase rice production.

Since the launching, the Coalition has successfully supported the formulation and implementation of the National Rice Development Strategies of the twelve First Group countries: Cameroon, Ghana, Guinea, Kenya, Madagascar, Mali, Mozambique, Nigeria, Senegal, Sierra Leone, Tanzania and Uganda. The Coalition, as a consultative group of research and development partners, serves as a useful mechanism for strengthening the linkage between research and development and therefore would like to welcome the recent development of the Global Rice Science Partnership (GRiSP) spearheaded by AfricaRice, IRRI and International Center for Tropical Agriculture (CIAT).

On behalf of the rest of the Steering Committee members, namely African Development Bank (AfDB), AGRA, Food and Agriculture Organization of the United Nations (FAO), Forum for Agricultural Research in Africa (FARA), International Fund for Agricultural Development (IFAD), JICA, Japan International Research Center for Agriculture Sciences (JIRCAS), and World Bank, I would like to express our strong support for GRiSP and hope that our partnership will bear the fruits of poverty reduction and economic development in Africa through accelerated development of the rice sector.

Sincerely yours,

Dr. Namanga Ngongi
Director of the Secretariat
Coalition for African Rice Development

COALITION FOR AFRICAN RICE DEVELOPMENT
CARD
SECRETARIAT
★ NAIROBI, KENYA ★

FARA

29th April 2010

DR. ABDOULAYE PAPE SECK
DIRECTOR GENERAL
AFRICA RICE
COTONOU, BENIN
Email: p.seck@cgiar.org

Our ref: 2010/FARA/EDU/GRISP/001

Dear Dr Pape Seck,

<u>LETTER OF SUPPORT FOR THE GLOBAL RICE SCIENCE PARTNERSHIP (GRISP)</u>

The Forum for Agricultural Research in Africa (FARA) and its constituent sub-regional fora (CORAF/WECARD, ASARECA and FANR), wish to place on record their total support and endorsement of the Global Rice Science Partnership (GRiSP), on behalf of the Africa region.

As you may be aware, rice is becoming more and more a very important staple and a strategic crop on the African continent. We therefore, need to address the main scientific research issues confronting this commodity in order to generate increases in productivity and improvements in quality. In this regard, there is no doubt that the GRiSP can be a very important tool to achieve the above stated goals. By using a participatory approach involving all the stakeholders, NARS, ARIs and CG Centers, this initiative can produce the critical mass needed for producing knowledge and technologies to improve Africa's agriculture, reduce poverty and ensure food security.

In addition, this initiative can be aligned with the objectives of the Comprehensive Africa Agriculture Development Program (CAADP), whose Pillar IV coordination is assumed by FARA. At FARA, we really appreciate this new partnership mode of doing business, as it provides the best way forward for the new CGIAR to deliver on its promise. This new rice science partnership has come at the right time and we fully support, and encourage its urgent implementation.

Yours sincerely,

Monty Jones (PhD,DSc)
Executive Director

CRS CATHOLIC RELIEF SERVICES Giving Hope to a World of Need

Dr Achim Dobermann
Deputy Director General (Research)
International Rice Research Institute

May 5, 2010

Dear Achim,

I am very pleased to see the Global Rice Science Partnership (GRiSP), led byIRRI, AfricaRice and CIAT, moving forward. The purpose of this letter is to express Catholic Relief Service's interest in and support for GRiSP.

Rice is a global crop and a potential pathway out of poverty for millions of poor farm families. CRS operates in over 100 countries with rice a priority crop in most. CRS hopes to play an effective role in impacting on poverty through increases in rice productivity and profitability at scale. To be successful, CRS needs GRiSP – to access research generated technologies and to strengthen our and our implementing partners' rice knowledge and skills.

CRS hopes to build on our promising partnerships with both IRRI and AfricaRice through GRiSP. Please do not hesitate to let us know how we can support you as GRiSP moves closer to reality.

Best Regards

Tom

Tom Remington (PhD)
Principal Agriculture Advisor
Catholic Relief Services
228 W. Lexington St
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Fondo Latinoamericano para Arroz de Riego
FLAR

May 3, 2010

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Robert ZEIGLER, Director General, IRRI
Papa SECK, Director General, Africa Rice Center
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Mahmoud SOLH, Director General, ICARDA
Sheggen FAN, Director General, IFPRI
Colin CHARTRES, Director General, IWMI

The Latin American Fund for Irrigated Rice, a public-private partnership among CIAT and rice related institutions from fifteen countries in this region, has been actively participating in the whole process of CGIAR Change.

FLAR is a regional alliance whose strength relays in its articulation and coordination of efforts on rice research and development, having CIAT and the entire CGIAR system as our up-stream support, FLAR as a delivery channel and the more than 25 institutions in the countries as the ones how reach farmers and other end users. CIAT as our strategic host Center and of rice research among all involved Centers in this change process is critical for our own future.

FLAR has been involved in the discussions of the Global Rice Science Partnership (GRiSP) initiative, together with IRRI, AfricaRice and CIAT. Latin America and The Caribbean regions are a potential source for increasing production helping to fulfill the challenges of food production as observed by IRRI and AfricaRice researchers who visited the region this year. So, we consider essential our participation in this global initiative in a very interactive way, not only receiving but also offering technologies and experiences such as recent implementation of large scale agronomical practices that could serve others.

The Administrative Committee of FLAR has discussed the GRiSP initiative and fully supports the research program proposed among the CGIAR system and its partners.

Ing. Agr. Gonzalo Zorrilla
Executive Director, FLAR

Dr. Mauricio Fischer
President, Instituto Riograndense do Arroz, Brazil
President Administrative Committee. FLAR

c.c. Carlos Pérez del Castillo, Consortium Board Chair
Monty Jones, GFAR Chair

Africa Harvest
BIOTECH FOUNDATION INTERNATIONAL

May 6, 2010

Dr. Papa Seck
Director General
Africa Rice Center (AfricaRice)
01 B.P. 2031,Cotonou
Benin

Dear Dr. Papa Seck

Sub: Africa Harvest expression of interest in membership of Rice Mega Program

On behalf of Africa Harvest Board and Management I write to thank you for enabling the participation of Dr Tareke Berhe in the writing workshop hosted at IRRI a week ago. Upon his return Dr Berhe made a report to the Africa Harvest Board that has just concluded its meeting in Nairobi.

In its deliberation on rice, the Africa Harvest Board noted the following:

- Africa Harvest commitment to enhance productivity of rice in East and Southern Africa as demonstrated by sending Dr Berhe to IRRI resulted in a positive feedback from IRRI
- In addition to the above, field visits by consultants to Mwea rice scheme in Kenya, and discussions with KARI and FAO in Kenya auger well for strengthening collaborative work in the region
- A number of varieties introduced from AfricaRice such as NERICA 4 are doing well in Uganda, Ethiopia and Kenya. In addition NERICA 1, 10 and 11 and some of the IRRI varieties have been released in the region and farmers are eager to adopt them
- FAO-Kenya and KARI expressed strong interest in working with Africa Harvest in the rehabilitation of rice schemes and expansion of upland rice production
- There is eagerness by stakeholders to share the positive lessons from Uganda and Ethiopia with countries such as Kenya and Tanzania
- CGIAR News of 20 April 2010 carried an interview with the D.G. of AfricaRice, Dr. Papa Sack's warning on the continuing vulnerability to food crisis in Africa.

The Board's response is a reaffirmation to embrace the urge for partnerships in the context of the revamped CGIAR as expressed by the Chair of the CGAIR. Based on the above, the Africa Harvest Board fully endorsed that the organization becomes a full member of the Rice Mega Program. This unanimous support from the Board takes cognizance of the organization's capacity in technology deployment.

The following are some of the strengths of Africa Harvest in Technology Deployment:

1. Capacity building of stakeholders along the value chain
2. Farmer mobilization and organization into functional groups
3. Farmers Capacity Building in agronomy, post-harvest handling and marketing through training, exchange visits and demonstration farms
4. Training of Trainers (TOT) for farmers who are easily accessible to other farmers
5. Providing extension services even in the most remote places
6. Communication for Development using appropriate community channels and spokespersons
7. Effective partnerships at the grassroots level
8. Market linkages and support for entrepreneurship development

With respect to rice, Africa Harvest has augmented its scientific team by engaging long-term consultants with experience in rice research and technology deployment. Two of these persons are Prof. Shellemiah Keya, a former Assistant Director General for Research and Development at Africa Rice and Dr Tareke Berhe of Sasakawa Global 2000/Sasakawa Africa. The latter has vast expertise in promoting rice production in Guinea, Ghana, Nigeria, Mali, Uganda, and Ethiopia to name a few countries.

Further the track record in spreading Tissue Culture bananas in East Africa and recently, sorghum, is a demonstration of the rich network of an Africa rooted organization with international breath.

In light of the above we are requesting the Director General of AfricaRice to facilitate the inclusion of Africa Harvest as a full member of the Rice Mega Program. We welcome the opportunity to interact with the IRRI and AfriceRice scientist in Tanzania in identifying early actions such as introduction of suitable varieties.

Should you require additional information about Africa Harvest, kindly let me know. In the meantime you are welcome to visit our website at www.africaharvest.org.

We appreciate your consideration of this request in advance.

Kind regards,

Dr. Florence Wambugu
CEO, Africa Harvest

100 years of scientific endeavour

cabi www.cabi.org

Dr Achim Dobermann,
Deputy Director General for Research
International Rice Research Institute
6776 Ayala Avenue
Suite 1009
Makati City
Philippines

20th August 2010

Dear Dr Dobermann,

Letter of support for the Global Rice Science Partnership (GRiSP)

On behalf of CABI and its member countries, I would like to offer the strong support of our organisation to you and your colleagues in CIAT and Africa Rice for the broad global partnership which you are building under the GRiSP banner. Growing sufficient rice is an essential element of global food security. Beyond this role as a staple food crop, rice also has a deep cultural and commercial significance in many of CABI's 44 member countries and they will receive significant positive benefits from this programme. We are very encouraged by the vision of this programme and its recognition of the importance of developing new varieties, ensuring the promotion of improved farm management practices, encouraging the implementation of new technologies and creating a supportive political environment in respect of government policies for agriculture and trade.

Further to our recent discussions, I would like to indicate areas of the GRiSP mega-programme in which I believe CABI can bring to bear relevant skills and experience. These are particularly relevant to CABI's core competencies in working with the national research and extension bodies in our member countries to communicate scientific knowledge to rural farming communities in ways that promote the successful uptake and implementation of new or existing technologies and practices. This will be a key factor for success of GRiSP and we believe will be particularly relevant in the following areas:

- Pest and disease management and innovative crop management techniques (Products 3.2, 3.4, 3.5)
- The Global Rice Information Gateway (Product line 5.3)
- Effective systems for large scale adoption of rice technologies (Theme 6)

These potential contributions to GRiSP would build upon the existing EU-funded project where CABI and IRRI are collaborating on integrated pest management for rice in the Mekong Delta. Furthermore, we are also working on NERICA Rice upscaling in Africa (DFID Research into Use funding) and have made significant differences to farmer awareness and practice through the SDC-funded Good Seed Initiative in Bangladesh and Uganda, as well as a DFID-funded project to facilitate the uptake of Resource Conserving Technologies (RCTs) in the Rice-Wheat Systems of the Indo-Gangetic Plain. We have also recently completed a very interesting pilot project, together with commercial partners, to provide farmers with crop management information via mobile telephone SMS messaging.

Our ability to provide these inputs will, of course, be subject to the availability of funding either through GRiSP or from separate donor funding. As the Mega-programme develops we would be interested to explore with you the specific ways in which CABI might contribute. Please let us know when the time is right for such a discussion.

With very best wishes.

Yours sincerely

Trevor Nicholls

Dr Trevor Nicholls
Chief Executive Officer

International Centre for development oriented
Research in Agriculture

Centre International pour la Recherche Agricole
orientée vers le développement

Dr Marco Wopereis
Deputy Director General
Research & Development
Africa Rice Centre
01 BP 2031
Cotonou
Bénin

Yr. ref.
Our ref. JD/SV/29230
Subject GRiSP

Wageningen, 09 September 2010

Dear Dr Wopereis,

ICRA is hereby expressing its strong interest to expand its existing and highly successful collaboration with AfricaRice and national ARD-partners throughout Africa in the new context of the Global Rice Science Partnership. Over recent years AfricaRice and ICRA have effectively joined hands to strengthen the capacity of people and organisations in the rice-sector to form multi-stakeholder platforms involved in co-generating knowledge and innovations that meet the needs of small farmers, men and women, and small agri-businesses in the rice value chain.

It is our strong believe that effective pro-poor innovation in agriculture and rural development requires the seamless integration of upstream and applied research with the actual application of knowledge to create economic, social and ecological value that reduces poverty and hunger. This is not a linear, but an iterative process in which different actors in and around the rice sector learn from each other by working and inventing together. ICRA is happy to contribute its expertise to strengthen capacities needed for this integration of the knowledge chain with actual innovation processes on the ground within the context of the GRiSP.

With best wishes and kind regards,

Yours sincerely,

Jon Daane
Director

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中国农业科学院
CHINESE ACADEMY OF AGRICULTURAL SCIENCES

10 September 2010

Dr. Achim Dobermann
Deputy Director General (Research)
International Rice Research Institute (IRRI)
DAPO Box 7777, Metro Manila, Philippines

Ref: Letter of Support for GRiSP led by IRRI

Dear Dr. Achim Dobermann,

Many thanks for your email message informing CAAS about the recent development of the Mega program particularly the Global Rice Science Partnership (GRiSP)! As we discussed last month in Beijing, CAAS is very pleased with the modified draft proposal for the project and would like to be one of the key leading partners in the program.

Considering rice is the most important crop in China and Asia-pacific region, CAAS strongly supports GRiSP led by IRRI, Africa Rice and CIAT in collaboration with more than 450 partners，my colleagues and myself highly appreciate the three objectives of the project: increasing rice productivity, fostering rice based sustainable agricultural systems that use natural resources efficiently, and improving the efficiency and equity of rice sector as well as the "models of operandi" for the implementation of this particular program through joint efforts and partnerships.

CAAS would like to contribute to this project through joint research in both conventional and molecular breeding, genetic resources exchange and information sharing, capacity building and eventually into the development of a joint research platform in China that can serve as important instrument in promoting research and capacity development as well as partnership building. CAAS will mobilize resources including both financial resources and in-kind contribution to support this project.

Again, I hope that through the GRiSP, CAAS can further develop and expand the partnership with IRRI as well as other institutions, and CAAS fully supports this GRiSP initiative and encourages its urgent implementation.

Best regards,

Huqu Zhai

Dr. Huqu Zhai
President & Professor
Chinese Academy of Agricultural Sciences (CAAS)

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Dr Achim Doberman
Deputy Director General (Research)
International Rice Research Institute

04 September 2010

Sub: Letter of Support and Partnership of ICAR (India) with Global Rice Science (GRiSP) programme

Dear Dr Doberman

ICAR and IRRI have been working together for the past several decades resulted great success in Rice research and developmental programme. We believe that co-operation will continue in a stronger way under the GRiSP programme.

General comments on the outline of GRiSP

Importance of rice in the food security of the world in general and Asia in particular is an established fact. This is especially true in case of Asia where 90% of the global rice is grown and consumed. The program on 'Global Rice Science Partnership (GRiSP) centers around 6 themes that covers almost all aspects of research and development in rice. However, the general feeling is that the role of NARES centres has been given a go by. India is interested in the programme along with the following suggestions for a strong and joint research partnership.

General interest in global and regional R&D product lines in GRiSP

Harnessing genetic diversity to chart new productivity, quality and health horizons.

Characterizing genetic diversity and creating novel gene pools (1.2)

Informatics support for germplasm management and gene discovery (1/6)

Improved rice varieties for intensive production systems in Asia and Africa (2.5)

Stress tolerance and climate proofing in the rainfed agro-ecosystem

Genes and allelic diversity conferring stress tolerance and enhanced nutrition (1.3)

Development and spread of stress-tolerant rice varieties, especially for drought and high temperature, salinity (2.3)

Innovations to cope with abiotic stresses under current and future climates (3.3)

Increasing the productivity, sustainability and resilience of rice-based production systems.

Integrated cropping system innovations for future intensive rice systems in Asia (3.4)

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Socio-economic and gender analyses for technology evaluation. **(5.1)**

A few issues for strong partnership development

Only a few projects to be selected. Emphasis should be laid on important projects like low light efficient photosynthesis, Sheath blight resistance, genomics and gene discovery and hybrid rice development.

In India, there will be different stakeholders like ICAR institutes, SAUs, NGOs. ICAR should be a nodal point and all the programmes should be run through the council. Extension of technology, if to be undertaken, should be done in partnership of ICAR.
GRiSP should concentrate on research component and leave extension programme for NARES.

Planning and Management Team (PPMT) and Oversight Committee (OC) should include ICAR Staff

India has strong programmes in rice work and it can play a leading role for Africa programme. ICAR can facilitate in promotional projects in other countries including Africa by sparing scientists for a shorter period as consultants.

The programme should indicate infrastructure development for NARES

Training programmes should be incorporated including joint PhD programmes in the GRiSP with ICAR/Universities.

Specific suggestions

It is expected that IRRI, as the nodal international agency for rice research, should concentrate on development of collaborative upstream research programs with the help and support of NARES centres and should not dilute their energy and resources in actually spreading the varieties developed by them, a work that should be left for the NARES partners who obviously understands the local scenario much better but also can be done together.

We appreciate your consideration and support for the greater Global Rice Research and its urgent implementation.

S. K. Datta

Best Regards,

Prof. Dr. Swapan K Datta
Deputy Director General (Crop Science), ICAR, India

IRRI

1960-2010

Rice Science for a Better World

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Africa Rice Center

Centre du riz pour l'Afrique

AfricaRice

CIAT

Centro Internacional de Agricultura Tropical
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