Fund

Fund Council

2nd Meeting (FC2)—Rome, Italy

July 14-16, 2010

Global Rice Science Partnership (GRiSP) Proposal

(Working Document - For Discussion Only)

Document presented for Agenda Item 8:
Mega Program Proposals

Submitted by:
GRiSP

Subject: Consortium Board approval letter on GRiSP for submission to the Fund Council

Date: 9 July 2010

Dear Kathy,

The Consortium Board (CB) of the CGIAR has the pleasure to submit to the Fund Council (FC), for its consideration and approval, the first fast-tracked Mega Programme (MP), entitled Global Rice Science Partnership (GRiSP). This MP is the first submission by the CB of the MPs within the CGIAR reform process.

GRiSP is a work plan for global research on rice promoted by three of the CGIAR Centres: IRRI, Africa Rice, and CIAT. It has involved the active participation of a whole range of partners and aims to achieve quantitative outcomes towards 2020 and 2035 in line with the CGIAR vision.

This MP reflects the joint work and effort of the three Centres-sponsors since December 2006, geared at aligning their rice research programmes. The GRiSP proposal submitted on 10 May 2010 was the subject of three external reviews, as well as a thorough examination by the CB, which resulted in a number of comments and recommendations for its improvement. Such assessment was exercised in accordance to the agreed criteria established by the CB at the Nairobi meeting, as requirements for approval of MPs. These criteria are in line with those developed by the ISPC. These observations included the need for more clarity and specific commitments in areas such as: interaction and boundaries with other MPs; partnerships; impact pathways; monitoring and evaluation; articulation with the Generation Challenge Programme; gender; management; budget and capacity building.

A revised version of GRiSP was submitted to the CB by its sponsors on 25 June 2010. The CB considers that the sponsors of this proposal have properly addressed the majority of the comments, guidelines and recommendations suggested. The research programme presented is comprehensive and there is a strategic coherence in the definition and presentation of the six global R&D themes. The approach is both conceptually and technically sound and it is written in an articulate and convincing style.

GRiSP proposal reflects the CGIAR objectives of reducing poverty and hunger, improving food security, and environmental sustainability, well defined in the CGIAR Strategy and Results Framework (SRF). Moreover, GRiSP conforms to the objectives of the Thematic area “Sustainable production systems for ensuring food security”, also established in the SRF. It is in the light of crop productivity improvements that rice research addressing the needs of the poor should be judged in this programme.

One of the priority objectives of the reform process is to enhance collective actions and to build complementarities and synergies among centres. In order to achieve the most efficient results and avoid overlaps and duplications, a clear definition of the interaction between the different MPs is needed. GRiSP provides three major models of interaction with other MPs: full participation, project collaboration and co-investment. Some indications to that effect are explained in Table 1 of the GRiSP document. However, in view of the less advanced stage of development of most research programmes in the MP portfolio, it is difficult to provide conclusive evidence on how this interaction between GRiSP and other various MPs will be addressed and adhered to in the implementation stage. How research responsibilities and resources will be allocated and results shared among MPs will need to be further articulated. The CB acknowledges that this is a learning process, and that the implementation of GRiSP will provide valuable lessons for the development of future MPs and the interactions among them.

Gender must be an essential ingredient embedded in all MPs. A number of relevant and useful suggestions have been put forward on gender by the sponsors of GRiSP. The CB is commissioning a gender scoping study to analyze the options and strategies for integrating and mainstreaming gender research in the entire MP portfolio. This work is in progress and should be finalized by September. The CB has advised the sponsors of GRiSP to wait for the results and recommendations that the scoping study will provide to the Consortium before defining specific gender inputs into this programme.

There are two further issues that the CB would like to highlight in submitting this MP for the consideration of the Fund Council.

The first one relates to the definition of the Monitoring and Evaluation Plan, which is missing in the current version of GRiSP. This is one of the criteria established by the CB for all MPs, and the sponsors of GRiSP have assumed a commitment to organize a workshop in 2011 in order to define the methodology to be used in the monitoring, evaluation and reporting of this MP, including the development of key indicators and providing information on how M & E data will be collected. The CB is in agreement with this proposal.

The second aspect relates to the Budget. When the reform was conceived, a doubling of the budget through the Fund was foreseen, but an economic crisis has intervened since which has diminished donors´ flexibility. When GRiSP submitted its first version, it was evident that there was a substantial gap between the donors' financial realities as a result of the current budget constraints, and the funding requirements expected by this proposal.

Consequently, and to address this funding gap, the CB requested the sponsors to reformulate GRiSP's budget. The CB asked that a priority ranking of activities be established, starting with the budget for year one based on 2009 audited figures plus 10% in 2010, and increasing this budget over the next three years to reach a total by the end of this period that is at least 30% lower than what was requested. In addition, the CB asked the proponents to include two scenarios in the amended budget, for postponing some of the proposed activities (indicating which ones) in the event of a budget shortfall in year two of: (i) 20% and (ii) 40%.

In their new version, the sponsors of GRiSP did not consider advisable to address the Board's recommendations with regards to the budget. In their view: "The program we lay out requires a certain level of resources to support it. These must be presented clearly. The reality of funding for the foreseeable future is that only a fraction (well under half) will come from the Fund. We will be required to raise bilateral support for the program from donors participating in the Fund, other donors and other sources. In order to do this, we must be able to show the full cost of the program and how it was derived. The Board and Fund Council will determine how much of the available resources in the Fund can be directed to GRiSP and we will adjust our fund raising strategies accordingly".

The CB reflected over the implications that this non compliance could have for the financing of this MP, as well as the financing of the rest of the MP portfolio. There is agreement with donors that financing of fast trackers will not be at the expense of the financing of the other MPs in the CGIAR portfolio. Moreover, the CB has on countless occasions stated its concern with the uncertainties regarding donors´ finance. It has furthermore insisted there is a need to ensure, as part of the balance of responsibilities and obligations between the CB and FC in the CGIAR reform process, a greater stability of funding when we address multiyear long term MP research undertakings. So far, little indication has been provided by donors with regards to their financial plans for the next three years, including the financing of fast track MPs. This is an issue that needs to be urgently addressed as current levels of financial uncertainty are not manageable and cannot continue.

In the light of the above considerations, the CB has decided that rather than request the sponsors of GRiSP to adhere to our budget recommendation, it may be advisable to submit the GRiSP as it is, expressing clearly the different perspectives on the budget, for the Fund Council consideration. It is felt that the two lines of thought may promote a productive debate among donors, and lead to much needed clarification and more concrete information from the Fund Council to the CB on budgetary issues. This would be of great help for future MP submissions. The GRiSP sponsors have already acknowledged that they would adjust their fundraising strategy in view of the availability of resources.

In conclusion, and subject to the safeguards expressed, the CB considers that GRiSP is a well conceived MP which has adequately responded to the comments and suggestions from the CB as well as from external reviewers. It fulfills the main assessment criteria developed by the CB and, as such, is a comprehensive and strategic work plan for global rice research ready for submission to the Fund Council for approval. The first presentation of a fast-tracked MP for approval by the Fund constitutes an important step forward in the CGIAR reform process.

With my best regards on behalf of the CGIAR Consortium Board,

Carlos Pérez del Castillo

CGIAR Thematic Area 3:
Sustainable crop productivity increase for global food security

A Global Rice Science Partnership (GRiSP)

Proposal for a Consortium Research Program

Revised Draft: 25 June 2010

with CIRAD, IRD, JIRCAS as key participating institutions and over 450 other partners

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
BECA	Bioscience East and Central Africa
BMGF	Bill and Melinda Gates Foundation
BMZ	German Ministry for Development Cooperation
CAADP	Comprehensive Africa Agriculture Development Program
CAAS	Chinese Academy of Agricultural Sciences
CARD	Coalition for African Rice Development
CEMAC	Communauté Economique et Monétaire des Etats de l'Afrique Central (Economic and Monetary Community of Central African states)
CeTSAF	Center for Tropical and Subtropical Agriculture and Forestry, Göttingen
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
CIAT	International Center for Tropical Agriculture
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
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)
GCARD	Global Conference on Agricultural Research for Development
GCDT	Global Crop Diversity Trust
GCP	Generation Challenge Program (CGIAR)
GFAR	Global Forum on Agricultural Research
GRiSP	Global Rice Science Partnership

GSR	Green Super Rice (CAAS-IRRI-AfricaRice)
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
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
MAFF	Ministry of Agriculture, Fisheries and Forestry, Japan
MDG	Millennium Development Goal
MP	Mega Program (within a Thematic Area) of the CGIAR Strategy and Results Framework
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
PPP	Purchasing power parity
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
STRASA	Stress-Tolerant Rice for Africa and South Asia
TA	Thematic areas 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 first strategic and work plan of the Global Rice Science Partnership (GRiSP) is the fruit of a process that began in late 2006 when IRRI, together with hundreds of stakeholders worldwide developed a new strategic plan and three CGIAR centers involved in rice, IRRI, AfricaRice, and CIAT, started discussions on aligning their rice research programs. The process was greatly accelerated by the CGIAR change process, including regional consultations organized by the Global Conferences on Agricultural Research for Development (GCARD). GRiSP was recommended to be developed as a Mega Program on rice-based systems, under Thematic Area 3 (Sustainable Crop Productivity Increase for Global Food Security) of the new Strategy and Results Framework. Three more research organizations working on rice in a global context, CIRAD, IRD, and JIRCAS joined the effort on developing GRiSP. Consultations with many stakeholders, particularly national research and extension systems and several global and regional NGOs helped shape the GRiSP proposal. The resulting draft proposal thus 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 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 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 is illustrative of the crop's importance to the world's growing population. There can be no doubt that future global food security and the precarious livelihoods of the world's poor will depend on maintaining reliable and sustainable growth in rice production and productivity. Yield growth rates have stagnated because of decades of neglect in research and infrastructure, and area expansion has nearly stopped. Projected demand will outstrip supply in the near to medium term unless something is done to reverse current trends. 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. In order to meet future rice demand, the world must increase rice yield growth rates on the remaining rice lands in Asia in a resource-efficient, ecologically resilient manner, and judiciously and sustainably expand both area and yield growth rates in Africa and Latin America.

Enhancing rice production faces many future challenges, not the least of which is climate change. The rice of the future 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. These "future" problems are exactly the same as those that plague most of the poor rice farmers who did not directly benefit from past scientific advances. Thus, preparing rice for future climate uncertainties also prepares rice farmers, especially the women to better deal with today's certain constraints to yield. Extreme variability in climate pushes young men to migrate leaving the elderly and the women behind with greater work burden as they do more field work and farm management responsibilities. Technologies for rice improvement designed with and for women farmers will differentially improve their well-being as well as that of their children. 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.

Rice contains a tremendous array of genetic diversity that scientists have only just begun to tap. Applications of the newest scientific tools have led to the development of rice varieties that tolerate stresses, such as prolonged submergence and saline soils, which just a few years ago were considered to be intractable. Powerful computation and communication technologies coupled with remote-sensing capacity offer unprecedented opportunities for integration across biological, physical, and social sciences not only to address challenges but also to create opportunities for improving the livelihoods of rice farmers and consumers. The very recent entry of the private sector in product development for rice producers in developing countries offers an additional opportunity to expand partnerships beyond the public sector. At the grass-roots level, many civil society organizations do excellent work with farmers, small entrepreneurs, and their families, but could benefit greatly from better linkages with the agricultural research sector—and also provide important feedback to the product-oriented and basic research conducted there.

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

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 will be fully explored in all objectives, and capacity building in rice science and extension will be emphasized to ensure adequate skilled personnel for future rice development. GRiSP has enormous potential to generate benefits for the poor, the hungry and the environment. Ex-ante assessment of expected benefits, based upon conservative assumptions about productivity contributions, finds the following by 2035:

- GRiSP directly affects the lives of 1 billion people involved in growing and processing rice worldwide, as wells as another 1 billion consumers who depend on rice as their staple food. This includes nearly 600 million of the world's poorest people.
- GRiSP attributable reductions in food prices will effectively lift 133 million Asian people above the $1.25 PPP poverty line, reducing the number of poor by 15%.
- As a result of increased availability and reduced prices, 107 million undernourished Asians will reach caloric sufficiency, reducing hunger by 20%.
- 3 million hectares less land will be used for rice, saving natural ecosystems.

Production systems and value chains will form the overarching organizing principle of the partnership. All research will use an interdisciplinary approach 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, with a total of 32 global and regional R&D product lines:

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

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

Theme 3: Increasing the productivity, sustainability, and resilience of rice-based production systems

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

Theme 5: Fostering improved policies and technology targeting to enable improved rice production and marketing

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. Under each theme, R&D product lines are 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 Mega Programs.

GRiSP will have a 25-year vision of success and an initial 10-year road map, which will be implemented through 5-year rolling work and business plan addressing the six research and development themes described above. GRiSP will evolve over time, re-defining its priorities and approaches based on evidence of impact potential and actual impact, 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 approaches, 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. Capacity building and gender are fully integrated in all GRiSP themes, but will also be supported through centrally managed GRiSP funds.

Partnerships will be the main drivers for reaching GRiSP's vision of success. At present, the three principal CGIAR centers involved in GRiSP, IRRI, AfricaRice, and CIAT, have more than

450 active partnerships that contribute to the rice research and development sector (252 NARES, 72 ARIs, 54 private sector, 31 CSOs and farmers' associations, 20 foundations, 19 international and regional organizations, and 18 other CGIAR centers, Challenge Programs, and systemwide initiatives). GRiSP will provide a new umbrella for strengthening and expanding partnerships.

IRRI is the lead center for GRiSP, with each of the three CGIAR centers assuming a leadership role at the continent level (Africa: AfricaRice; Asia: IRRI; Latin America: CIAT). 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). The OC and PPMT will be assisted by a small Program Management Unit (PMU), comprising the GRiSP Program Director and two assistant managers recruited by the lead center (IRRI).

The first 4-year GRiSP budget for 2010 through 2013 is USD 457.5 million. To initialize the program and several new high-priority activities with partners, a GRiSP budget of USD 98.6 million is anticipated for 2010, of which USD 88.6 million (90%) are currently committed unrestricted funds, restricted (bilateral) grants, and other income of IRRI, AfricaRice, and CIAT (as per 2010 mid-term plans of these centers). GRiSP investments are projected to rise at an annual rate of 10%, reaching USD 131.2 million in 2013 (33% increase over planned 2010 level or 48% over currently secured 2010 level). Although this represents a significant increase in funding over time, it still falls far short of the stated CGIAR goal to double funding for agricultural research and development. Annual co-investments by three global partners in GRiSP (CIRAD, IRD, and JIRCAS) are expected to exceed USD 20 million.

GRiSP is more than a "rice program"—it aims to develop integrated solutions for a wide range of cropping systems that include rice, but often also other crops and commodities. Through cross-cutting projects in different regions of the world, GRiSP will be linked with other Mega 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 Mega Programs, and active participation by IRRI, AfricaRice, and CIAT and their partners in other Mega 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 MPs. 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.

Justification

Importance of rice and challenges

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. In developing countries alone, more than 3.3 billion people depend on rice for more than 20% of their calories. 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. 1).

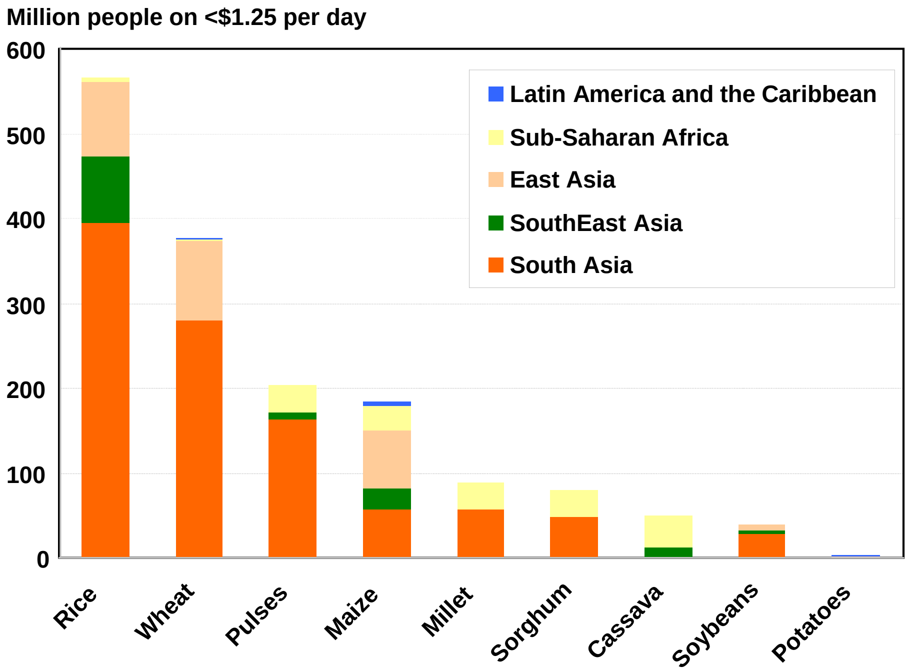


Fig. 1. Number of people below the $1.25 per day (purchasing power parity) poverty line who live in areas dominated by different crops (2005 data). Numbers are based on areas more than 10% covered by the dominant crop. Some areas have more than one dominant crop and thus overlap.

Asia, where about 90% of rice is grown, has more than 200 million rice farms, most of which are smaller than 1 hectare. Rice is the staple food for most of the poor in Asia, where poverty remains staggering, particularly in South Asia (Fig. 1). 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*.** 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.

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.

The importance of rice to the overall sense of well-being for most rice consumers cannot be ignored. And, 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.

***Major problems affecting future rice production*.** A variety of factors, from falling yield growth to climate change, threaten future rice production.

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 opportunities for 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.

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?

Global and regional rice demand growth and challenges. Global rice consumption remains strong, driven by both population and economic growth in many Asian and African countries. 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 future, the rising standard of living in the low- and middle-income countries is likely to put more pressure on rice.

Based on population projections from the United Nations and income projections from the Food and Agricultural Policy Research Institute (FAPRI), global rice demand is expected to rise from 439 million tons (milled rice) in 2010 to 496 million tons in 2020 and further increase to 553 million tons in 2035 (Fig. 2). 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 11% 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. 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 24% over the next 25 years.

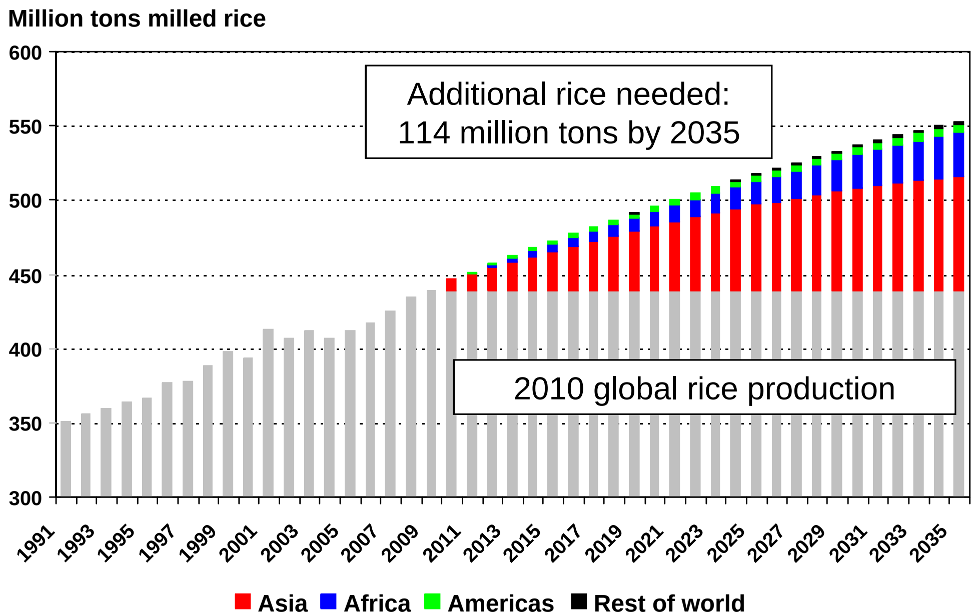


Fig. 2. Global rice production increases needed to meet demand by 2035.

With further area expansion unlikely, global rice yields must rise much faster than in the recent past if world market prices are to be stabilized at affordable levels for the billions of consumers (Fig. 3). 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 tons per hectare 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.

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.

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, while 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.

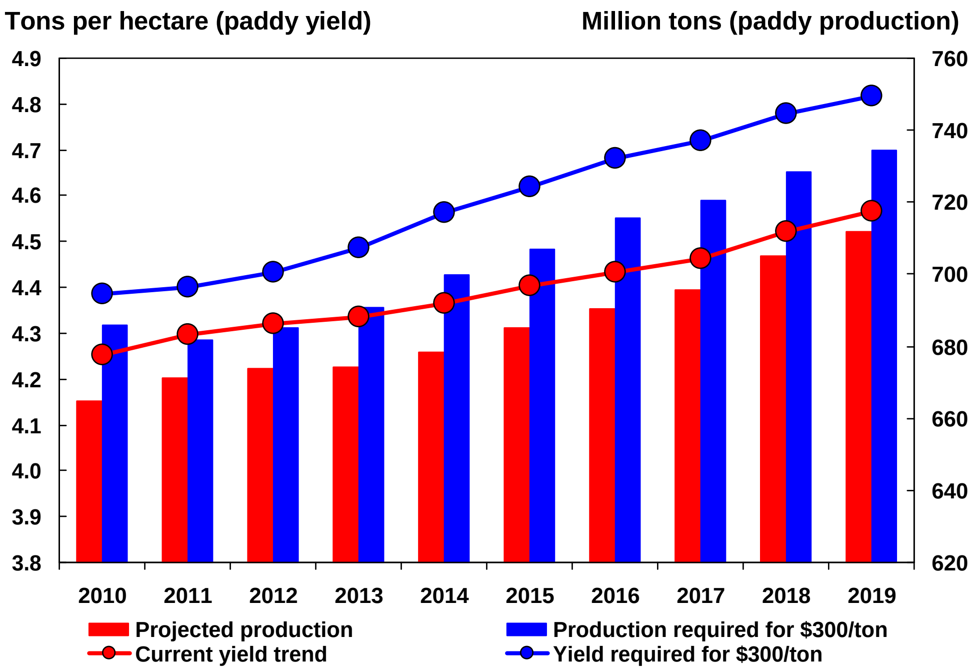


Fig. 3. What the world needs to keep rice prices affordable at around $300 per ton (red columns and lines: current rice production and yield growth rates, respectively; blue columns and lines: yield and production growth required to stabilize rice prices at $300 per ton). Simulation was done using the Arkansas global rice model.

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.

What accelerated international rice research can contribute

Evidence of past 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. This research has also prevented 13 million hectares of natural ecosystems from being brought under cultivation, with attendant environmental benefits. 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. As the agricultural product associated with the largest proportion of

[1] Sum of Asian estimates adjusted to 2010 prices from Evenson RE, Gollin D, editors. 2003. Crop Variety Improvement and Its Effect on Productivity: The Impact of International Agricultural Research (CAB International, Wallingford, UK) 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, editors. Impact of rice research, proceedings of an international conference, 3-5 June 1996, Bangkok, Thailand. p 405-428. Bangkok, Thailand Development Research Institute and International Rice Research Institute.

the income, expenditures, and food intake of poor populations, rice must be a core focus of agricultural research for poverty reduction and food security. 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.

Potential future impact of a global rice research partnership. As an example, an assessment of the potential impact of GRiSP-spearheaded technologies and practices in South Asia shows that a 26% net increase in rice production over the next 25 years, in addition to other sources of yield growth, can be reasonably expected in the region (Box 1). Of course, getting those technologies adapted to local contexts and into farmers' fields depends on much more than the GRiSP alone; regional and national investments, especially in adaptive research and extension, will be needed. However, based on modest assumptions specific GRiSP efforts are directly attributable for a 12% net rice production increase over the period in this subregion.

A global assessment of the impact on poverty and hunger attributable to GRiSP was made using a lower global production increase, 8.5%—equivalent to an average of 15 additional kilograms per hectare per year additional yield growth over the period. This would result in a 10–23% rice price reduction in Asian countries and 7–10% reduction in major Latin American and African markets. These price reductions would have huge poverty reduction effects in Asia, which contains 70% of the word's poor and where rice is the largest item of expenditure for poor households, as shown in the following (details are given in Appendix 1):

- Expenditures on rice by those under the $1.25 (PPP) poverty line would decline by PPP $9.5 billion annually in Asia (holding consumption constant).
- Counting those reductions as income gains means that 133 million Asian people would be lifted above the $1.25 poverty line, reducing the number of poor by 15%.
- As a result of increased availability and reduced prices, 107 million undernourished Asians would reach caloric sufficiency, reducing hunger by 20%.
- 3 million hectares less land would be used for rice (1.5 million hectares of averted expansion plus 1.5 million hectares of reduced area), reducing pressure on natural ecosystems.

These are impressive numbers, considering that they arise from an aggregate global 25-year investment of $3 billion, or $23 per person lifted above the poverty line. Very few other development investments have similar efficacy in poverty eradication. Large benefits to the poor can also be expected in Africa and Latin America. To achieve this, GRiSP will include systematic strategic foresight and impact assessment research (see theme 5).

Other analyses have 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.[2] Similarly, in the Global Conference on Agricultural Research for Development (GCARD) subregional analysis for Southeast Asia,[3] productivity enhancement for rice was found to have nearly as much poverty reduction potential as all other agricultural products combined.

---

[2] 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.
[3] 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

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-reducing and yield-limiting. 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 $5.0 billion by 2035, largely as a result of a $40 million annual investment in the GRiSP for South Asia, as well as complementary efforts and investments by national and local partners. Figure 4 provides a breakdown over time by constraint and opportunity addressed. As a result of this increased productivity, there is a 29.9% increase in net rice production 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 $32.4 billion of discounted attributable benefits would be generated by $1.04 billion in investment starting now, with a benefit-cost ratio of 31.2:1. Productivity growth specifically attributable to GRiSP would be 13.6% by the end of the period under these assumptions. Additional details are given in Appendix 1.

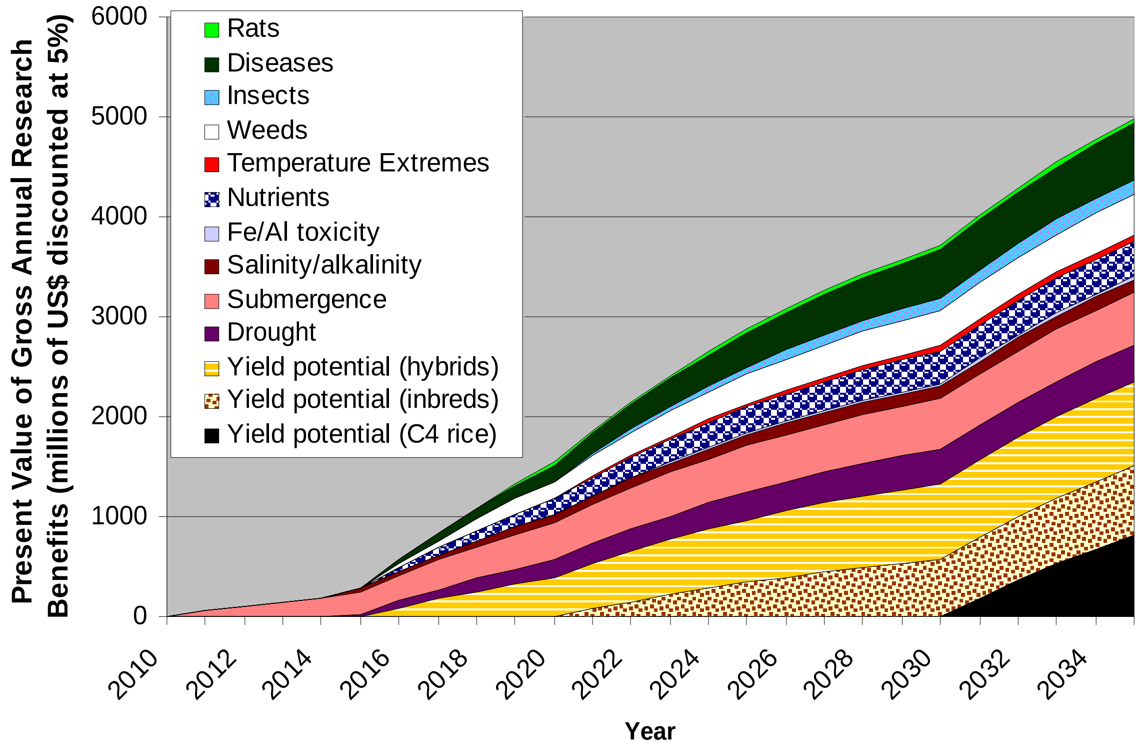


Fig. 4. Attributable gross annual research benefits expected over time from the adoption of GRiSP-developed technologies to address constraints and raise yield potential in South Asia.

***Opportunities*.** 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. Post-harvest losses may be as high as 30%. Closing yield gaps and reducing post-harvest losses constitute clear opportunities to enhance rice production. These 'quick wins' will require mostly applied research based on solid partnerships at 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 identifying 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. New information and communication technologies have made the time ripe for maximum exploitation of the economies of scale possible in rice research.

A global rice program would greatly boost the ability of national partners to increase farmers' yields and crop value and to do so much more quickly, by making possible far more rapid advances than previously possible in gene discovery, providing new germplasm and improved management technologies, and backing by global information, advisory, and delivery mechanisms. Specific advantages of a global 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 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 proposed partnership program herein intends to make use of such opportunities and advantages. The time for fragmented, uncoordinated efforts to increase world rice production has passed. Rice production, an absolute necessity—nutritionally, economically, and culturally—for a large proportion of the world's population, faces shortfalls in the future that could cause a major calamity on a global scale by increasing widespread hunger, poverty, and social unrest. The 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. To use these opportunities effectively, the efforts of the organizations involved around the world can and must be combined and their full force directed at overcoming the projected production shortfalls. In the following, 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 described. The partnership combines, makes more efficient, and sharpens the focus of the large existing regional and national investments in research toward agricultural development.

Vision of Success and Objectives

The Global Rice Science Partnership (GRiSP), led by IRRI, AfricaRice, and CIAT in collaboration with CIRAD, IRD, JIRCAS and more than 450 partners worldwide, is proposed as a CGIAR Mega 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, and enhance ecosystem resilience 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 2035, global average rice yield will have risen by at least 60 kilograms of paddy rice per hectare per year during 2010-35, through increased productivity of the world's rice land and reduced post-harvest losses. At least 30% of this increase is directly attributable to faster availability of better technologies, production methods, and policies as a result of the GRiSP. Rice prices paid by the urban and rural poor will be at least 15% lower in 2035 than without investing in GRiSP, saving PPP $11 billion in annual expenditures by those under the $1.25 per day poverty line, and lifting at least 145 million people above that poverty line. Africa, where demand growth is highest, will be able to feed itself in terms of rice production and to export surplus African-produced rice to non-rice-producing countries outside the continent.

Adoption rates of the latest input-efficient, stress-tolerant, higher-yielding, and enhanced-quality rice varieties will have accelerated, and a revolutionary rice with a new photosynthetic pathway is receiving an enthusiastic response from farmers. 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.

Hunger reduction and improved nutrition. By 2035, the world will be capable of producing an additional 170 million tons of paddy rice more than in 2010, matching the projected total demand of around 830 million tons of paddy. As a result of GRiSP's contributions to increased supplies and reduced rice prices, at least 110 million undernourished people will reach caloric sufficiency, reducing hunger by more than 20% 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.

Contribution to sustainability and resource efficiency. 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. Rice-based cropping systems will be sustainable and 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 be improved by at least 30% in key high-input rice-growing areas of Africa, Asia, and Latin America, saving at least 4 million tons of nitrogen fertilizer annually and 12 billion cubic meters of irrigation water—equivalent to nearly 5 million Olympic-sized swimming pools—annually by 2035.

In Asia, increased productivity will save 3 million hectares of land by averting 1.5 million hectares of rice area expansion and returning another 1.5 million hectares from rice to natural ecosystems or other productive purposes. 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. More effective water-control measures and ecological intensification and diversification options will have led to a sustainable expansion of rice-based cropping in both rainfed lowland and irrigated areas, greatly contributing also to self-sufficiency of the African continent in rice production.

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 priority setting, 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 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

The Road to GRiSP

This first strategic and work plan of the Global Rice Science Partnership (GRiSP) is the fruit of a process that began in late 2006 when IRRI, together with hundreds of stakeholders worldwide developed a new strategic plan and three CGIAR centers involved in rice, IRRI, AfricaRice, and CIAT, started discussions on aligning their rice research programs. At that time, and despite existing collaboration in some areas, the research programs of IRRI, AfricaRice, and CIAT had no joint strategic plan. Although each center had partnerships with many international, regional, and national research and development organizations, no formal mechanism existed for a better alignment of the regional and global rice research agendas. Hence, thinking evolved toward forming a Global Rice Science Partnership, GRiSP, so as to combine expertise, avoid duplication and the lack of a critical mass, and thus enable economies of scale and cross-learning.

Since early 2007, numerous consultations and meetings have taken place and feedback has been collected from many organizations, including farmer organizations such as the West African farmer organization ROPPA (which has observer status in national expert committee and council of ministers meetings of the Africa Rice Center), NGOs, NARES and regional NARES organizations, private sector and regional economic communities involved in rice research and development worldwide on the overall vision and strategy for GRiSP (Appendix 2). In response to the emerging discussions on creating new Strategy and Results Framework (SRF) for the CGIAR, a first draft of an embryonic GRiSP was developed in May 2009. The process was greatly accelerated by the discussions during the various Global Conferences on Agricultural Research for Development (GCARD). During the remainder of 2009, the concept was discussed widely with major regional bodies and research partners, who provided strong endorsement as well as important feedback.

In January 2010, a GRiSP vision and strategy document, outlining the proposed future joint research agenda of IRRI, AfricaRice, and CIAT, was drafted and circulated widely among many stakeholders. Further discussions were held with key partners in Africa during the Africa Rice Congress and during GCARD in March 2010. A writing team met in April 2010 to draft the first full GRiSP work plan and proposal. At present, the GRiSP work plan mainly combines the rice research programs of IRRI, AfricaRice, CIAT, CIRAD, IRD and JIRCAS, who have all sought extensive feedback from their partners and other stakeholders in the research and development community for setting their own priorities.

Yet, the process of developing the GRiSP work plan is an ongoing and dynamic one. Over time and through a continuing process of strategic assessment and consultations with national partners, CSOs and others, the research themes and approaches in GRiSP will be shaped further to represent the highest priorities for the key target regions. Our vision for GRiSP is that of an umbrella mechanism, seeking to align strategic partners toward a harmonized global rice research strategy, including strong national systems that wish to seek opportunities to contribute more at the international level.

Research strategy and themes

Product-oriented research and development approach. Through partnering with the public and private sector and civil society organizations (CSOs), GRiSP is intended to become a global, demand-driven gene-to-market program that will develop increasingly more productive and sustainable climate-resilient cropping systems, including improved value chains, and support for large-scale dissemination to farmers, thus increasing their incomes while keeping prices for consumers stable. As a first step, GRiSP incorporates the rice research and development portfolios of IRRI, AfricaRice, and CIAT, as well as major parts of those of CIRAD, IRD, and JIRCAS. Together with more than 450 research and development partners worldwide, these institutions will facilitate an efficient global rice research program that follows an outcome-driven innovation approach and is meant to bring in many new partners who can benefit from it, but also make significant contributions to it.

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.

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

- six **global R&D themes**;
- an initial set of 32 **global and regional R&D product lines** (typically 3–8 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 the regional, subregional, and even local needs and impact pathways;
- produced-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; and
- milestones that provide measurable targets for each product and its uptake.

At the core of this approach lies a thorough understanding of the specific target environments for each product, in terms of both socioeconomic and biophysical factors that drive what farmers, agri-businesses, small entrepreneurs, consumers and many other actors in the value chain need from research. Details of 32 R&D product lines in GRiSP are provided in Appendix 3 (products, milestones, outcomes, lead centers, partners).

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 more important in the light of climate change, as well as to broaden the available gene pool for trait discovery. Theme 1 will also address two blue-sky research areas with very large long-term impact potential: re-engineering photosynthesis in rice to create a C_4-rice and developing rice with the capability to fix nitrogen from the air.

Theme 2: Accelerating the development, delivery, and adoption of improved rice germplasm*.* 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. Differences between the needs and priorities of male and female farmers who are both producers and consumers, will be examined and considered in the development, delivery and adoption of rice germplasm. 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: Increasing the productivity, sustainability, and resilience 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. In Africa, small-scale mechanization techniques will be developed to address the widespread “lack of energy” in areas with limited labor availability. Lessons from a recent “agronomic revolution” in Latin America will be transferred to other regions. Theme 3 addresses all these matters through linking basic research on designing future production systems (new experimental platforms) with participatory adaptive research conducted in research stations and farmers’ fields worldwide, involving numerous public, CSO, and private-sector partners at the regional to local level.

Theme 4: Extracting more value from rice harvests through improved processing and 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 microfinancing will be strengthened to allow farmers to maximize their economic yields from rice. New ways will be investigated to prevent postharvest losses of grain, which may add up to a third more marketed rice. 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 4 is an area of relatively small investment at present, but one that is expected to grow in GRiSP over time. Adding more value and linking production-oriented research in Themes 2 and 3 to whole value chains is seen as crucial for rural economic development in many parts of Asia and Africa. The roles and constraints of male and female farmers in the value chains will be examined to identify ways they can benefit rather displaced by improved processing and marketing systems and new products.

Theme 5: Fostering improved policies and technology targeting to enable improved rice production and marketing. 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 socio-economic categories and other actors, as well as the likely consequences of labor-saving technologies on 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. To this end, there are two thrusts. The first consists of new approaches for easy access to rice data for all sector participants, through an information gateway that will also include decision-support tools, linkages with output and input markets, and local communication sources. The second thrust is to use this information to foster harmonization of key rice policies, such as those related to value chains, varietal release, seed legislation, micronutrients, pesticide use, and legislation on pricing and water use.

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.

Although seemingly disciplinary in nature, 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 5 illustrates the R&D approach in GRiSP, using the product line (2.5) on high-yielding irrigated rice varieties as an example. This product line includes three products: 2.5.1—a new generation of high-yielding inbreds for Asia; 2.5.2—rice varieties for direct seeding in aerobic rice and conservation agriculture systems; and 2.5.3—irrigated rice varieties for Africa. 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. Theme 1 provides critical genetic innovations to these breeding programs. 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.

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.

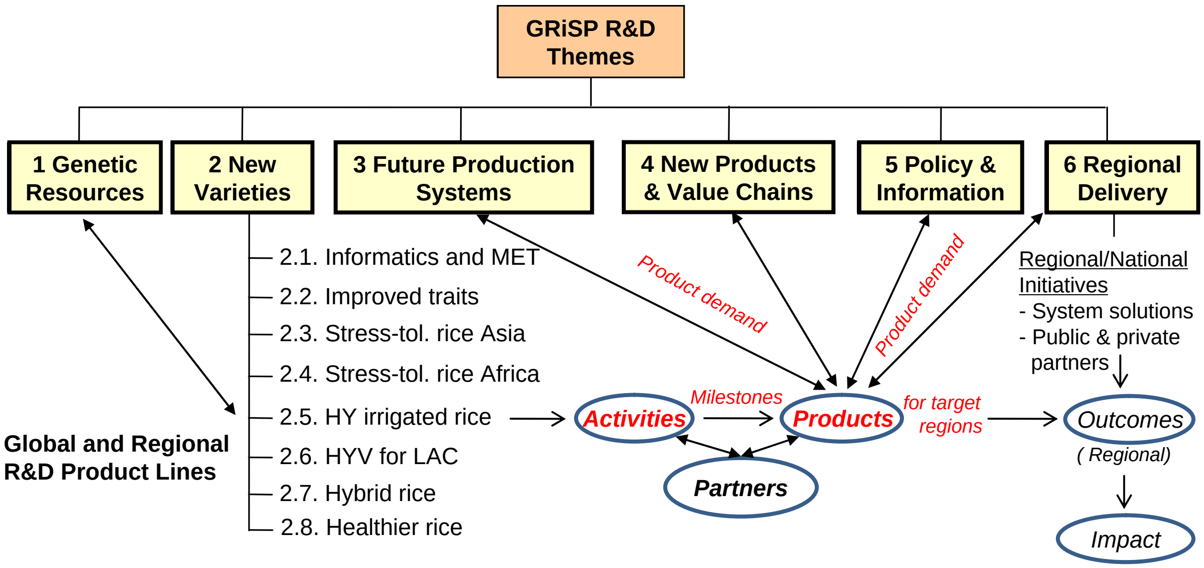


Fig. 5. Outcome-driven innovation through integrated product-oriented R&D in GRiSP.

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 (Box 2). Projects for this already exist, but more needs to be invested in order to tackle climate change in a more effective manner.

Box 2. Climate change adaptation and mitigation in rice systems

GRiSP will take a holistic approach for tackling climatic change issues specific to rice. Adaptation to climatic extremes and more gradual climate change is a major goal of developing new stress-tolerant varieties in Themes 1 and 2. To fully use these new climate-resilient varieties, research on optimizing cropping systems management will be carried out in Theme 3, which also addresses management practices for reducing the global warming potential of rice fields. We also hope to find new uses for rice byproducts in bioenergy generation and make breakthrough inventions that could lead to major energy savings, for example, in cooking rice (Theme 4). Theme 5 will include wide-ranging socioeconomic and policy research relevant to climate change. Broad dissemination of adaptation and mitigation technologies will be carried out through supporting regional development efforts (Theme 6).

Climate change research in GRiSP will be carried out through interdisciplinary national or regional projects, which seek to provide holistic solutions in the most vulnerable hotspots. For its early success, the rice-specific research in GRiSP will require information on the likely extent of change and on the hotspots in much finer geographic detail than available now. This information will come from interaction with the CGIAR Mega Program on climate change, to which the climate-change-related technologies for rice from GRiSP will in turn contribute. Additionally, GRiSP's comprehensive climate change approach will also provide attractive incentives to some youth to become rice scientists, and GRiSP will support them through the rice science leadership program and other capacity-building and gender-related activities.

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. Blue-sky research will therefore play a significant role in GRiSP, for example, in Theme 1. Priorities will be continuously assessed and new opportunities will be aggressively pursued, leading to an evolution of the GRiSP R&D portfolio over time.

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.

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

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 learn from plant species with better photosynthetic efficiency (Box 3) and nitrogen-fixing capability how to redesign the rice plant for greater productivity for the future.

Box 3. C_4 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.

***Product lines and outputs*.** The R&D product lines in Theme 1 are

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
1.5. Nitrogen-fixing rice
1.6. Informatics support for germplasm management and gene discovery.

These product lines will provide the foundation for new international rice breeding programs, leading to new and improved rice varieties (addressed in Theme 2) 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;
- producing a more efficient rice plant (C_4) for the future; and
- exploring nitrogen fixation in rice to reduce dependency on nitrogen fertilizer.

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, and private companies. They 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, exchange, and use of these materials are essential because demand for them to address 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 national agricultural research systems, 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 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 and nitrogen-fixing projects, which will engage a broad community of researchers around the world.

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

***Rationale and objective*.** From identifying desirable rice traits to the wide 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 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.

***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 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. 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.

***Product lines and outputs*.** The R&D product lines in Theme 2 are

2.1. Breeding informatics and multi-environment testing
2.2. Improved donors and genes conferring valuable traits
2.3. Stress-tolerant rice varieties for South and Southeast Asia
2.4. Stress-tolerant rice varieties for Africa
2.5. Improved rice varieties for intensive production systems in Asia and Africa
2.6. Improved rice varieties for Latin America and the Caribbean
2.7. Hybrid rice for the public and private sector
2.8. 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 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 quality and 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 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, JIRCAS, the Generation Challenge Program (GCP), NARES, advanced research institutions, 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 4), which started in 2010.

Box 4. 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.

Breeding networks involving dozens of partners in Asia will focus on specific target production environments, including drought-prone, flood-prone, and saline-prone 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 more important in Latin America. Some existing models that will be expanded are the Hybrid Rice Development Consortium (HRDC) and FLAR.

***Impact pathways*.** Products from this theme will be delivered at an accelerated pace through the establishment of a molecular rice breeding platform 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 national 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 greatly stimulate 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, 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).

Theme 3: Increasing the productivity, sustainability, and resilience of rice-based production systems

***Rationale and objective*.** About three-quarters of the world's rice is obtained from irrigated lowlands, which have been demonstrated to be extremely sustainable by three millennia of continuous production in Asia. This sustainability is now threatened, however, by recent rapid population growth that leads to a declining share of land, water, and energy resources. Labor shortages are growing because of rural-urban migration, and the burden of agriculture falls increasingly on the shoulders of women and older men who remain behind. Other threats to sustainability arise from inefficient use of production inputs, which 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. In some 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. It is estimated that pests (nematodes, insects, rodents, and birds), diseases, and weeds are responsible for a 25–45% loss of rice production in tropical and subtropical Asia. Market-driven diversification, while offering potential for increasing farm income, also presents new challenges for sustainable management. Overarching these issues are the threats of—and opportunities from—climate change.

In Africa, lowland rice is cultivated along an intensification gradient, with practically undisturbed inland valleys at one end and intensively cropped irrigation systems at the other end of the development spectrum. Fertilizer use in these systems is generally still very low, among others because of high prices and poor distribution networks. Rice yield gaps between attainable and actual yields are high, even in input-intensive systems. However, in contrast to Asia, most rice in Africa is grown under rainfed conditions. Drought is a major determinant of crop yields, 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 areas 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.

Rice monoculture with one or two crops a year is the most common system in the irrigated regions of tropical Latin America, while one crop a year and rotation with pastures and other crops is predominant in the southern temperate regions. There is no reliable information on the sustainability of these systems, but it is clear that some of them are stressing natural resources and have severe environmental impact.

There is still large scope for significant increases in rice productivity globally through improved agronomic practices that aim at exploiting persistent yield gaps. Such an agronomic revolution—perhaps one of the most powerful short- to medium-term interventions—must focus on the integration of better adapted germplasm and improved field and landscape management practices. This requires good understanding of these yield gaps and interdisciplinary approaches that aim at designing sustainable, highly efficient, and ecologically resilient rice-based cropping systems. Much can be learned in that by sharing experiences across different world regions.

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). Given the fragility of this environment and the poverty of the often small holders in this ecosystem, innovative low input cropping management based on conservation agriculture, diversification of farming systems, and improved value chains is needed there to improve livelihoods of the poor.

***Research approach*.** Research in this theme will focus on developing new crop, resource, and pest and disease management options in response to major drivers of change that will shape the future of rice production: increased market linkages and options for diversification, climate change, and land, water, energy, and labor scarcity. Strategic and process-based research will be conducted in greenhouses and experimental fields to derive generic scientific principles that will underpin the development of improved crop and natural-resource management options.

Location-specific management options will be developed through on-farm adaptive and participatory research, for example, in sub-Saharan Africa (Box 5). In areas that specifically suffer from drought, submergence, iron toxicity, or salinity, management technologies to accompany the introduction of newly developed stress-tolerant rice varieties will be introduced simultaneously. In intensive rice production systems, research will focus on opportunities for, and challenges to, ecological intensification and crop diversification (e.g., rice-wheat/maize/pulses/potato).

Box 5. 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, and CIAT, 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.

In addition to experimentation, GRiSP, through collaboration with the world's leading modeling groups, will develop and use simulation modeling tools (crop, water, pest, and disease epidemics) to scale-up site-specific experimental results, to assess impacts of climate change, and to explore options of management interventions. 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. Principles to enhance ecological resilience to control rice pests will be developed through ecological engineering and regionally targeted deployment of resistance genes in rice varieties. The research will be carried out at plant, field, landscape, regional, and global scales.

***Product lines and outputs*.** The R&D product lines in Theme 3 are

3.1. Innovative technologies for ecological intensification of rice production systems under current and future climates
3.2. Methods to enhance ecological resilience for pest and disease control under current and future climates in Asia, Africa, and Latin America
3.3. Management innovations to cope with abiotic stresses under current and future climates
3.4. Integrated cropping system innovations for future intensive rice systems in Asia
3.5. Farm management innovations for lowland rice-based systems in Africa across an intensification gradient
3.6. Farm management innovations for upland rice-based systems

Short-term outcomes will be strengthened research and development partnerships for adaptive research on crop, soil, and water management technologies. In the medium term, frontier farmers in project areas will have adopted integrated crop management options through trained extension and development agents.

***Innovative contributions*.** This theme will develop, combine, and apply principles of "ecological intensification" with principles of "ecological resilience" not only to increase farmers' incomes and livelihoods of the poor through increased rice productivity and resource-use efficiency but also to reduce the environmental footprint and negative externalities of rice production. Key innovations in Theme 3 include

- 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
- harmonized, science-based management principles for increasing the efficiency of rice production systems, closing yield gaps, and reducing externalities, with particular emphasis on water-saving irrigation technologies and new tools and technologies for site-specific nutrient management
- conservation agriculture solutions for diversified lowland rice systems of South and Southeast Asia and Latin America and upland rice systems in Africa
- new approaches for weed management in direct-seeded rice
- small-scale mechanization of rice production system in Africa
- ecological engineering approaches for pest management

***Partnerships*.** NARES, advanced research institutions, the private sector, farmer organizations and NGOs are key partners in Theme 3 to provide the research power needed to accelerate the development and diffusion of new management technologies. Innovation partnerships on participatory and adaptive research and development will ensure that indigenous and local knowledge is 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 climate change, 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.

This theme will interact much with many other Mega Programs, particularly Mega Programs under TA 3 (wheat, maize, pulses, livestock) and TA 1 (aquatic systems/coastal zones; humid zones), and on climate change (TA 7) and land and water (TA 5). Development challenges that cut across GRiSP and these other MPs will be addressed through joint projects in major target environments, such as the Cereal Systems Initiative for South Asia (CSISA) and others. Collaborating CGIAR centers include CIMMYT, CIP, ICARDA, ICRISAT, IFPRI, IITA, ILRI, IWMI, and WorldFish.

***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 in Africa; and FLAR in Latin America. These networks help to channel management innovations into adaptive efforts by NARS, NGOs, agricultural development initiatives, and extension efforts. 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 (see above).

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

***Rationale and objective*.** Drawing on various products of Themes 1–3, this theme aims to develop novel ways to add economic and environmental value to the crop through a reduction in postharvest losses, improved access and supply of quality grain and rice products to current markets and emerging specialty markets, improved value chain linkages and efficiencies, and innovative uses of husks and straw to produce biofuels, cut carbon emissions, and increase carbon sequestration.

Present postharvest processing in the developing world causes physical and quality losses of 20–30%. One reason for the slow progress in improving the postharvest value of rice is 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 rice varieties as well as better understanding of causes of and solutions for postharvest losses.

Further, about 550 million tons of rice straw and about 110 million tons of husks are produced in Asia each year. Disposal of these, for example, by burning, causes emission of 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 straw so it can be used as livestock feed.

There is increasing global awareness of the nutritional value of food and the environmental impact of producing it. For example, identifying low glycemic index rice will assist Type II diabetes sufferers. Unpolished, or partially polished, rice is currently vacuum-packed to prevent rancidity. Eliminating the biological causes of rancidity will increase consumer access by decreasing packaging costs. Faster-cooking rice will greatly minimize the carbon emissions from cooking rice (Box 6). Other opportunities to add value are rice products, such as high-value oil from the bran, and high-energy biscuits for malnourished children. Supplying rice varieties to these high-value markets will increase economic benefits to farmers and nutritional benefits to consumers worldwide.

Box 6. 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. 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*). Theme 4 will explore whether this discovery may soon allow us to breed rice varieties with lower GT, which could decrease average cooking time by up to 4 minutes, while minimizing its effect on yield. Although this might initially seem insignificant, by computing the number of times rice is cooked in any one day by 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 and is of particular relevance to poor rural households that depend on scarce local supplies of fuel. It is also a potential major contribution to reducing fossil-fuel use in the life cycle of rice, and thus greenhouse gas emissions.

***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 Cambodia, the Philippines, and Vietnam and in GRiSP will be extended to other Asian countries as well as to African countries through a special task force on rice postharvest, processing, and markets. Ways to upgrade the postharvest link of the rice value chain include tools and methodologies for analysis, improved information systems on markets and consumer needs, improved linkages within the postharvest subsector, and the adoption of business models. We will determine the variability in digestibility of rice 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. Selection for specialty traits will be made using newly developed techniques for identifying compounds that contribute to taste and flavor, and identifying the components of the grain that determine specialty, sensory, and cooking properties. Tools to evaluate these traits will be developed, and varieties meeting different market requirements for quality will be developed.

***Product lines and outputs*.** The R&D product lines in this theme are

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. Specialty rice and innovative rice-based food products

The new products and technologies in this theme will add economic, environmental, and nutritional value to rice harvests and byproducts. Also, they will integrate the different parts of the rice sector to improve information flows among them, thus improving the overall efficiency of the sector and leading to more stable rice prices, increased income for farmers, healthier consumers—which will increase labor productivity and decrease the cost to poor families and national health budgets of treating the chronic conditions that arise from untreated Type II diabetes—and better use of the large volume of byproducts, which can result in significant climate-change mitigation.

***Innovative contributions*.** The research and development activities under Theme 4 include many innovative products and technologies:

- New rice varieties with improved straw digestibility for livestock feed.
- Improved nutritional and health value of rice.
- New tools and new traits to break through the quality plateau and allow high quality and high yield to be combined without penalty.
- Innovative ways to process broken grain to add value and generate employment opportunities, especially for women farmers in Africa.
- Production and use of rice biofuels to generate electricity for small enterprises.
- Adaptations of improved postharvest technologies to different conditions.
- Entrepreneurial business models for sustainable adoption of postharvest technologies and management options.
- Innovative market information systems management and links between cross-sector actors.
- Establishment of learning alliances among stakeholders for capturing new knowledge and disseminating new information on postharvest technologies and new phenotyping tools to evaluate the quality of breeding lines.
- Options to lower carbon emissions and add value by participating in carbon trading.

***Partnerships*.** Work under this theme will rely heavily on public-private partnerships and multi-stakeholder 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 processing and marketing, and in distributing new rice varieties and other rice-based foods, on the other. Links are strong with Themes 2 and 3, with Theme 5 on information dissemination and knowledge of consumer preferences, and with Theme 6 for widespread distribution and scaling-up of products, including extension capacity building for postharvest. Collaboration with other CGIAR centers will include ILRI (straw for livestock) and IFPRI (value chains), through current projects, and the new CGIAR Mega Programs on policy (TA 2), livestock (TA 3), and climate change (TA 7).

***Impact pathways*.** Products developed in this theme address the major opportunities to add value to the crop: improving food security by reducing postharvest losses, mitigating climate change by new options for husks and straw, and improving nutrition and health of consumers through specialty rice, products, and access to emerging and high-value markets. Uptake of the technologies and products requires networks of stakeholders to ensure that (i) appropriate end-users and consumers are aware of the products and their benefits, (ii) technologies are scaled up and products distributed through appropriate business models, and (iii) flows of information and feedback among actors are improved. Key intermediaries and disseminators for generating awareness and communicating information and providing support for adoption of processing products include in-country networks, NARES, NGOs, farmer groups, processors, technology and service providers, and retailers. Specific product lines on higher nutrition rices will also benefit from local promotion by health organizations. The use of bioenergy products depends upon appropriate carbon credit systems developed by climate change scientists, and carbon traders. Speciality rice and the associated high-value chains may be a particularly attractive way for raising the income of poor farmers in upland areas, where low-input farming is common and, due to many constraints, increases in productivity through improving conventional management systems are difficult to achieve. This requires complementary actions by partners to link upland farmers with value chains for upscale niche markets for rice.

Theme 5: Fostering improved policies and technology targeting for sustainable rice production and marketing

***Rationale and objective*.** Governments have to be at the forefront of any concerted effort to improve the rice sector in their country, to create the enabling environment and resources for the many public and private stakeholders to carry out the required research, development, and extension. But, 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 information on the global rice situation can have a strong impact on rice market prices and influence policies. Indeed, better and 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, so as 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*.** 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. Data will be collected and analyzed, disaggregated by gender, 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.

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.

***Product lines and outputs*.** The R&D product lines under Theme 5 are

5.1. Socioeconomic and gender analyses for technology evaluation

5.2. Spatial analysis for effective technology targeting and deployment strategies
5.3. A global rice information gateway for market analysis and policy planners
5.4. Sustainable rice policies for a globalized world
5.5. Strategic foresight, priority setting, and impact assessment for rice research

Theme 5 cuts across themes, providing 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 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 will be a substantial innovation, not only in terms of analytical methods but also in terms of institutional culture.

The much-improved household-level data, agro-ecological information, and the information gateway will provide unprecedented availability of information on all aspects of the rice sector worldwide. It will allow many previously impossible analyses to be made, from local to global scales. Real-time crop monitoring and forecasting will become possible (Box 7).

Box 7. Real-time crop monitoring and forecasting

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 under Theme 5, 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.

***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. Collaboration with advanced research institutes 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), and Economic Community of West African States (ECOWAS) and farmer organizations such as the Network of Farmers' and Agricultural Producers' Organizations of West Africa (ROPPA) or 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, 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 by 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—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.

Theme 6: Supporting the growth of the global rice sector

Rationale and objective**.** GRiSP aims to achieve large-scale productivity increases in rice, improved environmental sustainability, and gains in global, regional, national, and household food security. At the regional level, 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 workplans 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 chains.

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 homogenous irrigated systems. Best ways to reach poorer households, women, or disadvantaged groups are highly location-specific. Innovations in communication technology 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 (feed forward and feed back loops) between research networks and development or business investments.

Approach**.** The facilitation of large-scale testing, adaptation and adoption by farmers of rice technologies and agro-ecological and socio-economic principles requires that international and national research centers connect to a much greater number of farmers, using existing networks and new partnership models (Box 8, Fig. 6). This type of 'last-mile delivery' effort is likely to vary in form and scale according to regional, national, and local differences and 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 capacities.

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 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 post-conflict countries, such as Liberia, building on IRRI's experience in Cambodia.

In Asia, IRRI has, for example, promoted good agricultural practices for rice in many countries or sub-regions 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 for roles an international center can play effectively in supporting such national efforts. At more local level, an example is the work of IRRI and its research and extension partners in the 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 activities. At a local level, 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 such as CSISA and STRASA (Stress-Tolerant Rice for Poor Farmers in Africa and South Asia) that aim to disseminate new management options and new varieties of stress-tolerant rice to millions of poor farmers through hundreds of partner organizations. Strong links have also been built with 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 resource base for partners will be developed to greatly 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 will be 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 multi-skilled service providers. A grass-roots competitive fund will be established to nurture innovative initiatives to disseminate technologies by NGOs and local associations 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 multimedia 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 the centers and national RKBs will be the principal platforms. These resources will include information on specialist topics as well as extension training materials.

***Product lines and outputs*.** The development product lines for theme 6 are

6.1. Effective systems for large-scale adoption of rice technologies in South Asia
6.2. Effective systems for large-scale adoption of rice technologies in Southeast and East Asia
6.3. Effective systems for large-scale adoption of rice technologies in Africa
6.4. 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 agro-ecological 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. Further, all target countries will have a system of knowledge management and a national rice knowledge bank that provides effective delivery in suitable media. 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. 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 at national and international levels 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 record the performance of the different delivery approaches, overall acceptance of technologies, and the inclusion of women, ethnic minority groups, and poorer households.

Box 8. Consortia, learning alliances, civil society, poverty and women

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 such as from technology adaptation, seed systems development, micro credit, to a positive policy environment. In Asia, the Irrigated Rice Research Consortium (IRRC) and the Consortium for Unfavorable Rice Environments (CURE) provide examples of platforms for a wide range of partners involved in adaptive research and delivery of technologies to a variety of end-users. These consortia facilitate timely and effective transfer of knowledge and technologies to extension agents -- both 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" (Fig. 6).

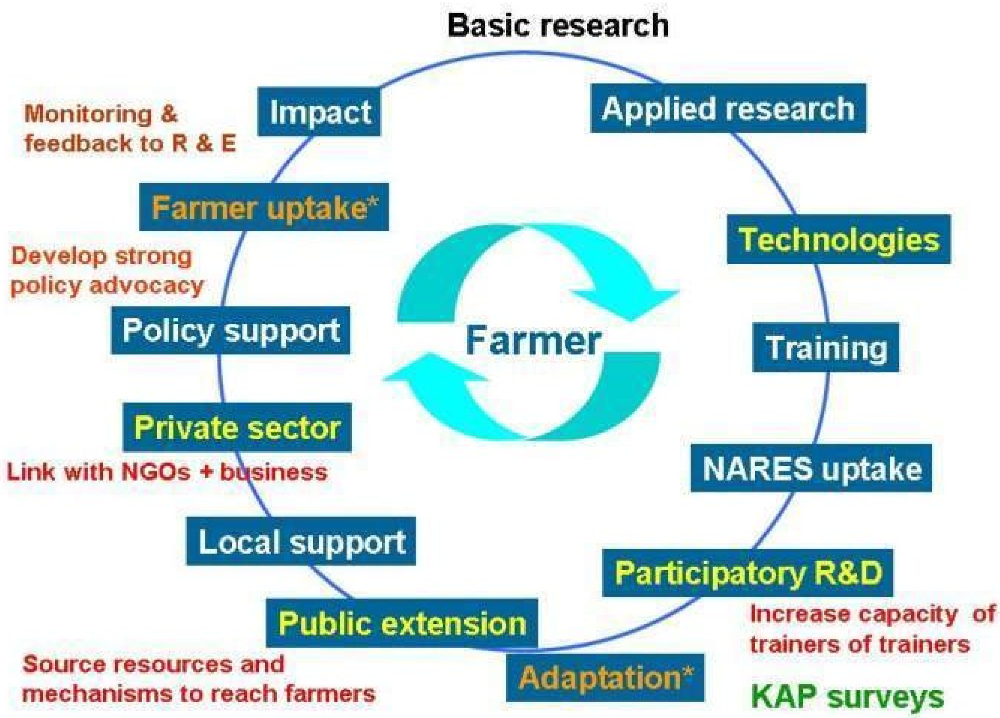


Figure 6. Cycling from research to impact through multiple channels and learning alliances

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 the 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 centre- 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, for adaptive research, seed production and farmer to farmer extension. Poorer farmers and women were the particular targets of these efforts. NGO linkages involving farmer groups, savings and micro-credit and capacity building are an integral part of direct engagement with grassroots civil society organizations and building. 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.

***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 (Box 8). 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 grass-roots-level delivery fund, which will be part of the centrally managed Global Program Support budget. On a regional basis, Theme 6 will interact with many other Mega Programs, particularly Mega Programs under TA 3 (wheat, maize, pulses, livestock) and TA 1 (aquatic systems/coastal zones; humid 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 may include CIMMYT, CIP, ICARDA, ICRISAT, IFPRI, IITA, ILRI, IWMI, and WorldFish, and AVRDC as a non-associated 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.

General impact pathway of GRiSP

Rice research is the single largest documented source of agricultural research benefits in the developing world, mainly through productivity-enhancing research and in particular new varieties. Expanding on this track record, the challenge for GRiSP is to, on one hand improve the existing research to impact pathways, and on the other hand maintain a continuous stream of international public good innovations, 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 7. More specific descriptions of the key uptake and impact pathways for each product line in GRiSP can be found in Appendix 3.

Farm level technologies and their antecedents are the primary ultimate products of GRiSP Themes 1, 2 and 3, in terms of improved germplasm and varieties, as well as improved management techniques. Theme 4 complements this with processor level postharvest technologies and new products for added value. Upstream scientific outputs, such as identified genes, C4-rice and the molecular rice breeding platform under Theme 1 will be primarily used by larger NARES (e.g. India and China) and the private sector, whereas more downstream scientific products, such as breeding lines with new traits, varieties and management recommendations, will be used by other NARES, NGOs and the private sector.

For each of the target intermediate users and environments 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 will form a key means of fostering local adaptation, testing and participatory feedback by partners (Box. 8, Fig. 6), which will help to further refine GRiSP product development. Theme 6 will help to ensure that the technologies, once locally adapted, become key components of effective local delivery systems by extension systems, development agencies, machinery and input suppliers, service providers and processors so that they reach the final users to improve productivity, input efficiency, environmental sustainability and quality of the produce. As an ultimate result, producer returns will rise and be more resilient for adopters, rice supplies will be increased, prices paid by the poor will decline, and food security and nutritional health will improve. Farmers, particularly the poor, will thus also be enabled to invest more in environmental stewardship, education, healthcare and other social development. More productive rice land and more valuable rice products will also enable them to set aside land for growing other crops, and thus further raise incomes through diversification of farming systems, which also result in diversifying risk. The urban poor will benefit from GRiSP by having access to affordable and more nutritious rice.

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. The intended influence of this information is to help avoid national trade policies with high deadweight losses, such as expensive government procurements or export bans, which are often harmful to the poor, and can be avoided without detriment to national food security.

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 for agricultural development agencies and Theme 6. In turn, use of this feedback should help to improve the overall impact potential of GRiSP activities.

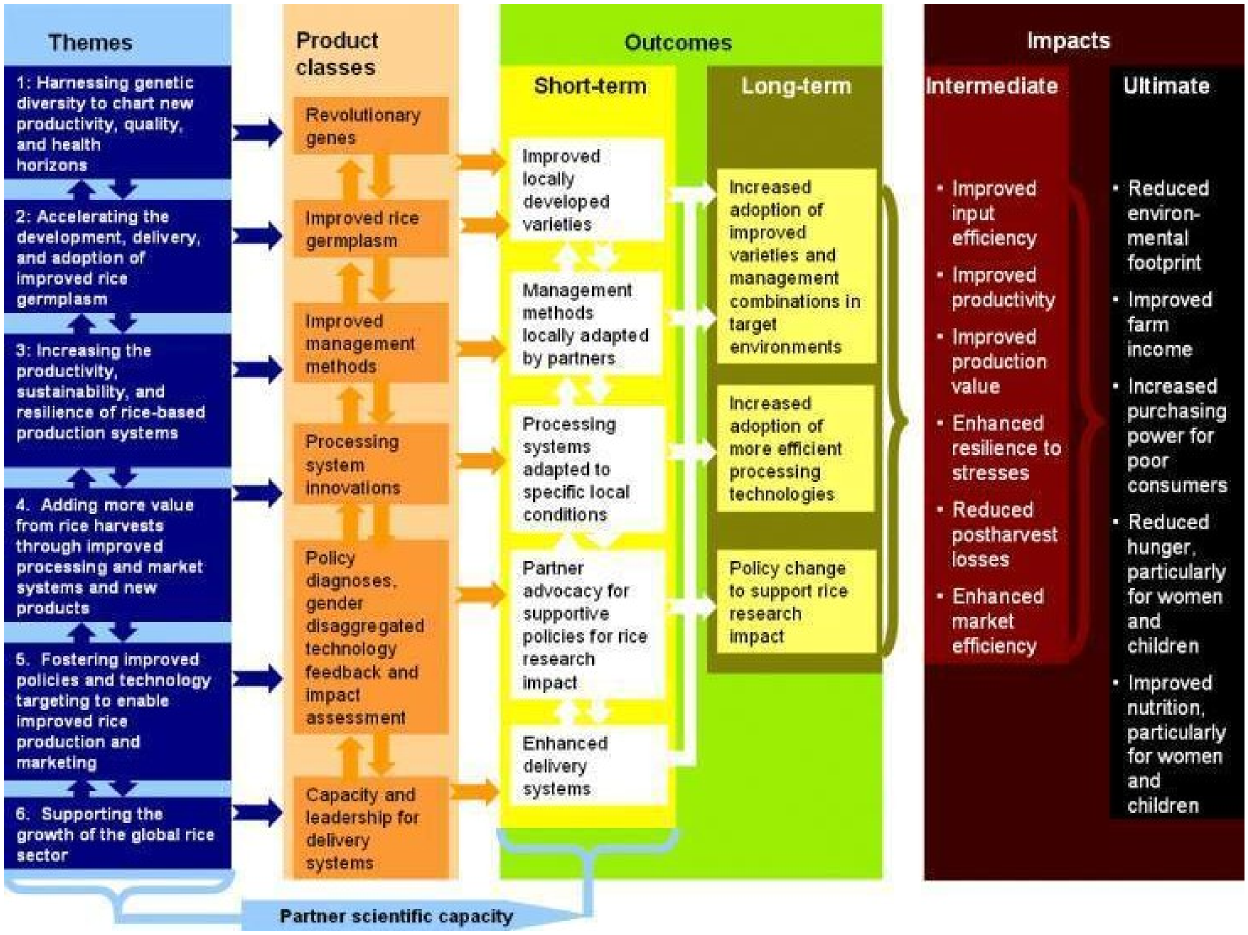


Figure 7. Overall pathways from products to impacts in GRiSP.

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 9 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 policy makers, the private sector and advanced research institutions 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:

- <u>Global Rice Science Scholarship</u>**:** This will develop research capacity at the PhD and MSc level. Scholars will be capable of designing, conducting and reporting research that addresses farmer 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 centres. Preference will be placed on a sandwich program approach in which the research agenda focuses on local issue that also contributes 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.
- <u>Masters 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 NARS. By 2015 at least 30 graduates will complete the Masters program. This program is open to students from other disciplines and we expected that it could be expanded to other CGIAR MPs.
- <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 give to region specific needs like capacity building of research technicians in Africa.

- Attracting new talent to rice research: It is critical that there is 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 pre-university to expose young people to the excitement of rice science

Box 9. 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:

- 90 PhD and MS scholars graduate each year (Asia 50; Africa 30 and LAC 10) through expanded scholarships programs with international centers), with 30 percent of graduating scholars women.
- 30 graduates each year obtain a Masters in Rice Science Leadership degree (18 from Asia, 10 from Africa and 2 from LAC, of whom 30 percent are women).
- CIRAD's new international doctoral schools for plant breeding accept at least 5 GRiSP scholars annually.
- Scholarships for 100 persons per year for short course science capacity building for NARS institutions, CSOs, and private sector (Asia 40; Africa 30 and LAC 10 with 30 percent women
- Rice Research to Production course for 30 young scholars per year, with field placement for 10 students per year in project locations across Asia, Africa and LAC.
- Each year, 50 internships of up to six 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, CSO and private sector
- Annual leadership training course for women in rice science and development (15-20 participants).
- Science education lab established at IRRI for providing rice science exposure for students
- Rice agronomy and post-harvest training center established at AfricaRice Senegal
- Accreditation schemes for certified extension-agronomists and inputs dealers are operating in 3 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
- Need based training of local women leaders who will provide training to women farmers on farm management, technical information and skills from production to post harvests
- Trained resources provide continuous training for at least 1000 grassroots extension leaders

***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 post-harvest and processing in each country – officers skilled in assessing farmer 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.

Gender strategy

Women in rice-based farming systems in Asia, Latin America and the Caribbean, and sub-Saharan Africa have played and continue to play crucial roles as producers/farmers and consumers, farm managers, income earners, and processors of small-scale value-adding activities for rice products and are often responsible for food storage and seed selection/storage. They are mainly responsible for ensuring household food, health, and nutritional security. Their roles and those of rural men are conditioned by several inter-related socio-economic (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 socio-economic factors influence a community (i.e. changing economy, etc). Men and women have different knowledge, needs and priorities, as well differences in access to control of resources which need to be considered in the research agenda particularly in technology design, testing, evaluation, impact assessment and dissemination.

Despite women’s important contributions in farming and livelihoods, women have less access than men to 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.

Many measures are needed if women and men are to become equal beneficiaries of, and contributors to, rice-sector development. GRiSP will conduct a gender audit to identify key research opportunities for addressing gender concerns and assist with the inclusion of women farmers in technology evaluation, adaptation, and dissemination; and strengthen the capacity of women as scientists, development and extension workers, and farmers.

Gender concerns will be addressed in all GRiSP themes, with greater attention in Themes 5 and 6 and through all capacity strengthening activities. Milestones with gender-specific targets are contained in most of the GRiSP R&D product lines described in detail in Appendix 3 (see the logframe tables for each product line). Only brief summary statements can be provided here:

Theme 1. Young women scientists will be given support to pursue their careers in various rice scientific fields eg genetics, molecular breeding, crop physiology, etc., including presenting their papers in international scientific forums. Gender roles and the needs in seed systems and work on in situ conservation will involve women since they are often the repositories of knowledge on seeds and responsible for seed storage and selection.

Theme 2. The differences between men and women’s needs and preferences as producers, processors and consumers, will be evaluated through PVS .

Theme 3. The consequences of climate variability on resource management of men and women among rice farming households in Asia and Africa will be examined. Male and female farmers will participate in adaptive trials on farm management innovations

Theme 4. Men and women will be involved in the evaluation and dissemination of post harvest technologies and uses of new rice-based products. .

Theme 5. Comparative strategic research will be carried out in the three regions on thematic gender issues (factors enabling and constraining the adoption of technologies), knowledge on changing gender roles due to broader changes (economic, environmental, technological, etc.), consumer preferences and gender-differential impact of technologies, best practices for sex-disaggregated data collection, and impact assessment.

Theme 6. Inclusion of men and women in effective systems for large-scale adoption of rice technologies in the three regions. Capacity-building support for extension agencies will target 30% women. Small grant funds will be available for gender research and projects with positive gender impacts; both will be competitive and open to national, regional, and international research and development centers.

Partnerships

No rice research program can be effective on its own. Partnerships with organizations along the two-way research-development-extension continuum are needed to contribute to iterative cycles of research priority setting and technology development, adaptive research and diffusion, monitoring and evaluation and impact assessment and funding.

The three main CGIAR centers GRiSP (IRRI, AfricaRice, CIAT) have solid advantages in International Public Goods generation through the upstream areas of rice improvement, and through their ability to conduct upstream and downstream research on production systems across borders, in work on principles for more productive and sustainable management of rice. 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 international public goods and 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.

Not counting donors, the three lead CGIAR centers in GRiSP already have about 450 active rice research and development partnerships outside the CGIAR system (Fig. 8) that will be further coordinated and focused on the clear objectives and verifiable impacts that GRiSP will articulate.

Major program partners outside the CGIAR system and their roles are:

- National agricultural research and extension systems (NARES), which are in constant contact with CGIAR centers through projects, networks, and consortia. 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 Asia (e.g., China, India, others), and Latin America (e.g., Brazil) that will play a key role in many activities. NARES are instrumental in this 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.

- International agricultural research organizations, such as CIRAD, IRD, and JIRCAS, all working in many countries. Although funded to a large extent by national governments, these partners have an international mandate for research and they are, therefore, natural partners in GRiSP. Their active involvement in GRiSP will ensure distribution of tasks according to comparative advantage and regional presence, avoidance of duplication and maximizing synergies.

- Other advanced research institutes with significant investments in rice science, often of an academic nature, but with vast scientific resources. Mobilizing some of these institutions in the framework of GRiSP will be of great importance to deliver on anticipated science-based innovations.
- The agricultural donor community, consisting of public bilateral, multilateral, and local, national, and multinational private organizations. The active involvement of the donor community in GRiSP will help build confidence, leading to increased funding with enhanced time horizons, streamlined reporting procedures and ultimately greatly enhanced impact.
- Civil society, or nongovernmental, organizations, which are increasingly involved at the downstream end of rice production, particularly in cooperatives, and will be essential partners for dissemination. International NGOs, such as the World Wildlife Fund and Catholic Relief Services, are also involved in more upstream aspects of rice development. These organizations operate at the grassroots' level and are well placed to ensure full participation of farmer organizations and other stakeholders in GRiSP activities. Their participation is crucial to achieve impact. Examples are provided in Boxes 8 and 10.
- Regional economic communities (RECs) with a major interest in development of the rice sector, such as the Economic Community of West African States (ECOWAS). RECs are playing an increasingly important role in agricultural development. 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.
- The private sector, which has long been involved in rice seed development and delivery, particularly of hybrid rice, and is broadening its interests to other production aspects. Particularly in South Asia, numerous private companies and NGOs are investing heavily 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. A clear example of a partnership with the private sector is the Hybrid Rice Development Consortium hosted by IRRI (see Box 11)

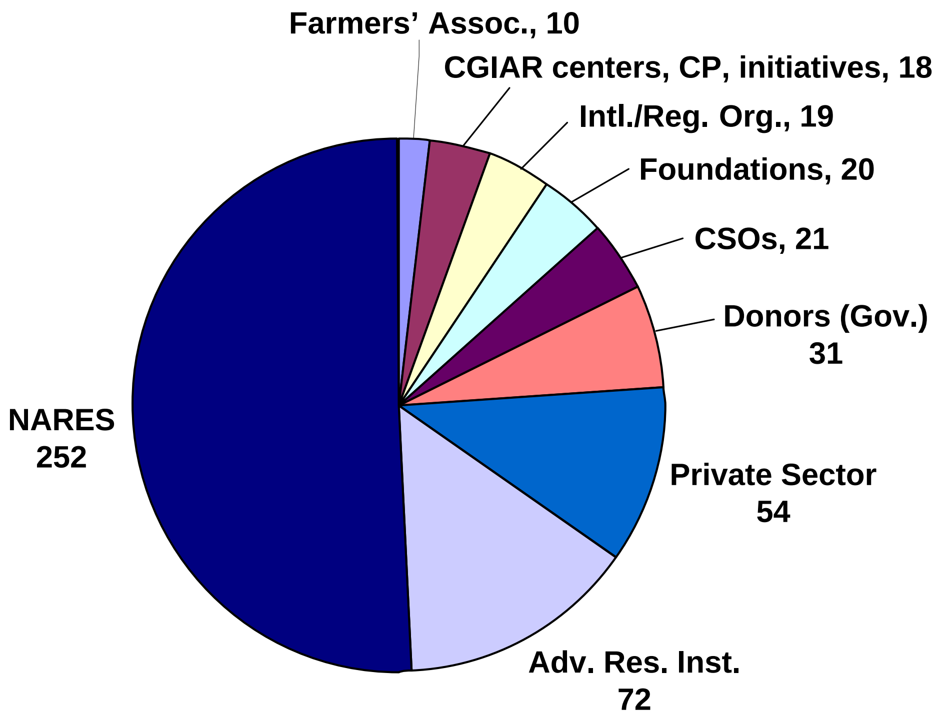


Fig. 8 Current active partnerships of IRRI, AfricaRice, and CIAT (only rice sector). The graph includes only partnerships that involve flow of funds and/or joint research and development activities.

Overall, GRiSP plans to spend at least 14% of its budget on supporting partners outside the CGIAR. Key examples for worldwide partnerships in basic research include 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).

Many partnerships in GRiSP 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, see Box 12), 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).

One concrete example is the currently ongoing project on Stress-Tolerant Rice for Africa and South Asia (STRASA), led by IRRI and AfricaRice. The 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 counts about 200 partners who are engaged, mostly part-time, in project activities. There are 129 recognized partners in seed production in South Asia alone, allowing rapid outscaling 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.

GRiSP will seek to expand its partnerships, particularly with the CSO sector, including global, regional, national, and local NGOs, farmers' associations, and other groups representing the agricultural, social, and environmental sector (Box 10). In all GRiSP regions, we seek to engage actively with leading CSOs in implementing grass-roots-level development work, as captured in Theme 6. Two specific initial measures will be taken to foster this: (i) 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 (ii) funds will be made available from the central GRiSP Support and Coordination budget to catalyze grass-roots-level dissemination activities with CSO partners.

Box 10. FLAR—a south-south public-private partnership for irrigated rice production

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. The fund is responsible for the initial crossings and selection, while local institutions are responsible for evaluation, final selection, release, and seed production. Twenty-two rice varieties have been released since 2003 and some are now the most widely planted varieties in the region.

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

These successes result from FLAR's modus operandi, with CIAT providing new germplasm and technologies, FLAR using these in its applied research projects and passing the results to its members, and national public and private institutions adopting and adapting them in farmers' fields. 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 and extension models.

The three CGIAR centers in GRiSP already have active partnerships with 54 private companies or organizations representing different areas of the private sector (Fig.8). Public-private partnerships, with a wide range of small to multinational companies and enterprises, are an important mechanism for achieving GRiSP's vision by drawing upon the different strengths of each sector. GRiSP will thus play an active role in forming and facilitating such partnerships at global, regional, national, and local levels. This also includes developing 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 is the international Hybrid Rice Development Consortium (Box 11), which consists of 25 seed companies and 25 public-sector institutions.

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 and other projects), 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).
- WorldFish is expected to collaborate with GRiSP (and vice versa) in projects on coastal zones and other aquatic systems that involve rice and fish.

Box 11. 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 prebreeding, 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.

Integration with other Mega Programs

GRiSP is more than a "rice program"—it aims to develop integrated solutions for a wide range of cropping systems that include rice, but often also other crops and commodities. GRiSP will work closely with other CGIAR Mega Programs (MPs) as summarized in table 1. 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 MPs. Through cross-cutting regional or national projects (see the CSISA example, Box 12), GRiSP will be linked with other Mega Programs that focus on a wide range of commodities, production systems, and health and environmental issues, but that often also include rice.

Interactions with other MPs follow three major models:

- Full participation of IRRI, AfricaRice, CIAT and other GRiSP partners in other MPs that address rice-related issues beyond the focus of GRiSP and require wider collective action.
- Project collaboration in which GRiSP interacts with other MPs through bilateral projects (and vice versa) in the thematic areas that are also addressed by other MPs, but require a systems approach. Often this is done through cross cutting regional projects such as CSISA (see Box 12) and the Inland Valley Consortium.
- Co-investment from other MPs into GRiSP (or vice versa), through which outputs of one MP are also cross-listed as outputs in another; this model may be preferred for research that is better conducted in another MP, but contributes to the thematic area of the sponsoring MP. One may also refer to that as "outsourcing".

Table 1. Interaction of GRiSP with other CGIAR Mega Programs

Thematic Area/MP	Interaction	GRiSP Product Lines
1.1 Drylands	Project collaboration in South Asia (crop-livestock systems, with ILRI) and in the CWANA region (rice germplasm for irrigated drylands, through the TRRC)	2.5., 3.4., 4.2., 5.1.
1.2 MP humid tropics & highlands	Project collaboration in Africa on inland valleys development (IVC, with IITA, IWMI, and others),	3.5., 3.6.
1.3 Coastal and aquatic ecosystems	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.
2 Policies, institutions, markets	Project collaboration and co-investment by MP2 into GRiSP. Rice-specific policy research is integrated in GRiSP, but done in collaboration with MP 2. Ongoing projects with IFPRI.	5.1.-5.3.
3.2 Wheat	Project collaboration on rice-wheat systems in South Asia and China (with CIMMYT; see Box 12 on CSISA); joint CIMMYT-IRRI Crop Informatics Lab;	1.6., 2.1., 3.1., 3.4., 5.1., 6.1.
3.3 Maize	Project collaboration on rice-maize systems in South Asia (with CIMMYT)	3.4., 6.1.
3.4 Pulses and legumes	Project collaboration on rice-pulses systems in South Asia (with ICARDA and ICRISAT)	3.4., 6.1.
3.5 Roots, tubers, bananas	See MP 1.2, may be overlapping. Project collaboration in South Asia in systems that involve rice and tuber crops	3.5., 3.6. 3.4.
3.6 Millets, sorghum, and barley	None.	
3.7 Livestock & fish	See MP 1.1., may be overlapping	2.3., 3.3., 4.2.
4 Agriculture, nutrition and health	Co-investment by MP Nutrition into GRiSP for biofortification rice breeding (Harvest+), but the breeding is part of IRRI's and AfricaRice's mainstream breeding program.	2.8.
5 Land, soils, water, and ecosystems	Full participation. IRRI, AfricaRice and CIAT contribute to large-scale research on land and water resources, irrigation systems, and ecosystem services in MP 5. GRISP feeds technologies and know-how into MP 5. Regional projects on system-level water management issues (with IWMI)	3.1., 3.2., 3.4, 3.5., 3.6.
6 Forests and trees	None, except for possible collaboration on upland and highland systems improvement and ecosystem services.	3.6.
7 Climate change and agriculture	Full participation. 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 MP 7.	2.3. - 2.7., 3.1. - 3.5., 4.2., 4.3., 5.1., 5.2., 6.1.-6.4.

Generation Challenge Program (GCP) integration. 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 also actively participate in the proposed GCP transition towards a cross-cutting Genomics and Integrated Breeding Service (GIBS). The GCP has proposed that this GIBS will be demand-driven and designed to support MPs, NARS and other partners in genomic research and molecular breeding. Expanding on 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 GIB Service will be integrated into the crop MPs within the new CGIAR logframe. The GIB Service will be a one-stop shop via a web-based portal providing information for accessing genetic stocks and pre-breeding materials, with seed maintained and distributed by Crop Lead Centres. The portal will provide high-throughput services for genotyping and specialised physiological or metabolic measurements, informatics tools and support services. The GIB Service will support capacity and community development for genomic 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 centres will have overall responsibility for rice data management and storage, and will become major drivers of the GIB Service.

Box 12. Cereal Systems Initiative for South Asia (CSISA)

High-yielding irrigated cropping systems that include rice, wheat, maize, and other crops are widespread in South Asia. They are the main economic activity in many rural areas, providing the staple food for hundreds of millions of people. In many areas, significant yield gaps still exist, which can be exploited through more precise agronomic management. Labor cost is rising. Natural resources, such as water for irrigation, are becoming scarce. Much soil organic matter has been lost to frequent tillage.

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. The Cereal Systems Initiative for South Asia (CSISA) was established in 2009 as a new regional platform for bringing different themes and programs together, focusing on complete systems solutions for South Asia's most important cereal systems, from genetic improvement to improving cropping systems and market and delivery systems. It currently involves nearly 200 local public, CSO and private sector partners.

CGIAR Mega Programs on rice, wheat, maize, pulses, and livestock will contribute to CSISA in India, Pakistan, Bangladesh, and Nepal, and CSISA thus also plays a key role for connecting such Mega Program for collective action on the ground, and at the same time ensure interdisciplinary, demand driven research within each program. IRRI currently leads CSISA, and GRiSP will contribute to CSISA through new breeding products for climate change adaptation and conservation agriculture in South Asia (themes 1 & 2), improved management practices for rice-based cropping systems in the region (theme 3, with CIMMYT and ILRI), utilization of rice straw for livestock feeding (theme 4, with ILRI), socioeconomic research (theme 5, with CIMMYT, IFPRI, and ILRI), new extension capacity building models and partnerships for delivery (theme 6, with CIMMYT).

GRiSP will also enable a high degree of south-south learning and technology transfer, drawing from CSISA experiences for other world regions.

Program Management

Oversight, planning, and management

In establishing the Global Rice Science Partnership (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 MPs. IRRI, as the lead center of GRiSP, has the capabilities and is willing to assume the significant 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
2. High involvement of stakeholders
3. Transparency
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 9. GRiSP strategic guidance will be provided by an Oversight Committee (OC); planning and management will be coordinated by a Program Planning and Management Team (PPMT) and a Program Director with a small Program Management Unit (PMU); and implementation will be through regional and global teams. With the exception of the OC and PMU, GRiSP will be entirely managed through existing staff and processes.

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 composition of the OC is: 2 Board members from IRRI (including current Board Program Committee Chair), 2 Board members from AfricaRice (including current Board Program Committee Chair), 1 Board member from CIAT (current Board Program Committee Chair or member), and 3 external experts (independent, world-class thinkers from different regions that represent key stakeholders and have a excellent understanding of science and development issues). One of the three external experts will serve as the Chair of the OC. The OC will also be composed so as to ensure representation of all major scientific disciplines in GRiSP. Members of the OC will be appointed for 3 years, but terms of 2-4 years may be used 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) 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, (iv) oversee financial impacts on research activities, (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 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 address specific issues of high priority. Topics for the Annual Science Forum may be proposed by the OC and the PPMT. The members of the PPMT (see below), the Director Generals and the Board Chairs of IRRI, AfricaRice and

CIAT may attend meetings of the OC as observers. Once annually, the OC prepares a written report, which the Chair of OC will present in person or via video conference to the Boards of the three major centers.

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.

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 assurance work required by the performance agreement with the Consortium. Center boards will ensure that the centers assume their leadership role at the continent 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. The IRRI Board Chair and DG will report to the Consortium Board on GRiSP as a whole, including annual financial and progress report in relation to the performance contract signed between the Consortium Board and the Lead Center (IRRI).

GRiSP research leaders will continue to interact with the centers Boards of IRRI, AfricaRice, and CIAT to provide updates on research progress. After the creation of a new OC, the two rice-focused centers may consider dissolving their current Board Program Committees and nominate two current Program Committee members as members of the new OC. These two Board members will then report to the center Boards on scientific progress in GRiSP.

Regional oversight and linkages. 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) 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. Its goal is to support the efforts of African countries to double rice production on the continent within 10 years. AfricaRice will 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 through 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.

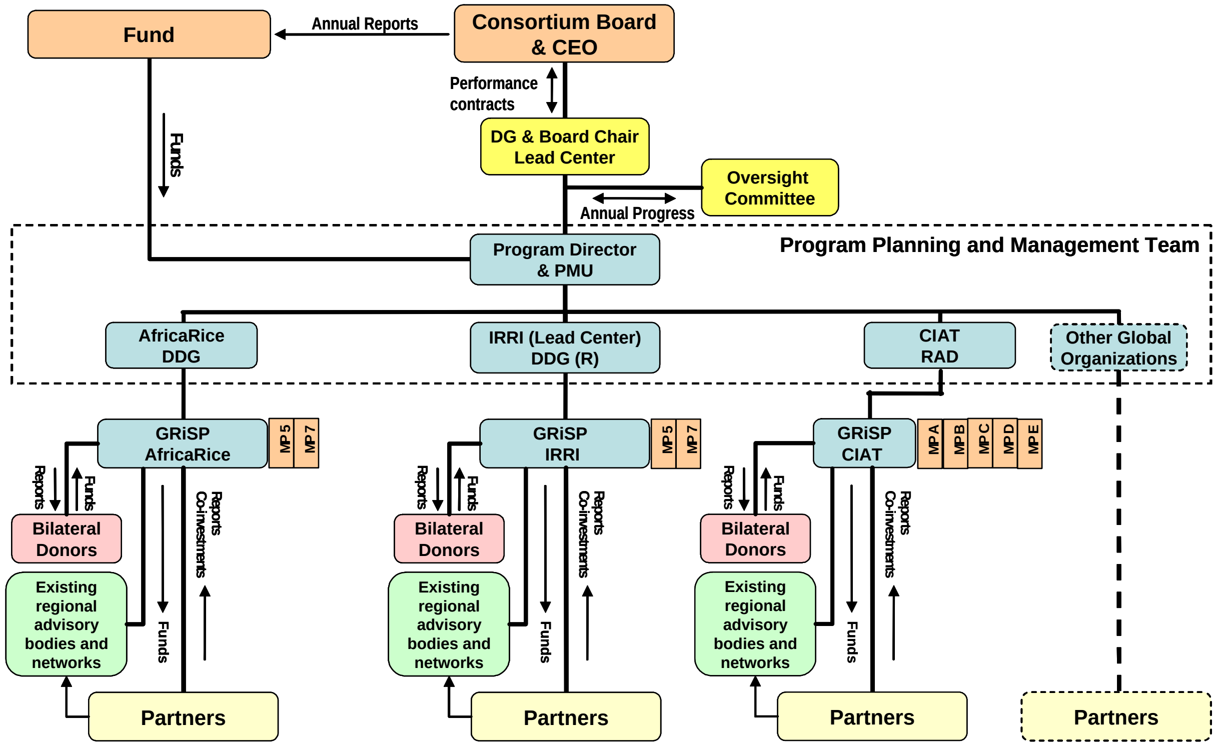


Fig 9. GRiSP organizational and management structure.

Program Planning and Management Team (PPMT). The PPMT will be composed of the DDG (R) of IRRI, the DDG of AfricaRice, the research area director (RAD) of CIAT, and the GRiSP Program Director. Representatives of institutions that have an international mandate and significant investments in global rice research (such as JIRCAS, CIRAD, and IRD) may join the PPMT if these institutions wish to integrate their research programs with the GRiSP strategic and work plan and they provide significant financial and human resources. Applications for membership in the PPMT will be reviewed and approved by the OC, upon recommendation from the PPMT. PPMT meetings will be held once a year in conjunction with the Annual Science Forum. Regional GRiSP theme leaders will also attend the annual meetings as deemed necessary. PPMT members will also meet monthly via video/phone conferencing and maintain frequent communication through other means.

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 annual budget requests. The PPMT will determine the allocation of resources coming from the CGIAR Fund to the research themes in GRiSP, 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 GRiSP activities (gaps), the decision of the PPMT will be final. Key decisions will be made in a consultative and subsidiary manner among PPMT members. In the event that the PPMT is not able to come to agreement on allocation of Fund Council resources, the OC will be the final authority. 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. It will organize periodic research reviews to be held in conjunction with existing periodic scientific conferences organized by the two rice centers. The PPMT will commission ad hoc external reviews and 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.

For the foreseeable future, many GRiSP activities will be supported via direct bilateral grants to the member centers. The individual centers will be responsible for obtaining and maintaining these grants, including technical and financial reporting. 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.

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. The OC and PPMT will be assisted by a small Program Management Unit (PMU), lead by the Program Director (PD) and supported by two assistant managers to be recruited by the lead center (IRRI). The Program Director acts on behalf of all participating centers and will be responsible for:

- Coordinating strategic foresight, planning, and reporting at the GRiSP level
- Preparing, with the PPMT and the regional theme leaders, the 5-year and annual work plans and budgets
- Interface between GRiSP and the Consortium board and Fund (budgets, contracts, financial reporting);
- Coordinate contracts with AfricaRice and CIAT; centers will continue handling all other subcontracts with their respective partners
- Representation of GRiSP at major events of the global/regional research and development communities
- Fund raising (together with the centers and other partners in GRiSP)
- Monitoring and evaluation of progress against agreed milestones
- Managing the PMU, including the global program support and coordination budget, as approved by the PPMT. Funds in this budget include (i) a fund to help catalyze teamwork, new research, and delivery activities with partners; (ii) funds to implement cross-cutting activities related to gender, science capacity building, and strategic foresight functions; (iii) and general program management funds, including communication, GRiSP workshops and travel, and CGIAR integration.
- Preparing and conducting annual meetings of the OC, PPMT, and research leaders in GRiSP themes, and other small workshops with the research and development community worldwide

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. The work and business plan will contain the research work plan as well as the business plan for GRiSP, with annual updates made for both. Annual financing plans will be developed by the PPMT with support from the PD/PMU and submitted to the OC for approval. For the initial transition, the first business plan for GRiSP was developed for 3 years only (2011 to 2013), but it also includes 2010 as the starting point for moving to a full GRiSP.

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 8 product lines per theme). Product lines are aggregations of products. 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 MPs). Product lines will have a minimum investment volume of $2 million per year. 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 to $3 million. Products and product lines can be global or regional/subregional. 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 product and the milestones in it. AfricaRice, CIAT, and IRRI will have the responsibility for leading work and business plan development in their areas of expertise and geographic focus. Leadership for product lines, products, and specific milestones will be assigned to IRRI, AfricaRice, CIAT, or strategic research partners in GRiSP, depending on the comparative strengths of these institutions. The PPMT will make these decisions and also periodically review and adjust the leadership roles as needed.

Implementing the product-oriented research activities. Research will be product-oriented and product development will be well connected with research grants or existing investments by strategic GRiSP partners, which currently form the vast majority of investments in GRiSP. Coordinators of major grants will generally also assume the role of product line managers in GRiSP, ensuring coherence, low transaction costs, and synergies between different grants contributing to one or more products. Product managers 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 or both, depending on the nature of the product. Planning and reporting on progress will be done at the product level and aggregated up to product line and GRiSP theme, allowing for a transparent investment and monitoring mechanism.

IRRI, AfricaRice, and CIAT will appoint regional theme leaders (e.g., Africa Theme 1 leader, Asia Theme 3 leader, etc.) to coordinate research related to their theme in their respective region. Regional theme leaders across the three centers will interact on a regular basis to facilitate collaboration and synergies among the three regions for a specific theme. 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 managers and partners to plan, execute, and monitor the research on the different product lines.

The six themes (and product lines in them) will be well connected with each other and also with other MPs of the CGIAR 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 restricted grants and gradually evolve towards more funding from at the MP and theme level. The theme leaders and product managers will develop an efficient communication strategy among the scientists and key partners involved.

Research fund. To foster new ideas and partnerships in research or grass-roots-level delivery, GRiSP will have a flexible fund under the centrally managed Global Research Support budget. This mechanism will be used, in a nonbureaucratic manner, to (i) issue modest seed grants for discovery research or for fostering teamwork, new project development, and other innovations in product development (Themes 1–5); (ii) commission specific research to strategic partners on a competitive and noncompetitive basis (Themes 1–5); or (iii) provide small initial support to grass-roots-level extension work of NGOs, farmers' organizations, and other groups that wish to collaborate with GRiSP (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.

Gender strategy. The DGs of IRRI, AfricaRice, and CIAT will each assign a gender focal point for implementing the gender strategy in GRiSP, to ensure support of senior management. The gender team will include representatives from all GRiSP themes and various key partners and 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 the GRiSP for effective development effectiveness 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 MPs. 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 themes will require human and financial resources. Financial resources should also be provided to the gender focal point or gender teams 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 modules and materials that highlight best practices of addressing gender issues in rice research for development. To meet these needs, GRiSP, as part of the global program support and 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. GRiSP Theme 6 devotes a special product line to building rice extension capacity on all three continents, with special emphasis on sub-Saharan Africa. To address global science capacity needs through new initiatives (see section on capacity building under Program Design), GRiSP, as part of the global program support and 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 PMU will be responsible for all communication related to GRiSP and housed at IRRI. 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 main external communication vehicles for GRiSP will be (i) a GRiSP Web site (linked with the sites of the participating centers) and (ii) the well-established and widely circulated *Rice Today* magazine (quarterly). GRiSP will also explore the use of new media for bringing its mission, vision, objectives, and progress to the attention of the general public. For higher-level communication with regional and global political bodies, we will seek to provide specific briefings and organize or participate in major events on food security, climate change, and other subjects.

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. 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. 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. Any revenue generated from such IP will be used to support research and capacity-building programs of that institution and its partners in GRiSP.

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 line 5.5 in Theme 5 (Annex 3).

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. 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 dissaggregation of yield gaps into efficiency gaps, abiotic yield limitations, and biotic yield reductions for particular agroecologies and countries. 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 end of 2010 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 every five years (i.e., another update will be done in 2015). New research opportunities will be evaluated for inclusion in the GRiSP portfolio as they arise. 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.

Ex post impact assessment (product line 5.5.) will focus on the magnitude and distribution of GRiSP's economic, poverty, and environmental effects, including gender impacts where possible. Such analysis will be used when research products are near their peak level of adoption, while more immediate feedback to scientists will be provided through evaluation approaches focused on early adoption (product line 5.1.), in which gender is a primary focus. Ex post impact assessment may be done in collaboration with key partners in GRiSP and other Mega Programs, particularly MP2.

To ensure that strategic foresight and impact assessment work in GRiSP is funded properly and a true priority-setting and impact culture is developed, funding for these activities will come from two major sources: (i) existing and future bilateral grants (for more specific impact assessment studies on rice) and (ii) a budget for strategic foresight and impact assessment work at the whole GRiSP level, which will be part of the global program support and coordination budget, to be managed by the PD under the direction of the PPMT.

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 Mega Program on Policies, Institutions, and Markets for Enabling Agricultural Incomes for the Poor (CGIAR TA 2).

Monitoring and evaluation

The PPMT has the primary responsibility for monitoring progress, with support by the PD/PMU. A small workshop will be held in 2011 to define the 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. Research to impact pathways for each GRiSP product line will be explored in detail early on to establish a successive set of intermediate indicators, and progress along impact pathways will be assessed. Project success will be assessed on the basis of outcomes defined in the logframe. Product-specific measurable milestones, with clearly assigned roles and responsibilities of lead and partner institutions, will form the basis for 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 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 3-4 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.

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.

Theme 1 includes a substantial amount of basic research, particularly on gene discovery, C_4-rice, and biological N fixation, but also needs to be connected well with Theme 2 research to which its products will be fed. 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 for that, following the model of already existing consortia on SNPs and C_4-rice. A key measure will also be to develop new mechanisms for public-/private-sector partnership in that area.

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 and private sector. The latter requires detailed understanding of target environments and markets, and of research to delivery pathways. Another risk in Theme 2 is a potential disconnect of the breeding work with research in Themes 3, 4, and 5. Hence, risk mitigation measures in Theme 2 will focus on fostering interdisciplinary work as well as evidence-based priority setting 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 far easier to reach high adoption rates for new germplasm than it is to bring more knowledge-intensive technologies to wider-scale adoption. Hence, non-adoption by farmers is the greatest risk for theme 3. The key mitigation measure in Theme 3 is to ensure that research is demand-driven, not supply-driven, and is grounded in solid science as the basis for deriving new management recommendations. Experimental sites should be carefully selected, taking into account the potential for rapid out-scaling, for example, through links with investment programs of major development partners. GRiSP partners have established mechanisms for that in recent years, but more resources will be needed than are currently available.

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. If those conditions are not met, the risk of not being able to extract more value from rice harvests is quite high. The quality and timeliness of crop management before and at harvest will determine to a large extent 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 rices, bears the risk that these products may not be adopted by farmers or others in the value chain. Hence, theme 4 requires strong interactions with new grassroot and business partners who can provide critical expertise for providing farmer, processor, and consumer feedback for developing new products from rice.

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. 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 a suitable political environment, and a policy framework that enables development. 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 (PPMT). 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

Budget narrative

IRRI will be the lead GRiSP center and thus 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 if that is desirable.

The budget narrative and 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.

GRiSP budget summary. The projected GRiSP budget (including all CGIAR and non-CGIAR sources of the participating CGIAR Centers) for 2010 through 2013 is USD 457.49 million (Table 2). This includes USD 412.9 million (90%) for the 6 research themes, USD 9.5 million (2%) for supporting global program activities and capacity building, USD 8.6 million (2%) for program coordination and monitoring, and USD 26.49 million (6%) for investments in core institutional capacity of CIAT, AfricaRice and IRRI, which include the rice germplasm collections (genebanks) of these centers. Rice research in Asia will be allocated 60% of the GRiSP resources with 29% in Africa, 7% in Latin America and the remaining 4% assigned to Global Program Support and Coordination and thus contributing proportionally to all regions too (Table 3). In terms of natural expense classification, the allocation in the GRiSP budget is (Table 4):

Personnel cost	38%
Supplies and services	19%
Travel	6%
Partners/ collaborators	18%
Depreciation	8%
Contingency	1%
Institutional overhead	10%

GRiSP involves many participants including CGIAR centers and partners. IRRI, AfricaRice and CIAT will directly require 77% of the Research Theme budget. Other CGIAR centers will be allocated USD 18.4 million (4%) mostly for collaborative projects and regional initiatives in GRiSP themes 2, 3, 5 and 6, connecting those also with other MPs. Non CGIAR partners such as NARES, NGOs and ARIs will receive USD 68.5 million (14%) 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.

To initialize the program and several new high-priority activities with partners, a GRiSP budget of USD 98.6 million is projected for 2010, of which USD 88.6 million (90%) are currently committed unrestricted, funds, restricted (bilateral) grants, and other income of IRRI, AfricaRice, and CIAT (as per 2010 mid-term plans of these centers). GRiSP investments are projected to rise at an annual rate of 10%, reaching USD 131.2 million in 2013 (33% increase over planned 2010 level or 48% over currently secured 2010 level). Although this represents a significant increase in funding over time, it still falls far short of the stated CGIAR goal to double funding for agricultural research and development. In developing the budget, GRiSP centers assumed a general 3% increase per year on all ongoing themes so as to maintain their purchasing power versus inflation through the planning period. The remaining, and largest, portion of the projected annual budget increases represents investments in high priority product lines of GRiSP, including some new ‘blue sky’ research, but also funds needed for global program support and coordination.

Detailed budget allocations by Product Lines (available upon request) will be further fine-tuned during annual program review and planning meetings. The Program Planning and Management Team (PPMT) will make these strategic choices based on regular prioritization exercises done in consultation with stakeholders. GRiSP includes an investment from the Generation Challenge Program (GCP) of USD 3.21 million over the 2011-2013 period in rice research plus another USD 0.69 million for the Genomics and Integrated Breeding Service at IRRI. These investments are allocated to GCP (USD 0.45 million), IRRI (USD 1.27 million) and AfricaRice (USD 2.18 million).

Global research support and science capacity building. During 2011-2013, GRiSP aims to allocate USD 3.4 million to additional science capacity building activities in our beneficiary countries, and an additional USD 0.40 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 research and development fund managed by the PMU, 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). During 2011-2013, GRiSP plans to invest at least USD 4.5 million in such activities (Table 5).

Program coordination. Global program support and coordination consists of those functions necessary for the success of a global research initiative (Table 5). 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.

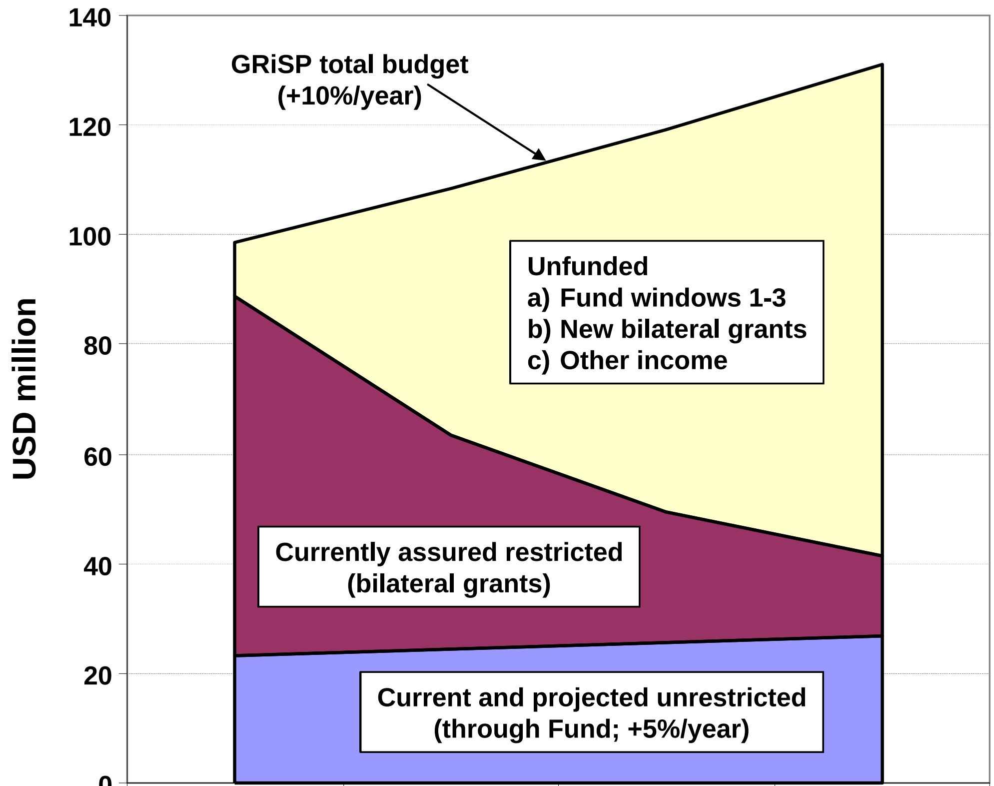
The budget includes centrally managed funds, 0.3% of research resources, to support monitoring, evaluation, strategic foresight, priority setting and impact assessment work at the global program level (center staff and external resources). Additional, larger investments in strategic foresight, priority setting, and impact assessment are made through the activities in theme, particularly product lines 5.1. and 5.5. 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 Web based communication tools.

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 6). The most notable elements are the Genebanks and other genetic collections maintained by IRRI, AfricaRice and CIAT, the long term trials at IRRI and AfricaRice, and the libraries which provide valuable support to CGIAR and partner scientists. **Genebank functions are fully integrated in the GRiSP work plan (Product line 1.1.). Therefore, funding is included as a separate line item in the GRiSP budget to specify the amount required. The mechanism for funds flow from the new Fund to support genebanks remains to be determined by the Consortium Board and Fund Council.**

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.

An area of chronic underfunding within CGIAR centers is staff development. The GRiSP proposal provides an amount equivalent to 1.5-2% of base salaries for training and other staff development activities which is in line with survey results from the American Society for Training and Development.



	2010	2011	2012	2013
Funding gap	9.9	44.9	69.9	89.7
Assured restricted	65.3	39.1	23.7	14.6
Projected unrestricted	23.3	24.5	25.7	26.9

Fig. 10. Required and committed funds for GRiSP for the 2010 to 2013 period. Committed funds only include ongoing restricted projects and unrestricted funding expected for 2010 and other income.

Investment gaps. Table 7 and Figure 10 summarize the investments required to implement GRiSP and identify the known funding gaps -- in other words, those resources needed beyond the assumed unrestricted and assured restricted grants already in place (as of May 2010). The unfunded gap amounts to USD 9.95 million in 2010 and rises to USD 89.68

million by 2013 as currently restricted secured grants run out. We have assumed in these projections that the current level of unrestricted funding funding continues to grow at an annual rate of 5%. **The projected funding gaps are expected to be filled through funds flowing through Windows 1-3 from the CGIAR Fund, from bilateral grants to the participating centers in GRiSP (under full cost recovery policies) and small other income by centers.** No projections were made about continued restricted funding levels beyond already assured grants, or on how much of the unfunded gap would come from the new CGIAR Fund mechanism vs. new bilateral grants. It is hoped that, over time, an increasing share of the gap will be funded through the new Window 1 and Window 2 mechanisms instead of restricted bilateral grants to centers.

Whereas the participating centers will continue their fundraising efforts to fill the projected research funding gaps, entirely new funds, through the CGIAR Fund, will be required for all aspects of GRiSP global support and program coordination, which also includes cross-cutting capacity building and gender activities. This amounts to USD 0.6 million in 2010 and rises to USD 4.8 million in 2011 (Table 5).

GRiSP contains several Product Lines and Products that represent new research areas with little current investment, which will be gradually developed over time as more funding becomes available. Examples include nitrogen-fixing rice (Product Line 1.5.), innovative uses of rice straw and rice husks (Product Line 4.2.), speciality rices and innovative rice-based food products (Product Line 4.3.), or the global rice information gateway (Product Line 5.3.). Investments in Theme 6 (Supporting the growth of the global rice sector) will largely be driven by bilateral grants.

Co-investment by partners. GRiSP will be a global partnership with many non-CGIAR partners participating and contributing resources. It is not feasible to calculate those investments in the shared agenda 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). Over USD 10 million of this co-investment has already been integrated in the current GRiSP work and business plan draft, with clearly assigned leadership roles for these institutions. Likewise, current GRiSP-related activities of JIRCAS amount to approximately USD 4 million per year (excluding salaries, Appendix 4).

GRiSP has received strong endorsement from NEPAD, FARA, CARD, APAARI, FLAR and other regional and sub regional organizations and initiatives, and it is expected that their members will also invest significant resources.

21st -century research facilities. IRRI, AfricaRice and CIAT will require investment in new research facilities over time. Table 8 lists these facilities but the GRiSP proposal does not include these amounts in the budget since the timing is fluid unlike the recurring research costs.

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.

Budget tables

Table 2. Projected GRiSP expenditures by year, currently committed funds (unrestricted and restricted for 2010; restricted only for 2011-2013), and investment gaps to be filled through funds from the CGIAR Fund or through bilateral funding (USD million).

Research Theme	IRRI	AfricaRice	CIAT	Other CGIAR Centers	NARES, NGO, ARI	Global Support & Coord.	Total	Share
GRiSP Total, 2010 - 2013								
T1-Genetic Resources	47.27	8.07	8.16	0.32	11.93	-	75.75	**16%**
T2-New Varieties	70.50	17.04	11.77	2.16	15.66	-	117.13	**26%**
T3-Production Systems	50.32	16.52	1.25	7.39	19.69	-	95.17	**21%**
T4-Value Chains	12.22	6.65	0.33	-	1.49	-	20.70	**4%**
T5-Policy and Information	21.48	9.68	0.33	3.94	6.07	-	41.50	**9%**
T6-Delivery	27.13	20.37	0.86	4.57	9.70	-	62.63	**14%**
Institutional Capacity	16.36	5.52	4.61	-	-	-	26.49	**6%**
Global Support & Science Capacity	-	-	-	-	-	9.50	9.50	**2%**
Program Coordination	-	-	-	-	-	8.62	8.62	**2%**
Total 2010-2013	**245.29**	**83.85**	**27.32**	**18.37**	**64.54**	**18.12**	**457.49**	**100%**
Percentage	**54%**	**18%**	**6%**	**4%**	**14%**	**4%**	**100%**	
2010								
T1-Genetic Resources	10.56	1.81	1.85	0.07	2.57	-	16.86	17%
T2-New Varieties	16.98	3.81	2.67	0.46	3.37	-	27.30	28%
T3-Production Systems	11.39	3.70	0.28	1.59	4.24	-	21.21	21%
T4-Value Chains	1.79	1.49	0.08	-	0.32	-	3.67	4%
T5-Policy and Information	4.71	2.17	0.08	0.85	1.31	-	9.11	9%
T6-Delivery	6.09	4.56	0.20	0.98	2.09	-	13.92	14%
Institutional Capacity	3.62	1.32	0.96	-	-	-	5.90	6%
Global Support & Science Capacity	-	-	-	-	-	0.10	0.10	0%
Program Coordination	-	-	-	-	-	0.50	0.50	1%
Total 2010	**55.14**	**18.85**	**6.11**	**3.96**	**13.91**	**0.60**	**98.58**	**100%**
2011								
T1-Genetic Resources	10.51	1.90	1.92	0.08	2.83	-	17.23	16%
T2-New Varieties	16.69	4.00	2.77	0.51	3.71	-	27.68	25%
T3-Production Systems	11.74	3.88	0.29	1.75	4.67	-	22.34	21%
T4-Value Chains	2.96	1.56	0.08	-	0.35	-	4.95	5%
T5-Policy and Information	5.23	2.27	0.08	0.93	1.44	-	9.95	9%
T6-Delivery	6.61	4.78	0.20	1.08	2.30	-	14.98	14%
Institutional Capacity	4.05	1.36	1.10	-	-	-	6.51	6%
Global Support & Science Capacity	-	-	-	-	-	2.30	2.30	2%
Program Coordination	-	-	-	-	-	2.50	2.50	2%
Total 2011	**57.79**	**19.75**	**6.44**	**4.35**	**15.30**	**4.80**	**108.43**	**100%**
2012								
T1-Genetic Resources	12.10	2.08	2.09	0.08	3.11	-	19.46	16%
T2-New Varieties	17.88	4.39	3.02	0.56	4.08	-	29.93	25%
T3-Production Systems	12.90	4.26	0.32	1.93	5.13	-	24.53	21%
T4-Value Chains	3.50	1.71	0.09	-	0.39	-	5.69	5%
T5-Policy and Information	5.55	2.49	0.09	1.03	1.58	-	10.74	9%
T6-Delivery	6.97	5.25	0.22	1.19	2.53	-	16.16	13%
Institutional Capacity	4.24	1.40	1.21	-	-	-	6.85	6%
Global Support & Science Capacity	-	-	-	-	-	3.15	3.15	3%
Program Coordination	-	-	-	-	-	2.75	2.75	2%
Total 2012	**63.13**	**21.58**	**7.04**	**4.79**	**16.83**	**5.90**	**119.28**	**100%**
2013								
T1-Genetic Resources	14.11	2.29	2.30	0.09	3.42	-	22.21	17%
T2-New Varieties	18.96	4.83	3.31	0.62	4.49	-	32.21	25%
T3-Production Systems	14.29	4.69	0.35	2.12	5.65	-	27.09	21%
T4-Value Chains	3.97	1.89	0.09	-	0.43	-	6.38	5%
T5-Policy and Information	5.99	2.75	0.09	1.13	1.74	-	11.70	9%
T6-Delivery	7.46	5.78	0.24	1.31	2.78	-	17.57	13%
Institutional Capacity	4.44	1.44	1.34	-	-	-	7.22	5%
Global Support & Science Capacity	-	-	-	-	-	3.95	3.95	3%
Program Coordination	-	-	-	-	-	2.87	2.87	2%
Total 2013	**69.22**	**23.66**	**7.72**	**5.27**	**18.51**	**6.82**	**131.20**	**100%**

Table 3. Projected GRiSP expenditures by region, total for 2010-2013 (USD million)

Research Themes	Asia	Africa	LAC	Global Support & Coord.	Total
T1-Genetic Resources	51.12	14.10	10.54	-	75.75
T2-New Varieties	70.89	32.26	13.98	-	117.13
T3-Production Systems	67.56	26.17	1.44	-	95.17
T4-Value Chains	11.80	8.51	0.38	-	20.70
T5-Policy and Information	25.81	15.12	0.56	-	41.50
T6-Delivery	34.29	27.29	1.05	-	62.63
Subtotal Themes	**261.47**	**123.45**	**27.95**	**-**	**412.88**
Institutional capacity	14.75	7.03	4.71	-	26.49
Global Support & Capacity	-	-	-	9.50	9.50
Program Coordination				8.62	8.62
Total	**276.22**	**130.48**	**32.66**	**18.12**	**457.49**
Percentage	**60%**	**29%**	**7%**	**4%**	**100%**

Table 4. Projected GRiSP expenditures by cost categories, total for 2010-2013 (USD million).

Cost group	Description	2010 Amount (in USDm)	2011 Amount (in USDm)	2012 Amount (in USDm)	2013 Amount (in USDm)	Total
1	Personnel Cost	37.76	40.53	44.90	49.70	172.90
2	Supplies and Services	17.54	20.60	22.79	25.14	86.07
3	Travel	5.48	6.52	6.97	7.49	26.46
4	Partners / Collaborators					
	CGIAR Centers	3.96	4.35	4.79	5.27	18.37
	NARES/ARI	13.91	15.30	16.83	18.51	64.54
5	Depreciation	8.40	8.54	9.17	9.89	36.00
6	Contingency	1.33	1.42	1.55	1.70	6.01
	Total	**88.37**	**97.27**	**107.00**	**117.71**	**410.35**
7	**Institutional Overhead (% of direct cost)**	**10.20**	**11.17**	**12.27**	**13.50**	**47.14**
	Total Projected Cost	**98.58**	**108.43**	**119.28**	**131.20**	**457.49**

Table 5. Global program support and coordination budgets, 2010-2013 (USD million)[1]

Research support & science capacity building					
	2010	**2011**	**2012**	**2013**	**Total**
Global research teams support	0.10	0.40	0.50	0.60	1.60
Special grants (new research/delivery partnerships)	0.00	1.00	1.50	2.00	4.50
Gender capacity building	0.00	0.10	0.15	0.15	0.40
Science capacity building	0.00	0.80	1.00	1.20	3.00
Total	**0.10**	**2.30**	**3.15**	**3.95**	**9.50**

Program Coordination					
Program Management Unit staff	0.05	0.30	0.35	0.37	1.07
Program operations (travel, PMU office, consultants)	0.05	0.30	0.35	0.40	1.10
Workshops, reviews	0.10	0.50	0.50	0.50	1.60
Advisory Panel	0.00	0.10	0.10	0.10	0.30
Administrative support (grants, finance, reporting)	0.20	0.50	0.60	0.60	1.90
Rice Today magazine	0.05	0.30	0.30	0.30	0.95
Other communication (website, newsletter, reports)	0.05	0.10	0.10	0.10	0.35
M&E/impact assessment/ priority setting	0.00	0.40	0.45	0.50	1.35
Total	**0.50**	**2.50**	**2.75**	**2.87**	**8.62**

Total research support, capacity, coordination	**0.60**	**4.80**	**5.90**	**6.82**	**18.12**

[1] Only includes new, additional funds to be provided by the Fund to support GRiSP research interactions, capacity building, and program management.

Table 6. Institutional capacity funds, 2010-2013 (USD million)

IRRI					
Institutional Capacity	**2010**	**2011**	**2012**	**2013**	**Total**
Genebank + other collections	0.88	1.02	1.12	1.23	4.25
Long term trials	0.15	0.17	0.19	0.21	0.73
Library	0.53	0.61	0.67	0.73	2.53
Capital *	2.00	2.00	2.00	2.00	8.00
Staff Development	0.06	0.25	0.26	0.27	0.85
Total	**3.62**	**4.05**	**4.24**	**4.44**	**16.36**
AfricaRice					
Genebank + other collections	0.30	0.31	0.32	0.33	1.26
Long term trials	0.01	0.01	0.01	0.01	0.04
Library	0.05	0.05	0.05	0.05	0.21
Capital *	0.45	0.46	0.48	0.49	1.88
Mbe Station, Bouake	0.47	0.48	0.50	0.51	1.97
Staff Development	0.04	0.04	0.04	0.04	0.17
Total	**1.32**	**1.36**	**1.40**	**1.44**	**5.52**
CIAT					
Genebank + other collections	0.32	0.36	0.40	0.44	1.52
Long term trials	0.08	0.09	0.10	0.11	0.37
Library	0.12	0.13	0.15	0.16	0.55
Capital *	0.40	0.46	0.51	0.56	1.94
Staff Development	0.05	0.06	0.06	0.07	0.23
Total	**0.96**	**1.10**	**1.21**	**1.34**	**4.61**
Grand total GRiSP	**5.90**	**6.51**	**6.85**	**7.22**	**26.49**

* Includes capital required to maintain steady scenario. Major upgrades (e.g. plant growth facilities) need to be resourced through other means outside the GRiSP budget and are included in Table 8.

Table 7. Currently committed funds and investment gaps to be filled through the CGIAR Fund or through bilateral funding (USD million).[1]

Centers	Current + projected unrestricted	Current restricted (bilateral)	Other income	Total Committed	Required (Table 2)	Gap to be funded by Window 1-3 or new bilateral
GRiSP Total, 2010-2013						
IRRI	60.71	99.62	4.40	164.73	324.45	(159.72)
Themes	60.71	99.62	4.40	164.73	306.33	(141.60)
Global Support & Capacity	-	-	-	-	9.50	(9.50)
Program Coordination	-	-	-	-	8.62	(8.62)
AfricaRice (Themes)	25.34	38.88	-	64.22	102.15	(37.93)
CIAT (Themes)	9.94	4.15	-	14.09	30.89	(16.80)
Total	**95.99**	**142.65**	**4.40**	**243.04**	**457.49**	**(214.45)**
2010						
IRRI	14.09	47.12	1.10	62.30	68.90	(6.60)
Themes	14.09	47.12	1.10	62.30	68.30	(6.00)
Global Support & Capacity	-	-	-	-	0.10	(0.10)
Program Coordination	-	-	-	-	0.50	(0.50)
AfricaRice (Themes)	5.83	14.30	-	20.13	22.79	(2.66)
CIAT (Themes)	2.31	3.89	-	6.19	6.88	(0.69)
Total	**22.22**	**65.30**	**1.10**	**88.63**	**98.58**	**(9.95)**
2011						
IRRI	14.79	28.95	1.10	44.84	77.06	(32.22)
Themes	14.79	28.95	1.10	44.84	72.26	(27.42)
Global Support & Capacity	-	-	-	-	2.30	(2.30)
Program Coordination	-	-	-	-	2.50	(2.50)
AfricaRice (Themes)	6.19	9.84	-	16.03	24.09	(8.06)
CIAT (Themes)	2.42	0.27	-	2.69	7.29	(4.60)
Total	**23.40**	**39.05**	**1.10**	**63.55**	**108.43**	**(44.88)**
2012						
IRRI	15.53	15.72	1.10	32.35	84.95	(52.60)
Themes	15.53	15.72	1.10	32.35	79.05	(46.70)
Global Support & Capacity	-	-	-	-	3.15	(3.15)
Program Coordination	-	-	-	-	2.75	(2.75)
AfricaRice (Themes)	6.50	7.95	-	14.45	26.35	(11.90)
CIAT (Themes)	2.54	0.00	-	2.54	7.97	(5.43)
Total	**24.57**	**23.67**	**1.10**	**49.34**	**119.28**	**(69.94)**
2013						
IRRI	16.31	7.84	1.10	25.24	93.55	(68.30)
Themes	16.31	7.84	1.10	25.24	86.73	(61.48)
Global Support & Capacity	-	-	-	-	3.95	(3.95)
Program Coordination	-	-	-	-	2.87	(2.87)
AfricaRice (Themes)	6.82	6.79	-	13.61	28.91	(15.30)
CIAT (Themes)	2.67	-	-	2.67	8.75	(6.08)
Total	**25.79**	**14.63**	**1.10**	**41.52**	**131.20**	**(89.68)**

[1] Current + projected unrestricted: unrestricted from 2009 audited financial statement, growing at 5%/yr for 2010-2013; beginning in 2011, this will come from the Fund. Current restricted (bilateral): only includes currently secured and high probability restricted grants of each Center.

Table 8. 21st Century research facilities (USD million, not included in GRiSP budget)

Center	Infrastructure	Estimated Cost
IRRI	New state-of the art plant growth center	12.00
	Upgrade of existing plant growth facilities to include environmental growth chambers	8.00
	Major upgrade of the Experimental Farm	5.00
	Genebank/plant breeding center upgrade and renovation	40.00
	Upgrade and renovation of Training Center and dormitories	2.00
	Renovation of Drilon Hall for research office space	1.00
	Renovation of riceworld and development of conference facilities	1.00
	C4-rice, BNF-rice and other new Laboratories	5.00
	Digital campus	0.50
	Solar energy	10.00
Africa Rice	Rice agronomy and post-harvest training center, Senegal	1.00
	Biotic stresses phenomics and upgraded MAS facility, Benin	1.50
	Long-term storage facility GRU, Benin	1.00
CIAT	Upgrade of phenomics, transgenics and marker lab facilities	5.00
	Upgrade of field management systems for confined biosafety trials	0.50
	Upgrade and renovation of Training Center	0.25
Total		**93.75**

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 this exercise, based on one world region, South Asia, to illustrate the approach and to give an evidence-based indication of the overall impact potential of GRiSP. This chapter provides supplementary information to the section on *What accelerated international rice research can contribute*, including Box 1.

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 Mha of irrigated rice and 28.5 Mha 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 & biotic stresses
- Those that increase yield potential (inbreds, hybrids, C4 rice)

Using experimental data and literature sources, GRiSP scientists compiled estimates of the effects of yield reducing and yield limiting factors in 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 forecasted 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 forecasted, 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 dramatically could 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. 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 2011-2035 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 was 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 t), 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 who 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 eventually available 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, this finds that current average exploitable yield gaps are about 2 t/ha in irrigated systems (difference between attainable yield and current average yield) and 1t/ha in rained systems. Nutrients, water, diseases & weeds play a large role for current yield gaps in both environments, relative to specific abiotic stresses, such as submergence, salinity, heat stress, or Fe toxicity. 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 $58 billion of discounted gross benefits by 2035, with $5.0 billion of discounted benefits and 67 million net additional tons of production in that year alone, as a result.

Assuming that the availability of GRiSP technologies would happen, but would be moderately delayed in GRiSP's absence, the GRiSP is attributable for $ 32.4 billion of these gross benefits, and 30.7 million net additional tons of production by 2035. Set against $1.04 billion of South Asian investment over the period, this translates into a 31.2:1 benefit cost ratio under a 5% discount rate.

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

Regional analyses of the expected benefits of specific technologies, such as the example provided for South Asia in Box 1, reveal that GRiSP could make a net average global yield growth contribution of at least 360 kilograms of paddy per hectare by 2035. This overall attributable productivity growth estimate was fed incrementally over time into a global rice trade model to calculate domestic price effects. These were then fed into a series of equations to calculate poverty and food security impacts for poor consumers.

Modeling price effects of productivity increases. IRRI's new global rice trade model is a partial equilibrium structural econometric model of 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 estimated 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 some preliminary impacts of GRiSP. The dataset used in this study was compiled from various sources, including national partners, FAPRI, the Foreign Agricultural Service (FAS) of the U.S. Department of Agriculture, and FAOSTAT.

Translating price effects into benefits for the poor and food-insecure. This analysis determined how the rice price effects projected from the 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. Household rice expenditure shares for those under $1.25 per day were calculated from various national expenditure surveys conducted in the mid-2000s. Aggregate expenditure savings were converted to additional rice consumption enabled, and then to calories to calculate the number of people lifted out of hunger.

Results in terms of price effects and supply response. Specific national price effects calculated through the model are presented in Table A1. Overall, the results suggest that domestic prices in major Asian countries are expected to be on average 16% lower than the baseline level by 2035 if sufficient investments in GRiSP are made and the research is successful, also in terms of meeting the assumed adoption rates. Global rice area is projected to increase by 1.5 million hectares in the baseline, whereas lower prices in the GRiSP scenario would reduce rice area by 3 million hectares relative to the baseline level in 2035.

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 Table A1. As a result of the GRiSP, expenditures on rice by those under the $1.25 (PPP) poverty line decline by $9.5 billion (PPP) annually in Asia (holding consumption constant). Adding those reductions to income means that 133 million Asians are lifted above the $1.25 poverty line, reducing the overall number of poor by 15%. Considering that this arises from an aggregate global 25-year investment of $3 billion, this means that the cost of lifting one person above the poverty line is $23. As a result of increased rice availability and reduced prices, 107 million undernourished Asians can afford to reach caloric sufficiency, reducing the number of food-insecure by 20%. In certain countries, such as Laos and Bangladesh, hunger is halved.

This study is meant to illustrate the potential impact of GRiSP and how it can be assessed. Similar analyses will be conducted for all rice-growing regions of the world, as part of the work on strategic assessment and the rice information gateway (GRiSP Theme 5).

Table A1. Benefits to the poor and food-insecure from an 8.5% improvement in rice productivity attributable to the GRiSP by 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.)

Country	**Number of food-insecure (2004-06)**	**Pop. below $1.25/day (2005)**	**Rice expend. share (pop. below $1.25/d)**	**Price effect of prod. growth (from trade model)**	**Reduction in annual expenditure (PPP, pop. below $1.25/d)**	**Number of people lifted above the $1.25 PPP poverty line**	**Number lifted out of hunger**
	Million	Million	%	%	$ Million	Million	Million
Cambodia	3.5	5.6	22.2	22.1	111.3	1.1	1.3
China-rural	121.7	198.4	22.4	14.6	2,766.5	46.9	26.7
China-urban	5.7	9.3	10.5	14.6	64.6	9.3	0.6
Indonesia	36.7	21.4	24.1	11.2	252.3	6.1	6.9
Lao PDR	1.0	2.0	40.4	18.5	62.8	0.8	0.5
Malaysia	ns	0.1	12.3	18.5	1.4	0.1	ns
Philippines	12.7	19.1	20.1	10.6	175.3	3.5	2.2
Thailand	10.7	0.3	12.1	18.5	2.6	0.2	2.9
Vietnam	11.2	19.0	24.4	23.5	472.9	10.7	4.8
Bangladesh	40.2	77.4	26.3	23.3	1,852.0	14.3	22.2
Bhutan	ns	0.2	13.1	18.5	1.7	0.03	ns
India-rural	189.2	342.9	15.5	13.6	2,939.0	30.2	30.1
India-urban	62.3	112.9	8.7	13.6	544.7	5.9	5.6
Nepal	4.2	14.8	21.3	13.6	157.1	0.9	1.1
Pakistan	36.5	35.2	2.9	12.6	55.2	1.4	1.6
Sri Lanka	4.1	2.0	20.7	13.6	25.6	1.6	1.0
Total	**539.7**	**860.6**			**9,485.0**	**133.0**	**107.5**

Appendix 2. The road to GRiSP: key events

Dec. 2006	IRRI and AfricaRice seek support from CIDA to help with centers' desire to align research programs building on earlier efforts to increase collaboration
Mar. 2007	IRRI BOT Chair and Vice Chair attend the AfricaRice Board meeting in Benin as observers
June 2007	Programmatic AfricaRice–IRRI–CIAT alignment workshop (Benin) for sub-Saharan Africa (CIDA support)
Mar. 2008	Joint AfricaRice–IRRI meeting attended by 21 IRRI staff, including DG and interim DDG-R (Benin)
Mar. 2008	Joint IRRI–AfricaRice presentation during TICAD IV experts' meeting
May 2008	Joint IRRI–AfricaRice presentations at launching of CARD, Yokohama, Japan
Aug. 2008	Joint IRRI–AfricaRice mission to East and Southern Africa to develop joint strategy
Sep. 2008	Two AfricaRice Board members attend IRRI BOT meeting as observers
Oct. 2008	DG and DDG-R AfricaRice visit IRRI
Dec. 2008	Launching of joint IRRI–AfricaRice Eastern and Southern Africa Rice Program (ESARP) during AGM 2008
Dec. 2008	First sketch of a global rice program in response to AGM 2008
Apr. 2009	Opening of joint AfricaRice–IRRI office in Dar-es-Salaam
May 2009	DDG-Rs of IRRI and AfricaRice develop first draft of GRiSP with input from CIAT rice scientists
June 2009	Joint IRRI–AfricaRice presentations during 2nd General Meeting of CARD
Aug. 2009	Further improvement of GRiSP strategic plan
Sep. 2009	Endorsement of GRiSP by AfricaRice BoT, National Experts' Committee, and Council of Ministers of AfricaRice (24 ministers of agriculture)
Oct. 2009	Endorsement of GRiSP by IRRI Board
Oct. 2009	Discussion and endorsement of GRiSP by NARES leaders in Asia (CORRA and by APAARI)
Dec. 2009	Further discussion of GRiSP at ESARP annual meeting in Tanzania
Dec. 2009	Support for GRiSP expressed by FLAR and Catholic Relief Services
Jan. 2010	Joint IRRI–AfricaRice visit to CIAT, Colombia, and EMBRAPA and IRGA in Brazil to discuss cooperation in GRiSP
Jan. 2010	GRiSP Vision and Strategy document completed and shared with key donors and partners
Mar. 2010	Regional consultations for Africa and discussion of GRiSP, Africa-wide strategy, and GRiSP implementation at Africa Rice Congress, Bamako, Mali
Mar. 2010	Discussion of GRiSP at GCARD with CIRAD and IRD leaders; research leaders of IRRI, AfricaRice, and CIAT met to further develop the portfolio of GRiSP products and its overall structure
April 2010	GRiSP proposal development workshop in Los Baños, 26-30 April, with partners from CIRAD, IRD, JIRCAS, MAFF-Japan, CARD, Sassakawa Global, and AfricaHarvest. Integration of key parts of rice research agendas of CIRAD and IRD into GRiSP. Feedback from ICAR, CAAS, and CRS
April 2010	GRiSP presentation to APAARI, New Delhi
May 2010	Proposal writing and submission to Consortium Board by 10 May. Proposal shared with key partners for feedback
June 2010	Submission of revised proposal to the Fund
July-Oct. 2010	Meetings with key national reserach partners for further alignment, including CAAS (China), ICAR (India), JIRCAS & JICA (Japan), and EMBRAPA (Brazil). Discussion of GRiSP with regional NARES bodies and CSO partners, and with donors and other organizations, including FAO and the Global Crop Diversity Trust
Aug. 2010	Development of refined GRiSP work plan and business plan in conjunction with the IRRI Annual Program Review
Aug.-Nov. 2010	Presentation of GRiSP to research communities in Germany, Switzerland, the UK, Japan, and the U.S.
Oct.-Nov. 2010	Align research management structures in IRRI, AfricaRice, and CIAT for GRiSP; form GRiSP management teams
Nov. 2010	Complete strategic assessment of R&D priorities for rice; fine-tune GRiSP investment priorities
Nov. 2010	Official launch of GRiSP at IRC 2010, Hanoi, 9-12 Nov.

Appendix 3. Global and regional R&D product lines in GRiSP

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

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

Rationale

Over 130,000 accessions of rice germplasm are held by the GRiSP genebanks: The TT Chang Genetic Resources Center (GRC) at IRRI holds over 110,000 accessions from more than 120 countries (*Oryza sativa*, *O. glaberrima*, and wild relatives). AfricaRice holds a collection of more than 20,000 accessions, of which 2500 are of African origin. CIAT, CIRAD, and IRD hold small but important working collections and genetic stocks. The germplasm 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.
For germplasm to be used, it must be securely conserved, maintained, characterized, documented, and distributed according to known best practices. This will require investment to maintain and upgrade facilities, with staffing levels sufficient to meet germplasm demand. To date, rice genebanks have mostly operated independently of each other. Coordination among genebanks is a key target of the Global Rice Conservation Strategy (GRCS) to enhance conservation of diversity. GRiSP provides the framework to extend and implement the GRCS and reduce duplication of efforts. For example, creating a common GRiSP database for rice genetic resources will help to rationalize conservation and use and to identify gaps in coverage. This database can then be extended to encompass other significant rice collections.

Evidence now exists that current best practices for germplasm conservation are in fact not optimal. There is an urgent need to conduct novel research on maintaining the genetic integrity of conserved germplasm and on optimizing the physiological quality of conserved seed; and to use these results to improve all genebank operating procedures. Finally, the possible contribution of an accession to a development objective is largely unknown, since the objective-specific values of its genes has not yet been discovered. Understanding the value of each accession for its more effective use is the subject of product lines 1.2 to 1.6. in theme 1.

Activities

Each GRiSP partner has the mandate to conserve and manage their germplasm according to best practices. The GRC is recognized as a flagship crop genebank. It operates a 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 their seed processing and storage facilities for maintaining its working collections. These collections will be duplicated for conservation in the GRC and fully documented in IRIS GRIMS.

To maximize the effective conservation of each collection while avoiding duplication of efforts and capturing rice germplasm not currently available, an integrated rice germplasm documentation and sourcing system will be deployed (product 1.6.1), initially covering the genebanks of the key GRiSP institutions. To ensure that the GRiSP genebanks continue to be at the forefront of germplasm conservation methodology, and to disseminate best practices, both within and outside of GRiSP genebanks, a research program is planned on regeneration, post-harvest, and management procedures to maximize seed quality and longevity in storage and to prevent the loss of genetic integrity of conserved material. Coordination with NARES on national germplasm collections under the GRCS will ensure proper conservation of rice genetic diversity through long-term and backup storage.

Products

1.1.1. Enhanced and sustained collections of the T.T. Chang Genetic Resources Center at IRRI
1.1.2. Enhanced and sustained collections of the AfricaRice genebank
1.1.3. Enhanced and sustained rice germplasm collections at CIAT
1.1.4. Global system for rice diversity conservation and its use
1.1.5. Improved methods for maintaining genetic integrity and physiological quality of seeds

Uptake and impact pathway

The immediate users are GRiSP researchers and the global community who use rice genetic resources, including advanced research institutes, the private sector and national agricultural research systems. A key assumption for meeting uptake and impact targets is continued funding from the Global Crop Diversity Trust (GCDT) and its extension to AfricaRice and CIAT.

The resources maintained and distributed by genebanks are central to all germplasm research; continuous inputs and feedback are needed from Theme 1 and Theme 2 researchers and other users. Sequence information will be an increasingly important component of the genebank database and is expected to grow dramatically over the next 5 years. Operation and database support will be provided by the Theme 1 informatics team. Theme 2 research will provide trait evaluation data from breeding lines and Theme 4 research on quality and specialty rices.

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 address a substantial share of these problems, it is necessary that relevant germplasm should be made readily available to any and all projects; and that the relevant germplasm for each project can be readily identified. It is assumed that each project has the competence to exploit germplasm provided under this product line.

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

The renewed recognition of the importance of genebanks and their functions has led to a rising trend in funding at about 15% per year over past levels. The GCDT has played a key role in the development of the GRCS and provides a long-term grant to IRRI to maintain its genebank while the AfricaRice genebank is funded by special projects and CIAT's working collection is maintained from center funds. The objective of the GCDT is to establish a trust fund that will ultimately support 100% of the basic operating costs of genebanks and the development and implementation of the GRCS. There is an urgent need for alternative secure funding for AfricaRice and CIAT to fill this gap before the trust fund is able to support GRiSP as a whole. Investments at national or regional levels are needed to ensure linkage of operations and research agendas of NARES with international genebanks.

Funding for the three genebanks in GRiSP (Products 1.1.1, 1.1.2. and 1.2.3) is included under the institutional window of IRRI, AfricaRice and CIAT, not the theme 1 research budget. Additional sources of funding will need to be identified to undertake research objectives to improve procedures for best practices, such as minimizing loss of genetic integrity and ensuring seed viability.

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 not only can help solving current production problems but also create opportunities for future rice production and respond to climate change. To utilize 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 program. Rapid advances in DNA sequencing with declining costs will allow decoding 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 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, modelling 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 datasets 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 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 the entire rice germplasm collection (over 100,000 accessions) once sequencing technologies deliver a low enough cost per accession. We will initiate preparing a comprehensive DNA bank for at least 100,000 rice accessions using a high-throughput pipeline (2011-2014). Low cost sequencing techniques will be tested and optimized to determine the cost per accession (2012-2013), followed by sequencing of all 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 2500 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 where 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, *O. glaberrima,* will include development of intraspecific and interspecific materials and deep sequencing of the parental set used to construct CSSLs and I-bridges lines. These multi-purpose populations will enable precise QTL estimation and gene identification for both the cultivated and wild rice gene pools.

Products

1.2.1. High-resolution SNP genotypes of diverse accessions and high-throughput SNP genotyping platform (Rice SNP Consortium)
1.2.2. 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

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, national agricultural research systems and the private sector. The knowledge and novel genetic resources produced will accelerate the varietal development objectives in Theme 2, 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 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 at multiple traits. Due to the large amount of data produced, this Product Line requires bioinformatics support (Product 1.6.2 in theme 1). Across MPs, the genotype and phenotype datasets 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 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 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 on modern, high-throughput phenotyping facilities is needed for rapid evaluation of multiple traits. On-going funds will be needed to support large-scale trait evaluation for the phenotyping network. The genebank sequencing project will require major funding, especially from 2013-2015.

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

Rationale

Tolerance to 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 a) show evidence of having large effects on the phenotypes, b) are needed to solve a major constraint, c) 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, nematodes, and insects). Besides stress tolerance, research efforts will be devoted to understanding root and panicle development, for yield potential, nutrient uptake, and tolerance to multiple stresses.

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 function(s) 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 pre-breeding events for stress response genes
1.3.8. Gene identification and validation pipeline

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 between 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 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 (Product 1.6.3).

Linkage with theme 2 will be in two ways. Functionally-validated genes can be used for transgenic products and gene-base 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. C_4 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 particularly relevant to solving the problems faced by resource-poor farmers in developing countries.

Activities

Specific objectives of the C_4 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 testing for yield, water use, and nitrogen fertilizer requirement under a range of agronomic conditions.
- produce a tool kit for 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 collaboration 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 are 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 and network of regulatory genes for C_4-function. Molecular tool kits are being developed to define elements that allow specific expression of transgenes in mesophyll cell and bundle sheath cells of rice.

Products

The single most important product is 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 locally cultivated rice lines and evaluated its benefits in some farmers' fields.

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 towards 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, a molecular toolbox specific to 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 the product lines 1.2 (Characterizing genetic diversity) and 1.5 (Nitrogen-fixing rice). Novel genotypic variation created by recombination of the cultivated and wild rice gene pools will provide new resources for screening C_4 photosynthetic properties. The new initiative on nitrogen-fixing rice has the potential of reducing the dependency on high nitrogen input in productive C_4 rice and of enhancing the use of increased photosynthetic capacity in rice. With other MPs, C_4 rice is linked to research on the impacts of climate change on yield via high CO_2 in MP 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 start-up funds to initiate the C4 rice project in 2008. The project is currently supported by the BMGF for the first 3-year phase ($11.1 million for 2009-2011). New funding will be required from 2012 onward. We expect the same level of annual funding for the next phase. The initiation of the C_4 rice project has attracted considerable interest from governmental agencies. Discussion is on-going to engage research organization in China and India to leverage co-investments. Co-investment 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, provided that suitable IP management solutions can be designed for that.

Product Line 1.5. Nitrogen-fixing rice

Rationale

Nitrogen (N) is an essential component for achieving higher yields. This fundamental relationship cannot be easily broken because, for each ton of rice yield, rice plants need to accumulate about 15–20 kilograms of nitrogen per hectare in their vegetative and reproductive organs. Lowland rice in the tropics can use enough naturally available N to produce 2–3 t ha^{-1}. Higher yields require more nitrogen in the plant, and they may also require applying more fertilizer. For this reason, the Green Revolution in Asia has often been criticized for stimulating unprecedented growth in the use of nitrogen fertilizer on rice.

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. Scientists must now focus on breaking the nitrogen barrier. Building on research conducted during the past two decades, and using new tools and opportunities, research in GRiSP will tackle this problem in several ways. Over the short term, new guidelines and tools for well-tailored fertilization—in both space and time—will be disseminated widely to ensure that higher yields can be achieved with greater efficiency of nitrogen fertilizer (themes 3 and 6). Over the longer term, new research must be conducted to engineer new rice varieties with better N-use efficiency, or developing rice with the capability for biological nitrogen fixation (BNF), which is a very energy-intensive process. Therefore, having such a BNF trait in a C4-rice would allow saving N fertilizer without sacrificing yield.

The overall scientific goal of product line 1.5. is to invent nitrogen-fixing rice that would decrease our dependency on nonrenewable sources of nitrogen. The N fixation trait will likely help realize the full potential of C4 rice (product line 1.4.) and of new varieties with high stress tolerance theme 2).

Activities

Advanced research institutions with active research interest in nitrogen fixation in rice and other cereals will be involved globally through a new “BNF in rice” consortium to be formed. We will explore the following strategies of enabling rice to fix its own N:

- improving the endophytic associations between rice and nitrogen-fixing bacteria,
- genetic engineering of rice plants capable of forming legume-like symbiosis/nodules with rhizobia,
- transforming rice with genetic mechanisms to ensure the expression of nitrogenase and protection of nitrogenase from inactivation by oxygen, and
- refining the processes to enhance N-use efficiency in rice.

Several endophytes have already been isolated from cultivated and wild rices, and their genetic diversity studied. Interestingly, an aquatic wild rice species, *Oryza longistaminata,* was recently found at the University of Bremen to support BNF. Thus, wild rice species and possibly other land races or traditional cultivars may be a potential source of useful genes to increase the input of fixed nitrogen in *O. sativa.*

In the short to medium-term, we expect to a) improve the associations between rice and nitrogen-fixing soil bacteria, b) identify compatible rhizobia and varieties of rice, and development of strategies for genetic enhancement of rice to accommodate rhizobial symbiosis,

c) examine the defense response of rice to find ways to avoid them as they would inhibit symbiosis or the nitrogen fixation process, and d) increase the understanding of nitrogen metabolism in rice and impact of N_2 fixation on carbon and energy budgets.

We also know that rhizobium and rice roots interact and that some of the elements found in the legume symbioses are also present in rice. With better understanding of BNF in legume model plants (e.g., *Medicgo trunculata*), comparative biology between legumes and rice can open new leads for critical genetic pathways for BNF. The next steps are to identify and improve association, and evaluate the contribution through N fixation and growth promotion. A systematic approach will be followed to genetically modify rice to recognize and form symbiosis with rhizobia. In the long-run, rice will be transformed with *nif* genes to ensure expression of nitrogenase, protection of nitrogenase from inactivation by oxygen, and an energy supply for N_2 fixation without compromising yield.

Products

1.5.1. N-fixing rice with endophytic diazotroph association
1.5.2. N-fixing rice with rhizobia symbiosis

Uptake and impact pathway

The next users of products from N fixation research will be global plant scientists interested in biological nitrogen fixation, who are largely in advanced research institutes and larger national research systems. There are potential spillover benefits to other crops if rhizobia or endophytica diazotroph fixation can be made effective.

The intermediate users will be researchers and breeders in national systems and the private sector who are interested in reducing reliance on nitrogenous fertilizers. The final users will be farmers who can grow rice cultivars with lower input costs and higher productivity.

The goal to make cereals fix their own N is long term, and the probability of success is uncertain. However, if it succeeds, the impact on rice production and global agriculture will be large and wide-ranging. If a BNF system could be assembled in the rice plant, it could greatly reduce the amount of fertilizer-N farmers need to apply to obtain optimal yields. This is a long-term strategy with large public and environmental benefits, while helping resource-poor farmers. If half of the N fertilizer applied to the 120 million ha of lowland rice could be obtained from biologically fixed nitrogen, the equivalent of about 7.6 million t of oil would be conserved annually. Developing N fixation is the only way to improve rice in all the ecosystems and partnerships will be formed between IRRI and representatives of rice farmers to ensure acceptance of such novel rice.

Financing strategy

Led by IRRI, GRiSP will launch a global BNF in rice consortium to facilitate collaboration among scientists all over the world with active research interests in nitrogen fixation in rice and other cereals. The consortium will develop a detailed roadmap, first work plan and financing plan with collective or individual proposals to seek funding support from multiple sources. We estimate that a total budget of US$50 million will be required over 10 years.

Product Line 1.6. Informatics support for germplasm management and gene discovery

Rationale

Theme 1 is a data generation and analysis program focused on the curation and characterization of germplasm. The large quantity and the complexity of data to be managed in Theme 1, and the sophistication of scientific questions to be posed on such data, will require dedicated research informatics support to capture, store, annotate, integrate, analyze, visualize and interpret data for effective decision making.

This product line aims to provide such research informatics support to theme 1 by curating available rice germplasm, genetic, and genomic data and providing novel tools to access and interpret this data. The target user community represents the global partnership of germplasm researchers in GRiSP, particularly rice genetic resource managers, genetic and genomic researchers, and, to some extent, molecular breeders (who are also served by theme 2). The key impact of this product line is to accelerate rice genetic research by empowering germplasm researchers to develop new hypotheses, to plan cost-effective experiments, to interpret their research results with a broad and evolving knowledge base, and to make further scientific innovations.

Activities

For genetic resource researchers and users, we will continue to improve informatics systems for genebank sample conservation and distribution (Product 1.6.1). This will build on many years of effort at IRRI in developing the International Crop Information System (ICIS). We have adapted the germplasm documentation facilities of ICIS by augmenting its schema and engineering specialized data entry and validation tools to create the Genetic Resources Information Management System (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 also need 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.

For genetic and genomic researchers, two related products are designed: one geared to management and analysis of high-throughput rice data (Product 1.6.2) and the other for comparative genomics across a broad range of species (Product 1.6.3). For Product 1.6.2, we will create a database to manage and visualize rice genetic and phenotype data from thousands of genomes that is linked to IRIS GRIMS along with a toolkit to analyze this data. For Product 1.6.3, a comparative genomics portal will be developed that addresses the need to access, mine, and integrate the rapidly expanding information on non-rice species. This product will not replicate data in existing ARI crop/plant databases – such as in Gramene (rice, wheat, and maize), MaizeGDB, TAIR and EnsemblPlant. It will, however, complement them through the value-added curation of information on priority genes and pathways relevant to GRiSP research products, such as C4 rice and Nitrogen-fixing rice.

For both products, existing technology and information from public open-source database and software solutions will be adapted, and then deployed to meet specific needs of rice. This will be done in partnership with ARI partners who have expertise in high throughput data analysis and management, and comparative biology so that existing tools and resources are effectively cross-liked to those developed by GRiSP. For instance, we will build on 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 evidences from heterogeneous distributed rice resources will be developed.

Products

1.6.1. Global rice germplasm information and management system to support genetic resources conservation

1.6.2. Global genotyping-phenotyping database and bioinformatics tools to support gene discovery

1.6.3. Comparative crop information resources for plant design

Uptake and impact pathway

The continued evolution of the ICIS GRIMS will ensure sustainable and high quality conservation and documentation of GRiSP-hosted genetic resources. As a “gold standard” system, GRIMS will also support implementation of the Global Crop Diversity Trust (GCDT) endorsed Global Rice Conservation Strategy (GRCS) through a “global rice crop registry.” It will also develop ”best practices” solutions for genetic resources data management to facilitate the flow of under-utilized genetic resources into breeding programs, and will be cross-linked to emerging genetic resource indexes such as GENESYS. As such, the genetic resources product has clear linkages to varietal development needs of theme 2.

The immediate users of the two genetic research-focused products will be researchers involved in gene discovery. In the longer term, these products will serve as “global public goods” for NARES and ARI partners striving to elucidate the genotype – phenotype associations of rice that underlie traits for current breeding targets as well as those for future needs. Elucidation of the fundamental genotype/phenotype relationships is directly linked to the development of the “Integrated Breeding Platform” in theme 2. The comparative genomics product also serves as a valuable resource for global research in non-rice crops in MP3. Both products are linked to the Agricultural Genomics Network of “Genomics and Integrated Breeding Service (GIBS)” coordinated by the Generation Challenge Program for several commodities in MP3. In turn, better understanding and identification of specific gene –trait associations will enable introgression of characteristics of interest into varieties developed by national systems, the private sector and Theme 2.

Financing strategy

Over 2010–2015, a minimum investment of $1,200,000 per year will be required for this product line. This baseline funding is sufficient for the genetic resources product line 1.6.1; however, fresh donor commitment to informatics for genetic resources is required, since designated funding is not currently in place. The 1.6.2 genotype - phenotype product is supported in part by the Japan/World Bank Breeding Project for the public “Rice Genetic Diversity Platform.” 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. The 1.6.3 comparative genomics resource product has already been initiated in part through the C4 rice project. Extension of the concept to other research projects and engagement of ARI partners into 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 MP3.

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

R&D Product Line: 1.1. Ex situu conservation and dissemination of rice germplasm

Intermediate users: Geneticists, conservation biologists, molecular biologists, and breeders working on rice
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: Global Crop Diversity Trust, GTZ ATT

Products	Milestones	Outcomes	Target region/key countries	<u>**Lead institution**</u> **in GRiSP and key partners**
1.1.1. Enhanced and sustained collections of the T.T. Chang Genetic Resources Center at IRRI	**M1.1.1.1 (On-going)** Accessions distributed as requested in compliance with ITPGRFA**.** **M1.1.1.2 (On-going)** Existing accessions maintained (regenerated and safeguarded) according to best practices to ensure their viability and availability. **M1.1.1.3 (2015)** Accessions correctly classified by species and variety groups and characterized for morphological, agronomic, quality and other traits so that selection for the end-users is facilitated**.** **M1.1.1.4 (2015)** All information regarding the accessions (passport, characterization, maintenance, distribution, and IPR) documented in the IRIS GRIMS.	Short-term: Rice genetic resources conserved for future generations and actively utilized by breeders worldwide. Long-term: Enhanced use of the conserved germplasm through added value (from these and other product lines such as 1.2)	Global	<u>**IRRI**</u> AfricaRice CIAT CIRAD/IRD GCDT Bioversity/SGRP NARES
1.1.2. Enhanced and sustained collections of the AfricaRice Genebank	**M1.1.2.1 (2011**) 2000 accessions processed each year; installation of the barcode system completed. **M1.1.2.2 (2013)** 1500 accessions collected and processed. **M1.1.2.3 (2015)** Morphological characterization completed; molecular characterization commenced; mini-core collection generated. **M1.1.2.4 (2015)** Morphological and agronomic characterization for different clusters of traits for use by breeders.	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.	Africa and Global	<u>**AfricaRice**</u> IRRI CIAT CIRAD/IRD Bioversity/SGRP NARES

1.1.3. Enhanced and sustained rice germplasm collections at CIAT	**M1.1.3.1 (On-going)** Maintain working collections and specialized stocks (CSSL, mutants) with information documented in IRIS database. **M1.1.3.2 (2012**) Upgraded facilities for processing and storage to enable effective maintenance of CIAT working collections (CSSL, mutants; ~5,000 accessions). **M1.1.3.3 (2013)** Duplication of all accessions to the GRC at IRRI, as part of the Global system (1.1.4).	Short -term: Rice genetic resources conserved for future generations and actively utilized by breeders worldwide Long-term: Enhanced use of the conserved germplasm through added value (from these and other product lines such as 1.2).	Latin America and Global	**<u>CIAT</u>** IRRI AfricaRice CIRAD/IRD GCDT Bioversity/SGRP NARES
1.1.4. Global system for rice diversity conservation and use	**M1.1.4.1 (2012)** Coherent strategy for maintenance and supply of rice genetic resources, including mutants, DNA and other genetic stocks and breeding materials. **M1.1.4.2 (2015)** Gaps in collections through geographic, trait and molecular characterization identified, and collection missions conducted in partnership with NARES.	Short-term: Gaps in conserved genetic resources reduced ensuring that the maximum biodiversity is represented within collections. Reduced duplication of conservation efforts. Long-term: Increased efficiency and effectiveness, through collaboration and sharing of responsibilities with national as well as international rice genebanks.	Global	**<u>IRRI</u>** AfricaRice CIAT IRD/CIRAD GCDT National genebanks
1.1.5. Improved methods for maintaining genetic integrity and physiolo-gical quality of seeds	**M1.1.5.1 (2013)** Identify and obtain base-line samples, against which loss of genetic diversity can be assessed. **M1.1.5.2 (2013)** Critical review of current genebank procedures completed, and seed physiology and genetic studies carried out to define best practice. **M1.1.5.3 (2015)** Storage maturity and seed longevity characteristics for 12 wild species determined. **M.1.1.5.4 (2015)** Revised procedures for improved conservation established and implemented.	Short-term: Optimized and updated best operating practices for rice genetic resource conservation adopted by genebanks worldwide. Better understanding of the seed physiology of cultivated rice (O. sativa and *O. glaberrima*) utilized in genetic improvement. Long-term: Genebanks have better procedures in place for sampling, regenerating, and distributing cultivated and wild species germplasm while retaining their genetic integrity. Reduction in regeneration rates as a consequence of improved quality when seeds are placed into storage.	Global (genebanks)	**<u>IRRI</u>** AfricaRice CIAT IRD/CIRAD GCDT National genebanks

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-Breeding, Bayer-SKEP, Syngenta-SKEP, GCP, BMGF-GSR, USDA

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
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. **M1.2.1.2 (2012)** Genotype data from 600K SNP chip on 2,500 accessions acquired and available for analysis. **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. **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 **M1.2.1.5 (2015)** 2500 *O. glaberrima* lines analyzed for SNP variation	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 marker-assisted selection.	Global	**IRRI** AfricaRice CIAT Cornell University CIRAD USDA Syngenta Bayer CropScience Taiwan Agricultural Research Institute (TARI) Other Rice SNP Consortium members
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). **M1.2.2.2 (2012)** High throughput digital system for yield and related traits. **M1.2.2.3 (2014)** Non-invasive controlled environment and field-based phenotyping tools for assessing stress responses.	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	Global	**IRRI, CIRAD, CIAT** AfricaRice Cornell University Colorado State University USDA JIRCAS Taiwan Agricultural Research Institute (TARI)

	M1.2.2.4 (2015) Effective protocols for quantifying stress responses for current and emerging biotic and abiotic challenges. **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	development		CAAS (CNRRI) Selected NARES partners in IRRI Breeding Networks Syngenta Bayer CropScience other Rice SNP Consortium members
1.2.3. **Whole genome sequencing of all unique germplasm accessions held in the genebanks at IRRI, AfricaRice, and CIAT 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. **M1.2.3.2 (2014**) DNA bank containing 100,000 rice accessions completed and made available for sequencing. **M1.2.3.3 (2015)** Whole genome sequence data obtained for 10,000 rice accessions and made available for analysis (at an estimated cost of sequencing and support of $10 million for 100,000 accessions).	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.	Global	**IRRI** AfricaRice CIAT Cornell University Arizona State University CAAS (BGI, other institutes)
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. **M1.2.4.2. (2014)** CSSL and AA-genome MAGIC populations established and genotyped by SNP markers. **M1.2.4.3. (2014)** A synthetic population derived from recombining 50 indica and japonica elite accessions developed. **M1.2.4.4. (2015)** Fixed interspecific lines (*O. sativa* x *O. glaberrima*) for rainfed and lowland ecosystems; new variation in resistance to lodging and grain	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	Global	**IRD, IRRI, AfricaRice** CIRAD CIAT USDA Cornell University Selected NARES

	shattering obtained in radiation-induced mutants. **M.1.2.4.5. (2015)** Description and mapping of interspecific sterility genes between the two cultivated species**.** **M.1.2.4.6. (2015**) Improved populations of *O. glaberrima* obtained.	breeding rice in at least 15 countries. Novel genes and QTLs from the secondary gene pool for biotic and abiotic stress 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	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
1.3.1. Genes for drought-tolerant and aerobic rice	**M1.3.1.1 (2012)** At least two drought QTLs sequenced, and candidate genes short-listed and gene-based markers provided to breeders **M1.3.1.2. (2012)** Several genes and alleles for drought adaptation identified by whole-genome association study based on phenotyping network **M1.3.1.3 (2015)** Major drought tolerance genes validated and function determined	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	South and Southeast Asia, South America, Africa	**IRRI, AfricaRice, CIRAD** NIAS-Japan
1.3.2. Genes for flood-prone environments	**M1.3.2.1 (2013**) Transcriptional regulation of SUB1A understood and interacting factors characterized. **M1.3.2.2 (2014)** Major gene(s) for anaerobic germination validated and their function understood. **M1.3.2.3 (2015)** Major gene(s) for enhanced tolerance of submergence (from non-FR13A sources) validated and their function understood.	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	Myanmar, Cambodia, Vietnam, Philippines, Indonesia, Bangladesh, India, Sierra Leone, Guinea, Liberia	**IRRI** UC Riverside Max Plank Institute AfricaRice NARES
1.3.3. Genes for nutrient deficiency and problem soils	**M1.3.3.1 (2013)** Major gene(s) for P-deficiency tolerance identified and function understood **M1.3.3.2 (2013)** Major gene(s) for salinity tolerance at Saltol locus identified and function understood. **M1.3.3.3 (2013)** Major genes for salinity tolerance	Short-term: At least two major genes for soil-related stresses and gene-based markers used for breeding rice with enhanced yield in problem soils. Phenotyping platform established and QTL genes identified for NUE	South Asia, Southeast Asia, Africa, South America	**IRRI, CIAT** AfricaRice JIRCAS ICABIOGRAD Cornell University UCR

	within the temperate japonica group identified en fin mapped. **M1.3.3.4 (2014)** Major genes for salinity tolerance at two other major loci identified, precise markers developed, and function understood. **M1.3.3.5 (2015)** At least two sets of population for NUE and BNI traits developed and two major QTL identified for NUE (CIAT).	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		
1.3.4. Genes for temperature extremes and grain quality	**M1.3.4.1. (2012)** Several genes and alleles for chilling and heat tolerance identified by whole-genome association study based on phenotyping network **M1.3.4.2 (2014**) Major gene(s) for tolerance of heat at flowering identified and function understood. **M1.3.4.3 (2015)** Major gene(s) for tolerance of cold stress at seedling and reproductive stages are identified and function understood. **M1.3.4.4 (2015**) Major gene(s) and gene interactions that improve/maintain yield and grain quality in a warmer climate identified, function understood, and markers available for breeding.	Short-term: Major new genes conferring tolerance of extreme low or high temperature during vegetative and reproductive growth identified and markers used by NARS 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.	South and SE-Asia, Africa, South and Central America, Chile, Brazil, Uruguay	**IRRI, AfricaRice, CIRAD** MPI-Golm, CIAT, selected NARES CIAT FLAR RDA Korea Selected NARES
1.3.5. Genes for disease and insect resistance	**M1.3.5.1 (2012)** Cloning of RYMV2 resistance gene from *O. glaberrima*. **M1.3.5.2 (2013)** New resistance genes to African Gall midge identified. **M1.3.5.3 (2014)** Genes involved in resistance to rice tungro spherical and bacilliform viruses validated. **M1.3.5.4 (2015)** Broad spectrum resistance genes for blast (large effect genes, Pi40) and bacterial blight (*Xa7*) validated and gene-based markers available for breeding; cloning of recessive resistance gene against African *Xoo* strains.	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	South and Southeast Asia such as Philippines, Indonesia, Bangladesh and India, Africa and Latin America	**IRRI, AfricaRice, IRD, CIRAD** CIAT RDA (Korea) Ohio State U Kyushu U Hokkaido U Colorado State U Kansas State Univ NIAS (Japan) Univ of Leuven, CeTSAF, George August U, Göttingen, NARES
1.3.6. Genes for improving the architecture of	**M1.3.6.1 (2013**) Candidate genes (transcription factor and miRNA encoding genes) expression patterns/functional analysis completed.	Short-term Superior alleles identified; markers for panicle architecture used in breeding applications. High	Global	**CIRAD, IRD** CIAT AfricaRice IRRI

rice roots and panicles	**M1.3.6.2 (2014)** Isolation of several QTLs involved in root architectural response to water and nutrients. **M1.3.6.3 (2014)** Facilities and protocol established for characterization of root traits; in situ screening and post harvest data generation to characterize panicle development; screening facilities and protocol for low radiation adaptation. **M1.3.6.4 (2015)** Function of major genes involved in meristem maintenance, radial patterning, and lateral/crown root formation established through functional analyses.	throughput phenotyping protocols for root traits; improved understanding of sink traits (panicle development) and source characteristics for low radiation adaptation employed in NARS breeding; 10-12 superior genotypes identified and used as parental material. Long-term: Enhanced development of new cultivars with improved drought avoidance and capture of nutrients. NARES breeders from at least 8 countries apply MAS technologies and use superior genotypes to develop rices that are widely adopted to mitigate drought.		NARES
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 and tested through multiple contained trials. **M1.3.7.2 (2015)** At least 10 lead events for disease resistance identified through field evaluation (CIAT). **M1.3.7.3 (2015**) At least 10 lead events for extreme temp resistance identified through field evaluation (CIAT).	Short-term: Trait genes validated for drought, extreme temperature and disease resistance, leading to pre breeding materials that are widely used by NARS and the private sector. Long-term: Stress resilient varieties widely adopted by farmers to mitigate risk.	Global	**IRRI, CIAT, IRD** JIRCAS RIKEN Uni. California Davis
1.3.8. Gene identifica-tion and valida-tion pipeline	**M1.3.8.1 (2015)** Gene-validation pipeline upgraded for functional SOPs and at least 10 abiotic-stress tolerance genes analyzed. **M1.3.8.2 (2015)** Gene-function pipeline for stress-related genes established and applied to at least 5 major abiotic and biotic proteins. **M1.3.8.3 (2015)** Novel transformation system with site-specific integration, and temporal and spatial control of transgene expression established.	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	Global	**IRRI** CIRAD, IRD CIAT, USDA, Mae Fah Luang Univ. (Thailand), NARA Institute of Sci. and Technol. (Japan), University of Wisconsin, National Plant Genome Res.Centre (India), Intl.Centre for Genetic Engineering and Biotechnology (India), IPK, Newcastle University

R&D Product Line: 1.4. C_4 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

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
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. **M1.4.1.2 (2012**) Kranz anatomy regulators and transcriptome atlas of mesophyll cell and bundle sheath cell in sorghum determined. **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. **M1.4.1.4 (2012) Wild** rice accessions showing C_4-ness characters identified. **M1.4.1.5 (2012) Molecular** toolbox developed to isolate promoters that drive mesophyll cells and bundle sheath cell-specific gene expression in rice.	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 varieites by NARS Long-term: Large increases in productivity and resource-use efficiency as a result of adoption of C_4 mega varieties.	Global	**IRRI** University of Cambridge, University of Oxford, Cornell University, University of Sheffield, University of Nottingham, University of Toronto, CSIRO, Washington State University Univ Düsseldorf Pohang University Australian National University, Shanghai Institutes for Biological Sciences, Academia Sinica, Simon Fraser University, and others to join

R&D Product Line: 1.5. Nitrogen-fixing rice

Intermediate users: Global plant scientists
Final users: Rice farmers worldwide
Expected impact: Large reduction in dependency of nitrogen fertilizer, hence minimize production costs and environmental impact.
Key current projects: None

Products	**Milestones**	**Outcomes**	**Target region/key countries**	**<u>Lead institution</u> in GRiSP and key partners**
1.5.1. N-fixing rice with endophytic diazotroph association	**M1.5.1.1 (2012)** Identification of rice genotypes and endophytic diazotrophs that form intimate and predominant associations. **M1.5.1.2 (2013)** Determination of the mode of invasion and extent of colonization by endophytic diazotrophs. **M1.5.1.3 (2014)** Assessment of the contribution of endophytic diazotrophs to rice growth and yield through nitrogen fixation and growth promotion**.**	Short-term: Identification of potential associations between rice and nitrogen-fixing soil bacteria leads to rice with an active nitrogen-fixing endophytic system, which is adopted into partner breeding efforts. Long-term: Wide adoption of rice with an active nitrogen-fixing endophytic system leads to growth promotion with less reliance on chemical fertilizers	Global	**<u>IRRI</u>** University of Bremen (Germany)
1.5.2. N-fixing rice with rhizobia symbiosis	**M1.5.2.1 (2011**) International workshop organized for formulation of strategies for harnessing BNF. **M1.5.2.2 (2012**) Effects of rice root exudates on expression of the nodulation (nod) genes in rhizobia determined. **M1.5.2.3 (2014**) Developmental and defense responses in rice roots determined in rice-rhizobia interaction. **M1.5.2.4 (2014)** Genetic engineering of rice to recognize and respond to rhizobia**.** **M1.5.2.5 (2015)** Estimation of nitrogen fixation and impact of N-fixation on carbon and energy budgets of rice.	Short-term: Rice engineered to accommodate legume-like symbiosis with rhizobia becomes a mainstream element of partner rice breeding efforst. Long-term: Wide adoption of rice with root rhizobia leads to growth promotion with less reliance on chemical fertilizers	Global	**<u>IRRI</u>** Key partners will be finalized after the workshop to be organized for the formulation of the project.

R&D Product Line: 1.6. Informatics support for germplasm management and gene discovery

Intermediate users: Rice researchers and germplasm users world-wide
Final users: Rice researchers and germplasm users world-wide
Expected impact: Enhanced usage of rice genetic resources and new genes in breeding programs.
Key current projects: GCDT-GPG2, GCP-Drought, BMGF/GCP-MBP

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
1.6.1. Global rice germplasm information and management system to support genetic resources conservation	**M1.6.1.1 (2012)** Establish online genetic resources seed request processing system with enhanced SMTA system support to comply with developing requirements of the Treaty. **M1.6.1.2 (2013)** GRIMS (Genetic Resources Information Management System) upgraded to control all germplasm management operations. **M1.6.1.3 (2014)** Cross-linkage of genetic resources information system with Integrated Breeding Platform (Global Crop Diversity Trust/GRIN-Global/GENESYS collaboration).	Short-term: Improved quality control in genebank management worldwide Long-term: Rice genetic resources conserved and used more effectively through improved data quality and adherence to best practices for quality assurance	Global	**IRRI** GCP-GIBS, AfricaRice CIMMYT CRIL, genetic resources scientists of other partners
1.6.2. Global geno-typing-pheno-typing database & bioinforma-tics tools supporting gene discovery	**M1.6.2.1 (2012)** 2500 SNP genotyping data loaded into database with web visualization. **M1.6.2.2 (2013)** Software tools and computing hardware platform for bioinformatic analyses of genotyping-phenotyping datasets. Trained users. **M1.6.2.3 (2015)** 10,000 germplasm line genome sequences loaded into database with annotation and web visualization. **M1.6.2.4 (2015**) Integrated interface to rice genomic, genetic and genomic resources established	Short-term: Theme-specific bioinformatics solutions (software suite/analyses workbench) employed in genetic characterization worldwide. Long-term: Publicly available high-quality genotyping-phenotyping data for rice breeders worldwide enables faster and more efficient genetic improvement, with enhanced varieties, as a result.	Global	**IRRI** CIRAD, CIAT, AfricaRice Genotyping/sequencing projects; Bioinformatics experts and genomic scientists of other partners
1.6.3. Comparative crop information resources for plant design	**M1.6.3.1 (2011)** Initial online comparative genomics data portal and gene/pathway catalog with cross-links to existing international databases. **M1.6.3.2 (2012)** In depth data mining, comparative analysis and data integration for a preliminary target set of priority genes and pathways.	Short term: Enhanced access to structural and functional information about high impact candidate genes and pathways for priority GRiSP targets applied to enhance genetic improvement by partners	Global	**IRRI** CIRAD, CIMMYT (CRIL), GCP-GIBS, IRD, AfricaRice, Global genomics & biology initiatives (ARI); Bioinformatics experts

	M1.6.3.3 (2013) Global crop data/plant data integration network in collaboration with public international plant/crop/biology databases	Long term: Infrastructure and methodology for accelerated discovery of gene function and genotype-phenotype associations through comparative genomic analysis enables faster and more efficient genetic improvement, with enhanced varieties, as a result.		and genomic scientists of other partners.

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

Product Line 2.1. Breeding informatics and multi-environment testing

Rationale

The success of modern rice breeding is dependent 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 of different sources (phenotypic, genetic, genomic, etc) and provides efficient analytical pipelines and decision supporting tools. This can lead to shortening of the breeding cycle while minimizing resource requirements. An efficient system for genotyping markers tightly linked or diagnostic of the 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 the genotype-by-environment interaction (GEI). Efficient multi-environment testing (MET) networks are needed for determining the stability and adaptability of genotypes and discrimination power of specific environments. The MET network can also facilitate the exchange of germplasm among breeding programs that can potentially speed up the development of new varieties while increasing genetic diversity.

Products

Breeding efficiency can be increased by using more accurate selection criteria, shortening breeding duration and minimizing resource requirements. Approaches for improving phenotyping and genotyping information quality are efficient management of breeding logistics, well designed and 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 breeding duration and resource requirements can be designed using appropriate decision supporting 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. Integrated breeding platform with rice-specific marker applications and decision tools

The IRIS content will be greatly improved through quality check and reorganization of existing datasets and uploading well-curated historical datasets. Efficient analytical pipelines will be developed for predicting breeding value (genetic merit) using pedigree, marker and phenotypic data. A suite of decision supporting 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. The development of decision supporting tools will be done through collaboration with the Integrated Plant Breeding Platform (IBP) project of the Generation Challenge Program (GCP).

2.1.2. 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 supporting tools to support the implementation of modern rice breeding strategies. Data integration is one of the key components in breeding informatics development. The system includes data curation tools, data processing pipeline, web visualization and simple data mining tools. The breeding decision supporting tools (2.1.1.) will also be migrated into the integrated data environment. This will add critical value through web-based data access and utilization to the key products of the IBP project.

2.1.3. Multi-environmental testing (MET) and international germplasm evaluation through INGER
The new MET system will be a systematic and multi-stage testing scheme for promising breeding lines developed by GRISP breeding programs. To be managed by GRISP, the METs 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 sectors. Thru INGER, NARES can exchange superior materials amongst themselves for release directly to farmers or use in hybridization. Aside from seeds, INGER will facilitate the worldwide exchange non-seed biological materials and breeding-related information. In Africa, INGER will be embedded in an Africa Rice Breeding Task Force. This Task Force will be established to regroup scarce human resources devoted to rice breeding in Africa and aims to achieve higher rice productivity through (a) identification of required plant types responding to farmers' needs and consumers' preferences in well-characterized target populations of environments; (b) establishment of a regional rice variety testing network using extensive METs and centralized GxE analyses; (c) development of accelerated and regionally accepted varietal release procedures; and (d) development of alternative and effective models for seed production systems.

Uptake and impact pathway
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 thru MET/INGER system and the Africa Rice Breeding Task Force. The availability of high quality phenotypic data on key agronomic traits and the 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 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 national and internationally-funded development projects will facilitate delivery of improved varieties to the farmers (theme 6).

Financing strategy
The breeding informatics activities (2.1.1. and 2.1.2.) will be partially funded by the GCP/BMGF IBP Project (about $700,000 for the next 2 years). The trait-specific SNP marker development will be funded by the Syngenta-IRRI SKEP project ($300,000 for 2010-2012). The work on products 2.1.3. and 2.1.4. will be partially supported by the Japan Breeding, 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 the level of about $5k 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 four products under this product line.

Product Line 2.2. Improved donors and genes 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 (yield and quality). There is an urgent need to broaden the gene pool of rice varieties through transfer of genes from diverse sources. Advances in tissue culture, molecular markers and genomics offer new potentials to broaden the gene pool of rice by tapping genetic variability hidden in the wild species and further to 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. Requirements for quality differ by province, region and country. Quality traits are key factors that determine adoption of a new variety, so new varieties for each region must contain the correct combination of quality traits for physical, sensory and now, nutritional quality. For quantitative traits such as yield many genes and many environmental factors collectively determine trait performance. The 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 to increase the chance of creating novel allelic combinations.

Products
2.2.1. Inter-specific crosses
New genes will be introduced from *Oryza* species through hybridization and backcrossing. The favorable genes or alleles will be tagged with molecular markers for marker assisted selection. *O. glaberrima* strains will be used to developed stress tolerant cultivars and develop new inter-specific 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
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 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/tolerant rice
A number of resistance genes/QTLs have been identified for resistance against planthoppers and leafhoppers. Resistant and tolerant varieties have been identified against stemborers in Asia. 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 stemborers). 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 multi-line approach for mega varieties and commercial hybrids.

2.2.4. Markers and genes for quality traits

A number of populations derived from high and low quality parents have been created. The parents have been selected by consumers as high and low quality for particular traits. For traits of physical quality, we have identified 5 genetic regions that contribute to physical quality and created QTL NILs for these. In this product line, those populations will be genotyped at 384 loci, and associated with appropriate phenotype data collected in theme 4, illustrating collaboration between themes 2 and 4, in order to identify QTLs. Once loci are identified for currently known and newly identified (in Theme 4) traits, molecular tools will be designed to enable development of varieties with unique and desirable combinations of quality traits that meet the requirements of markets in the range of target regions.

2.2.5. Population improvement

About one hundred 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 IR 36 mutant and the dominant male-sterile gene contained in the PXDMS will be transferred into 5 parental lines, respectively. 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 affecting 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

Next users for pre-breeding products and genetic characterization are rice breeders working in GRiSP, the private sector and in the 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 utilize 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 ACIAR-Chalk, Japan-Breeding, BMGF-CSISA, ADB-Planthoppers, and Pioneer-SKEP. Additional funding of $1 million would be needed over 5 years to support epidemiology and crop health research (personnel and equipment).

Product Line 2.3. Stress-tolerant rice varieties for South and Southeast Asia

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 < US$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 in high elevations and where rice is being grown during winter season in subtropics, and heat stress is emerging as a serious threat to rice production as the consequence of climate change. Considerable opportunities exist to at least double the yield in these areas through the use of stress tolerant varieties.

Products

2.3.1. Drought-tolerant rice

Recent research at IRRI demonstrated the potential for achieving an increase in yield by 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 at IRRI and NARES, 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.

2.3.2. Submergence-tolerant rice

Rice is sensitive to flooding during germination, hindering direct seeding in rainfed areas; and also during vegetative stage when completely submerged. Stagnant partial flooding of 20-50 cm for most of the season also affects considerable areas, estimated as over 5 m 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 to 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 to anaerobic germination will be developed from the best sources identified, and through use of marker assisted selection. Tolerance to all submergence traits will be characterized at the physiological level and the best donors for breeding will be identified and used in crosses.

2.3.3. Improved varieties tolerant to salt stress and other adverse soil conditions

Poor soils with excess salts 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 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 with 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. Varieties tolerant at seedling stage will be developed through incorporation of *Saltol,* a major QTL for tolerance, into popular varieties. At least two more QTLs for seedling stage tolerance and one for reproductive stage will be targeted to develop varieties tolerant at both stages, and 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 wide spread 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 major QTLs identified and used in breeding.

2.3.4. Varieties tolerant to extreme cold or hot temperatures in Asia
High temperature will become an increasing problem due to climate change. 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. These will be used in a crossing program to incorporate tolerance to high temperate into elite cultivars suitable for different growing environments. QTL mapping will facilitate the use of marker assisted selection in developing improved heat tolerant cultivars. Cold tolerant cultivars are needed both in temperate regions and in the high-elevation tropical areas. New genes and QTLs are being mapped that confer tolerance to low temperature at different growth stages. Donors for cold tolerance are crossed with elite varieties to develop improved breeding lines with tolerance to low temperature and high yields.

Uptake and impact pathway
Next users are rice breeders working in GRiSP, the private sector and in the NARES. Intermediate users are seed producers and distributors, including the public sector, private companies, and NGOs, and final users are the 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 the farmers. Government policies should facilitate the release of stress tolerant cultivars. 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 a 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. Linkage with national and internationally-funded development projects will facilitate delivery of improved varieties to the farmers.

Financing strategy
The research is currently funded by several restricted grants that need to continue and expand, including BMGF-STRASA (products 2.3.1 - 2.3.4), USAID-CSISA (2.3.5), funds from Japan-Breeding, and by other projects from BMZ and GCP. 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 to stagnant flooding and salinity (delta areas).

Product Line 2.4. Stress-tolerant rice varieties for Africa

Rationale

The bulk of the rice produced in Africa is grown under rainfed conditions, accounting for more than 80% of the total rice cultivation. Consequently stresses such as drought, salinity, submergence, low temperature, and iron toxicity are widespread in rice fields in Africa contributing to persistent low rice yields. These stresses can be amplified by climate change, which is manifested in erratic rainfall patterns and extreme temperatures. An important approach to raise rice yields in Africa is to introduce rice varieties tolerant to these abiotic stresses in farmers' fields.

Products

2.4.1. Drought tolerant varieties for rainfed uplands and rainfed lowlands

All uplands have potentially a risk of water deficiency, and it is also a problem in rainfed lowland ecosystems. In the last decade short-duration inter-specific (NERICA) upland varieties have been widely deployed in Africa and now occupy over 300,000 ha. In addition, deep rooting varieties are also being used to develop drought tolerant varieties with the potential to extract water from deeper soil layers. A wide range of genetic resources (*O. sativa* and other *Oryza* species indigenous in Africa) will be used for the development of drought resistant varieties. Identification of QTLs associated with drought resistance will be continued. Phenotyping facilities especially for rainfed lowland drought will be upgraded and harmonized protocols with NARES partners will be developed through a special drought initiative funded by the Generation Challenge Program (GCP).

2.4.2. Flood tolerant varieties for inland valleys

Frequent rainstorms often produce flash floods that inundate bottoms of inland valleys. 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 multi-location trials at hot spots in Africa.

2.4.3. Salinity tolerant varieties for mangrove swamps

Both coastal and inland salinity are common in Africa. Salt stress is often accompanied with other nutrient toxicities such as iron and aluminum toxicities as well as deficiencies of zinc and phosphorus. Thus, breeding for such ecologies requires developing multiple-tolerant rice varieties. Presently salt tolerance breeding at AfricaRice is mainly using *indica* donors to introduce salt tolerance into African-adapted germplasm. *Saltol* and other salt tolerance QTLs are also being introgressed into African mega-varieties through Marker-Assisted Selection.

2.4.4. Fe-toxicity tolerant varieties for rainfed lowland systems

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 to iron toxicity including both intra- and interspecifics. At AfricaRice, breeding is underway to validate iron toxicity tolerance and to identify new QTLs for use in MAS.

2.4.5. Varieties tolerant to extreme cold or hot temperatures in Africa

In high altitude areas of East and Central Africa and Madagascar, cold is one of the major rice production constraints. Cold stress can be experienced during the whole crop cycle and thus resistance is needed at both seedling and reproductive 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. Both conventional breeding and MAS using existing markers are being used.

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 potentials in sensitive rice varieties. Donors for heat tolerance have been used in crosses with African varieties with the aim of developing breeding and QTL mapping populations for heat tolerance. *O. glaberrima* could be a useful genetic sources since it has a habit of early morning flowering and high transpiration with sufficient water, both of which are convenient traits to avoid heat stress.

Uptake and impact pathway
Next users are rice breeders working in GRiSP and in the NARES of Africa. Intermediate users are seed producers and distributors, including the public sector and NGOs, and final users are the 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 the farmers. Government policies should facilitate the release of stress tolerant varieties. For instance, varieties released in one country in West Africa should automatically qualify for release in other ECOWAS member countries for the same ecology. Germplasm sources should be available from Theme 1, and management practices for unfavorable areas will be developed in Theme 3, requiring a close linkage. Participatory Varietal Selection (PVS) is a method that is necessary for the effective evaluation of improved germplasm with farmers and the first step of dissemination, and participation of social scientists is essential. Seed production and dissemination will be handled through linkage with Theme 6. Linkage with national and internationally-funded development projects will facilitate delivery of improved varieties to the farmers. The Africa Rice Breeding Task Force, revitalized in 2010 by Japan’s support, will greatly accelerate region-wide varietal development/evaluation, dissemination and harmonization of varietal nomination and release systems.

Financing strategy
Abiotic stress tolerance research is currently financed mainly by BMGF-STRASA, CAAS/BMGF-GSR, and other projects funded by GCP as well as by RISOCAS which is funded by GTZ. The new Japan-Breeding project will assist in multi-location evaluation of materials developed. Funding from STRASA is expected to continue and hopefully will increase; however, new funding will be required for work on high-temperature stress. In general, more funding is needed to allow widespread testing of varieties developed under this product line at NARES level in all of AfricaRice’s 24 member states and beyond.

Product Line 2.5. Improved rice varieties for intensive production systems in Asia and Africa

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. The urban, as the 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.

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

2.5.1. 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. While 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 multi-environment yield trials (Product 2.1.3)..

2.5.2. Rice varieties for direct-seeding in aerobic rice and conservation agriculture systems

Water shortage is becoming an increasing problem in traditionally irrigated areas because of depleting ground water 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 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 negative impact on natural resources. However, cultivating rice under such conditions requires new genotypes adapted to dry direct-seeding, i.e., 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.

2.5.3. 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

Next users are rice breeders working in GRiSP, the private sector and in the NARES. Intermediate users are seed producers and distributors, including the public sector, private companies, and NGOs, and final users are the 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 the farmers. Germplasm sources should be available from theme 1, and management practices for intensive systems will be developed in theme 3, requiring a close linkage. Seed production and dissemination will be handled by linkage with theme 6. Linkage with national and internationally-funded development projects will facilitate delivery of improved varieties to the farmers. Theme 5 will provide feedback to the breeding programs on target environments, market segments, consumer and farmer preferences.

Financing strategy

At present, these mainstream breeding programs of IRRI and AfricaRice are largely dependent 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 the BMGF/USAID-CSISA, Japan-Breeding, BMGF-STRASA, MAFF-IRRI, Philippines-IRRI, ICAR-IRRI, and RDA-IRRI projects. 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.

Product Line 2.6. Improved rice varieties for Latin America and the Caribbean

Rationale

Rice is the leading food staple in LAC, and demand for rice is growing. During 1990-2004 rice yield in LAC expanded annually at 3.5%. There are unique pests and diseases in LAC, as well as distinct grain types and cropping systems. Diverse crop production systems ranging from low yielding upland acid soils to high-yielding irrigated rice conditions constrained by a wide range of biotic and abiotic stresses are found in LAC. Rice blast (leaf and neck) Rhizoctonia, Helminthosporium, and leaf scald are some of the most relevant biotic stresses found across the region whilst rice hoja Blanca virus (vectored by *Tagosodes* sp.) is confined in Colombia, Venezuela, Ecuador, Panama, Costa Rica , and the Caribbean. Iron toxicity and low soil fertility are common problems in some areas, whilst low temperature is confined to Southern Brazil, Uruguay, Argentina and Chile. Climate models for LAC are predicting 2-3 ^{o}C increases in mean temperature and greater variability in rainfall distribution. Varieties having long and slender grain types with intermediate to high amylose content with excellent eating and milling quality and high yield potential are preferred by both consumers and millers. There are large differences in rice yields across the region. There is a need to develop germplasm and technology appropriate for diverse type of rice production systems and different breeding strategies and rice materials are needed. 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.

Products

2.6.1. Climate-ready varieties with tolerance to drought and high and low temperatures

Developing drought-tolerant varieties is the best approach for improving productivity in drought-prone areas. Recent research at IRRI demonstrated the potential for achieving an increase in yield by at least 1.0-1.5 t/ha through breeding. By using recurrent selection and transformation methods progress is being made at CIAT, as well as in the establishment of phenotyping methodology to screen rice genotypes under water stress conditions.

Cold tolerant cultivars are needed both in the Southern Cone (Brazil, Uruguay, Argentina, and Chile) temperate regions and in some high-elevation tropical areas. Phenotyping techniques are being standardized to select for cold tolerance at both vegetative and reproductive stages for the implementation of a marker assisted selection program. New donors for cold tolerance are crossed with elite varieties to develop improved breeding lines with tolerance to low temperature, good grain quality and high yields. High temperature will become an increasing problem due to climate change. Rice plants are most sensitive and 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. These will be used in a crossing program to incorporate tolerance to high temperate into elite cultivars suitable for different growing environments. Segregating populations from IRRI will be evaluated and selected at CIAT. Rice lines with improved water-use efficiency and more resilience to temperature changes are needed to mitigate climate change.

2.6.2. High-yielding varieties for irrigated systems with multiple resistances to pests

Rice production in LAC accounts for 26 million tons of paddy rice with a total value of about 8 billion dollars a year. It is the most important crop in terms of food security and hundreds of million people depend on this cereal for their basic diet, especially the poorest. Technological development of LAC rice sector has had a big impact in rice yields and total production but the 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 resistances to insects and diseases, and superior grain quality.

Uptake and impact pathway

Next users are rice breeders working in GRiSP, in the NARES, the private sector, and FLAR. Intermediate users are seed producers and distributors, including the public sector, private companies, and NGOs, and final users are the farmers. It is assumed that there will be assured funding from donors, national governments, and FLAR to produce and deliver the required amount of seed to the farmers. Government policies should facilitate the release of stress tolerant cultivars. Germplasm sources should be available from theme 1, and management practices will be developed in theme 3, requiring a 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. FLAR will be a key player in this scheme. Linkage with national and internationally-funded development projects will facilitate delivery of improved varieties to the farmers.

Financing strategy

The research is currently funded by CIDA, Agrosalud, Ministry of Agriculture and Rural Development of Colombia, Fedearroz, FLAR, Peru, and by other projects from GCP, and CIAT Core. Work on low-temperature tolerance is funded largely through a project with FONTAGRO; however, new funding will be required for work on high-temperature stress and to support more work on breaking the yield barrier. National partners are contributing through in-kind support and research personnel.

Product Line 2.7. Hybrid rice for the public and private sectors

Rationale
Hybrid rice generally out-yields 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 hectares. Outside China the major hybrid rice growing countries are India, Bangladesh, Indonesia, the Philippines and Vietnam in Asia, and USA and Brazil in the Americas. In Africa, no hybrids are in large-scale commercial rice production yet. IRRI, collaborating with the 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 rice 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 the collaboration between the private and the public sector, and enhancing the dissemination of hybrid rice technology. Hybrid rice R&D programs in IRRI and in other public institutes are currently shifting to a product-oriented approach, focusing more on product development to key private sector partners, but also NARES and programs and selected NGOs.

Products
2.7.1. Rice hybrids for Asia
Developing hybrids derived from male sterile systems is the best and most stable approach of using heterosis in rice currently. Among the factors affecting hybrid rice dissemination, yield in hybrid seed production is the most critical component because it will produce hybrid seeds with reduced cost and acceptable seed prices by 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 level, 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 pattern 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 needs 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 quality improvement. 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.

2.7.2. Rice hybrids for Africa
F1 hybrids from Egypt, IRRI and other Asian sources will be tested with parental lines in multi-location 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.

2.7.3. Rice hybrids for Latin America
Parents of Asian and other hybrids will form the basis of identifying the best hybrids for Latin American conditions. CIRAD activities include integration of molecular markers into the

reciprocal recurrent selection scheme through QTL mapping for combining ability, within the B and R breeding populations, for combing ability and pyramiding of QTLs of interest.

Uptake and impact pathway
Next users are rice breeders working in GRiSP, private enterprises and in the NARES. Intermediate users are seed producers and distributors in the public and private sectors, and final users are the 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 the farmers. Government policies should facilitate the release of commercial hybrid cultivars. For the countries in Asia, 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 socio-economic 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 multi-location 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 2.8. 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 sub-clinical prevalence of vitamin A deficiency ranges 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 quantities of micronutrients required to lead 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 the rice grains would have a significant impact on the 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 grown and sourced locally and is expected to have impact in a sustainable manner.

Products

Research in product line 2.8 will be done in collaboration with a wide range of partners and includes participation of IRRI, AfricaRice and CIAT in HarvestPlus and associated MP Health & 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.

2.8.1. 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 South East 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 the known bioavailablity data and on the bioefficacy date to be determined before wide scale promotion and will be linked to consumers' understanding of nutrition and health.

2.8.2. 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 while superior recombinants will be selected using newly developed high throughput screening methods. The initial launch country will be Bangladesh and this country 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.

2.8.3. 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 while superior recombinants will be selected using newly developed high throughput screening methods. The project benefits from the 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 HarvestPlus target and above. In the following phase, the identified lead events will be transferred into mega varieties/elite breeding lines. In parallel, communicating high-Fe benefits to farmers and consumers to drive adoption and consumption would be undertaken.

2.8.4. 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 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 the rice grain, and evaluating lead events across diverse genetic backgrounds.

Uptake and impact pathway

Next users are rice breeders working in GRiSP, the private sector and in the NARES. Intermediate users are seed producers and distributors, including the public sector, private companies, and NGOs, and final users are the 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 the 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 a close linkage. Seed production and dissemination will be handled by linkage with theme 6 and the seed systems in the target countries. Linkage with national and internationally-funded development projects will facilitate delivery of improved varieties to the 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 Harvest Plus, USAID, B&M Gates Foundation, Rockefeller Foundation and CIDA. However, additional funding will be required, including co-investments from MP Health & Nutrition into this product line on healthier rice varieties.

Theme 2 logical framework: 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 breeding programs and collaborating NARES programs
Final users: Rice breeders/geneticists worldwide
Expected impact: The efficiency of rice breeding is significantly enhanced by fully utilizing multiple sources of information, better targeting to different environments and market segments and the use of new decision support tools.
Key current projects: GCP-BMGF-IBP/GIB, Japan-Breeding, Syngenta SKEP, BMGF-STRASA, BMGF/ USAID-CSISA, BMGF/CAAS-GSR, RDA-IRRI

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
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. **M2.1.1.2. (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. **M2.1.1.3 (2014**) Breeding decision supporting tools for cross selection, marker-assisted backcrossing and gene pyramiding developed. **M2.1.1.4 (2015**) Simulation system for optimizing marker-assisted recurrent selection developed.	Short-term: Rice breeders in IRRI, AfricaRice, CIAT and GRiSP partners 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.	Global	**IRRI** GCP-GIBS, CIMMYT-CRIL, CIAT, AfricaRice University of Queensland, University of Adelaide
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. **M2.1.2.2 (2012)** User friendly web access to germplasm associated trait genetic information.	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	Global	**IRRI** GCP, AfricaRice, CIAT, CIMMYT-CRIL

	M2.1.2.3 (2013) User friendly web access to germplasm associated genotype and genomic information, with access to preliminary breeding supporting tools. **M2.1.2.4 (2015)** fully integrated system with advanced breeding decision supporting tools.	Long-term: Rice breeders are able to manage and visualize their data in a fully integrated system with complete breeding decision support tools, enabling faster and more efficient varietal development.		
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 **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) **M2.1.3.3 (2013)** At least 1500 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 **M2.1.3.4 (2015)** Detailed global and regional analysis of GxE of key traits **M2.1.3.5 (2015)** At least 1000 INGER entries utilized in hybridization and at least 20 elite and multiple stress tolerant lines selected by at least 20 NARES for varietal release	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	S and SE Asia, Africa, LAC	**IRRI (Asia), AfricaRice & IRRI (Africa), CIAT (LAC)** New regional rice breeding task forces (NARES, NGOs, private sector), CIRAD, JIRCAS, CAAS

R&D Product Line: 2.2. Improved donors and genes 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, ACIAR-Chalk

Products	**Milestones**	**Outcomes**	**Target region/key countries**	**Lead institution in GRiSP and key partners**
2.2.1. Interspecific crosses	**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* **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* **M2.2.1.3 (2015**) Yield enhanicng loci "wild species alleles" introgressed from *O. rufipogon* into 5 elite breeding lines with 10% increase in yield over recurrent parent	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 the farmers. Yield of rice varieties increased with introgression of yield enhancing loci from wild species	Africa, Asia, LAC	**AfricaRice, IRRI, CIAT** NARES
2.2.2. Disease-resistant rice	**M2.2.2.1 (2012)** 5 pyramid lines for blast resistance and 10 for blight resistance developed and distributed **M2.2.2.2 (2013)** 2 new genes isolated for resistance to bacterial blight and at least 1 for tungro viruses (pathogenic and molecular diversity studies of RGSV and RRSV by IRD) **M2.2.2.3 (2014)** Phenotyping methods developed and strategies designed for breeding for host plant resistance to sheath blight. **M2.2.2.4 (2015)** Five components of brown spot resistance quantified; at least 2 resistance sources identified; QTLs accounting for at least 40% of PVE identified. **M2.2.2.5 (2015)** Broad spectrum resistance mechanism against bacterial blight and blast characterized based on knowledge of the pathogen population structure	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.	South and Southeast Asia, Africa, and LAC	**IRRI, CIRAD, IRD, CIAT, AfricaRice** RDA (Korea), NIAS (Japan), Kyushu University, Hokkaido University, Ohio State Univ., Ghent University, CeTSAF, George August U Göttingen, U. Milano, EMBRAPA, FLAR, ICAR, JIRCAS, NARES in Africa, Asia, private sector (Barwale F., Bayer)

2.2.3. Insect-resistant/tolerant rice	**M2.2.3.1. (2012)** At least 3 genes/QTLs for BPH pyramided. **M2.2.3.2 (2012)** 5 promising sources of stem borer resistance/tolerance identified, and mechanisms of resistance to BPH and stem borer determined in 2 genotypes. **M2.2.3.3 (2014)** Yield losses from at least 4 major pests in Africa and Latin America assessed, new screening techniques for resistance to BPH and stem borer devised. **M2.2.3.4 (2015)** Laboratory hopper strains from NILs/ pyramided lines produced for determination of gene compatibility in pyramiding.	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.	Asia, Africa, and LAC	<u>**IRRI**</u> CIAT, AfricaRice, NARES in Asia and Africa; private sector (Pioneer, Mahyco, Syngenta), Kyushu University, Wageningen Univ., Univ. College Cork, Chiayi Experimental Station (Taiwan)
2.2.4. Markers and genes for quality traits	**M2.2.4.1 (2012)** QTLs and their contribution to chalk known. **M2.2.4.2 (2012)** All phenotype datasets collected and associated with SNP maps of 3 populations. **M2.2.4.3 (2013)** At least 5 lines nominated to the Rice Breeding Task Force (Africa) **M2.2.4.4 (2014)** Markers for known quality traits identified and QTLs for sensory properties identified.	Short-term: Markers for chalk and new quality traits used by GRiSP team and partners. Long-term: High quality rices widely adopted in target environments.	Asia, Africa, and LAC	<u>**IRRI**</u> AfricaRice, CIAT, FLAR, INQR, other NARES and ARI
2.2.5 Population improvement	**M2.2.5.1 (2013)** Four 10-parent recurrent selection populations (high yielding, wide-adaptation, stable yield, physiological trait-oriented, and drought tolerant) developed based on agronomic, morphophysiological and genome SSR information of parental lines. **M2.2.5.3 (2013)** One cycle of marker assisted recurrent selection for yield potential and drought tolerance achieved in one upland rice population**.** **M2.2.5.4 (2014)** RS strategies designed based on computer simulation experiments. **M2.2.5.4 (2014)** The feasibility of genome-wide selection using genotypic and phenotypic information produced in Theme 1 for traits related to drought tolerance tested.	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 NARS varieties. New varieties breaking the yield barrier of irrigated rice in Asia and optimizing drought tolerance of upland rice in Latin America and Africa.	Asia, LAC	<u>**CIRAD & CIAT (upland rice), IRRI (lowland rice in Asia and CIAT for LAC)**</u>

R&D Product Line: 2.3. Stress-tolerant rice varieties for South and Southeast Asia

Intermediate users: NARES breeders NGOs, seed producers in Asia
Final users: Farmers in unfavorable rice environments of Asia
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

Products	**Milestones**	**Outcomes**	**Target region/key countries**	**Lead institution in GRiSP and key partners**
2.3.1. Drought-tolerant rice	**M2.3.1.1 (2011)** 60 new promising drought tolerant breeding lines developed and distributed to NARES for PVS evaluation by male and female farmers. **M2.3.1.2 (2013)** At least three major drought yield QTLs with multiple genetic background effect identified and characterized. **M2.3.1.3 (2013)** At least four high-yielding varieties introgressed with major QTLs for grain yield under drought. **M2.3.1.4 (2014)** Drought tolerance combined with submergence tolerance in at least two lowland varieties. **M2.3.1.5 (2014)** Drought phenotyping at IRRI and NARES strengthened and physiological interactions between QTLs deciphered.	Short-term: Rice breeders in at least 6 countries are using new drought tolerant lines. Long-term: Farmers grow new drought-tolerant varieties on at least 1.0 million ha.	South Asia, Southeast Asia	**IRRI** NARES in India, Nepal, Bangladesh, Thailand, Laos, Vietnam, Indonesia, Cambodia, Philippines
2.3.2. Submergence-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. **M2.3.2.2 (2013)** 10 lines with high anaerobic germination tolerance verified in field trials. **M2.3.2.3 (2014)** Three NILs with anaerobic germination tolerance QTLs developed; At least one NIL with non-FR13A submergence QTLs developed. **M2.3.2.4 (2015)** Mapping of QTLs for stagnant flooding tolerance and physiology understood.	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.	South Asia, Southeast Asia	**IRRI** NARES in India, Bangladesh, Nepal, Myanmar, Cambodia, Vietnam, Philippines, Indonesia; Univ of California

2.3.3. Improved varieties tolerant of salt stress and other adverse soil conditions	**M2.3.3.1 (2011)** 100 new promising salt-tolerant lines developed and distributed for evaluation under PVS system by male and female farmers. **M2.3.3.2. (2013)** 6 popular varieties introgressed with Saltol and at least 1 variety incorporating 2 additional QTLs developed **M2.3.3.. (2014)** 4 QTLs for other soil problems (Fe and Al toxicity, P, and Zn deficiency) identified for use in breeding. **M2.3.3.4 (2015)** Physiology of tolerance of salt stress and major nutrient toxicities and deficiencies unraveled, traits associated with tolerance identified for targeted breeding.	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.	South Asia, Southeast Asia	**<u>IRRI</u>** NARES in India, Bangladesh, Vietnam, Philippines, Cambodia, Univ of California, Cornell Univ, JIRCAS,
2.3.4. Varieties tolerant to extreme cold or hot temperatures in Asia	**M2.3.4.1 (2011)** 3 new sources of cold tolerance genes identified for seedling and reproductive stages cod stress. **M2.3.4.2 (2011)** Identified and validated at least 10 best heat tolerance donors for use in breeding. **M.2.3.4.3 (2012)** Major QTLs for cold tolerance traits identified and validated. **M2.3.4.4 (2013)** Selected 100 elite heat tolerant lines for multilocation testing in at least 6 countries. **M.2.3.4.5 (2015)** Seeds of 10 cold tolerant varieties distributed to NARES. **M2.3.4.6 (2015)** Developed a platform for breeding heat tolerant rice using MAS for sharing with NARES.	Short-term: Rice breeders in at least 6 countries are using new heat tolerant rice as donors in breeding. Rice breeders in temperate Asia and tropical highlands use new cold tolerant lines in breeding. Long-term: NARES release at least 10 heat tolerant varieties for use by farmers. Farmers in cold-affected regions of Asia use cold tolerant varieties.	South and Southeast Asia, Korea	**<u>IRRI</u>** NARES (India, Bangladesh, Sri Lanka, Philippines, Korea)

R&D Product Line: 2.4. Stress-tolerant rice varieties for Africa

Intermediate users: NARES breeders and national programs
Final users: Farmers in unfavorable rice environments of Africa
Expected impact: Higher productivity and income and less risk for farmers; better protection from climatic extremes
Key current projects: BMGF-STRASA, GCP-Rice Challenge Initiative, Japan-Breeding

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
2.4.1. Drought-tolerant varieties for rainfed uplands and rainfed lowlands	**M2.4.1.1 (2012**) 50 Elite and 200 Advanced lines from STRASA phases 1 & 2 available for PVS in WCA and ESA **M2.4.1.1 (2012)** Phenotyping of GCP-MARS populations (4 pops, 250 lines/pop) started (phenotyping facilities in both controlled and field environments were installed in 2010) **M2.4.1.3 (2015)** 50 Elite upland lines from STRASA-2 and fixed from GCP-MARS available for PVS in WCA and ESA.	Short-term: 5 varieties released in 3 countries Long-term: At least 0.5 million ha rainfed upland and rainfed lowland under new drought tolerance rice varieties in Africa	Sub-saharan Africa (key countries)	**AfricaRice** CIRAD, IRRI, JIRCAS, NARES of Burkina Faso, Mali and Nigeria and other countries including ESA
2.4.2. Flood-tolerant varieties for inland valleys	**M2.4.2.1 (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.	Short-term: 10 new flood tolerant varieties from PVS of STRASA released/adopted in 10 countries Long-term: At least 0.2 million ha under flood-tolerant rice varieties in inland valleys of Africa	Sub-saharan Africa (key countries)	**AfricaRice** GRiSP team, Breeding Task Force, seed producers
2.4.3. Salinity-tolerant varieties for mangrove swamps	**M2.4.3.1 (2011)** Varietal release (5 varieties) of materials evaluated in PVS in the STRASA phase 1. **M2.4.3.2 (2012)** 200 Advanced lines available from the new crosses made in the STRASA phase 1.	Short-term: 5 varieties from PVS of STRASA phase 1 released / adopted in 4 countries by 2011; 5 varieties from crosses made in STRASA released / adopted in 4 countries by 2015 Long-term: By 2020, 0.2 million ha under stress tolerant rice varieties for rainfed lowland systems in Africa	Sub-saharan Africa (key countries)	**AfricaRice** GRiSP team, Breeding Task Force, seed producers

2.4.4. Fe toxicity-tolerant varieties for rainfed lowland systems	**M2.4.4.1 (2011)** Varietal release (5 varieties) of materials evaluated in PVS in the STRASA phase 1. **M2.4.4.2 (2012)** 200 Advanced lines available from the new crosses made in the STRASA phase 1. **M2.4.4.3 (2013)** QTLs identified for application of MAS (collaboration with Hohenheim)	Short-term: 5 varieties from PVS of STRASA phase 1 released / adopted in 6 countries by 2012; 5 varieties from crosses made in STRASA released / adopted in 6 countries by 2015 Long-term: By 2020, 0.2 million ha under stress tolerant rice varieties for rainfed lowland systems in Africa	West-Central Africa	**AfricaRice** GRiSP team (JIRCAS, CIRAD), Breeding Task Force, seed producers, Hohenheim Univ.
2.4.5. Varieties tolerant to extreme cold or hot temperatures in Africa	**M2.4.5.1 (2011)** Cold tolerant upland varieties developed in Madagascar introduced in the PVS network of STRASA phase 1. **M2.4.5.2 (2014)** Two elite cold tolerant upland varieties and one lowland varieties introgressed with 3 blast resistance gene released in Madagascar and introduced in the PVS network of STRASA phase 2. **M2.4.5.3 (2015)** 80 Elite lines from STRASA phase 1 cross and from Madagascar population improvement by RS available for PVS in the target countries.	Short-term: 5 varieties from PVS of STRASA phase 1 released / adopted in 10 countries by 2013; 3 cold-tolerant and blast-resistant varieties developed in Madagascar and 5 varieties from the new crosses made in STRASA released/ adopted in 10 countries by 2015 Long-term: By 2020, 0.2 million ha under stress tolerant rice varieties in rainfed upland systems in Africa	Sub-saharan Africa (key countries), Madagascar	**AfricaRice, CIRAD** Fofifa, Africa Rice Breeding Task Force

R&D Product Line: 2.5 Improved rice varieties for intensive production systems in Asia and Africa

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 resistenc 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

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
2.5.1. New generation of elite inbreds with increased yield potential, premium quality, and resistance to key diseases and insects	**M2.5.1.1 (2011)** Plant type traits that are needed to break rice yield barrier under tropical conditions defined quantitatively. **M2.5.1.2 (2012)** 10 donor parents with desired plant traits and predominately indica genetic background identified. **M2.5.1.3 (2013)** Major QTLs and/or genes related to high-yielding plant traits identified. 100 promising elite breeding lines developed and distributed. **M2.5.1.4 (2015)** Genes governing plant architecture and yield component traits pyramided. **M2.5.1.5 (2015)** Multilocation testing of 10 pre-release varieties by NARES at target sites in major rice growing countries	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 in Asia. Farmers grow "super" rice varieties on at least 20 million ha.	Southeast and South Asia	**IRRI** NARES (PhilRice, ICRR, VAAS, CARD, NAFRC, PAU, BRRI, RRDI, NIBE)
2.5.2. Rice varieties for dry-seeding in aerobic rice and conservation systems	**M2.5.2.1 (2011)** Identification of appropriate donors with target traits (higher tillering, early vigor, weed competitiveness, lodging resistance, good root system). **M2.5.2.2 (2012)** 40 new promising aerobic rice lines for water short areas. **M2.5.2.3 (2014)** 50 promising lines developed and distributed. **M2.5.2.4 (2015)** Multi-location testing of 5 pre-release varieties by NARES at target sites in major rice	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.	Southeast and South Asia	**IRRI** NARES (PhilRice, ICRR, CLRRI, CARD, PAU, BRRI, RRDI, PARC), private sector (Barwale F., Syngenta, Bayer CropScience)

	growing countries **M2.5.2.5 (2015)** At least two presently cultivated varieties for aerobic adaptation.	Farmers grow new aerobic varieties on at least 2.0 million ha.		
2.5.3. High yielding varieties for irrigated systems in Africa	**M2.5.3.1 (2011)** Large scale evaluation of the selected advanced breeding lines from CAAS, IRRI, AfricaRice, CIAT and other sources with desired traits for adaptation. **M2.5.3.2 (2013)** Varietal release of materials evaluated in PVS in STRASA phase 1. **M2.5.3.3 (2015)** Advanced lines available from new crosses made in STRASA phase 1. IRRI materials evaluated in African environments. **M2.5.3.4 (2015)** Chinese materials adaptable to African environments identified.	Short-term: 5 varieties from PVS of STRASA Phase 1 released / adopted in 4 countries by 2013; 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 under stress- tolerant rice varieties for rainfed lowland systems in Africa	Africa	**<u>AfricaRice, IRRI</u>** CAAS (China), NARES from rice growing countries in SSA

R&D Product Line: 2.6. Improved rice varieties for Latin America and the Caribbean

Intermediate users: NARES breeders and national programs
Final users: Seed producers in Latin America
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:

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
2.6.1. Climate-ready varieties with tolerance to drought and high and low temperatures	**M2.6.1.1 (2011)** 200 Improved breeding lines suitable for southern LAC. **M2.6.1.2 (2011)** 50 T2 lines with drought tolerance genes evaluated under confined field conditions. **M2.6.1.3 (2013)** 200 S2 lines extracted from recurrent selection populations. **M2.6.1.4 (2015)** 100 breeding lines developed from crosses with heat tolerant donors.	Short-term: Improved varieties with tolerance to drought and temperature extremes utilized by breeders in LAC. Long-term: Farmers grow new climate-proof rice varieties.	Latin America	**CIAT, CIRAD** FLAR members (15 countries)
2.6.2. High-yielding varieties for irrigated systems with multiple resistances to pests	**M2.6.2.1 (2011)** 5 elite breeding lines with 10% higher yield than the high yielding check variety **M2.6.2.2 (2012**) 50 improved lines combining resistance to blast, rice hoja blanca virus, and Tagosodes. **M2.6.2.3 (2013)** 5 high-yielding elite breeding lines evaluated in multi-location trials by 5 national programs. **M2.6.2.4 (2013)** 2 new blast resistance genes introgressed into elite cultivars.	Short term: Rice breeders in major rice growing countries are using newly developed lines with enhanced genetic diversity in their breeding program Long-term: A new generation of high yielding rice varieties with superior grain quality and multiple resistances to pests available to irrigated farmers in LAC.	Latin America	**CIAT** FLAR members (15 countries)

R&D Product Line: 2.7. 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**	**Outcomes**	**Target region/key countries**	**<u>Lead institution</u> in GRiSP and key partners**
2.7.1. Rice hybrids for Asia	**M2.7.1.1 (2011)** 50 new breeding populations developed and distributed to partners **M2.7.1.2 (2013)** 5000 New hybrid parents and hybrids were test-crossed and evaluated at IRRI and other locations **M2.7.1.3 (2015)** 10 new hybrids released for commercial production by NARES or private partners.	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 over local inbred rice varieties and affordable seed cost.	South and Southeast Asia	**<u>IRRI</u>** Companies that are members of the HRDC, Pioneer, Bayer, Syngenta, Devgen, NARES and NGOs in India, Bangladesh, Philippines, China, Indonesia, Vietnam, Sri Lanka
2.7.2. Rice hybrids for Africa	**M2.7.2.1 (2012)** Initial multi-location evaluation of Chinese and IRRI F1 hybrids and parental lines in Africa completed. **M2.7.2.2 (2013)** Hybrid rice breeding programs functional in at least 3 countries **M2.7.2.3 (2015**) Release of first hybrids bred for Africa	Short-term: Performance of Asian rice hybrids is 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.	Africa	**<u>AfricaRice</u>** Egypt, CAAS, IRRI, AfricaRice Breeding Task Force
2.7.3. Rice hybrids for Latin America	**M2.7.3.1 (2013)** 500 New hybrid parents and hybrids testcrossed and evaluated in multi-locations in L. America (CIAT) **M2.7.3.2 (2013)** Three hybrids yielding 10% higher than the control inbreed lines identified (CIRAD) **M2.7.3.3 (2015)** >2 new hybrids are released for commercial production by NARES or private partners. **M2.7.3.4 (2015)** Feasibility of marker assisted selection for combining ability within a recurrent reciprocal recurrent breeding schema established.	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. At least 400,000 ha under hybrids in Latin America.	Latin America	**<u>CIAT, CIRAD</u>** IRRI, EMBRAPA, IRGA, El Aceituno

R&D Product Line: 2.8. 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: Harvest+, USAID, BMGF, Rockefeller Foundation, CIDA

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
2.8.1. Pro vitamin A-enriched rice (Golden Rice)	**M2.8.1.1 (2011)** Transfer of material to NARES partners. **M2.8.1.2 (2011)** Selection of agronomically superior high betacarotene lines for regulatory and varietal submissions. **M2.8.1.3 (2013)** Obtain biosafety approval in the Philippines for GR2. Selection of optimal gene promoter combination to increase carotenoid retention in GR2 **M2.8.1.4 (2014)** Bioefficacy of GR2 demonstrated in community trial in the Philippines. **M2.8.1.4 (2015)** Consumer marketing activities lead to the successful adoption of GR by farmers and consumers. **M2.8.1.5 (2015)** Selection of agronomic ally superior GR2 plus for regulatory and varietal submissions.	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 bioforitified varieties leads to a reduction in the prevalence and persistence of vitamin A deficiency.	South and SE Asia (Philippines, Indonesia, Bangladesh, India)	**IRRI** PhilRice, BRRI, ICRR, Health NGOs, Univ. of Freiburg; Biosafety Resource Network, India GR Network, MP4
2.8.2. High-Zn rice	**M2.8.2.1 (2011)** Transfer of lead materials (as donors and as advance breeding lines) to NARES partners. **M2.8.2.2 (2013)** Identification of QTLs and genes for grain Zn content, derivation of markers and their use in all breeding Zn grain breeding program. **M2.8.2.3 (2013)** Ten promising high-zinc breeding lines developed and distributed to NARES partners. **M2.8.2.4 (2013)** Release of high-zinc varieties starting in target countries (IRRI and 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 a reduction in the prevalence and persistence of zinc deficiency	South and SE Asia, Africa	**IRRI** AfricaRice, HarvestPlus, BRRI, Flinders Univ., BRRI, TNAU, DRR, UAS, MP4

2.8.3. High-Fe rice	**M2.8.3.1 (2012)** Transfer of promising high-Fe lines to NARES countries (CIAT, AfricaRice) **M2.8.3.2 (2014)** Lead transgenic event identified and tested in multiple genetic backgrounds (IRRI) **M2.8.3.3 (2015)** Transfer of material to NARES partners completed (IRRI). **M2.8.3.4 (2015)** High Fe varieties identified for release in at least 3 countries of LA and Africa (AfricaRice, CIAT)	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	South and SE Asia, Latin America, Africa	**IRRI, CIAT, AfricaRice** HarvestPlus, U. of Tokyo, Zhejiang U., Melbourne U., MP4
2.8.4. Rice with enhanced folic acid	**M2.8.4.1 (2012)** Decision on extant mat1`erials meeting the product performance criteria **M2.8.4.2 (2013)** Selection of optimal gene promoter combinations to deliver the product performance criteria **M2.8.4.3 (2015)** Selection of agronomically superior high folate lines for regulatory and varietal submissions	Short-term: Folic acid, a novel nutritional and health trait is used for rice breeding Long-term: Adoption of bioforitified varieties leads to addresses folate deficiency in rice-consuming population	South and SE Asia	**IRRI** U. of Ghent, Southern Cross U., NARES, MP4

Theme 3: Increasing the productivity, sustainability, and resilience of rice-based production systems

Product Line 3.1. Innovative technologies for an ecological intensification of rice production systems under current and future climates

Rationale

New, generic and science-based principles for natural resources management need to be developed to address major and future (anticipated) constraints to sustainable rice production across ecosystems (irrigated, rainfed, upland). While mitigation of greenhouse gas emissions from rice production remains a goal, unavoidable climate change necessitates the development of adaptation strategies for rice cropping systems. Water, land, labor, and energy are increasingly scarce and threaten the productivity base of many rice ecosystems. This product line delivers generic management technologies and the underpinning science as global public goods to enhance rice productivity in the face of these drivers of change. Since the developed science and its derived product line are generic in nature, key target regions are major rice ecosystems across the globe. Potential impact is improved food security and enhanced livelihoods, which is derived from productivity-increasing management technologies that are climate-change resilient.

The key research question is how rice productivity and resource-use efficiency can be improved under increasing resources scarcity and in the face of climate change.

Activities

This product line will focus on upstream, strategic, and process-based research as well as development of research tools (simulation modeling) through detailed greenhouse and field experimentation. Generic scientific principles will be developed to generate natural-resource management options for rice-based systems in response to major drivers of change that will shape the future of rice production: climate change, land, water, energy, and labor scarcity. We propose to establish detailed field experiments to study the effect of climate change on rice crops and their energy balances, greenhouse gas emissions, plant diseases, pests and weeds, and water use to underpin the development of climate change mitigation and adaptation strategies for rice. Mechanized solutions will be developed to address labor shortages, which will be integrated with principles of conservation agriculture.

Modeling approaches are at the center of many of these cross-cutting issues. Tools and methodologies will be developed to link research on adaptation scenarios conducted within GRiSP with research on regional impacts of climate change-variability, risk analysis and zoning for climate index-based insurance undertaken in the framework of TA7 (climate change MP). CIRAD will ensure the coordination needed in terms of methodology, tool and data sharing. Similar methodological and data sharing coordination will be established between GRiSP's cropping systems research on climate change adaptation and mitigation and TA5's research on water management and ecosystem services.

Products

3.1.1. Assessment of impact of climate change on rice and development of adaptation strategies
3.1.2. Strategies to cope with irrigation water scarcity under current and future climates
3.1.3. Principles and tools for site-specific nutrient and soil health management
3.1.4. Mechanization and agronomic options to increase energy and labor efficiency

3.1.5. Field-farm simulation models and Decision Support Systems

These are global products within GRiSP. They will be addressed in a coherent scientific manner, including utilizing similar concepts and approaches, sharing information, technologies and experiences. Priorities will vary across regions. Short-term outcomes are that national R&D partners adopt principles and research tools (models) for ecological intensification of rice ecosystems. Long-term outcomes are that extension and development agents disseminate new management recommendations to farmers that are based on principles of ecological intensification.

Uptake and impact pathway

Within Theme 3, results of this product line feed into the more adaptive and farmer-participatory R&D of the other product lines (and vice versa, adaptive research results will feed back into product line 3.1). Next users are scientists from ARIs and NARES partners, but also selected private sector professionals. CIRAD plays a major role in many of the products, such as assessment of climate change on rice and crop modeling. Intermediate users include extension agents, as well as government and NGO agencies working on climate change adaptation projects for the agricultural sector. Final users are farmers and policymakers. The IRRC, CURE, STRASA, and CSISA are major mechanisms to link the more strategic research of this product line with the development of management technologies through adaptive research, and to accelerate diffusion through fostering and promoting innovation partnerships. Policymakers need to be engaged along the later stages of the impact pathway to ensure that enabling policies are put in place to support the uptake of new management technologies. Products feed into GRiSP theme 6 for accelerated and large-scale delivery and linkage with other co-investments at national or regional level, and into CGIAR Mega Programs on Land and Water (TA 5) and Climate Change (TA 7) where they are placed in a larger regional context.

Financing strategy

Beside the current investments through unrestricted and restricted mechanisms, there is a need for rapid build-up of investments to increase the research activities on (i) effects of increasing resource scarcity (water, land, energy, labor) and (ii) climate change on rice to enable the development of mitigation and adaptation strategies. The total volume of additional investments requested for climate change research is around 8 Million US$ over 5 years. Additional investments to accelerate the development of technologies to cope with water scarcity are about 1.0 Million US$/y. It is anticipated that funds available for climate change research can also be used to address the issue of increasing resource scarcity.

Product Line 3.2. Methods to enhance ecological resilience for pest and disease management under current and future climates

Rationale

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. These pests and diseases respond to changes in crop management and often limit cropping options available to farmers. Blast, Sheath Blight, and Bacterial Blight continue to remain a threat world wide while Brown Spot and False Smut emerge at an alarmingly rate in Asia. Recently, acute outbreaks of brown plant hoppers and rodents in Asia and of African Rice Gallmidge in Africa have ravaged rice crops. In Latin America, new fungus and bacterial disease problems are emerging, notably *Burkholderia glumae.* Plant hoppers not only directly damage rice crops but also indirectly by transmitting devastating virus diseases. The spread of new viral diseases is being observed alongside plant hopper outbreaks in East and South-east Asia. In Africa, rice yellow mottle virus can devastate farmers' crops, while in Latin America the Hoja Blanca Virus transmitted by Sogata plant hoppers continues to be a main threat. Ecological resilience of rice ecosystems and their capacity for natural control of rice pests is weakened by overuse of pesticides and break-down of rice host-plant resistance. 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. Climate change will not only directly impact on pest and disease epidemics (through changes in temperature, rainfall, and humidity), but also indirectly through changes in cropping patterns. This product line delivers management options and their underpinning science to protect rice from animal pests, diseases, and weeds under current and future climates. Special attention is paid to increasing the resilience of rice ecosystems through principles of integrated pest management. Since the science and derived products are generic, key target regions are the major rice ecosystems across the globe. Potential impact is improved food security and enhanced livelihoods, which is derived from crop-protection management technologies and resilient rice ecosystems.

Key research questions include how damage to rice by pests, diseases and weeds can be minimized under current and future climates.

Activities

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 as determined by weather and hydrology. A global network for crop health assessment 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. Scale levels of our research encompass the plant, field, landscape, regions, and the globe. The science-based principles for pest and disease management will be translated into concrete management guidelines through adaptive and participatory research. Pest and disease management guidelines will be integrated with water, nutrient, and crop management practices to arrive at best-bet integrated management recommendations.

Products

3.2.1. Integrated disease management options
3.2.2. Integrated animal pest management options

3.2.3. Integrated weed management options

These are global products within GRiSP. They will be addressed by scientists from Asia, Africa and LAC in a coherent scientific manner, including utilizing similar concepts and approaches, sharing information, technologies and experiences. Priorities will vary across regions. Short-term outcomes are that national R&D partners adopt principles and research tools (models) for enhanced ecological resilience to control pests, diseases, and weeds in rice ecosystems. Long-term outcomes are that extension and development agents disseminate new management recommendations to farmers that are based on principles of ecological resilience.

Uptake and impact pathway

Next users for locally adapting pest management methods are scientists from ARIs and NARES partners. Intermediate users are extension, agricultural development project, and NGO agents, and final users are farmers and policymakers. CSISA and the IRRC are 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. We will engage with policymakers along the later stages of the impact pathway to ensure that enabling policies are put in place to support the adoption of new management technologies and measures to enhance ecosystem resilience. Products feed into GRiSP theme 6 for accelerated and large-scale delivery and linkage with other co-investments at national or regional level, and into CGIAR Mega Programs on Land and Water (TA 5) and Climate Change (TA 7) where they are placed in a larger regional context.

Financing strategy

Beside the current investments through unrestricted and restricted mechanisms, there is a need for additional research investments in the order of at least 2 million US$/y.

Product Line 3.3. Management innovations to cope with abiotic stresses under current and future climates

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 to drought, submergence, and salinity. However, to fully benefit from the genetic potentials of these new varieties, new and adapted management strategies need to accompany their introduction in the target regions. Key target regions are the drought-prone rainfed lowlands in eastern India, NE Thailand, Indonesia, Laos, Cambodia, the submergence-prone areas in low-lying river deltas in poorly-drained inlands, and salt-affected inlands in Thailand, Indonesia and Myanmar, and coastal zones in the Mekong Delta and the Bay of Bengal. In contrast to Asia, rice in Africa is mostly grown under rainfed conditions. Drought is, therefore, a major determinant of crop yields in both upland and lowland environments, 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. Potential impact is improved food security and poverty alleviation among the world's poor, which is derived from productivity-increasing management technologies.

The key research questions are how to maximally exploit the genetic potential of varieties with increased tolerance to drought, submergence, and salinity, through adapted management practices (soil, nutrients, crop, weed control, establishment, etc).

Activities

Activities focus on 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. The more generic and process-based research results obtained in product line 3.1 feed into this product line (while more detailed research questions are fed back into product line 3.1). Innovation partnerships will ensure that indigenous and local knowledge is captured and that gender-specific issues are addressed in the design of new management technologies.

Products

3.3.1. Crop management technologies for drought-prone and P-deficient areas
3.3.2. Crop management technologies for submergence prone areas
3.3.3. Crop and water management for salt-affected areas, coastal zones, and mangroves

Short-term outcomes are strengthened R&D partnerships for adaptive research on crop, soil, and water management for environments that suffer from drought, submergence, salinity, iron toxicity or specific soil-nutrient stress. Long-term outcomes are that frontier farmers in project areas adopt integrated crop management options for these stresses through trained extension and development agents.

Uptake and impact pathway

Next users for abiotic stress management techniques are scientists from ARIs and NARES partners, who will perform local adaptation and validation. Intermediate users are extension agents, agricultural development projects and NGOs, and final users are farmers. 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 (and therefore its continued funding is warranted). Varieties developed in GRiSP Theme 2 are used as “inputs” into this project line. Products feed into GRiSP theme 6 for accelerated and large-scale delivery and linkage with other co-investments at national or regional level, and into CGIAR Mega Programs on Land and Water (TA 5) and Climate Change (TA 7) where they are placed in a larger regional context.

Financing strategy
In both Africa and Asia, the BMGF-STRASA project will be the major funding mechanism for this product line. STRASA is expected to last 10-15 years and its continuity is required to guarantee ultimate impact among poor farmers. CURE, currently mainly funded by IFAD, plays a pivotal role in linking the development of new varieties in theme 2 with the products of theme 3 product line. In Africa, links will be established with the Africa Rice Breeding Task Force and more funding will be sought for integrating varietal development with improved crop and resource management practices.

Product Line 3.4. Integrated cropping system innovations for future intensive rice systems in Asia

Rationale

Market forces are driving an intensification and diversification of rice-based cropping systems in irrigated and so-called favorable (sufficient rainfall, good soils, good market access) areas in Asia. In the tropics and humid subtropics of Southeast and East Asia, double cropping of rice occurs in large inland plains and major river deltas where irrigation allows for rice cropping in the dry season (e.g., the 'rice bowls' in deltas of the Mekong, Red River, Ayeyarwady, Ganges-Brahmaputra, Cauvery, Yangtze, Chao Phraya). 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). Overall, these unique, intensive rice monoculture occupy a land area of over 20 million ha and they account for more than 40% of the global rice supply. In addition, 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.

Intensive rice-based production systems are the main economic activity in many rural areas and provide the staple food for hundreds of millions of people, and greatly affect the livelihoods and health of the urban and rural poor. More profitable crop rotations with high yields, including higher-value crops, legumes and fodder crops, have good market potential and a promise of generating employment and income. To be sustainable, however, such intensive "future" cereal systems must be managed well. Overuse and losses of agro-chemicals (pesticides, fertilizers), consumption of limited resources (water, phosphorus), and emission of greenhouse gases degrade the environment, contribute to climate change, deplete precious resources, and diminish the capacity of rice ecosystems to sustain rice productivity and deliver other ecosystem services. Yield losses to diseases, animal pests, and weeds, remain a major concern for those systems.This product line includes management technologies and their underpinning science to enhance the profitability and productivity of intensive 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 is derived from profitable, sustainable, and environment-friendly rice-based 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 (footprints).

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, and these platforms will also serve product line 3.1. 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 outscaling. 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. Innovation partnerships will ensure that indigenous and local knowledge is captured and that gender-specific issues are addressed in the design of new management technologies.

Products

3.4.1. Cropping system options for single/double/triple monoculture rice
3.4.2. Cropping system options for diversified rice-based systems
3.4.3. Approaches to reduce greenhouse gas emissions and the environmental footprint

Uptake and impact pathway

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. Final users are farmers. It is assumed that extra funds can 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. The IRRC and CSISA 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. Products feed into GRiSP theme 6 and other national and regional co-investment programs for accelerated and large-scale delivery. Increasingly, work in 3.4. will link to the development of new varieties (Product Lines 2.3. and 2.4.) to (i) develop and adapt integrated genotype x environment x management solutions for key production systems and (ii) utilize the experimental platforms and hubs for adaptive research for varietal development, evaluation and diffusion. This product line involve collaboration with many other CGIAR research programs and centers (e.g., CIMMYT, ILRI, IFPRI, ICARDA, ICRISAT, CIP, IWMI, WorldFish) working in the target regions, particularly Mega Programs under TA 3 (wheat, maize, pulses, livestock), TA (aquatic systems/coastal zones) and TA 4 (nutrition). Theme 3 will also closely collaborate with CGIAR Mega Programs on climate change and land and water, where field/farm level rice technologies are placed in a larger regional context.

Financing strategy

The BMGF-USAID-CSISA project, the SDC-IRRC, several projects funded by ACIAR, IFAD and MAFF (Japan), private sector grants, and new projects focusing on future systems (DFG-ICON) and reducing greenhouse gas emissions are 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. Both the IRRC and CSISA play a pivotal role in linking the development of the new products of this theme 3 product line with large-scale diffusion efforts to support the growth of the rice sector (Theme 6). Substantial continued funding of 3.4. is of high priority. Beside the current investments through unrestricted and restricted mechanisms, there is a need for rapid build-up of investments to increase the capacity on quantifying and reducing footprints of rice production and enhancing ecosystem resilience. Total volume of additional investments requested in this area is around 0.7 Million US$/y.

Product Line 3.5. Farm management innovations for lowland rice-based systems in Africa across an intensification gradient

Rationale

In Africa, lowland rice is cultivated along an intensification gradient, with practically undisturbed inland valleys at one end and intensively-cropped irrigation systems at the other end of the development spectrum. Lowland rice is produced on at least four million ha; three quarters of it is rainfed (roughly half of the total rice production in Africa), while one quarter is irrigated (roughly one third of the total rice production in Africa). Irrigated rice and associated production systems are generally input-intensive and market oriented, although large differences exist between countries. Rice yield gaps between attainable and actual yields are high, even in input-intensive systems. Attainable yields with full water control are in the range of 7 to 9 t/ha, while actual paddy yields on farmers fields are 3 to 6 t/ha. The attainable yield without full water control is 4 to 5 t/ha, while the actual yield is typically 1 to 3 t/ha. To close the yield gaps, improved crop and natural resources management options are being generated and adapted to address the major constraints of irrigated rice-based systems. Major constraints in inland valleys are a lack of water control, soil fertility, weed management, and to a lesser extent iron toxicity, African rice gall midge, and rice yellow mottle virus, while irrigation systems may suffer from a lack of water supply, alkalinization, birds, and rice yellow mottle virus. The options for integrated crop and natural resources management, targeting savings in water and labor, gains in yield and product quality, and reduced production costs, are developed in experimental platforms, which combine process-based research in long-term experiments with adaptive and participatory research at the farm and village levels. Improving water use efficiency can make dramatic contributions to increasing productivity and household food security, and increase market opportunities. Moreover, increased water availability creates the opportunity to grow more than one crop per year. However, in inland valleys, land use intensification should not endanger environmental services, such as the water buffering capacity and natural biodiversity. Intensification can also result in build-up of weeds, pests, and diseases, while degradation of the resource base can lead to abandonment of the site. New challenges include competition for water with increasing demand from urbanization and expansion of irrigation schemes, and climate change, which may lead to a decrease in water availability and to increasing incidences of salinity and alkalinity. Finally, integrated systems, like rice and aquaculture, livestock, and vegetables offer an array of opportunities for intensification and diversification, leading to additional income and improved nutrition for the farming community.

Activities

This product line will focus on alleviating constraints in rice ecosystems along an intensification gradient from low-input inland valley systems to intensified irrigated lowlands. For pristine inland valleys, a crucial first step will be to work on low-cost land and water development options that reduce risk and open up new opportunities for farmers. The Asian Sawah system of small scale mechanization, land leveling, puddling, and bunding will be tested and adapted to African conditions to improve water control, reduce labor needs, and improve timing of management interventions. Participatory research will focus at the farm level to develop options for ecological intensification and diversification of inland valley lowlands while safeguarding as much as possible their environmental services. Inland valley development requires the input and consent of many stakeholders and decision-makers at system, municipality, and district level. This product line will test the usefulness of multi-stakeholder platform approaches in various countries in Africa to develop these lowlands in an environmentally-sustainable and socially-acceptable manner. For irrigated rice-based systems that are already intensified, activities will concentrate on closing yield gaps and increasing resource-use efficiency and profitability in a sustainable manner. Special emphasis will be given to combine long-term on-station field experimentation at so-called ‘experimental platforms’ with adaptive and participatory crop, water, 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, and these platforms will also serve product line 3.1. 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 outscaling. 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. Innovation partnerships will ensure that indigenous and local knowledge is captured and that gender-specific issues are addressed in the design of new management technologies.

Products

3.5.1. Land and water development options for inland valleys
3.5.2. Farm management options and decision tools for ecological intensification and diversification of inland valleys
3.5.3. Farm management options for enhanced resource use efficiency and closing yield gaps in irrigated environments

Uptake and impact pathway

Next users are scientists from ARIs and NARES partners, who will perform adaptive work on the management systems. The Inland Valley Consortium and the AfricaRice - NARS 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. Once 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.

Financing strategy

Research on the development of low-cost water control options, multi-stakeholder platforms and intensification and diversification of inland valley lowlands is funded through grants from Japan and the European Union. Additional funding of about US$ 1M per year is needed to conduct farm level research to enhance resource use efficiency in irrigated systems in Africa.

Product Line 3.6. Farm management innovations for upland rice-based systems

Rationale

Approximately 40% of rice cultivation in Africa is in upland ecosystems, mostly in the moist savanna and humid forest zones, and contributes one-fifth to the total rice production in SSA. These systems are usually still based on slash-and-burn practices. Yields in the uplands are constrained by frequent drought, low soil fertility (due to deficiencies of N, P), and soil acidity. Rice production is further hampered by biotic stresses such as blast disease, stem borers, termites and weeds.

Upland rice areas in Asia are mainly found in Indonesia, India, Lao PDR, Nepal, Philippines, Thailand, Vietnam, and China. They are highly heterogeneous, with climates ranging from humid to subhumid, soils from relatively fertile to highly infertile, and topography ranges from flat to steep. Increasing population and improved market access have put pressure on traditional shifting cultivation systems, and 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. Uplands world-wide are home to extremely poor farmers who rely on their rice crop for food self-sufficiency, even though yields are typically very low, in the range of 1-2 t ha^{-1} only.

For Africa it is important to introduce crop rotations that help build soil fertility and stabilize these slash-and-burn systems and gradually enhance rice yield. In Asia, options exist for rice intensification as stepping stone out of poverty through introducing lowland paddy rice or aerobic rice systems on terraces and in river valleys. Potential impact is improved food security and poverty alleviation among the world's poor, which is derived from productivity-increasing management technologies.

Activities

Activities will focus on farm level improvement because rice is rarely the only crop farmers grow under upland conditions. We will conduct adaptive and participatory crop, water, and soil management research to accompany the introduction of specific rice varieties that are suitable for uplands (e.g. direct seeding in mulch-based systems, weed competitive varieties and NERICA rice in Africa, and aerobic rice or lowland rice for rice terraces in Asia), and to develop new cropping systems that include non-rice crops and optimize scarce resources at the farm level. Innovation partnerships will ensure that indigenous and local knowledge is captured and that gender-specific issues are addressed in the design of new management technologies.

Relying on the long-term experimental platform and partnership model developed by CIRAD in Madagascar systems research approaches will be utilized to (i) understand the interactions between environmental conditions and cropping systems;(ii) diversify cropping techniques for sustainable rice production under upland conditions while optimizing natural resource use efficiency and (iii) develop integrated innovative upland rice cropping systems adapted to different types of farms and suited to the local rice commodity chain. The selection of cropping systems will be decided through a dynamic analysis of environmental and socio-economical constraints. Then the pertinence of innovative cropping systems is evaluated at field, farm, watershed, and local community levels. The integration of knowledge is made 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 development of conservation agriculture-based upland rice cropping systems for this region.

Products

3.6.1. Improved management technologies for rice systems in the uplands in Asia
3.6.2. Improved systems for rice production in the uplands in Africa
Improved cropping systems models, farm models and other decision support tools for selecting adapted cropping systems will be key cross-cutting outputs from both regions.

Uptake and impact pathway

Next users are scientists and experts from NARES and NGO partners, who will adapt upland farm management options to local conditions. Intermediate users are extension agents, agricultural development projects and NGOs, while final users are farmers. In Africa, CIRAD will play a lead role in the development of farm management innovations through their collaborative rice-based systems research platform in Madagascar. Similar platforms in West and East Africa and links with the AfricaRice – NARS Task Force mechanism need to be established to conduct adaptive research at a larger scale and to link with investment and grassroots' partners. 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 (and therefore its continued funding is warranted). Rice varieties developed in GRiSP theme 2 are critical inputs into product line 3.6.

Financing strategy

The BMGF-STRASA project and the IFAD-funded CURE are major 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. Substantial additional funding (US$ >1M/yr) is needed to conduct farm level research on upland rice-based systems across Africa. In Asia, CURE plays a pivotal role in linking the development of new varieties in theme 2 with the products of product line 3.6. Substantial additional funding is required in Asia to develop an R&D program with sufficient critical mass. In Africa, existing co-investments by CIRAD will be a key contribution to this product line.

Theme 3 logical framework: Increasing the productivity, sustainability, and resilience of rice-based production systems

R&D Product Line: 3.1. Innovative technologies for an ecological intensification of rice production systems under current and future climates

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; MAFF-IRRI, DFG-ICON; IFAD Facility (NAIP); BMGF/USAID-CSISA, SDC-IRRC; ADB-Water-saving; JICA-Bohol; ACIAR Rice-Maize; IFAD-CURE; Rice-Wheat Consortium, BMGF-STRASA; CFC, SMART-IV, IFAD-WCA (under dev.), GTZ-ESA, Cirad collaborative project in Madagascar (SCRID)

Products	**Milestones**	**Outcomes**	**Target region/key countries**	**Lead institution in GRiSP and key partners**
3.1.1. Assess-ment of impact of climate change on rice and development of adaptation strategies	**M3.1.1.1 (2011)** Knowledge on the consequences of climate variability on resource management of men and women among rice farming households **M3.1.1.2 (2012)** Prototype system for weather prediction in rainfed rice areas **M3.1.1.3 (2013)** Impact of elevated CO2, changes in humidity, and high temperature on rice and energy and GHG gas fluxes quantified to support development of adaptation strategies **M3.1.1.4 (2014)** Prototype DSS to respond to weather/climate forecasts in rainfed rice environments	Short-term: NARES partners integrate experimental set-up within national programs Long-term: Policymakers incorporate recommendations on climate change adaptation	Asia and Africa	**IRRI, CIRAD** AfricaRice, NIAES, ICAR, JIRCAS, Jamstec, ARIs in Germany, Egypt
3.1.2. Strategies to cope with irrigation water scarcity under current and future climates	**M3.1.2.1 (2011)** Nutrient management recommendations for Alternate Wetting and Drying in Asia **M3.1.2.2 (2012)** Knowledge about the roles of institutions and policies for equitable and efficient water use in large irrigated schemes as well as in small inland valleys **M3.1.2.3 (2013)** Nutrient management recommendations for Alternate Wetting and Drying evaluated in Senegal and Mali	Short-term: NARES partners integrate research on water saving technologies within national programs Long-term: Extension and development partners adopt water saving technologies	Asia, Africa (Egypt, Senegal, Mali, Burkina Faso, Ghana, Mozambique)	**IRRI (Asia), AfricaRice, CIRAD (Africa)** PhilRice, CLSU, NIA, Irrigation systems authorities (ZIS, BIS, UPRIIS), CAU, WU, Lindsay Corporation, ICAR, IWMI, NARES, MP5

	M3.1.2.4 (2014) Water management options for direct seeding and aerobic rice in Asia **M3.1.2.5 (2015)** Alternate Wetting and Drying evaluated in surface irrigation systems in surface irrigation systems.			
3.1.3. Principles and tools for site-specific nutrient and soil health management	**M3.1.3.1 (2011)** Prototype SSNM principles for rice-maize, rainfed cropping systems in Asia and uplands in Africa **M3.1.3.2 (2012)** Soil quality indices for rice (monoculture and rice-upland) production system **M3.1.3.3 (2013)** SSNM principles evaluated in rainfed areas in Asia and Africa **M3.1.3.4 (2015)** New management strategies and DSS for improved soil and nutrient management	Short-term: NARES partners integrate research on nutrient management options within national programs Long-term: Extension and development partners adopt nutrient management technologies	South and SE Asia, Africa (Madagascar, Guinea, Togo, Benin, Mali, Ghana)	**IRRI (Asia), AfricaRice & CIRAD (Africa)** NARES, private sector, TSBF-CIAT
3.1.4. Mechanization and agronomic options to increase energy and labor efficiency	**M3.1.4.1 (2011)** Mechanization options for rainfed lowland systems introduced and evaluated in representative farming communities in Togo and Benin **M3.1.4.2 (2012)** New prototype crop establishment and weed control strategies for dry-seeded seeded systems **M3.1.4.3 (2013)** Mechanized minimum and zero-till systems for rice-wheat/maize/pulses/potato cropping systems **M3.1.4.4 (2014)** Mechanization options for rainfed lowland and upland systems evaluated in farming communities in at least 4 countries in WCA	Short-term: NARES partners integrate mechanization and agronomic options within national programs Long-term: Development and extension partners adopt integrated mechanization and agronomic options	South and SE Asia, Africa	**IRRI (Asia), AfricaRice (Africa)** NARES,
3.1.5. Field-farm simulation models and decision support systems to support develop-ment and exploration of integrated management interventions	**M3.1.5.1 (2011)** Improved crop simulation models for drought, tillering, leaf development, and clumpiness (EcoMeristem, ORYZA2000) **M3.1.5.2 (2012)** Crop simulation module for cold damage and heat stress to support climate change adaptation research **M3.1.5.3 (2012)** Generic simulation models for global disease risk assessment developed.	Short-term: NARES partners integrate models and decision support tools within R&D programs Long-term: National research programs strengthened through adopted models and DSS and improved recommendations for farming	Global	**IRRI, CIRAD, AfricaRice** WUR, CSIRO

	M3.1.5.4 (2013) Samara crop growth model adapted to perform TPE analyses **M3.1.5.5 (2014)** Tools and models (SARRAH, APSIM) for impact, risk assessment, and adaptation strategies in the context of climate variability and climate change **M3.1.5.6 (2015)** Whole farm simulation model for rice-based cropping systems to support decision making and climate change adaptation strategies validated (African uplands and inland valleys)			

R&D Product Line: 3.2. Methods to enhance ecological resilience for pest and disease management under current and future climates in Asia, Africa, and Latin America

Intermediate users: Researchers and extension workers
Final users: Farmers and field agronomists,
Expected impact: Farmers in project pilot areas adopt new, ecologically sound integrated pest, disease and weed management options
Key current projects: BMGF/USAID-CSISA; BMGF-GSR; ACIAR-Sulawesi; SDC-IRRC, Syngenta-SKEP; ADB-BPH; Kadoori-Ecology; RDA-Weedy rice; ACIAR- Rodents; MICCORDEA, GTZ-ESA, AfroWeeds, PARASITE, DFID

Products	**Milestones**	**Outcomes**	**Target region/key countries**	**Lead institution in GRiSP and key partners**
3.2.1. Integrated disease manage-ement options	**M3.2.1.1 (2011)** Prototype strategies for sheath blight management in Asia **M3.2.1.2 (2011)** Diseases, injury profiles, and situations in hot spots of Asia and Africa determined **M3.2.1.3 (2012)** Growth parameters and pathogen diversity established **M3.2.1.4 (2012)** Integrated crop management recommendations for Burkholderia and related pest and diseases in LAC **M3.2.1.5 (2013)** Global network for crop health assessment and response to climate change **M3.2.1.6 (2014)** Prototype epidemiological model and management strategies for viral diseases **M3.2.1.7 (2014)** Integrated crop management recommendations for blast epidemic in upland ecosystems	Short-term: Strengthened R&D partnerships for adaptive research on rice disease management lead to locally appropriate disease control strategies disseminated by development partners. Long-term: Frontier farmers adopt integrated rice disease management options through trained extension and development agents	Global	**IRRI (Asia), AfricaRice (Africa), CIAT (LAC) CIRAD** NARES, FLAR, Syngenta
3.2.2. Integrated animal pest management options	**M3.2.2.1 (2011)** Prototype community-based rodent management strategies for Asia **M3.2.2.2 (2011)** Integrated management options of African rice gall midge available **M3.2.2.3 (2012)** Ecological engineering for insect pest control tested in Asia	Short-term: Strengthened R&D partnerships for adaptive research on animal pest management lead to locally appropriate pest management strategies disseminated by development partners. Long-term: Frontier farmers adopt	Global	**IRRI (Asia), AfricaRice (Africa), CIAT (LAC) CIRAD** NARES and FLAR members

	M3.2.2.4 (2013) Insect pest risk monitoring and forecasting tools developed for Africa **M3.2.2.5 (2014)** Regional gene deployment strategy for insect pests in Asia **M3.2.2.6 (2014)** Insect pest control strategies for preventing and mitigating climate-change induced stresses in Africa developed **M 3.2.2.7 (2014)** New tools for tracking rice pests movements in Africa developed **M3.2.2.8 (2015)** New integrated pest and disease management options for LAC	integrated animal pest management options through trained extension and development agents		
3.2.3. Integrated weed management options	**M3.2.3.1 (2011)** New weed control options for direct seeded systems in South Asia **M3.2.3.2 (2012)** CD-ROM and website on African rice weeds finalized and published **M3.2.3.3 (2013)** Management options for weed control in water-short rice systems of Asia **M3.2.3.4 (2013)** Social, economic and environmental impacts of parasitic weeds on rice in Africa assessed **M3.2.3.5 (2013)** Management options for herbicide resistance in LAC **M3.2.3.6 (2014)** Strategies for prevention and damage control of parasitic weeds on rice in Africa developed **M3.2.3.7 (2015)** Integrated weed management recommendations for LAC and SE Asia, including new options for red rice control	Short-term: Strengthened R&D partnerships for adaptive research on weed management lead to locally appropriate weedcontrol strategies disseminated by development partners. Long-term: Frontier farmers adopt integrated weed management options through trained extension and development agents	Global	**IRRI (Asia), AfricaRice (Africa), CIAT (LAC) CIRAD** FLAR, NARES, farmer organizations, seed producers

R&D Product Line: 3.3. Management innovations to cope with abiotic stresses under current and future climates

Intermediate users: Researchers and extension workers (public sector, private sector, CSOs)
Final users: Farmers and field agronomists
Expected impact: Farmers in key drought, submergence, and saline-prone areas of Asia and Africa adopt adapted varieties and management practices enabling increased productivity, diversified cropping, and reduced risk of crop failure
Key current projects: ACIAR-Laos; ACIAR-Cambodia agronomy; IFAD-CURE; MAFF-IRRI; BMGF-STRASA, BMGF-GSR, SARCCAB

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
3.3.1. Crop and resource management for drought-prone and P-deficient areas	**M3.3.1.1 (2012)** Prototype crop establishment and nutrient management options for new drought-tolerant rice varieties **M3.3.1.2 (2014)** Integrated crop establishment and nutrient management options for new drought-tolerant rice varieties	Short-term: Strengthened R&D partnerships for adaptive research on drought management lead to locally appropriate drought control strategies disseminated by development partners. Long-term: Frontier farmers adopt integrated drought management options through trained extension and development agents	Asia (India, Bangladesh, Nepal, Laos, Thailand, Indonesia), Africa	**IRRI, AfricaRice** ICAR, BRRI, NARC, NAFRI, RD, IIRI; JIRCAS, NARES in SSA (Liberia, Mali, Nigeria, Togo)
3.3.2. Crop and resource management for submergence prone areas	**M3.3.2.1 (2011)** Recommendations for seed and seedbed management under direct seeding in flooded soils **M3.3.2.2 (2012)** Nursery management recommendations for better survival and recovery in flood-prone areas **M3.3.2.3 (2014)** Integrated crop and nutrient management techniques for crop establishment and survival after floods in flood-prone areas **M3.3.2.4 (2015)** Cropping systems adapted to flood-prone areas	Short-term: Strengthened R&D partnerships for adaptive crop management research for flood-prone rice growing conditions lead to locally appropriate submergence control strategies disseminated by development partners. Long-term: Frontier farmers adopt integrated crop management options for flood-prone conditions through trained extension and development agents	Asia (India, Bangladesh, Myanmar, Laos, Thailand, Vietnam, Indonesia)	**IRRI** ICAR, BRRI, DAR, NAFRI, RD, CLRRI, IIRI
3.3.3. Crop and water manage-ment for salt-affected areas, coastal zones, and mangroves	**M3.3.3.1 (2011)** Affordable management recommendations for better productivity in inland salt affected areas **M3.3.3.2 (2012**) Recommendations for better crop establishment in salt affected area	Short-term: Strengthened R&D partnerships for adaptive crop management research in saline environments lead to locally appropriate salinity control strategies disseminated by	Asia (India, Bangladesh, Myanmar, Vietnam, Indonesia), West Africa (Senegal, Mali, Guinea), Eastern & Southern Africa (selected	**IRRI (Asia), AfricaRice, CIRAD (Africa)** NARES in Asia (ICAR, BRRI, DAR, CLRRI, IIRI) and

	M3.3.3.3 (2013) Field management options to accompany the introduction of salt-tolerant varieties **M3.3.3.4 (2014)** Cropping systems (incl rice-shrimp/fish) adapted to salt affected coastal zones and saline inlands **M3.3.3.5 (2014)** Cropping systems adapted to salinity in coastal zones and mangroves **M3.3.3.6 (2015)** Improved management of fresh-brackish/saline water resources	development partners. Long-term: Frontier farmers adopt integrated crop management options for saline environments through trained extension and development agents	countries)	Africa

R&D Product Line: 3.4. Integrated cropping system innovations for future intensive rice systems in Asia

Intermediate users:	Researchers and extension workers (public sector, private sector, CSOs)
Final users:	Farmers and field agronomists,
Expected impact:	Farmers in project pilot sites in intensive rice production areas in Asia adopt improved crop management practices that increase sustainable productivity, diversified cropping, and incomes, while reducing the environmental footprint.
Key current projects:	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, MAFF- IRRI, Kellogg-IRRI

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
3.4.1. Cropping system options for single/double/triple monoculture rice	**M3.4.1.1 (2011)** New generation of production-scale experimental platforms operational at key experimental sites in Asia and at IRRI **M3.4.1.2 (2011)** Adaptive and on-farm trials on integrated crop and resource management technological options operational at "experimental hubs" **M3.4.1.3 (2012)** Residue management strategies in the fallow period **M3.4.1.4 (2013)** Principles for crop health management under rice mono cropping evaluated **M3.4.1.5 (2013)** Principles of ecological intensification in rice-rice systems evaluated	Short-term: Strengthened R&D partnerships for adaptive research on ecological intensification of mono-culture rice systems lead to locally appropriate residue management strategies disseminated by development partners. Long-term: Frontier farmers adopt integrated crop management options for ecological intensification of mono-culture rice systems through trained extension and development agents	Southeast, East and South Asia	**IRRI** NARES, ARIs, NGOs, private sector, Kellogg, Yara, Bayer CropScience
3.4.2. Cropping system options for diversified rice-based systems (rice-maize/wheat/pulses/potato)	**M3.4.2.1 (2011)** New generation of production-scale experimental platforms operational at key experimental sites in South Asia and at IRRI **M3.4.2.2 (2011)** Adaptive and on-farm trials on integrated crop and resource management technological options operational at "experimental hubs" in South Asia **M3.4.2.3 (2012)** Residue management strategies in the fallow period **M3.4.2.4 (2013)** Alternative tillage and crop establishment systems for rice evaluated	Short-term: Strengthened R&D partnerships for adaptive research on ecological intensification of diversified rice systems lead to locally appropriate cropping system strategies disseminated by development partners. Long-term: Frontier farmers adopt integrated crop management options for ecological intensification of diversified rice systems through trained	South Asia	**IRRI** CIMMYT, ILRI, ICARDA, ICRISAT, CIP, NAREs, NGOs, private sector (input suppliers, equipment manufactures, seed producers)

	M3.4.2.5 (2013) Principles for crop health management under diversified rice cropping systems evaluated **M3.4.2.6 (2014)** System performance (productivity, profitability, WUE, NUE, EUE; crop health, ecological resilience) at experimental platforms assessed **M3.4.2.7 (2015)** Integrated crop and resource management of future cropping systems, following principles of conservation agriculture	extension and development agents		
3.4.3. Approaches to reduce greenhouse gas emissions and the environmental footprint of intensive systems	**M3.4.3.1 (2011)** Prototype rice management practices to reduce GWP **M3.4.3.2 (2013)** Prototype footprint calculator for rice life cycle analysis and economic assessment **M3.4.3.3 (2015)** Integrated management strategies and policy options to reduce the environmental footprint of rice	Short-term: NARES partners have integrated analysis environmental impacts of rice technologies within national programs Long-term: Crop management recommendations incorporating reduced environmental impacts of intensive rice production are widely adopted	South and Southeast Asia	**IRRI** CIRAD NARES, JIRCAS, Kellogg, Yara, Bayer CropScience

R&D Product Line: 3.5. Farm management innovations for lowland rice-based systems in Africa across an intensification gradient

Intermediate users: Researchers and extension workers (public sector, private sector, CSOs)
Final users: Farmers and field agronomists,
Expected impact: Farmers in Africa adopt improved crop management practices that increase sustainable productivity, diversified cropping, and incomes, while reducing the environmental footprint.
Key current projects: SMART-IV, EU RAP

Products	**Milestones**	**Outcomes**	**Target region/key countries**	**Lead institution in GRiSP and key partners**
3.5.1. Land and water development options for inland valleys	**M3.5.1.1 (2012)** Sawah system tested in Togo and Benin **M3.5.1.2 (2014)** Sawah system adopted in Togo and Benin **M3.5.1.3 (2015)** Tools for outscaling Sawah systems disseminated	Short-term: Strengthened R&D partnerships for adaptive research on land and water development options for inland valleys lead to locally appropriate land and water management strategies disseminated by development partners. Long-term: Frontier farmers adopt integrated land and water management options that allow reduced risk and ecological intensification through trained extension and development agents	Africa	**AfricaRice, CIRAD** IWMI, NARES
3.5.2. Farm management options and decision tools for ecological intensification and diversification of inland valley systems	**M3.5.2.1 (2011)** Decision support systems tested and adapted to improve resource efficiency of rice-vegetable systems **M3.5.2.2 (2012)** PLAR adaptive and on-farm trials on integrated crop and resource management options operational **M3.5.2.3 (2013)** Prototype integrated management strategies for ecological intensification and diversification of peri-urban rice-vegetable systems **M3.5.3.4 (2013)** Performance of multi-stakeholder platforms for sustainable development and improved market access determined	Short-term: Strengthened R&D partnerships for strategic and adaptive research on ecological intensification and diversification of peri-urban rice-vegetable systems lead to locally appropriate diversification disseminated by development partners. Long-term: Frontier farmers adopt integrated crop management options that allow ecological intensification and diversification of peri-urban rice-vegetable systems through trained extension and development agents	Africa	**AfricaRice** CIRAD, WUR, TSBF-CIAT, NARES

3.5.3. Farm management options for enhanced resource use efficiency and closing yield gaps in irrigated environments	**M3.5.3.1 (2012)** New production-scale, experimental platforms operational at key experimental sites in irrigated systems in Africa, focusing on water saving technologies **M3.5.3.2 (2013)** Adaptive on-farm trials on integrated crop and resource management technological options operational **M3.5.3.3 (2014)** System performance (productivity, profitability, WUE, NUE, EUE; and management of diseases, insects, and weeds) at experimental platforms assessed **M3.5.3.4 (2015)** New management scenarios in experimental platforms established (second generation)	Short-term: Strengthened R&D partnerships for strategic and adaptive research lead to locally appropriate strategies for resource use efficiency and closing yield gaps in irrigated rice systems disseminated by development partners. I Long-term: Frontier farmers adopt integrated crop management options that close yield gaps and enhance resource use efficiency through trained extension and development agents	Africa	**AfricaRice** IRRI, CIRAD, WUR, TSBF-CIAT, NARES in Africa

R&D Product Line: 3.6. Farm management innovations for upland rice-based systems

Intermediate users: Researchers and extension workers (public sector, private sector, CSOs)
Final users: Farmers and field agronomists,
Expected impact: Upland farmers in Africa and Asia adopt improved crop management practices that improve livelihoods through increased productivity, diversified cropping, and incomes.
Key current projects: SDC-NURIFAR; IFAD-CURE; BMGF-STRASA, BMGF-GSR, JIRCAS

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
3.6.1. Improved management technologies for rice systems in the uplands in Asia	**M3.6.1.1 (2011)** Options for lowland and aerobic rice in cropping systems in uplands assessed **M3.6.1.2 (2012)** Options for rice on the plateau uplands of south Asia assessed **M3.6.1.3 (2013)** Options for lowland and aerobic rice in cropping systems in uplands evaluated and ready for outscaling in Asia **M3.6.1.4 (2014)** Options for rice on the plateau uplands of south Asia evaluated and proposed for outscaling	Short-term: Strengthened R&D partnerships for adaptive research on land and crop management options in upland rice-based systems lead to locally appropriate upland management option disseminated by development partners in Asia. Long-term: Frontier farmers adopt integrated land and crop management options that reduce risk and enhance livelihoods through trained extension and development agents	Asia (India, Nepal, Lao, Indonesia, Philippines, Thailand, China, Vietnam)	**IRRI** CIRAD, NARES (ICAR, NARC, NAFRI, Philirice, IIRR, NOMAFSI), NGOs
3.6.2. Conservation agriculture for integrated management in low input/upland rice cropping systems of Africa	**M3.6.2.1 (2011)** Inventory of multifunctional cover crops to be used in CA upland rice cropping systems; tools to study the population dynamics and migratory habits of the rice pests **M3.6.2.2 (2013)** Role of multifunctional cover crops for controling blast, white grubs and parasitic weeds understood **M3.6.2.3 (2013)** Set of CA cropping systems for producing upland rice under different context and set of constraints; Economically viable options for a better exploitation of soil water in upland rice-based systems available **M3.6.2.4 (2013)** Establishment of a long-term partnership and experimental platform on alternative upland rice production systems in West Africa	Short-term: Strengthened R&D partnerships for adaptive research on land and crop management options in upland rice-based systems in Africa lead to locally appropriate upland management option disseminated by development partners in Africa. Long-term: Frontier farmers adopt integrated land and crop management options that reduce risk and enhance livelihoods through trained extension and development agents in Africa	Africa (Madagascar)	**CIRAD** AfricaRice, WUR, TSBF-CIAT, FOFIFA, GSDP, AFD, ANR

	M3.6.2.5 (2014) Impacts of CA and cover crops on water and nutrient efficiency and SOM evolution quantified **M3.6.2.6 (2015)** Tools to support innovative cropping systems based on CA and incorporating multifunctional cover crops **M3.6.2.7 (2015)** Decision-making tools at the farm level to use water conservation technologies for small holder farmers			

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

Product Line 4.1. Technologies and business models to improve rice post-harvest practices, processing, and marketing

Rationale

Modernization of the post-harvest sector has not kept pace with increased production and new problems caused by additional harvests during the wet season. Post-harvest losses in Asia and Africa of up to 30% are caused by spillage and grain loss in all post-harvest processes, losses to animals and pests, contamination e.g. mycotoxins, and through inefficient rice mills. In addition to physical loss, inappropriate post-harvest management practices, delays caused by labor shortage, outdated post-harvest equipment and low operator skills lead to loss in quality, reducing market price of milled rice by 10-30%. Farmers are often forced to sell immediately after harvest due to indebtedness, inability to dry, or poor on-farm storage. At harvest time, freshly harvested paddy swamps the markets, driving down prices so farmers cannot maximize their returns by timing their sales.

Activities

1) Initiation of sustainable post-harvest networks embracing key post-harvest stakeholders for identifying national impact pathways, establishing baselines, planning and implementation of interventions, studying adoption and impact and engaging policy. 2) Development, adaptation, optimization and participatory verification of harvesters, dryers, storage systems, village level quality assessment tools and post-harvest 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 microfinance through NGO and private sector channels. 5) Developing and verifying low-cost mycotoxin detection technology. 6) Developing and testing of training packages for post-harvest technologies, business model development, for farmers' intermediaries and facilitating training delivery.

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

Uptake and impact pathway

The products of this product line will be developed and out-scaled through a rice post-harvest, 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 private and public sectors (e.g. traders and millers associations, NGOs, farmers organizations), but also support for postharvest programs of other investors (e.g., World Bank funded Agricultural Competitiveness Project in Vietnam). Partnerships with NGOs will be strengthened for linking farmers to markets and microfinance. 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 investment levels are inadequate, including grants from ADB (US$ 1 million/year) and SDC-IRRC ($40,000/year). Doubling of investments within 2 years is necessary. Initial funding for the work in Africa has been sought from CIDA.

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

Rationale

Each year, about 25 and 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 no or only small commercial value. In intensive systems, where 2-3 crops are grown each year, the time for incorporated residue decomposition is very short and the remaining residues often disrupt soil preparation, crop establishment, and early crop growth. 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, this product line will conduct research 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 reduce negative environmental side effects.

Activities

1) Develop tools to select for high digestibility of rice straw through understanding the chemical composition; incorporate selection for highly digestible straw into breeding programs and variety release. This work will be carried out by ILRI in South Asia, under CSISA. 2) Inventory of existing bio-energy technology designs; Develop standards for operation, verification and monitoring; Adapt promising concepts to local conditions and verify on a pilot basis; life cycle analysis for selected residues usages and a road map for participation in CDM/carbon trading; and characterization and management options for biochar usage for carbon sequestration, nutrient recycling and increased soil health. 3) Improve rice mills to obtain better separation of husk and bran during milling; Evaluate a range of concepts for energy production using rice husk. 4) Evaluate a range of concepts for the production of cardboards and construction materials using rice husk; Evaluate the commercial viability of the production of rice husk based products in SSA.

Products

4.2.1 Rice straw with increased digestibility for feeding to livestock
4.2.2 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

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 carbon increases in the future and that waste products from bioenergy production can be minimized. 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 byproducts, the next users, who conduct local adaptation work, are in national research systems, while important intermediate users include private sector producers of postharvest equipment. The final users of that equipment are processors and small enterprises that will use byproducts as inputs.

Financing strategy

Product 4.2.1 is funded by CSISA; Annual investments of US$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. Specialty rices and innovative rice-based food products

Rationale

Demand for products that are organic, minimally processed, nutritionally beneficial, or environmentally friendly is growing globally; rice can meet a number of those demands. The compounds and structures that define speciality traits can now be identified. Speciality traits could penalise eating quality for some markets, thus it is necessary to find the right combinations of quality to ensure that eating quality is maintained. For example, by lowering gelatinization temperature to decrease the cooking quality of rice, the texture of the cooked rice will be softer. This can be prevented by slightly elevating the amylose content replacing the low amylose allele of the gene responsible for amylose with an allele that is more highly expressed. Our second approach to increasing incomes, especially for women farmers, is to determine innovative uses of the 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 the 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.

Activities

New phenotyping tools for new quality and speciality traits (slow digestibility, high dietary fibre, longer shelf-life, faster cooking) will be developed using new technologies, including sensory profiling. Demand for the different products will be determined. In collaboration with Theme 2, varieties will be developed and tested that carry these traits together with the other quality traits that are required by different markets. Broken and chalky grains that fetch low value in the market will be ground to 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. Phenotyping platform equipped to assess speciality, and processing traits
4.3.2. Specialty rices 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 speciality rices and rice-products

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, so as to help direct varietal development efforts. The products will be locally adapted specialty rices, 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 uptake of other speciality cereals, and products from them, indicates that these products will be popular in the global market.

Financing strategy

Funds are available for developing new phenotyping tools for the current traits of quality until 2014 from ACIAR and the Japan-Breeding project, but not for speciality traits. Developing speciality rices and processing methods are new areas of work and additional funding of US$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.

Theme 4 logical framework: Extracting more value from rice harvests through improved processing and 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, USAID, CIDA (under development).

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
4.1.1. Improved technologies and management options to increase post-harvest yield	**M4.1.1.1 (2011) Asia:** Supply chains established for hermetic storage and laser leveling technologies in target countries with stakeholders co-financing learning alliances; **M4.1.1.2 (2012) Africa:** Adapted, locally manufactured mechanization options (mini-combine harvesters, dryers, storage systems) **M4.1.1.3 (2012) Asia:** Dryers adapted and produced to local conditions; and information about locally suitable combine harvesters available to end users in the target countries. **M4.1.1.4 (2013)** Outscaling of technologies throughout sustainably funded PH networks in Asia and Africa using multistakeholder platforms e.g., learning alliance. **M4.1.1.5 (2013)** Outscaled technologies throughout sustainably funded PH networks in Asia and Africa	Short-term: Improved PH technologies and management options identified, adapted, and piloted by partners. Long-term: Improved technologies and management options widely scaled-up and -out.	Southeast and South Asia, Africa (8 countries in WCA and ESA)	**IRRI (Asia), AfricaRice (Africa)** Asia: NARES, NGOs in Cambodia, Vietnam, Philippines, India, Bangladesh, DAI, GTZ ; private sector (equipment manufacturers, component suppliers, distributors, service providers, millers associations), traders, farmer groups
4.1.2. Business models for post-harvest technologies and tools for improved rice	**M4.1.2.1 (2011)** Business models for postharvest technologies piloted, needs and strategies for MIS identified, local postharvest value chains analyzed in initial target areas, **M4.1.2.2 (2012)** Business models for PH technologies	Short-term: Business models piloted by partners for adoption of PH technologies and services, value chain linkages, market info flows, and efficiency improved.	Southeast and South Asia	**IRRI** NARES, NGOs, private sector

market information systems	scaled out, MIS networks and linkages established; local PH value chains analyzed, **M4.1.2.3 (2013)** Business models for PH technologies scaled out for wider adoption, MIS technologies and networks scaled out, PH value chains analyzed in additional target locations.	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.		
4.1.3. Post-harvest practices for reduced mycotoxin contamination of milled rice	**M4.1.3.1 (2011)** Mycotoxin contamination assessed in target regions, low cost mycotoxin detection methods verified. **M4.1.3.2 (2012)** Strategies and technologies for mycotoxin management developed. **M4.1.3.3 (2013)** Mycotoxin minimization options out-scaled to multiple stakeholders.	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.	Southeast Asia	**IRRI** NARES, NGOs, private sector
4.1.4. Institutional and organizational innovations enabling greater access to output markets for smallholder farmers	**M4.1.4.1** Institutional arrangements between (1) farmers and parboilers; (2) farmers and millers; (3) millers and traders/importers **M4.1.4.2** PLAR modules and videos on good practices for linking production, processing and marketing actors **M4.1.4.3** Innovative rice labeling, branding, marketing and generic promotion strategies to catalyze RVCs **M4.1.4.4** Risk management strategies and tools **M4.1.4.5** Active rice forum re-established in WCA	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.	Africa (8 countries in WCA and ESA)	**AfricaRice** NARES, NGOs, private sector

R&D Product Line: 4.2. Innovative uses of rice straw and rice husks

Intermediate users: Scientists in IARCS and NARS 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 under development

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
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 **M4.2.1.2 (2011)** Variability amongst cultivars and breeding lines in digestibility of rice straw determined. **M4.2.1.3 (2012)** Selection for digestible straw incorporated into breeding programs **M4.2.1.4 (2012)** Promising lines, varieties or hybrids with superior rice straw fodder quality identified and recommended to partners for further evaluation,	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. Long-term: Enhanced use of rice straw to feed livestock in target regions of South Asia, in balance with conservation agriculture needs.	South Asia (India, Bangladesh, Nepal)	**ILRI** IRRI, CIMMYT, NARES, NGOs, private sector
4.2.2. Renewable, profitable and sustainable energy product-ion and carbon sequestration based on rice residues	**M4.2.2.1 (2011)** A range of concepts for decentralized energy production using husk evaluated **M4.2.2.2 (2012)** Detailed analysis of bioenergy from straw conducted, options for use of biochar for carbon sequestration defined; **M4.2.2.3 (2013)** Carbon life cycle assessments conducted; concepts to tap carbon trading schemes. **M4.2.2.4 (2013)** Gasification technology associated with small/medium mills for energy and electricity production developed	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.	Asia, Africa	**IRRI, CIRAD, AIT** NARES, NGOs, private sector
4.2.3. Innovative, profitable and sustainable processing options for rice husks	**M4.2.3.1 (2011)** Rice mills improved to obtain total separation of husk and bran during milling **M4.2.3.2 (2013)** Technologies for energy production in small/medium mills using rice husk evaluated **M4.2.3.3 (2013)** Concepts for the production of cardboards or construction materials using rice husk. **M4.2.3.4 (2014)** Commercial viability of the production of rice husk based products in SSA evaluated.	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	Cameroon, Ghana, Sierra Leone, Senegal, and Uganda	**AfricaRice, CIRAD** NARES, NGOs, private sector, McGill University

R&D Product Line: 4.3. Specialty 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 Type ll diabetes
Key current projects: ACIAR, Japan-Breeding, CIDA (under development)

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
4.3.1. Phenotyping platform equipped to assess speciality, and processing traits	**M4.3.1.1 (2011)** 5 new traits of sensory quality and of specialty rices identified. **M4.3.1.2 (2012)** Candidate structures and compounds identified for potential phenotyping tools for new traits. **M4.3.1.3 (2013)** Phenotyping tools for new traits.	Short-term: Phenotyping tools applied by NARS partners to evaluate quality of specialized rices Long-term: Improved quality rices widely adopted by farmers.	Asia, Global	**IRRI** Members of the INQR worldwide, Cambodia (CARDI), Holland (Plant Res. Intl), Malaysia (MARDI), AfricaRice,
4.3.2. Speciality rices for high-value markets	**M4.3.2.1 (2011)** Indica varieties with nutritionally valuable carbohydrates identified **M4.3.2.2 (2012**) Phenotying tools and processing technologies for 6 specialty traits identified **M4.3.2.3 (2013)** Asia Combinations to capture speciality traits and maintaining desired cooking quality. Africa Varieties suitable for parboiling.	Short-term: Specialty traits being developed by all local GRiSP partners Long-term: Specialty rices and their products being grown and generated in Asia, Africa and LAC	Asia, Africa, and LAC	**IRRI and AfricaRice** CIAT/FLAR, Australia (CSIRO), Sri Lanka (RRDI), India (ICAR), Bangladesh (BRRI), Indonesia (ICRR)
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 **M4.3.3.2 (2013)** Processing tools for 2 rice products developed. Techniques communicated to farmers **M4.3.3.3 (2014)** Women-friendly parboiling technology developed in relation with women associations managing the parboiling industry in West Africa.	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	Cameroon, Ghana, Sierra Leone, Senegal, and Uganda	**AfricaRice** CIRAD
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 specialty rices and products of lower -value rice by male and female farmers. **M4.3.4.2 (2012)** Innovative rice labeling, marketing and generic promotion strategies to catalyze the value chain of speciality rice and rice-based products **M4.3.4.3 (2013)** Business models developed for linkages and resources for outscaling specialty rices and products from them and low-value rice.	Short-term: Processing techniques being promoted by partners in Africa. Long-term: Processing technologies increasing farmers' income in Africa, Asia and LAC.	Asia and Africa	**IRRI and AfricaRice** GRiSP team, NARES, NGOs, private sector

Theme 5. Fostering improved policies and technology targeting for sustainable rice production and marketing

Product Line 5.1. Socioeconomic and gender analyses for technology evaluation

Rationale

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 are 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 socio-economic and biophysical characteristics. Adoption is a dynamic process in which farmers adopt technologies incrementally over time as they learn more about the technology. Adoption levels may also differ between male and female farmers of different socio-economic categories and are conditioned by institutional and policy contexts that determine the land tenure and the working of the input markets.

Activities

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

Products

5.1.1. Knowledge of farmer technology needs and policy and institutional constraints for technology adoption by male and female farmers.
5.1.2. Knowledge of poverty dynamics, livelihood strategies, and gender roles in rice farming.
5.1.3. Institutional and policy reform options for improving technology adoption through analyses of input markets
5.1.4. Gender-disaggregated analysis of consumer perceptions and preferences for targeted product development.

Uptake and impact pathway

The feedback on technology needs and insights into the evolution of target farming systems generated in this product line is utilized by NARS, 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, rural investment portfolios, and address policy constraints to technology adoption. An increased understanding of livelihood strategies and gender roles will help to improve the on farm performance of technologies, technology adoption rates, and to improve the distributional effects of specific interventions.

Financing strategy

Several ongoing grants including STRASA, CSISA, GSR, IFAD facility grant, VDSA and Tracking Improved Varieties in South Asia (TRIVSA) currently support activities in this product line.

Product Line 5.2. Spatial analyses for effective technology targeting and deployment strategies

Rationale

Mapping and monitoring the biophysical and socioeconomic characteristics of rice producing areas is key for developing effective targeting strategies for the dissemination of new technologies. Apart from rice mapping, there is a wealth of information that can be derived from remotely sensed sources and spatial modeling that has not yet been fully realized. One key development would be to move away from static, coarse-scale crop calendars to high resolution, year specific phenology databases. The identification of key phenological stages provides valuable information for integrated pest and invasive species management, crop modeling and improves our understanding of agricultural production constraints. 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. The key message here is "providing actionable information to decision makers".

Activities

Remote Sensing techniques using high frequency MODIS imagery will allow rice areas and changes in rice areas to be mapped from year 2000 to present day. Components of this analysis include (i) ground truth surveys, (ii) 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 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.

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 have been developed to derive smooth temporal signals from this noisy data but have never been applied to areas of rice cultivation and research is needed to determine how we can derive accurate phenology information for rice under different agro ecological conditions. 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, (iii) relevant syntheses of climate data from key phenological dates, (iv) identification of failed seasons or changes in cropping intensity due to climate shocks or policy changes, and (v) assuming that MODIS or a similar product will continue to exist, then medium term climate change effects may also be observed.

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

A comprehensive database of relevant spatial layers and survey data for South, South East and Sub Saharan Africa will be developed and will form the basis of an agro-ecological zoning model for rice cultivation and multi-scale modeling of target domains 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 the African rice growing environments and adaptation of an existing model for mapping potential suitable areas for rice cultivation. Mapping and detection of hotpots of biotic and abiotic stresses will continue. This information will be incorporated into the GIS information system.

Products

5.2.1. Faster key-information delivery on rice agro-ecologies using innovative remote-sensing and mapping systems
5.2.2. Improved characterization of abiotic and biotic stresses in major rice growing areas of Asia and Africa
5.2.3. Spatial characterization of socio-economic domains and mega environments for technology targeting and delivery

Uptake and impact pathway

The short term outcome is 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 & communication mechanism for these large datasets. This product line provides baseline data to themes 3, 5 and 6 in GRiSP. It will benefit from collaboration with HPC providers (Amazon) and key satellite imagery providers (ESA or JAXA).

Financing strategy

Approximately $600,000 of additional annual investment is needed, starting in 2011. Current funding comes from GSR (2009-2011), STRASA (2008-2010), RSSP (2009-2011) and Japanese funded project on Next Generation Varieties (2010-2014) and amounts to $150,000 in 2010 and reducing significantly after that year on year.

Product Line 5.3. Global rice information gateway

Rationale

The global rice information gateway would provide a real-time crop information and forecasting platform by combining modern techniques such as satellite-based remote sensing with weather and crop modeling, and economic modeling. This system 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. The need for timely and reliable crop information on production, consumption, stocks, and trade is absolutely essential for the smooth functioning of the global rice market. The recent crisis is an example for which inaccurate information on the global rice situation led to the tripling of rice prices between November 2007 and May 2008 to a level not witnessed in the last three decades. In addition, the gateway would provide historical data and medium-term outlook for rice production, consumption, trade and prices both at the national and sub-national level for important rice growing countries. These projections are expected to be used by government agencies, agribusiness, commodity groups and others for their medium- to long-term planning.

IRRI and AfricaRice are uniquely positioned to provide unbiased and accurate information on the current and future conditions of the global rice market. IRRI and AfricaRice 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 on the global rice market. More importantly, our constant awareness of the ongoing technological and varietals developments and their possible effects on future rice yield growth makes us a leader in this area.

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 of 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, geographical information system (GIS) and global positioning system (GPS) technologies. The remote-sensing component is comprised of a largely automated protocol using multi-date radar imagery for mapping and estimating rice area and planting dates.

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

Products

5.3.1. Global rice monitoring and forecasting system
5.3.2. Medium-term outlook for global rice market using a new supply and demand model
5.3.3. Rice databases to support rice policy, technology targeting and impact assessment.

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. In the short-run, accurate information will lead to stabilization of the global market with lower price volatility. In the long-run, such system will benefit the poor and reduce resource misallocation.

The information generated in this product line will be utilized 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 (2011-2015) for the development and validation of the monitoring system. Initially, the system will include major Asian rice growing regions and will be expended 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 operation of the system.

Product Line 5.4. Sustainable rice policies for a globalized world

Rationale

Policymakers, commodity groups and agribusiness organizations are increasingly interested in having reliable information on the impact of expected or potential economic/trade, technological, and policy factors/trends on the domestic food security. 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 back into below poverty level.

IRRI, AfricaRice and CIAT are uniquely placed in providing unbiased policy solution to national Policymakers for sustainable rice production. Our presence at the grassroots levels and constant awareness of ongoing technological and varietal developments and their possible effects on future rice yield growth makes us ideal intermediaries in policy advocacy and consultation role. In addition, we can play important role in harmonizing rice policies at the regional level by providing quantitative assessments of policy reforms.

Activities

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 the end uses and identifies spatial trade flows for a few major exporters and importers. For 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 the country. For 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, time series analysis will be used in assessing effects of policies.

Products

5.4.1. Quantitative assessment of domestic and trade policies including input subsidies for sustainable rice production

5.4.2. Opportunities identified for regional integration of rice policies including trade and reserve policies

Uptake and impact pathway

In the short-run, 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 longer run, accurate policy assessments and policy dialogue will lead to harmonization of regional rice policies 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 national agricultural research and extension system partners in quantitative policy analysis will complement efforts to disseminate analytical results.

The information generated in this product line will be utilized in CGIAR TA2 (Policy) and GRiSP themes 4 and 6.

Financing strategy
Initial development of the global rice model has been started with support from IRRI and the BMGF-funded Global Futures for Agriculture grants. However, $100,000 of annual additional investment will be needed over the next five years to complete this work.

Product Line 5.5. 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 then essential to follow up these projections, improve future assumptions, and to demonstrate 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 assessment of projected yield gaps under future climatic conditions, mapping of rice agroecologies, and dissaggregation 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 identification of losses due to inappropriate policies. Parameters underpinning the assessment will be regularly reviewed and updated by a taskforce of leading GRiSP scientists, which will oversee a revision to the priority setting study every five years. In addition, regular interaction with MP2'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 to their peak level of adoption, while more immediate feedback to scientists will be provided through evaluation approaches focused on early adoption (product line 5.1). 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.

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 assessment 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 varietal and crop management practice diffusion

Products

5.5.1. Foresight and intelligence for strategic assessment of research priorities

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

Uptake and impact pathway

The short term outcome is 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 willingness of CGIAR managers, scientists and donors to respond to evidence of achieved impacts and impact potential. This product line will provides feedback to all other themes in GRiSP as well as is linked to CGIAR TA2 (Policy).

Financing strategy

Approximately $500,000 of additional annual investment is needed, starting in 2011.

Theme 5 logical framework: Fostering improved policies and technology targeting for sustainable rice production and marketing

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	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
5.1.1. Knowledge of farmer technology needs and policy and institutional constraints for technology 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 resource conserving technologies in South Asia (2011), Latin American countries (2011) and Africa (2011-2013). **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 and Latin America. **M5.1.1.3 (2012)** Analysis of adoption patterns and constraints to adoption of rice varieties in South Asia, Latin America and Africa. **M5.1.1.4 (2013)** Assessment of enablers and constraints to adoption of good agricultural practices in SE Asia and Latin America. **M5.1.1.5 (2014)** Analysis of supply chain constraints for adoption of improved technologies and best management practices in South and Southeast Asia.	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.	Africa, Latin America, South & Southeast Asia	**<u>IRRI (Asia), CIRAD & AfricaRice (Africa), CIAT (LAC)</u>** IFPRI, ILRI, CIMMYT, FLAR and NARES
5.1.2. Knowledge of poverty dynamics, livelihood strategies, and	**M5.1.2.1 (2011-15)** High frequency longitudinal dataset of 12 Bangladeshi villages for understanding poverty and gender dynamics in South Asia **M5.1.2.2 (2012)** Farmer livelihoods analyses in	Short-term: Use of high frequency data by scientists and graduate scholars for better understanding of poverty dynamics and farmers' livelihood.	Bangladesh, South, Southeast Asia & West Africa	**<u>IRRI (Asia), CIRAD (Africa)</u>** ICRISAT, CPD ,Socio Consult, NARES and NGOs

gender roles in rice farming	representative rice growing environments in South and Southeast Asia **M5.1.2.3 (2012)** Analysis of changing roles of gender due to climate change, migration and widespread technological changes. **M5.1.2.4 (2015)** Assessment of farmers' coping mechanisms during monga or seasonal hunger in Northwest Bangladesh	Long-term: Analysis conducted by scientists and scholars will help Policymakers in formulating more effective		
5.1.3. Gender disaggregated analysis of consumer perceptions and preferences for targeted product development	**M5.1.3.1 (2011)** Consumer survey in the Philippines for determining perceptions and acceptability of golden rice. **M5.1.3.2 (2012)** Consumer preferences among different categories of populations of 2 West African countries acheived **M5.1.3.3 (2014)** Consumer preferences for rice traits and for locally produced and imported rice determined for Asia, Africa (22 countries) and Latin America **M5.1.3.4 (2012)** Consumer preferences among different categories of populations of 2 West African countries acheived **M5.1.3.5 (2014)** Relationship between sensorial and instrumental characterization of "reference" consumer preferences established		Asia, Africa and Latin America, Philippines	**IRRI, CIRAD, AfricaRice (Africa) & CIAT (LAC)** NARES, H. Keller Intl., NARES, FLAR

R&D Product Line: 5.2. Spatial analysis for effective technology targeting and deployment strategies

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**	**Outcomes**	**Target region/key countries**	**Lead institution in GRiSP and key partners**
5.2.1. Faster key-information delivery on rice agro-ecologies using innovative remote-sensing and mapping systems	**M5.2.1.1 (2011-15)** Rice areas of Sub Saharan Africa, South, Southeast and East Asia mapped and classified **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 **M5.2.1.3 (2011)** Rice phenology (start date, end date, length of season, length of fallow period, amplitude) for different agroecosystems identified. **M5.2.1.4 (2013)** Annual crop calendar and fallow period database developed for Asia including climate data and potential yield estimates for 2000-2013	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.	South, SE, E Asia and Africa	**IRRI, Africa Rice** NARES, Lund University, CNR, PhilRice, SARMAP, European Space Agency, and IWMI
5.2.2. Improved characterization of abiotic and biotic stresses in major rice-growing areas of Asia and Africa	**M5.2.2.1 (2012)** Areas subject to drought and submergence in South and SE Asia mapped and classified based on duration and frequency **M5.2.2.2 (2012)** Areas subject to abiotic stresses in Africa mapped and classified based on duration and frequency **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 **M5.2.2.4 (2011-2012) I**nteractive maps of the distribution of biotic and abiotic stresses, frequency, areas affected and yield losses for the 21 CARD countries and Niger	Short-term: New rice technologies that are more targeted and appropriate for farmers needs and constraints. Long-term: Increased adoption of appropriate rice technologies and availability of new drought tolerant rainfed lowland elite lines for national	South and SE Asia and Africa	**IRRI, AfricaRice** NARES

	M5.2.2.5 (2011-2013) Interactive maps of the Participatory Varietal Selection (PVS) data			
5.2.3. Spatial characterization of socio-economic domains and mega environ-ments for technology targeting and delivery	**M5.2.3.1 (2011)** 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. **M5.2.3.2 (2012)** A biophysical characterization based on agricultural and ecological factors such as climate, soils and growth cycles and crop duration **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. **M5.2.3.4 (2015)** Assessment of how markets will change under economic, demographic and climate change scenarios.	Short-term: New rice technologies that are more relevant and appropriate for farmers needs and constraints as a result of better characterization of target environments. Long-term: Increased adoption of appropriate rice technologies.	South and SE Asia, Africa	**IRRI, AfricaRice** NARES

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	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
5.3.1. Global rice monitoring and forecasting system	**M5.3.1.1 (2011)** Development of monitoring and forecasting system. **M5.3.1.2 (2011)** Establishment of the Rice Information Gateway for Africa (RIGA) portal. **M5.3.1.3 (2012-2015)** Monthly updates on rice production during cropping season **M5.3.1.4 (2014)** New outlets (mobile phone) for dissemination of market updates.	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.	Asia and Africa	**IRRI & AfricaRice** PhilRice, SARMAP, European Space Agency and NARES
5.3.2. Medium-term outlooks for global rice markets using a new supply and demand model	**M5.3.2.1 (2011-2015)** Development of a partial equilibrium econometric model for Asia, Africa and Latin America and quarterly update on medium-term outlook for global rice market. **M5.3.2.2 (2011-2015)** Semi-annual briefing of the state of the rice economy to Policymakers, media and other stakeholders.	Short-term: Regular information on market outlook helps traders and policymakers in making timely decision on domestic support policies. Long-term: Informed decision making by Policymakers in formulating appropriate policies	Global & Regional	**IRRI & AfricaRice** IFPRI, CIRAD, NARES, University of Missouri, Iowa State University
5.3.3. Rice databases to support rice policy, technology targeting and impact assess-ment	**M5.3.3.1 (2011-2015)** Monthly update of national rice statistics (production, consumption, trade and prices). **M5.3.3.2 (2011-2015)** Annual update of sub-national rice statistics on area, yield and production. **M5.3.3.3 (2011)** The Africa Rice Trends and the Africa Rice Facts books are published on RIGA as Wikis. **M5.3.3.4(2011)** Capacity building for NARES economists and statisticians on the use of survey data management, processing, and publishing tools **M5.3.3.5 (2011-2015)** Existing household survey datasets updated and made available online.	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.	Global & Regional, Asia and Africa	**IRRI &AfricaRice** CIAT, CIRAD, and NARES

R&D Product Line: 5.4. Sustainable rice policies for a globalized world

Intermediate users: Analysts in ministries of agriculture, trade and finance, and private sectors
Final users: Policymakers, ASEAN Secretariat, ECOWAS Commission, agricultural development agencies and commodity groups
Expected impact: Improved decision making by policymakers in formulating national and international policies for sustainable rice production.
Key current projects: EU, CIDA, BMGF-Global Futures (IFPRI),

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
5.4.1. Quantitative assessment of domestic and trade policies including input subsidies for sustainable rice production	**M5.4.1.1 (2011-2015)** Five technical reports on effects of domestic and trade policies for major rice growing countries. **M5.4.1.2 (2011-2015)** Capacity building for national agricultural research and extension system partners in conducting rice policy analysis **M5.4.1.3 (2012)** Consultative frameworks for rice policy dialogue and for West Africa rice sector development strategy established with ECOWAS, UEMOA, ROPPA and the West Africa Women Rice Producers Association	Short-term: Timely information on policy effects helps policymakers in making accurate decision on domestic support policies. Long-term: Informed decision making by Policymakers in formulating appropriate policies for achieving national food security	Asia, Africa, ECOWAS, and UEMOA countries	**IRRI & AfricaRice** NARES, CIRAD, CIAT, IFPRI, University of Missouri, Michigan State University, ECOWAS and UEMOA Commissions
5.4.2. Opportunities identified for regional integration of rice policies including trade and reserve policies	**M5.4.2.1 (2011)** Comprehensive database of rice policies affecting production, consumption and trade for major rice growing countries. **M5.4.2.2 (2012)** Evaluation of the economic cost, benefit and viability of regional rice storage systems in the ECOWAS zone and the ASEAN region. **M5.4.2.3 (2013)** Economic costs and benefits of coordinating and harmonizing rice trade policies of West Africa and ASEAN regions **M5.4.2.4 (2013)** Rice policy research and advocacy conference with RECs and other regional rice stakeholders **M5.4.2.5 (2013)** Assessment of the competitiveness of domestic rice production for 12 CARD countries **M5.4.2.6 (2014)** Examination of various factors affecting international rice price fluctuations and transmissions using time series analysis.	Short-term: Comparative policy analysis helps with making decision on regional market integration. Long-term: Smooth functioning of rice market by reducing price variability.	Global, ASEAN Countries, UEMOA countries, ECOWAS, Africa	**IRRI for ASEAN, AfricaRice for West Africa and ECOWAS zone, CIRAD** ASEAN Secretariat, ADB ECOWAS and UEMOA Commissions, MSU, and NARES

R&D Product Line: 5.5. 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	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
5.5.1. Foresight and intelligence for strategic assessment of research priorities	**M5.5.1.1 (2011)** Comparative analysis of likely economic, poverty and environmental impacts expected from specific international rice research investment options in Asia and Afirca **M5.5.1.2 (2011)** Ex-ante and ex-post assessment of the impact of improved grain quality, post harvest and policy research in Africa. **M5.5.1.3 (2012)** Platform for rational decision-making on rice research and technology investment; report on rice prospective for 2050 for LAC. **M5.5.1.4 (2013)** Analysis of the evolving roles and foci of different agencies in global rice research systems **M5.5.1.5 (2015)** Updated comparative analysis of likely economic, poverty and environmental impacts expected from specific international rice research investment options in Asia and Africa	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	Asia, Africa, and Latin America	**IRRI, AfricaRice and CIRAD** IFPRI, NARES, ARIs, CIAT, and NARES
5.5.2. Ex post assessment of aggregate technology adoption trends and associated economic, poverty and environmental impacts	**M5.5.2.1 (2012-2013)** Assessment of the diffusion and adoption of modern rice varieties in Asia and Africa. **M5.5.2.2 (2013)** Assessment of the impact of agronomic research in Latin America **M5.5.2.3 (2013)** Assessment of economic, environmental and poverty impacts from the adoption of efficiency enhancing NRM technologies in subregions of Asia. **M5.5.2.4 (2011-2015)** Capacity building of NARES economists on impact assessment methodologies. **M5.5.2.5 (2014)** Global analysis of the economic, poverty and environmental impact of rice genetic improvement by the IARCs	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	Asia, Africa, and Latin America	**IRRI, AfricaRice and CIAT** PhilRice, BRRI, Humboldt University and NARES

Theme 6: Supporting the growth of the global rice sector

Product line 6.1. 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 a number of 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 ageing 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 post-harvest technologies. In the case of Sri Lanka, in addition, in certain regions there has been upheaval as a result of the recent civil war. There is the 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 are made with large scale or regional investments, and that there is 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 levels in rice production and post harvest 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

A new team of extension agronomists and business development specialists will be established at IRRI for linking research outputs to supporting the design and piloting of improved delivery systems, including business models for large scale roll-out of technologies. This cadre will be crucial for building awareness and linkages to national and regional investment for large scale diffusion of new technologies. IRRI will also seek to partner in new investments to support reconstruction in the war torn areas of northern Sri Lanka or other countries. An NGO summit will be held to frame an alliance for large scale rice technologies particularly to support technology delivery to women and poorer farm households.

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 grassroots 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 multi-channel 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 outscaled to other countries in the region. Women leadership training will be conducted and followed up with the formation of a network for women's leaders that will support the enhanced capacity of grassroots extension staff.

Through the STRASA and CSISA projects, IRRI in partnership with CIMMYT, ILRI, IFPRI and over 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 deliver of new information and technologies, including use of new Hub Communication Platforms. Evidence based information to support the above activities will be made available through the private and public sectors and civil society organizations for the intensive cereal systems and for the stress prone environments.

Products

6.1.1. Rice Knowledge Bank, training modules, and novel communication tools for enhanced diffusion
6.1.2. New models for seed multiplication and targeted delivery systems
6.1.3. New platforms for delivering agronomic, postharvest and processing innovations
6.1.4. New models for jointly building extension capacity building

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, there are opportunities 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 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 *grassroots* extension capacity with intermediary institutions and farmers organizations. Capacity building will link directly with the online up-to-date technical knowledge of the global, the country RKBs, the hub communication platform and innovative communication products. The above components will underpin the activities of skilled extension personnel and enable them to effectively deliver new rice technologies. In addition, a *grassroots* 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 projects currently provide support – CSISA and STRASA. The initial undertaking is for three years with expected support over a ten 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, also in Pakistan, Nepal and Sri Lanka. New funding is required to build up a strong, professional extension support team in IRRI to link science with development efforts on the ground. Further support is required to support the development of communication approaches and information systems.

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

Rationale

There is strong demand for new rice technologies by large numbers of farmers in Southeast and East Asia. This is reflected at national level, for example, in the Philippines with the government's *Rice Self Sufficiency Plan* and at provincial level with the local government and IRRC investment in An Giang province, Vietnam, which promotes Good Agricultural Practices (GAP) for rice. In Indonesia there is 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 to support for delivery in the irrigated and rainfed rice ecosystems. There remains considerable unsatisfied demand however in Southeast and East Asia for support in the delivery of agronomic, post-harvest 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. Development of information resources, training materials, communication methods and capacity building are required to facilitate the large scale delivery of resources. To support the delivery of innovations, this product line will aim develop the means to underpin and facilitate the large scale dissemination of rice technologies in Vietnam, Indonesia, 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 between various scientists in 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: i) Development of innovative diffusion pathways for AWD and SSNM in the Philippines; ii) 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; iii) IRRC Country Outreach Program (ICOP) on NRM of rice in Myanmar in 3 Divisions; iv) Delivery of “Good Agricultural Practices” for rice (Rice GAP) through ICOP in 5 provinces in Mekong delta, Vietnam; v) Linkages established with IFAD investment programs for outscaling of CURE technologies for upland and drought prone areas; vi) delivery of "Good Agricultural Practices" for unfavorable areas; and vii) delivery of technologies for salinity and submergence prone conditions in Mekong delta along with support for capacity in seed processing.

Products

6.2.1. Rice Knowledge Bank, training modules, and novel communication tools for enhanced diffusion

6.2.2. New models for seed multiplication and targeted delivery systems

6.2.3. New platforms for delivering agronomic, postharvest and processing innovations
6.2.4. New models for jointly building extension capacity

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

Large scale dissemination will build on experience derived from the IRRC's ICOPs dissemination experience that provide linkages between adaptive research and extension. RKBs along with innovative communication products will support the capacity building of extension and resource 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 grassroots 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 through theme 5.

Financing strategy
Financial support is provided through a number of research and development initiatives – SDC, ADB, ACIAR and private sector grants (IFA, IPNI, IPI) for supporting the IRRC; an IFAD grant for CURE and Philippines government grants for the RSSP. Co-investments are being made through the 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 sub-contractor for the rice component of larger projects. Project funds will be sought to develop the partnerships, and innovative communication and extension approaches required to be support large scale-delivery. New funding is required to build up a strong, professional extension support team in IRRI to link science with development efforts on the ground. Further support is required to support the development of communication approaches and information systems.

Product line 6.3. 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 national and regional level and from donor side is mounting to boost Africa's rice sector and invest in production, processing, storage and distribution and 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 sub-optimal 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 level 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 research products reach many more prospective users in Africa than through research networks alone. It will also be crucial to ensure that products will 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 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, entirely focusing 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).

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) that 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 delivery of technologies and principles of rice value chain development will include:

- 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
- Capacity building of extension agents, from both governmental and non-governmental agencies, actively targeting women leaders to play a pro-active role in their communities
- Rebuilding national rice research and extension capacity in post-conflict countries, such as Liberia

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

Products

6.3.1. Rice knowledge bank, training modules, and novel communication tools for enhanced diffusion
6.3.2. New models for seed multiplication and targeted delivery systems
6.3.3. New platforms for delivering agronomic, postharvest and processing innovations
6.3.4. New models for jointly building extension capacity
6.3.5. Rebuilt rice research and extension capacity in post-conflict countries

Uptake and impact pathway

Research products will be out-scaled through (i) the development of appropriate learning tools and media (training modules, videos, rice knowledge bank etc.) translated into local languages, (ii) capacity building of rice extension staff, effectively training trainers, and (iii) lasting links with large development projects and partners to promote large-scale adoption of agronomic, post-harvest 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 Africa 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 NARS partners, such as Egypt, Ghana and Mali.

Product line 6.4. Effective systems for large-scale adoption of rice technologies in Latin America and the Caribbean

Rationale

Rice production in LAC is done across a number of different environments, crop systems, land and water availability and farmer's size and socio-economic 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 like the ones in South 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 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 lack of effective seed systems. There is a range of problems from weak seed laws, lack of institutional support for variety maintenance, basic and certified seed production, effective certification programs and the education of farmers about the value of high quality seed. Finally, there are few technological options 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 it is properly used for production. There are good opportunities in the tropics for developing simple on farm water harvesting techniques that could help farmers shifting 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 like 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 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 directly involved institutions 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 their participation in designing and executing these programs is also needed. There is good experience at FLAR to implement and expand in the whole region this kind of program, starting with a diagnostic of few key management factors to improve, identifying innovative farmers to do initial validation plots, implement farmers' groups around these farmer leaders and conduct 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

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

6.4.2. Effective variety release mechanisms and seed systems for delivering high quality seed of new varieties

6.4.3. 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 adopt best management practices in 6 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 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 for product diversification, including corn, beans and fish production, and for higher and more stable income and countries improve food security

Uptake and impact pathway

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 policy makers. 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.

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 kind of development supports. For improving seed systems in selected countries there will be an initial diagnostic bottlenecks (variety purification, basic seed, lack of seed producers, seed industry, seed laws, etc) and identification of improvements, development of proposals targeting each country or region problems and implementation of these proposals in joint-venture with local public and private institutions. The whole process must be done in alliance with the farmers' associations, the NARS 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.

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 actively seek such links as a sub-contractor for the rice component of larger projects. Project funds will be sought to develop partnerships, and innovative communication and extension approaches required to be support large scale-delivery.

Theme 6 logical framework: Supporting the growth of the global rice sector

R&D Product Line: 6.1. 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, BMGF-STRASA, IFAD-South Asia, IFAD-CURE, IRRC (SDC, ABD, ACIAR, IFA, IPNI, IPI), ACIAR-R-M

Products	**Milestones**	**Outcomes**	**Target region/key countries**	**Lead institution in GRiSP and key partners**
6.1.1. Rice Knowledge Bank, training modules, and novel communi-cation tools for enhanced diffusion	**M6.1.1.1 (2012)** Country RKB/CKB with strong links to global rice knowledge providing up to date rice knowledge for large scale dissemination in rice investment projects **M6.1.1.2 (2014)** New mobile phone product for widespread dissemination extension established and used; **M6.1.1.3 (2014)** Extension methodology courses and rice production and processing training are available online, on CD, and through community radio **M6.1.1.4 (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)	Short-term: Up-to date rice knowledge is used by public and private extension and delivery systems for key hubs in South Asia. Teams of public and private sector professionals jointly develop local knowledge for delivery purposes. Long-term: Strong links with local and national extension, services, and information providers leads to more rapid spread of information on best management practices to farmers, including multiple public and private sector channels for last-mile delivery. Enhanced interaction between public sector, NGOs, private sector.	India, Nepal, Bangladesh, Pakistan, Sri Lanka	**IRRI** CIMMYT, national rice research institutions, NGOs, media bodies (tele-centers, community radio and mobile phone companies)
6.1.2. New models for seed multiplication and targeted delivery systems	**M6.1.2.1 (2012)** At least 10 public and private seed companies produce and deliver high quality seed for intensive cereal systems; **M6.1.2.2 (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	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.	India, Nepal, Bangladesh	**IRRI** State universities of India, NARC (Nepal), BRRI (Bangladesh), NGOs, private seed companies, state seed delivery services, large scale investors (national food security initiatives, IFAD, WB, ADB, others)

6.1.3. New platforms for delivering agronomic, postharvest and processing innovations	**M6.1.3.1 (2012)** A new team professional agronomists and business development specialists is formed at IRRI and provides technical support to large-scale development efforts. **M6.1.3.2 (2012)** At least five private companies sign up to successful and profitable business models for out scaling intensive cereal systems technologies **M6.1.3.3 (2013)** Hub Communication Platforms (HCP) established to provide seasonal monitoring information for extension service providers in five hubs (India, Nepal, Bangladesh) **M6.1.3.4 (2014)** IRRI provides rice technical support to at least two large scale investment projects in South Asia **M6.1.3.5 (2015)** Through improved management of intensive cereal systems at least 2 million poor rural households increased annual income by $350	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 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.	India, Nepal, Bangladesh	<u>**IRRI**</u> CIMMYT, NARES, private sector (large and small input and machinery manufacturers and supplies, service providers, retailers, processors, marketers), Awhere, grassroots NGOs, large scale investors (national food security initiatives, IFAD, WB, ADB, others)
6.1.4. New models for jointly building extension capacity	M6.1.4.1 (2012) New accreditation schemes for Certified Crop Advisors (CCA) in India with at least 400 certified agronomists trained M6.1.4.2 (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) M6.1.4.3 (2013) New retailer training and certification program for India and Bangladesh (with public and private sector) M6.4.1.4 (2015) Trained resources of milestones 6.1.4.1-3 provide training for at least 10000 grassroots extension persons, including women	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.	India, Nepal, Bangladesh	<u>**IRRI**</u> Agronomy Society of America, Inidan Ag Business Society, DSCL, National research institutions and universities, private sector, NGOs, local and national media

R&D Product Line: 6.2. 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:	IFAD-CURE, IRRC (SDC, ABD, ACIAR, IFA, IPNI, IPI), DA-RSSP, ACIAR-Cambodia & Laos

Products	Milestones	Outcomes	Target region/key countries	<u>Lead institution</u> in GRiSP and key partners
6.2.1. Rice Knowledge Bank, training modules, and novel communication tools for enhanced diffusion	**M6.2.1.1 (2012)** Country RKB with strong links to global rice knowledge (e.g., IRRI RKB) providing up to date rice knowledge for large scale dissemination in rice investment projects **M6.2.1.2 (2012)** New mobile phone product for SSNM extension used in widely in the Philippines (telecommunication company support) **M6.2.1.3 (2015)** Extension methodology courses and rice production and processing training available online, on CD, and through community radio for capacity building in local languages **M6.2.1.4 (2015)** Multi-channel communication approaches for rice technology dissemination established (with at least three telecenter networks, 2 cell phone companies, 2 TV companies and 2 community radio networks)	Short-term: Up-to date rice knowledge is used by public and private extension and delivery systems for key hubs in SE Asia. Teams of public and private sector professionals jointly develop local knowledge for delivery purposes. Long-term: Strong links with local and national extension, services, and information providers leads to more rapid spread of information on best management practices to farmers, including multiple public and private sector channels for last-mile delivery. Enhanced interaction between public sector, NGOs, private sector.	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	**<u>IRRI</u>** National rice research institutions, NGOs, media bodies (telecenters, community radio and mobile phone companies), post-harvest alliances
6.2.2. New models for seed multiplication and delivery systems	**M6.2.2.1 (2012)** Variety release and seed systems analyzed; recommendations for harmonization and improvement **M6.2.2.2 (2015)** Improved seed delivered through private and public sector channels	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.	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	**<u>IRRI</u>** NARES, NGOs, private seed companies, state seed delivery services, large scale investors (IFAD, WB, ADB, others)

6.2.3. New platforms for delivering agronomic, post-harvest and processing innovations	**M6.2.3.1 (2012)** A new team professional agronomists and business development specialists is formed at IRRI and provides technical support to large-scale development efforts. **M6.2.3.2 (2012)** At least two investment fund partnership being implemented with IRRI as key partner for rice; **M6.2.3.3 (2014)** Support for delivery and adoption of AWD and SSNM to at least 300,000 farmers in the Philippines **M6.2.3.4 2014** Support delivery and adoption of Rice GAP to 1 million farmers in Indonesia **M6.2.3.5 2015** Support delivery and adoption of Rice GAP to 400,000 farmers in the Mekong Delta, Vietnam	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 out-scaling through multiple public and private sector channels. 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.	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	**IRRI** NARES, private sector (large and small input and machinery manufacturers and supplies, service providers, retailers, processors, marketers), post-harvest alliances, grassroots NGOs, large scale investors (national food security initiatives, IFAD, WB, ADB, others)
6.2.4. New models for jointly building extension capacity	**M6.2.4.1 (2014)** New accreditation scheme for certified extension-agronomists (CCA) in one SE Asian country, with at least 400 trained professionals **M6.2.4.2 (2015)** Need based training of local women leaders who will provide training to women farmers on farm management, technical information and skills from production to post harvests (25 persons per year) **M6.2.4.3 (2015)** Trained resource of milestone 6.2.4.1 and 6.2.4.2 provide training for 5000 grassroots extension persons, including women	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.	Vietnam, Indonesia, Myanmar, Philippines, Laos, Cambodia, Thailand	**IRRI** IRRI, NARS, private sector and civil society partners

R&D Product Line: 6.3. 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, Japan, AfDB , World Bank, USAID

Products	Milestones	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
6.3.1. Rice Knowledge Bank, training modules, and novel communication tools for enhanced diffusion	**M6.3.1.1 (2010)** Joint release IRRI, AfricaRice and BRRI of e-seed training course; **M6.3.1.2 (2012)** 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 **M6.3.1.3 (2013)** Public-private partnerships for large-scale video diffusion tested, documented and extended in at least three countries **M6.3.1.4 (2013)** New series of organizational and institutional videos produced on water user groups, saving and credit groups, marketing, etc **M6.3.1.5 (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 **M6.3.1.6 (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	Short-term: Up-to date rice knowledge is used by public and private extension and delivery systems for key hubs in Africa. Teams of public and private sector professionals jointly develop local knowledge for delivery purposes. Long-term: Strong links with local and national extension, services, and information providers leads to more rapid spread of information on best management practices to farmers, including multiple public and private sector channels for last-mile delivery. Enhanced interaction between public sector, NGOs, private sector.	Africa	**AfricaRice** IRRI, NARES, Agha Khan Foundation, CRS, SAA, IFAD, CFC, Country-wise Communication, WUR
6.3.2. New models for seed multiplication and seed delivery systems	**M6.3.2.1 (2013)** At least 20 public-private partnerships established to strengthen the rice seed sector with functional seed board in 5 WCA countries **M6.3.2.2 (2013)** At least 10 private seed companies strengthened through supply of up to date information on farmers' needs and latest technologies in 3 ESA countries	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	Africa	**AfricaRice** IRRI, NARS, private sector and civil society partners

	M6.3.2.3 (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	channels. Long-term: Improved on-farm conservation and high proportion of farmers using improved varieties and high-quality seed.		
6.3.3. New platforms for delivering agronomic, post-harvest and processing innovations	**M6.3.3.1 (2011)** Link established with IFAD investment projects in 6 WCA and ESA countries **M6.3.3.2 (2013)** Productivity significantly enhanced in 60 key villages (rice knowledge centers) **M6.3.3.3 (2015)** Outscaling of innovations to second generation farming communities, reach at least 20,000 farming families per country **M6.3.3.4 (2015)** Public-private sector partnerships to stimulate mechanization of the rice sector established in at least 4 countries in SSA	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. 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.	Africa	**AfricaRice** IRRI, NARES, grassroots NGOs (CRS, SAA), private sector (machinery manufacturers, input suppliers, service providers, retailers, processors, marketers), large scale investors (national food security initiatives, IFAD, WB, ADB, others)
6.3.4. New models for jointly building extension capacity	**M6.3.4.1 (2014)** New accreditation schemes for extension-agronomists **M6.3.4.2 (ongoing)** Need based training of local women leaders who will provide training to women farmers on farm management, technical information and skills from production to post harvest **M6.3.4.3 (2015)** Trained resource of milestone 6.3.4.1 and 6.3.4.2 provide training for 2000 grassroots extension persons, including women	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.	Africa	**AfricaRice** ICRA, WUR, IRRI, NARES

6.3.5. Rebuilt rice research and extension capacities in post-conflict countries	**M6.3.5.1 (2011)** National rice research team established **M6.3.5.2 (2012)** National rice research strategy adopted **M6.3.5.3 (2013)** National rice research projects acquired **M6.3.5.4 (2011)** First national rice extension agents trained **M6.3.5.5 (2015)** National rice research and extension institutions fully operational	Short-term: National rice research and extension institutions are re-established and rice research projects are acquired. Long-term: National rice research and extension institutions are fully operational and supported by project funds and the national government.	Liberia	**AfricaRice** IRRI, CARI/Ministry of Agriculture, international development companies

R&D Product Line: 6.4. Effective systems for large-scale adoption of rice technologies in LAC

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	Outcomes	Target region/key countries	Lead institution in GRiSP and key partners
6.4.1. Systems for enhanced extension of improved crop management practices for closing yield gaps among farmers	**M6.4.1.1 (2013)** Access and use of information and technology improved **M6.4.1.2 (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	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	Colombia, Venezuela, Guyana, Surinam, Ecuador, Peru, Bolivia, Chile, Panamá, Costa Rica, Nicaragua, Honduras, Salvador, México, Guatemala, Cuba, D.Republic	**FLAR/CIAT** IRRI, NARS, NGO, Rice Grower Associations, Millers, Seed Companies, Catholic Relief Services
6.4.2. Effective variety release mechanisms and seed systems for delivering high quality seed of new varieties	**M6.4.2.1 (2013)** Variety release process improved and accelerated. Public breeding and certification agencies well organized and private seed industry developed. **M6.4.2.2 (2014)** Improved seed purification and basic seed production by partner organizations. Certified seed is produced in adequate volumes to cover demand **M6.4.2.3 (2015)** Increased volume of certified seed sold to farmers	High percentage of the farmers use certified seed of new varieties New varieties reach farmers in less time than previously Good quality seed reduce weed, pest and diseases problems Substantial increases in yields and in the quality of grain are obtained by farmers	Guatemala, Honduras, Nicaragua, Guyana, Ecuador, Bolivia	**FLAR/CIAT** NARS, FLAR members, seed companies, certifying agencies, Catholic Relief Services
6.4.3. Systems for enhanced adoption of water harvesting technology in the tropics for land transformation to irrigated agriculture	**M6.4.3.1 (2011)** Sites selected and reservoir designs prepared in the target regions **M6.4.3.2 (2013)** Water collecting facilities constructed. Transfer and extension programs in place in each pilot location. **M6.4.3.3 (2015)** Financial and technical support in place to expand water harvesting to more farmers; increased number of small reservoirs constructed	Small and medium rice farmers in the tropics changed from low yield low income upland rice to high yielding and highly efficient irrigated agriculture. Water availability allows for product diversification, including corn, beans and fish production Farmers have higher and more stable income and countries improve food security	Nicaragua, Costa Rica, Honduras, Mexico, Guatemala, Panamá, Colombia, Ecuador, Bolivia	**FLAR/CIAT** NARS, FLAR member, Government agencies, local and regional develop-ment banks

Appendix 4. Statements of support and contributions to GRiSP by strategic 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)
- Latin American Fund for Irrigated Rice (FLAR)
- Africa Harvest

Montpellier, May 10, 2010

Dr Achim Dobermann, DDG4R IRRI
Dr Marco Wopereis, DDG4R AfricaRice
Dr Joe Tohmé, DDG4R CIAT

Subject: 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

This is to confirm CIRAD and IRD's agreement and wish to fully participate in the construction and implementation of the MP3 - Rice/GRISP through the scientific contribution of our research teams and by participation in the future scientific management body of this Megaprogramme.

We appreciate that Cirad and IRD were invited to participate in the writing workshop (April 26-30) at Los Baños. This allowed integrating a significant part of our research activities in the product-lines of the GRiSP proposal.

We consider that a new round of interaction is needed in the coming weeks to fully integrate Cirad and IRD's offer to GRiSP and also to involve other main actors from South and North. We very much want to take a co-construction approach. We, with other French institutions, are enthusiastic about contributing to this global initiative with our human resources and scientific platforms.

You will find below a tentative estimate of the financial input of our scientific contribution as it is integrated in the current proposal, as well as a possible additional contribution that could be added in the near future.

Best regards

pp.

Bernard Dreyfus — Director Living Resources IRD

Etienne Hainzelin — Director of Research & Strategy, CIRAD

For Cirad + INRA[1] & SupAgro[1]

GRiSP Themes	Contribution Integrated in the GRiSP Log-frame			Additional contribution to be integrated in the future		
	Product lines	HR (FTE)	Estimated current annual investment (US $)	Product lines	HR (FTE)	Estimated current annual investment (US $)
1	PL1.2, PL1.3	10	2 080 000	PL1.1, PL1.3, PL1.6	9.5	1 976 000
2	PL2.2, PL2.4, PL2.7	6.8	1 414 400			
3	PL3.1, PL3.5, PL3.7	9	1 872 000	PL3.1, PL3.2, PL3.3, P3.4, PL3.5, PL.3.6	20	4 160 000
4	PL4.2, PL4.3	2.5	520 000	PL4.3	1	208 000
5	PL5.3, PL5.4	2	416 000			
6	-	-	-	-	-	-
Total		**30.3**	**6 302 400**		**30.5**	**6 344 000**

For IRD + CNRS/ University of Perpignan [2]

GRiSP Themes	Contribution Integrated in the GRiSP Log-frame			Additional contribution to be integrated in the future		
	Product lines	HR (FTE)	Estimated current annual investment (US $)	Product lines	HR (FTE)	Estimated current annual investment (US $)
1	PL1.2, PL1.3	14	2912000	PL1.2, PL1.3	8*	1 664 000
2	PL2.2	6	1248000			
Total		**20**	**4 160 000**		**8**	**1 664 000**

1: the rice blast team within the BGPI mixed research unit;
2: including 5 CNRS and University of Perpignan /FTE specialized in Rice comparative Genomics and structural genome annotation

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)

www.nepad.org
info@nepad.org
Tel: +27 (0) 11 256 3600
Fax: +27 (0) 11 206 3762

P.O. Box 1234
Halfway House 1685
Midrand, Johannesburg
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

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

CARD Secretariat, c/o AGRA
Eden Square, Block 1, 2nd Floor
PO Box 66773, Westlands, 00800
Nairobi, Kenya

T: +254-(0)20-3675-000
T: +254-(0)20-3675-236 (direct)
F: +254-(0)20-3750-653
E: cardsecretariat@agra-alliance.org

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

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,

LETTER OF SUPPORT FOR THE GLOBAL RICE SCIENCE PARTNERSHIP (GRISP)

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 by IRRI, 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
Baltimore MD USA

www.crs.org

May 3, 2010

CIAT – Apartado Aéreo 6713, Cali, Colombia
http://www.flar.org
Teléfono: (57-2) 445 0052
Fax: (57-2) 445 0094
E-mail: g.zorrilla@cgiar.org

Robert ZEIGLER, Director General, IRRI
Papa SECK, Director General, Africa Rice Center
Ruben ECHEVERRIA, Director General, CIAT
Emile FRISON, DIrector General, Bioversity International
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

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

Principal Contacts

Dr. Achim Dobermann
Deputy Director General (Research)
International Rice Research Institute (IRRI)
Telephone: +63 (2) 580-5600 ext. 2773 or 2212
Email: a.dobermann@irri.org
Mailing address: IRRI, DAPO Box 7777, Metro Manila, Philippines

Dr. Marco Wopereis
Deputy Director General
Africa Rice Center (AfricaRice)
Telephone: +229 – 21350188
Email: m.wopereis@cgiar.org
Mailing address: AfricaRice, 01 BP 2031 Cotonou, Benin

Dr. Joe Tohme
Agrobiodiversity Research Area Director
Centro Internacional de Agricultura Tropical (CIAT)
Telephone: +57 (2) 4450000
Email: j.tohme@cgiar.org
Mailing address: Km 17, Recta Cali-Palmira
Apartado Aéreo 6713, Cali, Colombia