


Rice Agri-Food System CRP, RICE



Full proposal and flagship projects; July 2016

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0.0 Executive summary

Rationale and scope

Rice is the world's most important staple food and will continue to be so in the coming decades, be it in terms of food security, poverty alleviation, youth employment, use of scarce resources, or impact on the climate.

Rice is a staple food for some 4 billion people worldwide, and it provides 27% of the calories in low- and middle-income countries. Based on expected population growth, income growth, and rice acreage decline, global demand for rice will continue to increase from 479 million tons milled rice in 2014 to 536–551 million tons in 2030, with little scope for easy expansion of agricultural land or irrigation—except for some areas in Africa and South America.

Rice farming is associated with poverty in many areas. About 900 million of the world's poor depend on rice as producers or consumers, and of these, some 400 million poor and undernourished people are engaged in growing rice, mostly on land holdings of less than 20 hectares

In the future, given declining environmental quality worldwide, rice will have to be produced, processed, and marketed in more sustainable and environment-friendly ways, despite the diminishing availability of resources (land, water, labor, and energy). Climate change is exacerbating the situation through the effects of higher temperatures, more frequent droughts and flooding, as well as sea-level rise, which threatens rice production in mega-deltas. Nevertheless, the necessary increases in rice production to meet future demand have to come mainly from increases in yield per unit of land and water.

While rice is an excellent source of calories and some nutrients, there is considerable scope to improve the nutritional quality of rice-based diets through biofortification, optimizing processing, and through dietary diversification.

Women make significant contributions to rice farming, processing, and marketing, and play a dominant role in buying rice for consumption. Yet, women still face many barriers and inequality in access to and control over resources such as information and inputs. These gender inequalities reduce women-managed farm productivity by 20–30% compared to that of farms managed by men. Such inequalities also hinder the progress of other development outcomes such as family planning; maternal, newborn, and child health; nutrition; education; and food security. With appropriate technological, institutional, and policy support, rice farming, processing, and marketing, could offer equal opportunities of employment for women and men and help to empower women, thus accelerating attainment of food security and poverty alleviation.

Structural transformation of the economies of some Asian countries is affecting rice farming. In so-called "dynamic zones" in these countries, the previous trend to small, hand-operated farms is changing because land consolidation and mechanization are offering farmers unprecedented opportunities to escape from poverty. However, farmers in Asian "hinterlands," in most of the northern part of South America and in Central America and the Caribbean, and in most of sub-Saharan Africa still need access to better technologies to increase productivity and cope with the effects of climate change in order to escape from poverty. In the Southern Cone of South America, farms are generally large; the

issues that farmers face there concern environmental sustainability, adaptation to climate change, and competitiveness in global markets.

With increasing youth unemployment in some parts of the world, especially in sub-Saharan Africa, and aging of the rural population in others, as in those parts of Asia undergoing rapid structural transformation, it is imperative to develop attractive job opportunities in the rice sector for the young.

Goals, objectives, and targets

The Rice Agri-Food System Research Program, or RICE, will address all these concerns. It aims to reduce poverty and hunger, improve human health and nutrition, adapt rice-based farming systems to climate change, promote women's empowerment and youth mobilization, and reduce rice's environmental footprint.

Through research and development in collaboration with large numbers of partners in public and private, national and international research and development institutions, national agricultural research and extension systems, and nongovernmental organizations, RICE expects to

- help at least 13 million rice consumers and producers, half of them female, to exit poverty by 2022, and another 5 million by 2030;
- assist at least 17 million people, half of them female, out of hunger by 2022, rising to 24 million by 2030; and
- assist at least 8 million people, half of them female, to meet their daily Zn requirements from rice by 2022, rising to 18 million by 2030.

These outcomes will be possible by

- helping at least 17 million more households to adopt improved rice varieties and/or farming practices by 2022 and a further 19 million by 2030;
- improving the annual genetic gain in rice (as measured in breeders' trials) to at least 1.3% by 2022, rising to 1.7% by 2030;
- helping increase annual global (milled) rice production of 479 million tons in 2014 to at least 536 million tons by 2022 and to 544 million tons by 2030;
- increasing water- and nutrient-use efficiency in rice-based farming systems by at least 5% by 2022, rising to 11% by 2030, and
- helping reduce agriculture-related greenhouse gas emissions in rice-based farming systems by at least 28.4 megatons carbon dioxide (CO_2) equivalent/year by 2022 and by a further 28.4 megatons CO_2 equivalent/year by 2030, compared to business-as-usual scenarios.

Impact pathway and theory of change

The impact pathways through which these outcomes will be achieved comprise a great many interventions along the rice value chain from farmer to consumer; for example, by intensification and diversification of farms, genetic improvement and improved crop and natural resource management, reduced pesticide use and development of pest- and disease-resistant varieties, integrated pest

management and ecological engineering, increasing the marketability and value of products and by-products, increasing participation in the value chain, increasing the content of minerals and micronutrients in rice grains, and improving the glycemic index of rice.

Different pathways exist by which agricultural research can increase the sustainability of production, reduce the use of precious resources, increase ecosystem services, and reduce negative environmental externalities such as greenhouse gas emissions and loading of agrochemicals in rice production. Increasing the productivity of inputs reduces their amounts used per unit of production. This increase can be realized through an increase in effective use, or uptake of these inputs, and the accompanying reduction in their loss to the environment. Changed water and soil management practices can reduce the emission of greenhouse gases. Crop diversification also contributes to increased sustainability, adaptive capacity to shocks, and more nutrient-diverse diets.

RICE will deliver international public goods as well as locally tailored solutions such as genes and markers, breeding lines, improved varieties, improved crop management and postharvest technologies, publicly accessible data and information systems, capacity development, training and dissemination materials, and policy briefs and other knowledge products. The delivery mechanism for these products and services will follow a pipeline approach with feedback loops: upstream research will result in discoveries and innovations, which will be translated into products that will be introduced, evaluated, improved, and disseminated to intermediate users, and finally become adopted by end users, who may be millions of beneficiaries.

RICE theory of change establishes the causal linkages through which products and services will flow through the pipeline and bring about the desired results. The overall theory comprises a variety of possible interventions in a results framework; for each intervention, context-specific theories of change are required, which are detailed in each flagship project description. Because research-to-impact is nonlinear, learning and feedback mechanisms are embedded in planning processes, and impact pathways and theories of change will be regularly reviewed and updated.

Gender

The barriers that women face in access to and control over resources such as information and inputs (new technologies and finance) mean they have a lesser role in decision making and less control over income and assets than men. RICE research and development products will contribute to gender equity and women’s empowerment by

- increasing crop yields through high-yielding varieties, improved farming practices, and higher resource-use efficiency; through lower production risk through stress-tolerant varieties; higher income from higher production, farm diversification, and short-duration varieties; and greater availability of nutritious food from improved grain quality and crop diversification;
- improving women’s access to resources (seed, inputs, technologies, and technical knowledge), which will increase their labor productivity;
- increasing women’s productivity and production, which will lead to increased marketable surplus, thus enabling women to increase their income share and purchasing power to buy quality food;

- producing labor-saving technologies and farm mechanization equipment especially relevant for women rice farmers who presently provide labor for backbreaking nonmechanized operations;
- contributing to women's livelihood opportunities and well-being by reduction in postharvest losses, improved processing technologies (such as parboiling), and improved marketing; and
- fostering transformative changes in the enabling environment to support the gender impact pathway.

Youth

Youth unemployment has recently emerged as a crisis in agriculture-based economies of low-income countries, especially in Africa and the hinterlands of Asia. Despite agriculture being the core sector of these economies, youth employment in agriculture has remained very low, mainly as family labor, due to lack of mechanization, high production risks, and low agricultural productivity. Employment opportunities outside agriculture have not been sufficient to absorb the growing youth labor force. In contrast, in many of the dynamic zones in Asia, outmigration from rural to urban areas is leading to the opposite problem—scarcity of young and able labor.

RICE will engage in strategic research on youth issues and develop business models and new opportunities for young people to be actively involved in rice value chains and earn attractive incomes.

Program structure and flagship projects

The impact pathways from the status quo to expected outcomes will result from a set of five highly interconnected flagship projects (FPs) that comprise the research program. The FPs are:

FP 1: Accelerating impact and equity
FP 2: Upgrading rice value chains
FP 3: Sustainable farming systems
FP 4: Global Rice Array
FP 5: New rice varieties

FP1 will provide overall guidance to RICE. It will engage in foresight, policy analyses, gender and youth studies, monitoring and evaluation of progress, and ex-ante and ex-post impact assessments across the research program portfolio. Through these activities, it will help the other FPs develop well-targeted and demand-driven products and delivery approaches to have impact at scale. FP1 will develop and support innovation mechanisms and strategic partnerships, strengthen the capacity of research and development partners, and manage and communicate new knowledge.

FP2 (Upgrading rice value chains) will analyze rice value chains and identify entry points for upgrading; technologies and mechanisms for upgrading will be developed and delivered by FP2 as well as by FPs3–5. FP2 will conduct market research, assess rice value chains, and identify opportunities for improved processes, reduced postharvest losses, novel and value-adding products (especially nutritious and quality rice), strengthened value-chain linkages, and improved (input and output) market access. It will provide guidance for specific product development in FPs 3−5 and connect novel farming systems developed in FP3 with markets.

FPs 3−5 focus on the production component of the rice value chain and will develop new rice technologies and rice-based farming systems. FP3 will develop and deliver sustainable intensification and diversification options for rice-based farming systems to improve farm livelihoods and rural diets, while minimizing their environmental footprint. Integrated rice management practices with novel varieties (from FP5) and alternative farming systems (that link to other agri-food research programs of the CGIAR will be developed based on current and future demand. Linking with the CRP on climate change, FP3 will develop and test innovations in rice farming systems to adapt to changing climates and mitigate greenhouse gas emissions. FP4 will establish a global network of field laboratories that will discover new genes and traits of rice, develop and test rice ideotypes, assess the suitability and robustness of novel genotype × environment × management options, and use the rice plant itself to characterize climate change. Outputs of FP4 will directly feed into FP5. FP5 will develop and deliver new varieties adapted to current and future climates and that have improved traits such as increased yield potential, resistance to biotic stresses (pests, diseases, and weeds) and tolerance for abiotic stresses (drought, submergence, salinity, heat and cold, problem soils, and low light). Seed distribution systems will be strengthened to ensure that the new varieties are available to millions of farmers.

Some of the upstream research is not particularly location-dependent (e.g., gene discovery); however, all downstream research and development activities will be concentrated in five mega-rice-growing environments: mega-deltas and coastal zones, irrigated systems, rainfed lowlands, uplands, and inland valleys. The mega-deltas and coastal zones and the irrigated environments contain the majority of dynamic zones; the rainfed lowlands, uplands, and inland valleys in general are characterized as hinterlands.

Cross-research-program collaboration and site integration

RICE will pursue thematic as well as geographic collaboration with other CGIAR research programs. Thematic collaboration will include joint and/or complementary development, testing, implementation, and evaluation of research approaches, tools, and methodologies. Some salient activities will include collaboration on foresight analysis, food supply-demand modeling, and impact assessment methodologies between RICE FP1 and the program on Policies, Institutions, and Markets (PIM); joint development and implementation of methodologies for value-chain analysis by RICE FP2 and PIM; development of diversified rice-based farming systems between FP3 and all other agri-food system research programs; collaboration between RICE FPs 4 and 5 and all other crop-based agri-food system research programs and with the Water, Land, and Ecosystems (WLE) program on development of genomics breeders' tools (also through the proposed platforms on Genebanks, Genetic Gains, and Big Data); collaboration between RICE FP5 and the Agriculture for Nutrition and Health (A4NH) program in mainstreaming the development of healthy and nutrient-dense rice varieties; and collaboration between FPs 3, 4, and 5 with the Climate Change, Agriculture, and Food Security (CCAFS) program in developing, evaluating, and disseminating climate-smart rice varieties and farming systems.

Geographic collaboration takes place through integration of research and development sites among the CGIAR research programs where practical. RICE's FP3 on sustainable farming systems will be a main mechanism for collaboration on the ground. An estimated average of 80−90% of on-site collaborative activities will be funded through specific bilateral grant projects.

Partnerships and comparative advantage

RICE continues to be led by the same institutes that led the first phase (2011-2016) of the CGIAR research program on rice: three CGIAR centers—the International Rice Research Institute (IRRI), the lead institute; Africa Rice Center (AfricaRice); and International Center for Tropical Agriculture (CIAT); and three other leading agricultural agencies with an international mandate and a large research portfolio on rice: Centre de Cooperation lnternationale en Recherche Agronomique pour le Développement (Cirad), L'lnstitut de Recherche pour le Développement (IRD), and the Japan International Research Center for Agricultural Sciences (JIRCAS). Together, these six centers align and bring to the table consortia, networks, platforms, programs, and collaborative projects with about 900 partners from government, nongovernment, public, private, and civil society sectors, roughly equally split among "discovery research," "proof of concept," and "scaling-up" partners. The first phase of the CGIAR research program on rice was synonymous with the Global Rice partnership (GRiSP), established in 2010. In the second phase, RICE will be the main CGIAR program contribution to a larger GRiSP. The comparative advantage of RICE to pursue its goals and objectives is that virtually all potential alternative suppliers worldwide have already become partners in its first phase.

The 2012 CGIAR survey on partnerships in its research programs reported that 82% of respondents were satisfied with their partnership in the CGIAR program on rice. The program performed strongest in research outcomes and expertise, with global expertise and innovation being the top two performing dimensions. Respondents described it as one of the best rice research programs in the world.

RICE maintains close collaboration and interaction with regional fora, subregional bodies, regional economic communities, and international development funds and banks.

Evidence of demand and stakeholder commitment

Demand for research and development investments in the rice sector are explicitly identified in national rice development strategies of most countries that RICE targets. The GRiSP intermediate development outcomes (IDOs) and indicators were validated against national targets and priorities, and these have been brought forward in the planning of RICE.

Many stakeholders will be either directly involved as partners in RICE or have representatives that take part. At a strategic level, RICE will obtain commitments by aligning with priorities and strategies of the national partners. RICE coordinating centers hold regular consultative meetings with their partner countries. Regionally, GRiSP has received support from major regional fora and economic communities that have a stake in the development of the rice sector—and RICE will continue to build on this.

Capacity development

The CGIAR Capacity Development Framework provides a comprehensive structure for systematically addressing capacity development along the impact pathways. RICE will adopt the 10 steps of this framework and address capacity from the farmer and village level to partner research and development organizations, scaling partners, and policymakers as follows:

CGIAR capacity development elements	RICE proposed capacity development activities
1. Capacity needs assessment and intervention strategy design	Needs assessment will be conducted across institutions and organizations along the impact pathway, taking account of both individual and institutional needs.
2. Design and delivery of innovative learning materials and approaches	FP1 will collaborate with all FPs to gather, consolidate, and translate information gained and lessons and principles learned into knowledge that can be disseminated and brought to scale. Training materials will combine innovative approaches such as distant learning and information communication technology (ICT), with practical methods that give participants experience in the field.
3. Develop CRPs and Centers' partnering capacities	RICE will establish, maintain, and expand partnerships with major scaling partners from the public and private sector to scale-out RICE technologies and services to reach millions of beneficiaries.
4. Developing future research leaders through fellowships	RICE will contribute to the development of the next generation of science leaders to ensure strong national research capacity. Vocational training across the value chain and the rice-based farming system will be carried out through local institutions and organizations.
5. Gender-sensitive approaches throughout capacity development	RICE will develop capacity enhancement programs to address gender concerns and raise gender awareness in the whole research and development process; to train women on all aspects of production, processing, and farm management; and to train women farmers and actors in the rice value chain.
6. Institutional strengthening	RICE will strengthen institutional capacity of research and scaling partners from the public and private sector and civil society organizations. This may involve technical competency, multipartner and village-level facilitation skills, ability to use new ICT extension tools, scaling-up appropriate mechanization, and business development and negotiation skills.
7. Monitoring and evaluation (M&E) of capacity development	RICE will test the proposed CGIAR capacity development indicators, evaluate their usefulness, and make adaptations based on experience in the coming years of implementation.
8. Organizational development	RICE will contribute to the organizational development of scaling partners from the public and private sector and civil society organizations. Particular emphasis will be placed on organizational engagement in multistakeholder platforms for collective impact. In addition, capacity development will involve technical competency, multipartner, and village-level facilitation skills, use of new ICT extension tools, scaling of appropriate mechanization and business development, negotiation skills, and the formulation of agreed metrics for impact and accountability.
9. Research on capacity development	RICE will undertake research on effective capacity development models.
	RICE will nurture an environment of local actors concerned with innovation for scaling-out technologies and concerned services. The establishment and/or strengthening of existing innovation platforms

	is a key activity.

Program management and governance

The management and governance structures of RICE will build on—and strengthen—the successful model of the current GRiSP. The 2013 internal audit of implementation and management of CGIAR research programs at IRRI headquarters gave the overall implementation and management of the research programs, including GRiSP, the highest rating possible. RICE will be managed by the same Program Planning and Management Team (PPMT) that manages GRiSP. It is chaired by a director and has a representative from senior management of each of the six coordinating partner.

As in the current GRiSP, the PPMT will oversee a gender committee, monitoring and evaluation committee, and communication committee, with senior representatives from each of the coordinating partners. The PPMT will also oversee and guide the team of FP leaders, who will coordinate activities within their FPs across the participating centers and institutes. They will be empowered by a dedicated coordination budget, while 20−40% of their salaries will be provided from the CRP management budget for this function.

Governance is to be provided by the Board of the lead center, IRRI, and by an Independent Steering Committee (ISC) built on the current GRiSP Oversight Committee. This ISC has a significant representation of external experts and is chaired by an independent external expert. Center representation draws on the boards of participating centers, while the directors general of IRRI and AfricaRice are members *ex officio*.

Intellectual asset and open access management

RICE regards the results and outputs of research and development activities as international public goods and will be committed to their widespread diffusion and use and to achieving the maximum possible access, scale, and scope of impact from them for the benefit of poor farmers and consumers in developing countries. It recognizes that careful management of intellectual assets is a prerequisite for effective development and delivery of RICE’s international public goods. The RICE strategy for management of intellectual assets is in line with the CGIAR Principles on the Management of Intellectual Assets and their Implementation Guidelines, The RICE CGIAR centers will manage their intellectual assets with integrity, fairness, equity, responsibility, and accountability, wherever they operate.

RICE acknowledges the value of its information products, including research data, and considers that widespread sharing of these products will produce scientific, economic, and social benefits. Hence, in line with the CGIAR Open Access and Data Management Policy and its Implementation Guidelines, RICE strives to make final versions of its information products openly and freely accessible for use and reuse by others.

Communication strategy

Good communication is critical for RICE to deliver its development impacts. RICE will build on the six elements of the communication strategy proposed by the CGIAR communication community of practice (shown in bold below):

1. RICE will **communicate and engage with partners** through collaborative and participatory approaches to R&D and convening various networks, CGIAR communication community of practice, platforms, and consortia, using tools as above.
2. RICE will **promote learning and sharing of information to improve communications and collaboration**, in general by active engagement in the CGIAR communication community of practice and, more internally in RICE through the learning and feedback mechanisms embedded in its results-based management framework.
3. RICE will **engage with actors on the ground to scale-out technologies and practices**, through the development of multistakeholder platforms and scaling-out activities, using tools such as participatory impact pathway mapping, stakeholder and outcome mapping, and problem tree definition and analysis.
4. RICE will **communicate about the program, the science, results, and progress**, using an array of tools such as a dedicated RICE website, specific project websites, newsletters, media briefs, radio and TV interviews, podcasts, and blogs.
5. RICE will **engage in policy dialogue to scale-up results**, through its engagement with numerous national and regional bodies, and through developing and communicating results of policy analyses.
6. RICE will **make CRP information and resources open and accessible**, as detailed in the RICE open-access and intellectual asset management strategies.

Risk management

RICE will continue the implementation of a formal risk management procedure initiated under GRiSP.
It applies the principle of subsidiarity to risk management by the RICE CGIAR centers for reducing duplication and transaction costs. Following international best practices in the field, RICE will maintain a risk register that records risks and their management that pertain to the program as a whole and that complements the risk registers of the GRiSP-participating CGIAR centers. With IRRI being the lead center for GRiSP, the GRiSP risk register follows IRRI protocols and procedures for risk management and approval processes, and becomes part of the IRRI institutional risk register. IRRI’s risk management strategy complies with the Risk Management Standard BS 31100:2011, Risk Management – Code of practice and guidance for the implementation of BS ISO 31000.

Budget summary

RICE budget, in US$.

Flagship project	2017	2018	2019	2020	2021	2022	Total
Accelerating impact and equity	14,202,524	14,654,190	15,123,063	15,609,843	16,115,259	16,640,072	**92,344,950**
Upgrading rice value chains	3,469,041	3,593,153	3,690,261	3,813,079	3,896,221	4,005,405	**22,467,159**
Sustainable farming systems	22,320,205	22,946,450	23,636,742	24,350,964	25,081,872	25,832,253	**144,168,488**
Global Rice Array	10,683,196	10,976,858	11,289,840	11,639,445	11,984,806	12,343,845	**68,917,990**
New rice varieties	25,881,376	26,609,118	27,402,741	28,221,620	29,086,018	29,982,515	**167,183,392**
Management	1,951,622	2,049,203	2,151,663	2,259,246	2,372,209	2,490,819	**13,274,762**
Total	**78,507,964**	**80,828,973**	**83,294,310**	**85,894,198**	**88,536,385**	**91,294,911**	**508,356,741**

1.0 CRP Narrative

1.0.1 Rationale and scope

Challenges facing the rice sector. Rice is the world's most important food crop and it will continue to be so in the coming decades. It is produced by some 144 million farm households, most of them having less than 2 hectares, and harvested from 166 million hectares annually (GRiSP 2013a). The total value of rice in 2013 was estimated at US$ 203 billion. Rice is a staple food for some 4 billion people and it provides 27% of the calories in the world's low- and middle-income countries (Dawe et al 2010, GRiSP 2013a). In Asia, the poorest of the poor derive up to 70% of their calorie intake from rice (Barker and Dawe 2002). Based on the simulation results of scenarios with different combinations of projected global population growth, income growth, and rice acreage decline, global demand for rice will continue to increase from 479 million tons milled rice in 2014/15 to 536–551 million tons in 2029/30 (see chapter 4 of the companion document to RICE proposal).[1] Rice farming is associated with poverty in many areas. About 900 million of the world's poor depend on rice as producers or consumers (Pandey et al 2010). Out of these, some 400 million poor and undernourished people are engaged in growing rice (chapter 3 of the companion document to RICE proposal). To help lift both producers and consumers out of poverty, rice production needs to be profitable while rice itself needs to remain affordable.

Women make significant contributions to rice farming, processing, and marketing, and play a dominant role in buying rice for consumption. Yet, women still face many barriers and inequality in access to and control over resources such as information and inputs (new technologies and finance) (Alkire et al 2013). Women are also less involved in decision making and have less control over income and assets than men. These gender inequalities reduce women-managed farm productivity by 20–30% compared to that of farms managed by men (FAO 2011). Such inequalities also hinder the progress of other development outcomes such as family planning; maternal, newborn, and child health; nutrition; education; and food security (Gates 2014). With appropriate technological, institutional, and policy support, rice farming, processing, and marketing, could offer equal opportunities of employment for women and men, enhance women empowerment, and thus accelerate attainment of food security and poverty alleviation.

With increasing youth unemployment in some parts of the world, especially in sub-Saharan Africa, and aging of the rural population, particularly in parts of Asia undergoing rapid structural transformation, it is imperative to develop attractive job opportunities for the young (van der Geest 2010, White 2012). While rice is an excellent source of calories and some nutrients, there is considerable scope to improve the nutritional quality of rice based diets through biofortification, optimizing processing, and through dietary diversification. Climate change threatens rice production through the effects of higher temperatures and more frequent droughts and flooding, as well as sea-level rise, which threatens rice production in mega-deltas and coastal zones (Wassmann et al 2009).

[1] The companion document to the RICE proposal contains background information on ex-ante and ex-post impact assessments of investments in RICE, and can be accessed in the folder: http://goo.gl/04VoSo

Globalization. Globalization increasingly affects the rice sector globally, nationally, and locally. Although the bulk of rice is still consumed domestically, the share of internationally traded rice increased from less than 4% before the mid-1990s (Pingali et al 1997) to 7–8% by 2010 (Timmer 2010). Sub-Saharan Africa has become a large importer of rice. Rice markets, however, still remain relatively volatile, with coefficients of variation of world market prices for rice often double those of wheat or maize (Timmer 2010). Other effects of globalization include the entry of the private sector into rice breeding, an increasing interest by international food companies in direct (North-South) sourcing of rice, increasing penetration of multinational input and service suppliers in national rice sectors, an increasing role of these companies as major providers of agronomic and management advice to farmers (often taking over this role from poorly functioning public-sector services), and the formation of global multistakeholder platforms,[2] combining the food sector, agri-businesses, academia, the public sector, and nongovernmental organizations (ISPC 2015).

Structural transformations. Rapid structural transformations are occurring in parts of Africa and Asia, and can be the basis for uplifting the lives of millions of poor people in the rice sector. They also provide unprecedented opportunities for women empowerment and youth employment. In such countries as China, India, Indonesia, Thailand, and Vietnam, the growing urban middle class is increasingly interested in food quality (Dwyer 2012). As a consequence, rice value chains have started to adapt (Reardon et al 2014). In wholesale and milling, entrepreneurs are investing in improved equipment, increasing scale, and diversifying into higher-quality, healthy, and nutritious rice to serve a growing and increasingly sophisticated urban population led by women buyers. Structural transformation processes include a decline in the share of agriculture and rice in gross domestic product and employment, rural-urban migration, rise of a modern industrial and service economy in rural areas, and rise of small and medium-size enterprises in rural town and village settings (Timmer 2010). Rural-urban migration has increased labor scarcity and rural wages, and feminization and aging of the agricultural labor force. This is bringing to an end the long-standing decline in farm size and the beginning of a reversal because of land consolidation and mechanization (Masters et al 2013). It also puts more women at the head of rural households and in decision-making positions.

Processes of structural transformation offer small farmers the unprecedented opportunity to escape from poverty and their small scale by developing viable and profitable modern farm businesses that benefit from economies of scale and exploit new market opportunities. In what Masters et al (2013) called "dynamic zones," farmers are participating in burgeoning markets for land rental and farming inputs, undertaking capital-led intensification, and shifting from subsistence to market-oriented commercial farms. Reardon et al (2014) studied dynamic, commercial zones that are the mainstays of rice supply to four major Asian cities: (1) Noagoan district, supplying Dhaka in Bangladesh; (2) West Uttar Pradesh (UP) supplying Delhi in India; (3) Heilongjiang province supplying Beijing in China, and An Giang and Hau Giang provinces in the Mekong River Delta supplying Ho Chi Minh City in Vietnam. They

[2] According to ISPC (2015), multistakeholder platforms 'concern structured alliances of stakeholders from public, private and civil society sectors. These include companies, policymakers, researchers, a variety of forms of NGOs, development agencies, interest groups, and stakeholders from local, national, regional, and international governance regimes. The key feature is the dissimilarity of partners.'

concluded that falling transaction costs and increased capital availability per worker have led to a remarkable "quiet revolution" in food supply chains within rural areas and from there to urban consumers. He estimated that half to two-thirds of Asia's food production is already fully commercialized, in the sense of being produced for intermediaries serving urban consumers.

Research plays a pivotal role in facilitating such opportunities by developing and providing the farmers with new market-differentiated rice varieties, mechanized crop management technologies, and diversified cropping/farming systems. Retooling farmers as business entrepreneurs empowers them with the skills to benefit from new market forces (Bouman 2014). Inclusive value-chain upgrading can improve livelihoods not only of farmers but also of all actors along the value chain, including millers, processors, and traders. By targeted interventions, women farmers and value-chain actors can preferentially benefit from these developments. Finally, there is a great opportunity to create modern and desirable jobs for millions of youth who will be looking for jobs in the coming years, by making rice production a less labor intensive, technology driven, and profitable enterprises of larger effective scale.

Farmers in the hinterlands. Millions of small and resource-poor farmers, however, who reside in so-called hinterlands (Masters et al 2013) are still poorly connected to markets and farm mainly for their own subsistence. They have little or no opportunity for scale increase or mechanization, and traditional role models typically constrain opportunities for development of women. Hinterland farmers mostly operate in harsh environments with many stresses (problem soils, drought, uncontrolled flooding, etc.), and are disproportionally affected by climate change. To improve their livelihoods, these farmers need access to technologies that increase their productivity, stabilize their yields, and enhance their resilience to climate change and other shocks. Such measures can provide a stepping stone out of poverty by generating a small capital surplus that can be used for enterprise and nutritional diversification or sending children to school to prepare them for better jobs. Where availability of diverse diets or food artificially fortified with minerals and vitamins is limited by the realities of the agro-ecosystem or poor access to markets, home production of biofortified staples such as rice can contribute tremendously to increased health and nutrition, especially of women, children, and the sick (De Moura et al 2014).

Africa and Latin America. In many countries of sub-Saharan Africa, rice has changed from being a luxury crop to one of the most rapidly growing staple food sources. This is driven by many factors, including urbanization, changes in employment patterns, rising income levels, shifts in consumer preferences, and rapid population growth (Wopereis 2013). Rice has now become the third-largest source of food energy in Africa as a whole and a staple food for the poorest sectors of urban populations, a trend that is expected to continue across the continent. Unlike in the dynamic zones of Asia, average farm sizes in Africa continue to decline and remain labor intensive (Masters et al 2013). Hence, pressing needs for technologies exist as for other hinterlands.

Rice consumption also continues to grow in Latin America and the Caribbean, where consumption has increased by 40% in the last two decades. Like Africa, the region is a net importer of rice. The large farms in the Southern Cone of South America (some larger than 1,000 hectares) will increasingly become important contributors to global food security as small farms will not be able to accomplish this alone (ISPC 2013). However, all rice-producing regions will have to contribute to increasing rice stocks to avert availability crises in the future. Problems in South American rice farming

systems mainly concern environmental sustainability, adaptation to climate change, and competitiveness in global markets. However, small-scale rice farmers in the northern part of South America and in Central America and the Caribbean can be found in both harsh hinterlands and in more favorable dynamic zones, and are included as targets of RICE.

Scope. The above problems and challenges facing the rice sector—which primarily relate to rice productivity and sustainable production and focus on poor farmers and consumers, the particular problems facing women and youth, and the risks associated with emerging issues such as globalization, structural transformation, and climate change—range from global to local and are virtually all interconnected. RICE will correspondingly embrace the whole sector in the major rice-producing regions to make rice-based systems more sustainable and profitable while keeping rice affordable to the poor. RICE will promote new opportunities to improve value chains and broaden them through farm diversification and novel rice-based products.

The ability of RICE to undertake these broad tasks is based on the key successes and learnings of GRiSP, in which international rice research made the step from a commodity approach to a systems approach and embraced all research and development aspects of the rice sector. RICE takes this development further by embarking on a more holistic agri-food system approach. An agri-food system includes all processes involved in feeding people: growing, harvesting, processing, packaging, transporting, marketing, consuming, and disposing of food and food packages.[3] It also includes the inputs needed and outputs generated at each step. Agri-food systems are large, complex, and multifaceted (Thompson et al 2007), and it is beyond the scope of RICE to address all their complexity, interactions, diversity, and uncertainty. Yet RICE can play a catalytic role in promoting positive change through its partner relationships. RICE addresses the global rice sector and rice value chains within the agri-food system. The addition of the term “agri” to “food system” emphasizes the production component of the food system and value chain, in which RICE focuses on the sustainability and diversification of farming enterprises in rice-based cropping systems into other crops, trees, fish, or livestock.

Nevertheless, the development and dissemination of improved rice varieties, which have produced the most documented impacts from CGIAR research (Evenson and Gollin 2003, Fan et al 2005, Raitzer and Kelley 2008, Renkow and Byerlee 2010), will remain a core business of RICE.

RICE will address diversification by teaming up with other CRPs to link rice-based farms with value chains for other commodities and study the complexity of their interactions (Annex 7). Although “step changes” will be introduced, the transition from a commodity focus in GRiSP to a diversified farming system approach and a value-chain lens in RICE will be progressively introduced and will require changes in the way the CGIAR operates as a system. Innovative approaches that define RICE and generate step changes are described in detail in the FPs. They include in summary (1) harnessing the full power of the human capital through women and youth; (2) a market-driven approach to the development of new rice varieties, rice by-products, and other farm products; (3) whole rice value-chain analyses and improvements; (4) a farming systems approach; (5) the use of systems approaches throughout the value chain; (6) exploitation of Big Data and state-of-the-art R&D tools; (7) partnerships for scaling-out and

[3] http://blogs.cornell.edu/garden/files/2011/05/cgbl-dofs-curriculum5.pdf

delivering impact at scale; and (8) establishment of a novel Global Rice Array to use the rice plant as an indicator of the effects of climate change.

1.0.2 Priority setting, goals, objectives, targets

Priority setting. Priority setting in RICE is a continuous process of political dialogue, infused with science-based evidence of impacts of research investments. The dialogue involves RICE's stakeholders, such as ultimate beneficiaries, local and national governments, program partners (public, private, civil society), donors, and others with a stake in the geographic areas where RICE operates (step 1 in Fig. 1a). Each of these stakeholders has its own interests and priorities as expressed in strategy and policy documents and—importantly for RICE— in national rice research and sector development strategies. The Strategy and Results Framework expresses the overall priorities of the CGIAR (funders and research providers) in terms of SLOs, IDOs, subIDOs, targets, and 'grand challenges'. The intersection of the various stakeholders' interests and priorities delineates out of the SRF the overall space for research and development in the rice sector. A combination of foresight analysis and assessment of the comparative advantage of the RICE partners and of alternative suppliers (such as other CRPs, private sector, advanced research institutes, and national partners), focuses this space on those areas where RICE can make significant and unique contributions and defines the program's overall goals and objectives (step 2). Next, within that space, scenario analyses, foresight studies, and ex-ante and ex-post impact assessments provide guidance on when and where research investments are expected to contribute most to the realization of the identified goals and objectives (step 3). Based on these analyses, a RICE 'implementation plan' was developed in the form of flagship projects (FPs) with clusters of activities and specific outputs and outcomes. As funding is a relatively uncertain parameter, RICE constructed three sets of outputs (and underlying activities), outcomes, and development targets that correspond with three investment levels.

In step 3, quantitative tools were used to identify research options with greatest expected economic and social benefits. The exercise included several steps: 1) mapping of rice production and potential and actual rice yields by agro-ecology; 2) constraints analysis; 3) identification of scientific solutions for each of the constraints, as well as additional opportunities; 4) estimation of the effects of each of technologies in terms of yield potential, yield loss reduction, postharvest loss reduction, cost reduction, and environmental effects; 5) estimation of indicative research costs, probability of success, and time of delivery; and 6) quantification of research impacts using econometric modelling. An example outcome is given in Fig.1b for the contribution of research efforts in five broad domains of research. A full description of the methodology and a synthesis of the results are found in chapters 5 and 6 of the companion document.

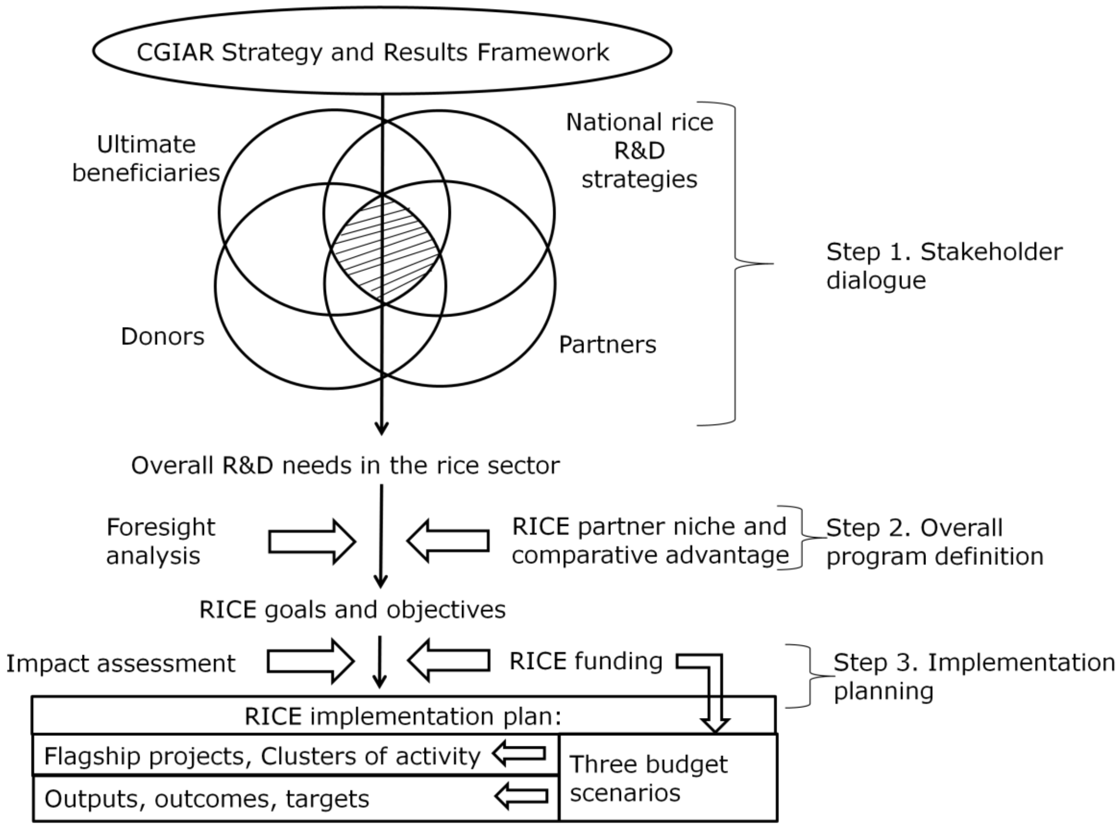

Fig. 1a. Conceptual framework of priority setting in RICE; steps are explained in the text.

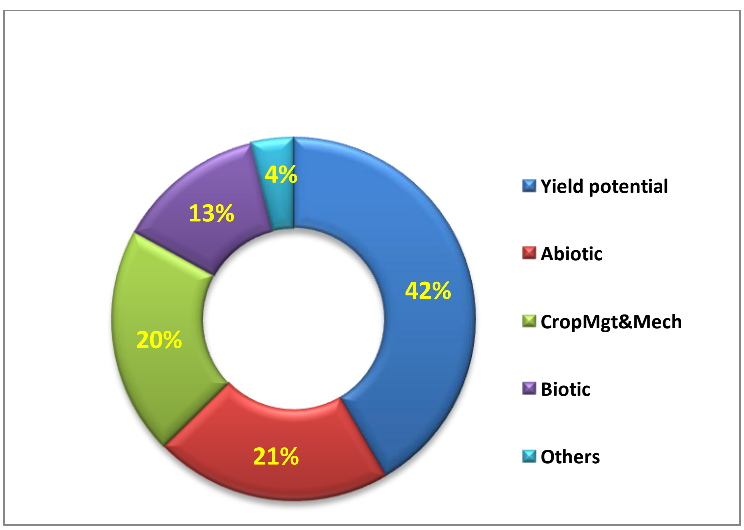

Fig 1b. Distribution of research contribution to an estimated 24 billion $ economic benefits (2005 Purchasing Power Parity $, discounted at 5%) in Asia over 2015-2035, over breeding to increase yield potential, breeding for tolerance of abiotic stresses, improved crop management technologies, breeding for tolerance of pests and diseases, and others.

Goals. The specific goals of RICE in the rice sector are to reduce poverty and hunger, improve human health and nutrition, adapt to climate change, promote gender equity and youth employment, and reduce the environmental footprint of the sector. Across the global rice sector, RICE will assist the emergence of the "farmers of the future" who will produce enough healthy and nutritious food to feed themselves, their families, and local and global consumers. In favorable environments and dynamic zones (in parts of Asia and Latin America), such farmers will manage fewer but larger farms that capture economies of scale and are sustainably managed as modern enterprises. In less favorable hinterlands (especially in Africa), small-scale farmers will have increased productivity and resilience, providing a stepping stone out of poverty through enhanced gender equity and small savings and investments in diversification, other businesses, or schooling of their children. Vibrant rice value chains, with increased participation of women and youth, will provide sufficient and affordable rice of high quality and nutritious value to a growing urban population. Beneficiaries of RICE range from farmers to intermediate value-chain actors to rural and urban consumers. To enhance gender equity and its positive multiplier effect on food and nutrition security and poverty reduction, RICE will pay particular attention to women beneficiaries.

Objectives. RICE will pursue these goals in the rice sector, harnessing the power of science, through the following IDOs and sub-IDOs:

1. Reduce poverty and hunger among rice producers and consumers by reducing production risks, improved access to financial and other services, diversifying enterprise opportunities and increasing livelihood opportunities, and increasing value capture by producers.
2. Improve food and nutrition security for health by reducing pre- and postharvest losses, closing yield gaps in production, enhancing genetic gain in rice, increasing conservation and use of genetic rice resources, and increasing access to productive assets and diverse, nutrient-rich foods.
3. Improve natural resource systems and ecosystem services by fostering more productive and equitable management of natural resources and reducing GHGs from agricultural activities.

Issues common to achieving these objectives include climate change, equity for women and employment for youth, presence of relevant policies and institutions, and capacity development.

- Climate change concerns will be addressed through technologies to reduce GHG emissions from farms and enhanced adaptive capacity to climate risks.
- Gender equity and youth employment in the rice sector will be achieved through increasing the capacity of women and youth to participate in decision making, developing technologies that reduce women's drudgery, and promoting equitable control of productive assets and resources.
- Policy and institutional concerns will involve ways to help beneficiaries adopt research outputs and help partner organizations enhance their research and development efforts.
- Capacity development will be carried out at different levels, from poor and vulnerable communities to partner organizations and institutions, through education, training, and exchange.

Table 1 summarizes the 19 sub-IDOs and 9 IDOs addressed by RICE. With these, RICE addresses all the grand challenges of the CGIAR SRF with the exception of marine habitats and oceanic systems (Annex

11). RICE also addresses 9 of the 17 United Nations Sustainable Development Goals (SDG), and 26 of their 169 targets (Annex 12; a summary narrative about RICE's contribution to the SDGs is found in: http://goo.gl/04VoSo).

Table 1. The sub-IDOs and IDOs of the CGIAR SRF addressed by RICE.

Sub-IDO	IDO	Flagship project
Related to SLOs		
Improved access to financial and other services	Enhanced smallholder market access	2
Diversified enterprise opportunities	Increased income and employment	2
Increased value capture by producers	Increased income and employment	2
More efficient use of inputs	Increased income and employment	3
Increased livelihood opportunities	Increased income and employment	3
Reduced pre- and postharvest losses	Increased productivity	2
Closed yield gaps through improved agronomic and animal husbandry practices	Increased productivity	3
Enhanced genetic gain	Increased productivity	4, 5
Increased conservation and use of genetic resources	Increased productivity	4, 5
Increased access to diverse, nutrient-rich food	Improved diets for poor and vulnerable people	3, 5
Enhanced adaptive capacity to climate risks	More sustainably managed agroecosystems	4
Reduced net GHG emissions from agriculture, forests, and other forms of land use	More sustainably managed agroecosystems Mitigation and adaptation achieved [to climate change]	3
Related to cross-cutting issues		
Enhanced capacity to deal with climate risks and extremes	Mitigation and adaptation achieved [to climate change]	3, 4, 5
Technologies that reduce women's labor and energy expenditure developed and disseminated	Equity and inclusion achieved	3
Improved capacity of women and young people to participate in decision making	Equity and inclusion achieved	1
Increased capacity of beneficiaries to adopt research outputs	Enabling environment improved	1
Enhanced individual capacity in partner research organizations through training and exchange	National partners and beneficiaries enabled	All – coordinated by and reported through 1
Increased capacity for innovation in partner research organizations	National partners and beneficiaries enabled	All
Increased capacity for innovation in partner development organizations and in poor and vulnerable communities	National partners and beneficiaries enabled	1

Targets and value proposition. Targeted impacts and outcomes of RICE depend on the level of donor investments and on commitment and resources from our partners. Because of the nature of funding mechanisms, annual funding levels in the CGIAR fluctuate and are unpredictable.[4] The guiding principles

[4] Between 2014 and 2015, the Consortium and Fund Offices issued eight financial updates with changed CRP budget allocations

for the new CGIAR state that “the CGIAR System will need to be sufficiently flexible and adaptable to respond to changing circumstances.”[5] The call for the 2nd phase CRP full proposals recognizes this need, and included the following parameters: (1) a total CRP portfolio of US$ 900 million/year in a base budget, and of US$ 1.35 billion/year in an uplift budget, with 25–30% funding through windows 1 and 2; and (2), for a rice agri-food system CRP, a minimum W1,2 budget of US$ 14.4 million/year and a target overall budget of US$ 86 million/year.

From the above, RICE posits a value proposition based on three levels of donor investments: a low investment scenario of US$ 65 million/year, a medium investment of US$ 85 million/year, and a high investment of US$ 105 million/year –with W1,2 contributions of 20-30%. The high investment scenario is roughly at the same level as that of GRiSP in 2011–2015. Using ex-ante impact assessment tools and extrapolating results from GRiSP, Table 2 presents the value proposition of RICE in terms of beneficiaries and target contributions to the CGIAR SLOs, under each of the three investment scenarios. Table A of the Performance Indicator Matrix presents the numbers of beneficiaries and targets by country. Please note that these numbers are indicative only, and reflect RICE’s expectations given favorable policy and development scenarios. Annex 16 explains how the target estimates were computed, and the RICE Addendum (Responses to ISPC and CO review) provides further information on the role of partners in the realization of the targets. Annex 6 (Results-based management and ME&L) lists a set of indicators that will be used to monitor progress toward these targets.

Detailed outcomes, milestones, and their associated costs are given in Tables B-D of the Performance Indicator Matrix for the medium investment scenario. Outcomes and milestones for the low and high investment levels will be prepared in a modular way, so that RICE can adapt to any actual investment level and respond with associated budget adjustments (see the RICE Addendum for more details of this process and for the role of partners in the realization of the outcomes).

A detailed indicative budget breakdown for the medium investment scenario is provided in section 1.1 for the whole of RICE, and in sections 2.1.2, 2.2.2, 2.3.2, 2.4.2, and 2.5.2 for the individual flagship projects. In any given year, actual budgets will fluctuate in accordance with actual investments through W1,2, W3, and bilateral projects.

5 http://www.cgiar.org/transitionmeeting1/ (January 2016)

Table 2. RICE value proposition under three investment scenarios, in terms of contributions to the CGIAR SRF targets in 2021-22 and 2030 (see Annex 16 for explanation).

Year		**2021-22**			**2030**
Investment scenario		**Low**	**Medium**	**High**	**Low-High**
Indicative average annual budget (US$ million/year):		**65**	**85**	**105**	**65-105**
SRF indicators and targets	**RICE contribution indicators**	**RICE targets**			
Cutting across SLOs					
1.1: 100 million more farm households have adopted improved varieties, breeds or trees, and/or improved management practices	No. of farm households that have adopted improved rice varieties and/or practices, with 30–40% women farmer participation, and 10% women-headed households (million households)	11	17	22	24-48
SLO 1: Reduced poverty					
1.2: 30 million people, of which 50% are women, assisted to exit poverty	No. of rice consumers and producers (men, women, and children; of whom 50% are female) assisted to exit poverty (<US$ 1.25/day) (million people)	9	13	18	12-24
SLO 2: Improved food and nutrition security for health					
2.1: Improve the rate of yield increase for major food staples from current <1% to 1.2-1.5% per year	Average genetic gain in rice across environments (as measured in breeders' trials) (%/year)	1.1	1.3	1.5	1.5-1.9
2.2: 30 million more people, of which 50% are women, meet minimum dietary energy requirements	No. of people (men, women, children; of whom 50% are female), assisted out of hunger and meet minimum dietary energy requirements (million people)	12	17	23	18-34
2.3: 150 million more people, of which 50% are women, without deficiencies of one or more of the following essential micronutrients: iron, zinc, iodine, vitamin A, folate, and vitamin B12	No. of people (men, women, children; of whom 50% are female) consuming high-Zn rice (million people) in Bangladesh, Indonesia, and Philippines	6	8	11	12-24
2.4: 10% reduction in women of reproductive age who are consuming less than the adequate number of food groups	No. of women of reproductive age in rice-based farming households consuming adequate number of food groups through farm diversification and increased expendable income (million women)	1.4	1.7	2	3-4
SLO 3: Improved natural resource systems and ecosystem services					
3.1: 5% increase in water and nutrients (inorganic, biological) use efficiency in agro-ecosystems, including through recycling and reuse.	5% increase in water and nutrient-use efficiency in rice-based agroecosystems at action sites (geographies), in Mali, Nigeria, and Tanzania; Bangladesh and India; China, Indonesia, Philippines, Vietnam (%)	3	5	10	7-22
3.2: Reduce agriculturally-related greenhouse gas emissions by 0.2 Gt CO2-e yr–1 (5%) compared with a business-as-usual scenario in 2022	Agriculturally-related greenhouse gas emissions reduced, compared with a business-as-usual scenario in 2022 (gigatons CO_2 equivalent/year)	0.0189	0.0284	0.0378	0.004-0.076

1.0.3 Impact pathway and theory of change

The impact pathway of RICE is grounded in a historical evidence base (chapters 1 and 2, companion document to RICE proposal), which is taken forward through conceptual and quantitative foresight exercises. Poverty can be decreased and food security enhanced by increased agricultural growth through improved productivity and income along food value chains (Hazell 2008, Timmer et al 2010, ISPC 2012b). Growth in agricultural productivity also contributes to the growth of national economies through "growth linkages," of which an important one is lowered prices of food. Low rice prices benefit poor consumers—including the urban poor, rural landless, and small rice and nonrice farmers who do not produce enough food to meet home consumption—disproportionally because rice makes up as much as 70% of their calorie intake (Barker and Dawe 2002).

Input intensification associated with yield growth results in greater demand for labor and wages, which contributes to increased farm income (Hazell 2010). Increased farm productivity can be brought about by intensification and diversification, including diversified enterprise opportunities. Increased crop productivity can be brought about by genetic improvement and/or improved crop and natural resource management. The contribution of genetic improvement of rice to poverty reduction is well documented. For example, Fan et al (2005) calculated that total rice variety improvement during 1991–1999 lifted 3−5 million people annually out of poverty in China and 1.5−5.0 million people in India.

The contribution of CGIAR institutes such as IRRI to varietal improvement and subsequent poverty alleviation is also well recorded. Brennan and Malabayabas (2011) found that in the 2000s, 40% of all new varieties released in the Philippines were direct IRRI crosses and 70% of the released varieties had an IRRI ancestry. In Indonesia, 89% of all new varieties released from the 1980s onward had IRRI ancestry, while this proportion was 77% in Vietnam. The economic value of IRRI's rice improvement in Indonesia, the Philippines, and Vietnam averaged US$ 1.46 billion per year in 1985–2009. Fan et al (2005) estimated that in 2000, 58% of the total rice area planted in India had an IRRI variety in its pedigree, and that IRRI's genetic improvement program had contributed 12−64% to the US$ 3.6 billion in benefits from rice research in India. In Africa, Basse et al (2013) estimated the net present value of benefits of the Sahel varieties introduced by AfricaRice in 1994/95 at US$24.6 million. The internal rate of return and economic internal rate of return are evaluated at 80.9% and 72.1%, respectively. The total area under NERICA was estimated at 0.6 million ha in 2008 and increased to 1.4 million hectares in 2013 (Arouna and Lokossou, 2015). They also estimated that the adoption of NERICA varieties has lifted about 8 million people out of poverty in 2013 in 16 African countries. All this evidence validates a focus of RICE on rice improvement as a major pathway to impact.

Other pathways to increasing farmers' income include reducing the costs of production, increasing the value of production, decreasing postharvest losses, and farm diversification (Hazell 2010). The value of production can be increased by increasing the marketability and value of the products and by-products, and through whole value-chain upgrading (ISPC 2012b). Enhanced overall productivity, more empowerment participation in the value chain, and diversification of farm output can protect farmers from lowered farm-gate prices.

With regard to health, human micronutrient deficiencies are prevalent in areas where rice is the major staple. Increasing the concentration of minerals and micronutrients in the grains of rice, such as

Fe, Zn, and beta-carotene, can help to alleviate these deficiencies (Dipti et al 2012). Also, crop and farm diversification increases diet diversity. Lowering the glycemic index of rice has the potential to contribute to efforts to reduce the incidence and ongoing treatment costs of type 2 diabetes, which is reaching epidemic proportions in population groups across South and Southeast Asia and sub-Saharan Africa (Dipti et al 2012). Reduced pesticide use through pest- and disease-resistant varieties and integrated pest management (IPM)/ecological engineering practices, help to reduce health risks to farmers. A reduction in plant uptake of arsenic and cadmium in grain reduces a potential consumer health threat.

Different pathways exist by which agricultural research can increase the sustainability of production, improve ecosystem services, and reduce negative environmental externalities such as water depletion, GHG emissions, and loading of agrochemicals (Rejesus et al 2014). Increasing the productive use of inputs reduces their amounts used per unit of production. This increase can be realized through an increase in effective use, or uptake, and the accompanying reduction in effect on the environment. Adapted water and soil management practices can reduce the emission of GHGs such as alternate wetting and drying of rice fields. Crop diversification also contributes to increased sustainability and adaptive capacity to shocks. The above generalized impact pathways are further elaborated in each RICE flagship project.

Theory of change*.* RICE delivers international public goods as well as locally tailored solutions with its partners, including publicly accessible data and information systems, genes and markers, breeding lines, improved varieties, improved crop management and postharvest technologies, policy briefs, and training and dissemination materials. Less tangible outputs/outcomes include knowledge (e.g., as captured in publications) and methodologies to improve capacity to conduct research (institutional and individual) and to foster innovation and collaboration. The delivery mechanism for these products and services follows a pipeline approach with continuous feedback loops: upstream research results in discoveries and innovations that are translated into concrete products that are introduced, evaluated, improved, and disseminated to intermediate users, and finally become adopted by end users, who may be millions of beneficiaries (Fig. 2). Intermediate users encompass a variety of actors such as research organizations, extension services, NGOs, and public- and private-sector agencies. End users are typically actors along the rice value chain such as farmers, millers, processors, traders, and consumers. End users can also be input suppliers such as seed producers and the fertilizer industry (which makes use of improved nutrient management guidelines). Partners play a key role in all stages of the pipeline and there are many feedback loops among researchers, development partners, and users. The pipeline approach implies that discovery research is continuously undertaken and continuously yields products being adopted by end users.

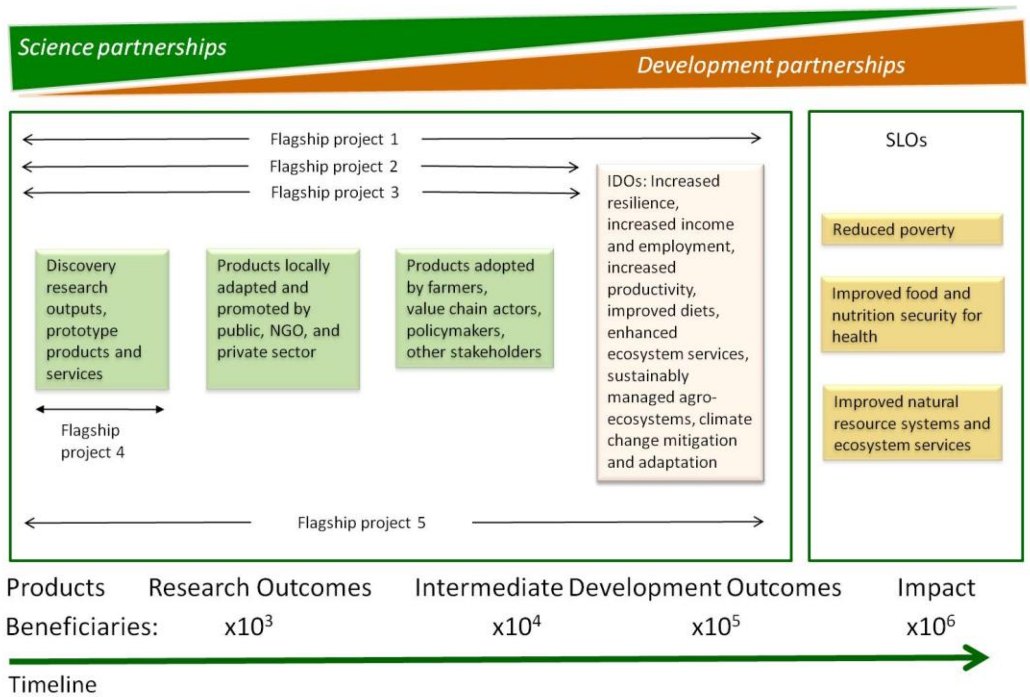

Fig. 2. Timeline showing the "discovery research to impact" pipeline, with changing composition of partners.

RICE theory of change establishes the causal linkages through which products and services flow through the pipeline and bring about the desired results. It comprises a variety of possible interventions in a logical framework. For each intervention, context-specific theories of change are required and are detailed in each flagship project description. Here, the generic framework is explained.

Realizing the need to catalyze changes (ISPC 2012a), RICE will develop the **enabling environment** for facilitating outcomes at and across various spatial scales (Fig. 3). RICE defines the enabling environment as the set of conditions that facilitate the scaling-out of products and services derived from agricultural research. Successful scaling-out depends on the (inter)actions and policies of all actors involved—from research to development—in developing and bringing to scale novel products and services that contribute to the realization of development outcomes. Building on relevant components of enabling environments proposed for civil society organizations and for science organizations[6], RICE proposes a set of six actionable and interconnected elements of its enabling environment:

1. Monitoring, Evaluation, and Learning (ME&L). To foster an impact pathway culture, a strong ethos is required of collective monitoring and evaluation of progress and of using learning data for continuous improvement. The collective effort is required in order to create a common

[6] Thindwa, 2002, referenced in open Forum for CSO Development Effectiveness, Issue paper 8 – Enabling Environment (http://www.ccic.ca/_files/en/what_we_do/osc_open_forum_wkshop_2009-10_paper_8_e.pdf). Environment Canada, http://www.ec.gc.ca/doc/scitech/mecrdp_e.html

vision that will strengthen linkages among partners along the whole impact pathway (from researchers to development agents and to end-users) (see Annex 7).

2. Communication. Good communication along the whole impact pathway is critical for RICE to deliver its development impacts. Good communication contributes to the achievement of research outcomes at different scales, enhances program visibility, and demonstrates accountability by widely sharing program results. The RICE communication strategy has six activities that interconnect with—and support—other elements of the enabling environment such as ME&L, capacity development, partnership building, and policy support. These activities are: 1) communicate and engage with partners; 2) promote learning and sharing of information; 3) engage with actors on the ground to scale-out technologies and practices; 4) communicate about the program, the science, results, and progress; 5) engage in policy dialogue to scale-up results; and 6) make research program information and resources open and accessible (see Annex 13).
3. Gender Awareness. 'Culture' is an important dimension of enabling environments (see references footnote 6). An important aspect of culture in the agricultural R&D arena is that of gender (in)equalities—and the perceptions of these—within and among all actors along the impact pathway (see section 1.0.4). RICE aims to contribute to positive and transformative changes on gender perceptions and gender equalities among its partners and its beneficiaries, especially farmers. (see Annex 4 and FP1 [cluster of activity 1.2]).
4. Capacity Development. RICE adopts the CGIAR capacity development framework as a comprehensive structure to systematically strengthen capacity among partners and actors along its impact pathway. The nature of capacity development varies with the location of the partner/actor on the impact pathway, from strengthening individual and institutional capacity for research to strengthening the capacity for partner formation (e.g., the creation of learning alliances and other multistakeholder platforms), adaptive research, ME&L, communication, knowledge dissemination, and policy engagement. Especially important for strengthening the enabling environment to support the process of scaling-out, are actions to develop space for innovation among research partners, development partners, and local communities (see Annex 3).
5. Partnership Building. RICE actively engages with partners along its whole impact pathway, from upstream research to downstream scaling-out. The private sector is increasingly recognized as a key player in bringing new technologies to markets/end users, and features prominently in RICE's partnership strategy. Of special importance are RICE's efforts in the development and fostering of multistakeholder platforms and outreach/scaling mechanisms, including seed systems, which are addressed specifically in clusters of activities 1.3 and 1.4 of FP 1 (see Annex 2 and the GRiSP Partnership report).
6. Policy Support. Like culture, 'policy' is an important dimension of enabling environments in the development arena (see references footnote 6). In the CRP II portfolio, the CRP 'Policies, Institutions and markets (PIM)' is the main avenue for developing and disseminating policy support to facilitate scaling-out and uptake of new technologies, products, and services. Through FP1, RICE collaborates with the CRP PIM, but also undertakes its own efforts on policy support in the rice sector.

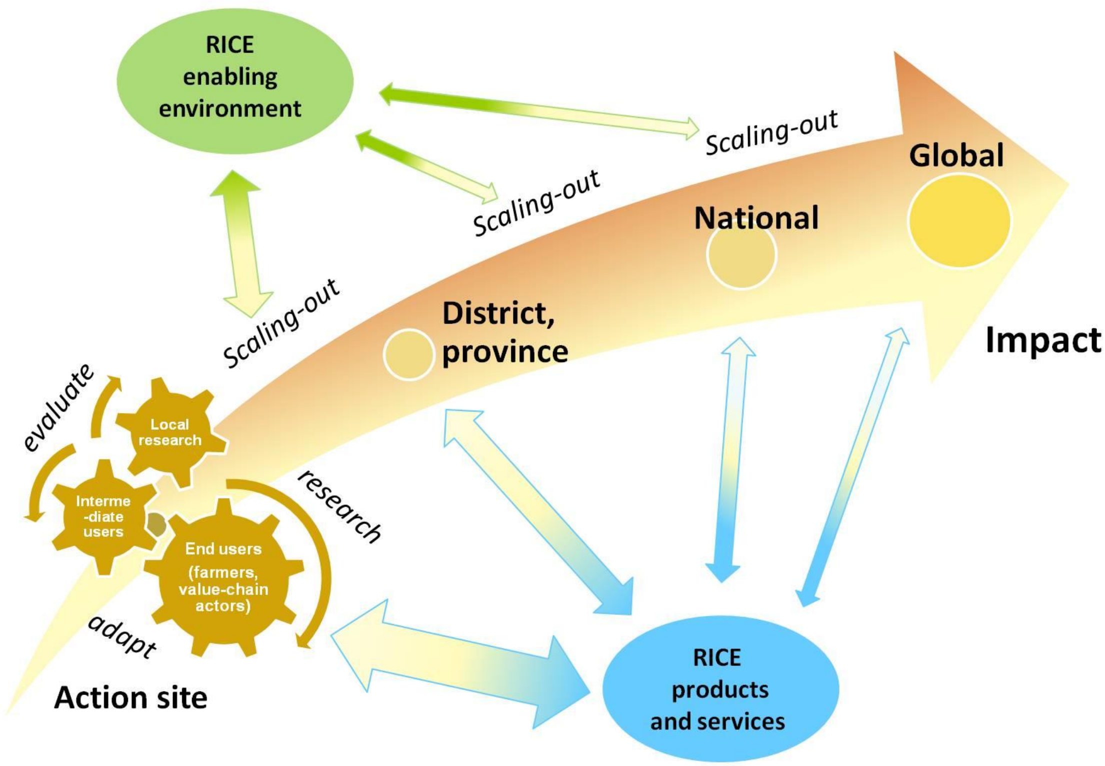

Fig. 3. Schematic diagram showing how products and services are taken up, adapted, used, and disseminated at different spatial scales. RICE strengthens the enabling environment for scaling-out and product uptake across spatial scales.

This proposed set of six actionable elements is a first attempt at a systematic framework for the concept of 'enabling environment' in agri-food systems. RICE takes action to mobilize, strengthen (capacity for research, innovation, and extension), inform, support, and link partners, and to promote equity—especially gender equity—throughout the rice value chain. Fig. 4 provides concrete examples, and each of RICE's FPs has identified a number of specific enabling actions to develop the right products and services in the rice sector, and to bring them to scale. In addition to the six generic elements of RICE enabling environment, specific actions are often needed as illustrated in Fig. 4 (e.g. conduct of surveys to gather additional stakeholder information, support for specific extension services).

To identify the required enabling actions for a specific product or service, RICE will first establish the assumptions associated with each step along the impact pathway for a specific product or service and the risks if these assumptions are not met. Fig. 4 gives an example for a generic product intervention (a new variety) at the farm level. From this analysis, the enabling actions are identified that need to be undertaken to minimize the risks and to ensure the flow of products. Because research-to-impact is nonlinear (ISPC 2012a), learning and feedback mechanisms are embedded in planning processes and impact pathways and theories of change are regularly reviewed and updated (see Results-based management, Annex 6). This is evident from the two-directional arrows between the impact boxes in Fig. 4. Many feedback loops exist which have been omitted from Fig. 4 for clarity.

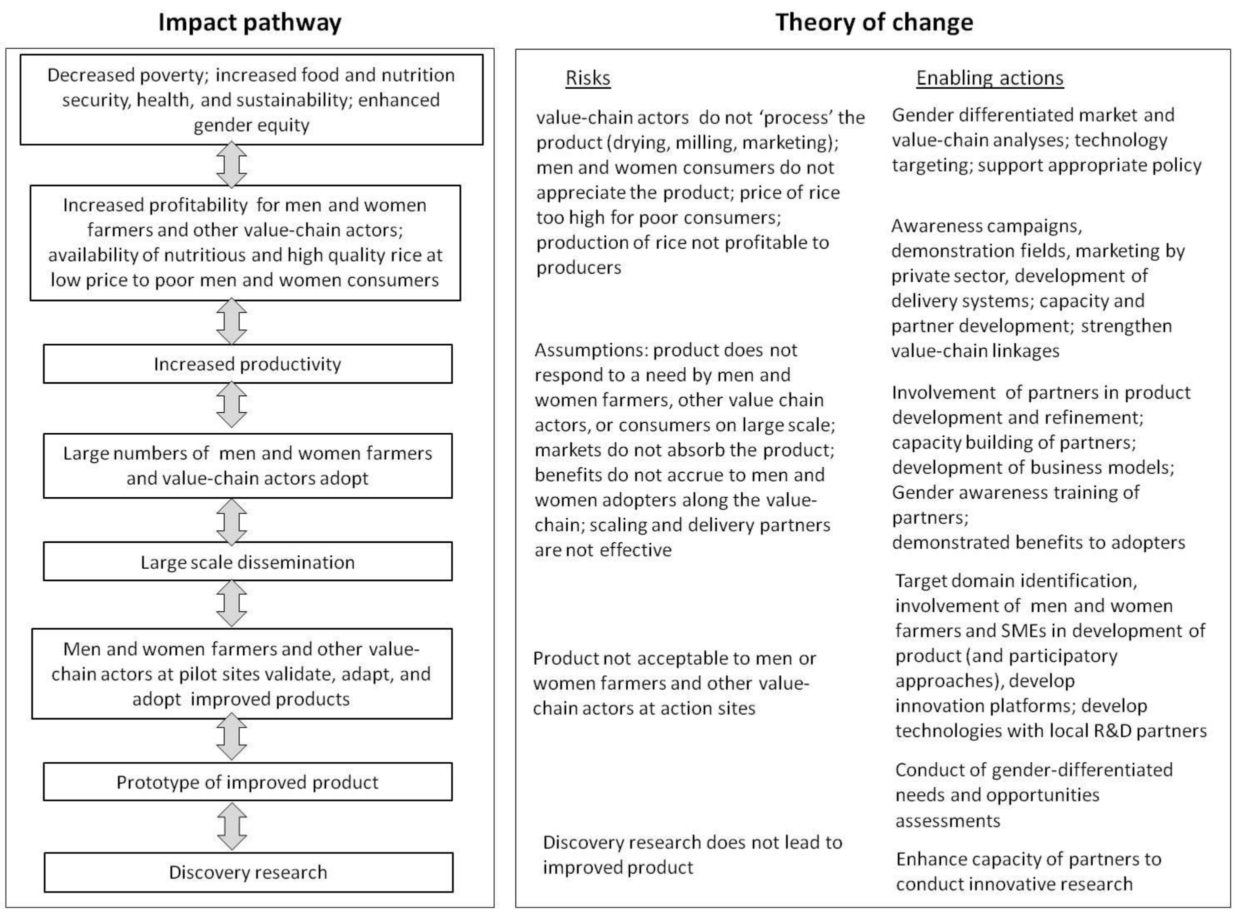

Fig. 4. Generic impact pathway and theory of change for an intervention that involves the introduction of a novel product along the rice value chain.

At the CRP level, a theory of change is specified at a relatively abstract or generic level. More specific theories of change are provided for each flagship project, but, even then, more refined theories of change are needed for specific products in specific action sites, countries, or target domains. Theories of change are living documents that will be regularly reviewed and revised. At the action sites, this will happen on time scales that are probably less than a year as progress along the local impact pathway is regularly monitored. At the FP level, reviews will take place annually, whereas at the CRP level, reviews will probably be held every 3 years in line with the CRP update process. Although reflective learning on theories of change will take place in all FPs, collective learning will be coordinated in FP1, guided by the RICE monitoring, evaluation, and learning (MEL) system. A summary description of the RICE results framework to guide the realization of its outcomes is presented in Annex 6. To achieve its outcomes, RICE will collaborate with the other CRPs; Annex 7 provides an overview of cross-CRP collaboration.

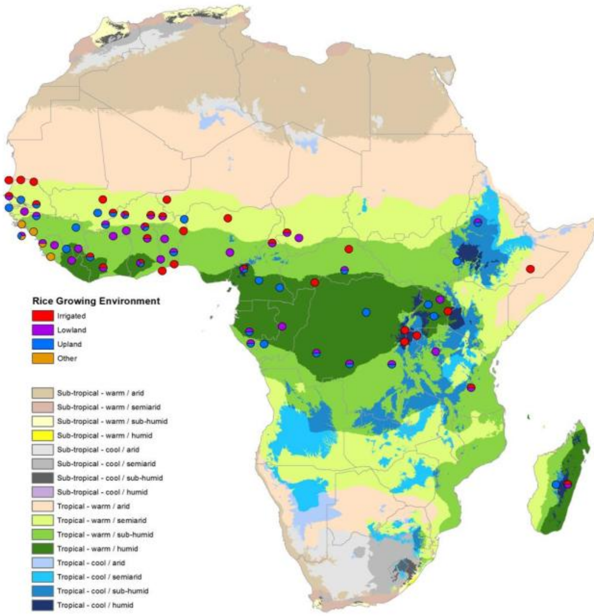

Fig. 5a. Examples of RICE action sites in Africa: rice sector development hubs (as of July 2015). Rice sector development hubs (or Rice Hubs) are regions where research products and services and local innovations are integrated across the rice value chain to achieve development outcomes and impact. These regions were selected by national partners of AfricaRice in 2011-12 based on the following criteria: importance of target growth environment for the country, large production area to have high impact, easy accessibility (to avoid high transportation costs), linkage with major national or regional rice development efforts, and existence of important value-chain actors (rice millers, input dealers, rice market) (www.ricehub.org/)

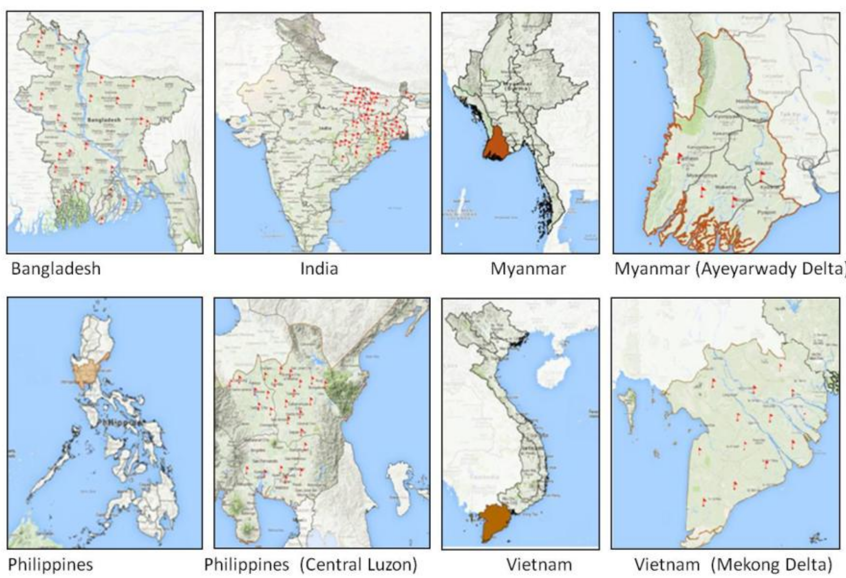

Fig. 5b. Examples of RICE action sites in Asia: rice development areas (as of July 2015). The dots indicate the locations where research and development activities on the ground are concentrated, and where detailed household surveys have been—and will be—conducted to monitor progress toward development outcomes. The rice development areas are roughly the areas that encompass the dots. For example, most of Bangladesh is considered a RICE rice development area, whereas, in India, the northeastern part is a RICE rice development area.

RICE aims to have impacts at spatial scales ranging from local action sites to national and global. Action sites are based on local partnerships in villages or districts where new technologies are developed, evaluated, improved, and disseminated in a highly participatory mode. Action sites also include laboratories, breeding locations (e.g., multienvironment trials), and field experiments. Examples of

action sites are the Rice Sector Development Hubs in Africa and the key development areas in Asia (Fig. 5).

At larger spatial scales, products adopted at action sites will reach more beneficiaries through engagement with strategic development partners for scaling-out and scaling-up. Because results at these scales are mainly delivered by partners to RICE, outcomes at these levels are less under direct control of RICE.

At the national and global level, RICE will actively promote the use of its products by making them widely and open-access available, by collaborating with many public and private sector partners, and by actively engaging with policymakers. As international public goods, many RICE products and services will be adopted and disseminated even without RICE's assistance. RICE works with —and in— most of the world's major rice-growing countries.

1.0.4 Gender

This section needs to be read in conjunction with Annex 4 on gender

The IEA evaluation of GRiSP concluded that GRiSP has played a central role in sensitizing and training its participating centers' staff and partners in gender analysis (IEA report, p 59–60). GRiSP successfully involved women as target beneficiaries in its activities for scaling-out technologies despite cultural barriers that are imposed in some societies. However, the evaluators also noted that GRiSP was less successful in incorporating gender as an integral part of research planning and technology design, and recommended that "GRiSP should do more in-depth analysis to understand opportunities and constraints of women in rice farming and value chains in order to better address the effectiveness and equity impacts of its research and technology delivery" (Recommendation 9, p xvii). In line with this recommendation, gender research has been strengthened to pay particular attention to gender issues upstream in the research-delivery pipeline, to conduct in-depth research on the role of women in rice farming and value chains, and to guide planning of research that explicitly incorporates gender dimensions in the early stage of technology design in RICE. Below, an analysis of the gender dimensions of RICE's impact pathway and theory of change is given. The analysis of the impact pathways was informed by gender assessments carried out in GRiSP, as synthesized in Annex 4. The operationalization of the gender strategy in the RICE FPs is also detailed in Annex 4.

Gender in the impact pathway. RICE's gender impact pathway provides the basis for understanding the role of gender in achieving development outcomes and indicates areas for integrating gender considerations into the process of product development and deployment, including research planning, design, implementation, and evaluation. Fig. 6 schematically summarizes the gender impact pathway that links RICE's gender-differentiated products to gender-specific outcomes and CGIAR SLOs.

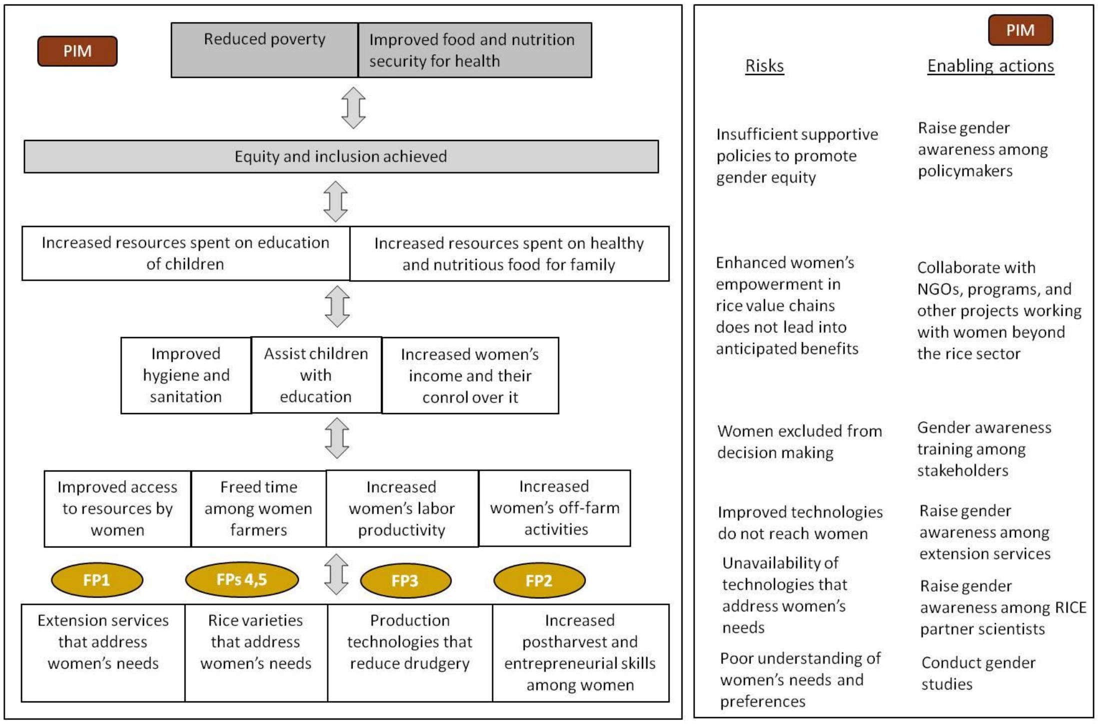

Fig. 6. Schematic gender impact pathway (left) and theory of change (right). Light grey boxes are IDOs, dark grey boxes are SLOs, ovals (with FP x) refer to links with other FPs, and the dark boxes refer to links with other CRPs (see Annex 12 for abbreviations).

RICE's emphasis on gender equity and women empowerment is based on two premises. The first is that women contribute significantly to rice production. Within rice value chains, female family members participate in rice production and in postharvest, processing, and marketing operations. Through farming, they significantly contribute to food security in the household, nationally, and globally. Women's contribution in rice farming is steadily growing due to the accelerating rate of male outmigration (Paris et al 2010). However, women's contribution in the rice sector is often overlooked and undervalued, and many impediments hinder women realizing their full potential. Women face barriers and inequalities in terms of access to and control over such resources as land, capital, and credit as well as access to agricultural inputs and technology. These inequalities reduce productivity in women-managed farms, resulting in acute poverty and food insecurity. Performing nonmechanized back-breaking farming operations (e.g., transplantation, weeding, and threshing) poses significant health risks for women. These time-consuming responsibilities, in addition to inherent household responsibilities, overburden women by reducing their leisure time and time they could otherwise devote to children's education and off-farm income generation. Ensuring women's equal access to resources, inputs, and information and improving their livelihood options and well-being (income, health, and nutrition) are thus crucial to achieving the development outcomes of RICE (i.e., poverty reduction and food security).

The second premise for emphasis on gender equity and women empowerment is that women are instrumental in development. Women work as a catalyst for change and are a major driver of growth and development (Gates 2014). Empirical studies have shown that women spend their additional income on food, healthcare, and children's education (an important stepping stone out of poverty),

while men spend more of their income on personal items (Smith and Haddad 2000). Often, a higher share of women's assets is associated with better health outcomes for girls. Equalizing women's status would lower child malnutrition in South Asia by 13% (13.4 million more children well nourished) and in sub-Saharan Africa by 3% (1.7 million more children well nourished) (Smith and Haddad 2000). Thus, empowerment of women by ensuring their equal access to resources, inputs, and technologies and allowing them to have greater control over income and assets can accelerate the pace of development, ultimately contributing to household food security, health and nutrition, and poverty reduction.

RICE products will contribute to gender equity and women's empowerment by increasing crop yields through high-yielding varieties, improved farming practices, and higher resource-use efficiency; through lower production risk through stress-tolerant varieties; higher income from higher production, farm diversification, and short-duration varieties; and greater availability of nutritious food from improved grain quality and crop diversification. Further, increasing productivity and production will lead to increased marketable surplus, thus enabling women to increase their income share and purchasing power to buy quality food; this will help them in their role of guarding household food, health, and nutrition security, especially of young children. With greater household rice supply, women may not have to purchase rice or queue for rice rations during periods of low supply. By also planting less labor-intensive crops such as vegetables and lentils, women will have more time for income-generating opportunities as well as access to balanced and nutritional diets. Evidence shows that females are more likely than males to suffer from malnutrition, due to the former's lack of access to nutritional food (Bhagowalia et al 2012). Since rice is widely consumed by the majority of the population in low-income households in Asia, Africa, and South America, increasing the nutritional quality of rice grains will have a direct impact on women's and children's nutritional security. Finally, providing women farmers access to stress-tolerant seeds in vulnerable, stress-prone areas will increase women's resilience to extreme climate variability by reducing crop losses.

RICE will further contribute to gender equity and women's empowerment by producing labor-saving technologies and farm mechanization equipment especially relevant for women rice farmers who presently provide labor for back-breaking nonmechanized operations. Examples of labor-saving practices are mechanical transplanters and direct-seeding equipment, mechanical weeders and/or the use of herbicides, harvesting machinery (combine harvester-thresher), mechanical thresher, and rice micro mill. New mechanization options for both pre- and postharvest interventions are expected to increase women's labor productivity and reduce their drudgery. This will free their time for enhancing their income through other on-farm or off-farm activities. Consequently, women will gain greater control over income, which they can invest on their families' well-being. With labor-saving technologies, women have better health, more leisure, and more time to take care of their children, prepare food, and clean their house. Studies have shown that with the adoption of the mechanical drum seeder in southern Vietnam, women from farming households were relieved of transplanting work, enabling them to have more time for their personal care, leisure, socializing/networking with other women, coaching their children in their studies, and taking care of livestock for income and home consumption (Paris et al 2009). Obviously, care must be taken with the introduction of labor-saving technologies that women workers are not deprived of their means of income and that alternative use of their time really constitutes an improvement.

RICE will contribute to women's livelihood opportunities and well-being by the reduction in postharvest losses, improved processing technologies (such as parboiling), and improved marketing. In many areas, women still practice the traditional postharvest operations, such as manual threshing and winnowing, and poor seed management, which result in significant losses (Paris et al 2013). Adoption of improved postharvest technologies will directly benefit women through reduced losses, thus increasing the amount of rice for consumption and ensuring food security. Improved processing, marketing, and other value-adding technologies will provide women with additional income. Improved quality and a variety of novel rice-based products for consumers can contribute to improvements in rice value chains. Development of value-added by-products can also help to improve farmers' income.

RICE will improve women's access to resources (seed, inputs, technologies, and technical knowledge), which will increase their labor productivity (Pandey et al 2010). Increased resource access can be accomplished by developing technologies and know-how (RICE products and services) specifically targeted to their needs, and by extension and advisory services geared toward reaching women. RICE will train women and marginal farmers to manage and multiply rice seeds to give them secure access to seeds for future crops. Some women will also be given entrepreneurship training to enable them to become seed entrepreneurs. Gender-equitable access to seeds of improved varieties, improved natural resources management practices and technical know-how, and involvement in participatory experiments and agricultural training programs will contribute to women's empowerment by building their knowledge capital and reducing the gender gap. Involving women farmers and farm managers in the R&D process and training programs will lead to gender-equitable development and delivery of technologies, inputs, technical knowledge, and skills. More examples of the impacts of RICE products and services on the livelihoods of women are given in each RICE FP.

The enabling environment: fostering transformative changes. RICE will foster transformative changes in the enabling environment to support the gender impact pathway by the following actions:

- RICE coordinating centers will carry out gender-in-the-workplace strategies that aim at increasing women's participation in (senior) management, research and development activities, training, and outreach activities. The provision of a gender-sensitive workplace and environment will be encouraged.
- Gender will not be viewed as an isolated component, but will be mainstreamed by incorporating gender consideration in the design, planning, implementation, and monitoring process.
- Baselines on women's roles, empowerment status, and sociocultural contexts in the rice sector will be improved and monitored, especially in Latin America.
- RICE researchers and their partners (public and private sector, NARES, NGOs, etc.) will be made aware of the gender aspects of their work—gender roles and cultural contexts. They will develop research questions about women's preferences for the products and services they develop and the potential impact of adoption of these on women's livelihoods. They will engage women farmers and other women actors along the rice value chain in the design, execution, and analyses of their experiments. Good examples are inclusion of women in participatory field trials, sensory panels, and variety testing. Through participation of women in variety testing, breeders will have a better understanding of women-preferred traits and selection criteria,

particularly cooking, eating, and storage quality; quality of rice straw for animal fodder; special traits for value-added products; postharvest qualities (ease of harvesting and threshing); and agronomic characteristics (height, which makes the crop easy to harvest). Information about farmers' preferences and adoption of new technologies will be gender disaggregated and analyzed.

- Access by women farmers and other women stakeholders to improved products and services (new varieties, crop management practices, postharvest technologies, inputs, knowledge, etc.) will be enhanced through better-targeted training and rural extension and advisory systems. Women farmers will be included in practical and field training, and the number and skills of women extension agents increased.
- Women will be more actively engaged in the research-for-development continuum.

The RICE overall theory of change and the transformative changes it will facilitate, are summarized in Fig. 7, which illustrates the flow of gender-related research questions, leading to gender-based outputs, research outcomes, intermediate development outcomes (IDOs), and ultimately CGIAR system outcomes (SLOs).

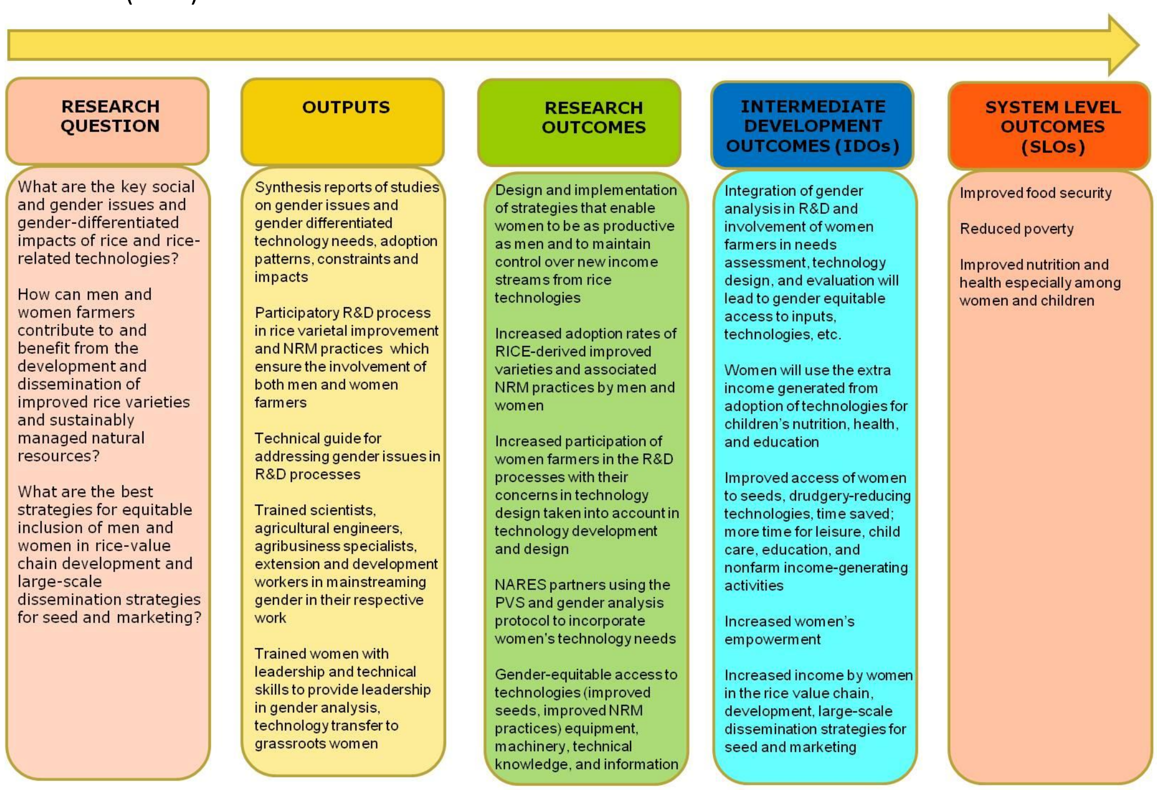

Fig. 7. Flow of gender-related research questions, leading to gender-differentiated outputs, research outcomes, intermediate development outcomes, and ultimately to CGIAR system level outcomes.

1.0.5 Youth

Youth unemployment has recently emerged as a crisis in agriculture-based economies of low-income countries, especially in Africa and the hinterlands of Asia (van der Geest 2010, White 2012). Despite agriculture being the core sector of these economies, youth employment in agriculture has remained very low, mainly as family labor, due to lack of mechanization, high production risks, and low agricultural productivity (Moore 2015). Employment opportunities outside agriculture have not been sufficient to absorb the growing youth labor force. Unemployment and underemployment of the vast majority of the youth workforce thus hinder the potential for economic growth and agricultural development.

In contrast, in many of the dynamic zones in Asia, outmigration from rural to urban areas is leading to the opposite problem—scarcity of young and able labor. The aging of the rural labor force has many countries worrying about who will grow their food in the coming decades (Li and Sicular 2013).

Annex 5 summarizes the RICE strategy to attract youth to the rice sector and rice value chains, both to combat unemployment in Africa and in Asia's hinterlands and to reverse the aging of the rural labor force in the dynamic zones of Asia. RICE will engage in strategic research on youth issues and develop business models and opportunities for young people to be actively involved in rice value chains and earn attractive incomes.

1.0.6 Program structure and flagship projects

Based on lessons learned during GRiSP, five highly interconnected FPs will develop and deliver RICE products and services for development outcomes (Fig. 8).

FP1 (Accelerating impact and equity) encapsulates RICE by providing overall guidance, fostering an enabling environment for large-scale delivery of outcomes, and leading monitoring, evaluation, learning, and internal feedback loops. It will engage in foresight, technology evaluation and targeting, gender and youth studies, scaling-out of technologies, monitoring and evaluation, and ex-ante and ex-post impact assessments across RICE. FP1 will help all other FPs develop well-targeted and demand-driven products and delivery approaches. To catalyze the scaling-out of RICE's products and services, it will foster partnerships with scaling and development agents (including private sector, public sector, NGOs, etc.), develop and support collective innovation mechanisms, strengthen capacity of research and development partners, and manage and communicate new knowledge. Specifically, seed distribution systems will be strengthened to ensure that the new varieties are available to millions of farmers. FP1 links with PIM on foresight and scenario analyses and on impact assessments.

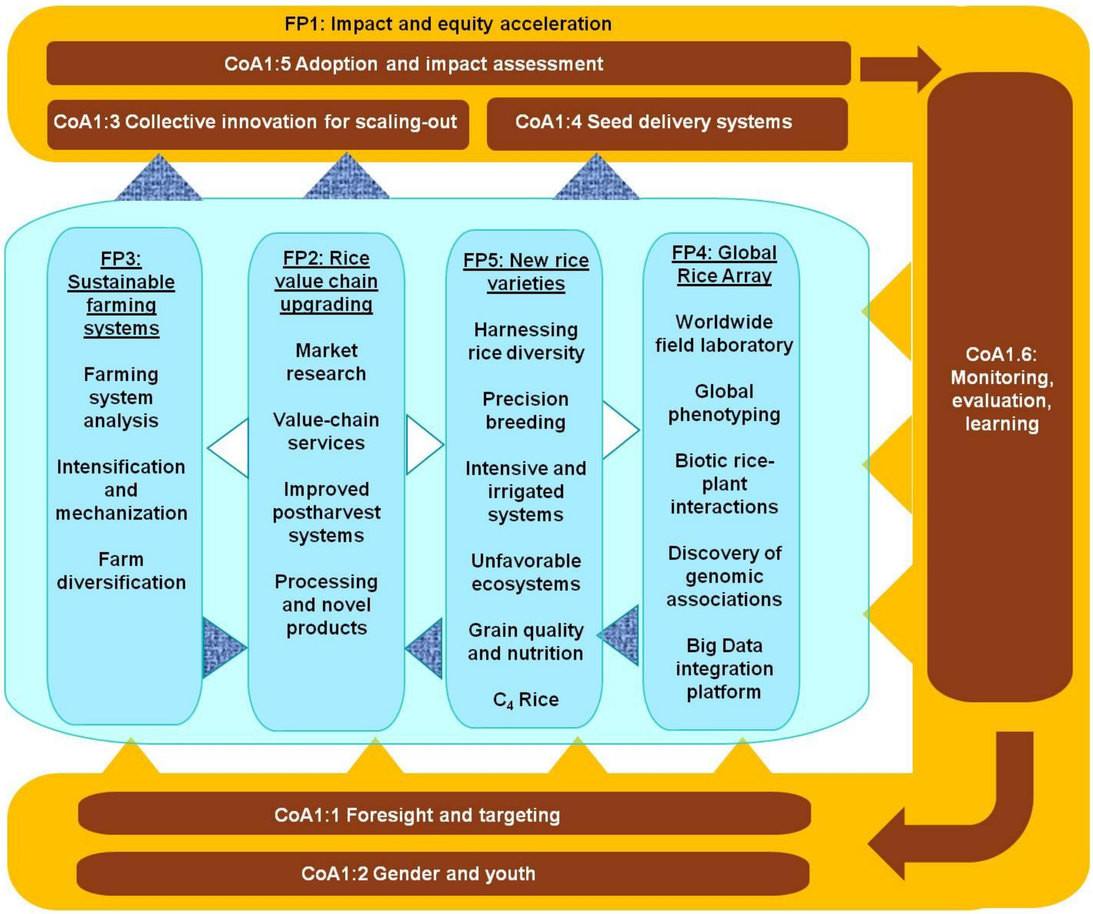

Fig. 8. RICE flagship projects and clusters of activity.

FP2 (Upgrading rice value chains) will study rice value chains and identify entry points for upgrading, some of which will be passed on to other FPs, while others will be developed and delivered in FP2 itself. It will conduct market research, assess rice value chains, and identify opportunities for improved processes, reduced postharvest losses, novel and value-adding products, strengthened value-chain linkages, and improved (input and output) market access. It will provide guidance for specific product development in FPs 3 and 5, and connect novel farming systems developed in FP3 with markets. FP2 links with PIM in developing tools and methodologies for value-chain analysis.

FPs 3–5 focus on the production component of the rice value chain and develop new rice technologies and rice-based farming systems. FP3 (Sustainable farming systems) will develop and deliver sustainable intensification and diversification options for rice-based farming systems to improve farmers' livelihoods, while minimizing the environmental footprint of production. Integrated rice management practices with novel varieties (from FP5) and alternative farming systems will be developed based on current and future demand. FP3 will link with other agri-food system CRPs in crop and whole farm diversification. Linking with the CRP on climate change, FP3 will also develop and test specific innovations in rice farming systems for adaptation and mitigation under changing climates. FP4 (Global Rice Array) will establish a global network of field laboratories to discover new genes and traits of rice, develop and test rice ideotypes, assess the suitability and robustness of novel genotype ×

environment × management options, and use the rice plant itself to characterize climate change. Outputs of FP4 will feed directly into FP5 (New rice varieties). FP5 will develop and deliver rice varieties that are adapted to current and future climates, respond to markets, and that have improved traits with regard to health and nutrition, yield potential, resistance to biotic stresses (pests, diseases, and weeds) and tolerance for abiotic stresses (drought, submergence, salinity, heat and cold, problem soils, and low light).

In GRiSP, the thematic nature of flagship projects has shown itself to foster cross-CGIAR center collaboration. However, both a self-assessment among GRiSP staff and the results of the IEA evaluation of GRiSP have revealed that it restricted multidisciplinary research. The IEA recommended the introduction of modalities to increase interdisciplinary research (recommendations 1 and 6, IEA report p xvi). Hence, a second organizing principle based on geographic area has been introduced in RICE. Whereas some upstream research is not particularly place bound (e.g., gene discovery), downstream research and development activities will be concentrated at action sites in five mega-rice-growing environments: mega-deltas and coastal zones, irrigated systems, rainfed lowlands, uplands, and inland valleys (Table 3). At action sites, multidisciplinary teams from across the FPs will work together to develop integrated and holistic solutions that are tailored to the needs of the intended beneficiaries (IEA recommendation 1), while not losing sight of the generic and international public good character of their solutions. At the action sites, RICE aims to collaborate with other CRPs and CGIAR centers through site integration/coordination (section 1.0.7 below). FP3 plays a key role in such integration, aided by a specific cluster of activities (CoA1.3) in FP1 that supports the development of multistakeholder platforms. The mega-deltas, coastal zones, and irrigated environments contain most of the dynamic zones, whereas rainfed lowlands, uplands, and inland valleys are more characterized as hinterlands (section 1.0.1).

Table 3. Mega-rice-growing environments.

In the mega-deltas and coastal zones in Asia, which account for 34–70% of national rice production area in countries such as Bangladesh, Myanmar, and Vietnam, productivity is hampered by too much water in the rainy season, too little water and/or salinity in the dry season, and cyclonic events. Acid and acid sulfates and peat deposits are common. Because of close proximity to many of the region's mega-cities, the effects of structural transformation are marked and emerging enterprises will offer agricultural services such as leveling, crop establishment, and harvesting. Integrated rice management practices with new and market-driven rice varieties, locally adapted mechanization, farm diversification, land consolidation, increased market connections, and value chains all offer scope for tremendous improvements in farm productivity.
Rice in irrigated systems is generally grown in bunded fields for one to three crops per year, and this system accounts for some 45%, 34%, and 46% of the rice area in Asia, Africa, and Latin America, respectively. Although irrigated systems have been intensified over the past decade or so, new science-based interventions are required to enable further enhancement of productivity and sustainability. Resource (land and water) and labor shortages mean that more efficient use of natural resources and mechanization, respectively, will be required. Also, reducing inputs of agrochemicals such as pesticides should be done through ecological approaches and diversification to reduce their negative impact on the environment and the health of rural communities. Similar processes that accompany structural transformation in the mega-deltas and coastal zones are often at play in irrigated systems.
The rainfed lowlands are mainly located on level to slightly sloping ground, with unbunded or bunded fields. Depending on site, season, and landscape, fields have too much water and/or too little water. Poor and very poor soils are dominant in the lowlands of Southeast Asia and Africa, with iron toxicity in African and Latin American soils. For greater adaptation to local agro-environments, field-specific crop management practices with climate-smart varieties are needed within this mega-environment. Another solution is diversification of cropping systems (e.g., crop rotation) for sustainable management of soils and to diversify income sources.
Uplands are characterized by drought-prone environments, poor soils (including acidity in Latin America), and various pest problems such as weeds and rodents. One solution is the transformation of high-risk rainfed production to more stable, more highly productive irrigated production, using water collected by water-harvesting technologies. Climate-smart agriculture combining improved cropping systems (e.g., conservation agriculture) with new rice varieties is needed to reduce production risk, improve soil health, increase biodiversity, and control major pests such as problematic weed species.
Inland valleys are found in the upper reaches of river systems on land with impeded drainage in Africa. There is great potential for expansion of cultivated area and increased production. Expansion of rice cultivation area needs low-cost technologies of land development that can create new job opportunities, for which the rice sector has the potential to employ millions of youth entering the job market. Furthermore, farming systems in inland valleys can be upgraded from rainfed systems to irrigated systems with intensification and diversification.

1.0.7 Cross CRP collaboration and site integration

RICE pursues thematic as well as geographic collaboration with other CRPs. Thematic collaboration will include joint and/or complementary development, testing, implementation, and evaluation of research approaches, tools, and methodologies. All FPs engage in such collaboration. Details for collaboration with other CRPs are provided in Annex 7, in the form of narratives and tables. Some salient activities will include collaboration on foresight analysis, food supply-demand modeling, and impact assessment methodologies between RICE FP1 and PIM; joint development and implementation of methodologies for value-chain analysis between RICE FP2 and PIM; development of diversified rice-based farming systems between FP3 and all other agri-food system CRPs; collaboration between RICE FPs 4 and 5 and all other crop-based agri-food system CRPs and WLE on development of genomics breeders' tools (also through the proposed Genebank, Genetic Gains, and Big Data platforms); collaboration between RICE FP5 and A4NH in mainstreaming the development of healthy and nutrient-dense rice varieties; collaboration between FPs 3, 4, and 5 with CCAFS in developing, evaluating, and disseminating climate-smart rice varieties and farming systems. Some of the collaboration takes the form of co-investments; other modes are coordination and complementary activities. Several center staff involved in RICE will also be involved in other CRPs (CCAFS, PIM, WLE, A4NH) and play a key role in the coordination of activities.

Geographic collaboration takes place through the CGIAR site integration. At a Consortium meeting in June 2015, two tiers were distinguished: (1) national and policy level, where the CGIAR will maintain high-level interactions with national governments and national system entities; and (2) at specific geographic sites where coordination and collaboration on the ground will occur in specific R&D activities with local and national partners. The GRiSP lead center IRRI has co-organized the Vietnam site coordination workshop and consultations with the government of Bangladesh; AfricaRice actively participated in the workshops in Ethiopia, Ghana, Nigeria, Senegal, and Tanzania, and CIAT in Nicaragua (representing both the institutes as well as RICE). Meeting reports are available on the CGARD3 website. Other national consultations and stakeholder engagements undertaken by GRiSP to prepare for RICE are listed in section 1.0.9.

Although the concept and mechanics of CGIAR site integration still need to be further developed, RICE's FP3 on sustainable farming systems will be a main mechanism for "tier two" collaboration on the ground. An estimated average of 80−90% of on-the-ground collaborative activities will be funded through specific bilateral grant projects (e.g., CSISA in South Asia, in which RICE, WHEAT, MAIZE, and PIM collaborate). W1 and W2 funds will be used for catalyzing activities to link across CRPs. In year 1, RICE will organize joint scoping studies and workshops in which joint teams (CRP centers and their local/national partners) will visit each other's ongoing activities and develop a common understanding of needs and opportunities for collaboration. Such joint scoping studies and workshops will foster ideas for collective action that will be further elaborated in joint next steps (e.g., joint experiments, thematic workshops, sharing facilities or platforms) and formulations of joint grant proposals. Such studies would also identify new partners that need to be included (e.g., AVRDC to explore introduction of vegetables into rice-based cropping system to increase dietary diversity at farm household and rural community level) on a needs basis. See Annex 7 for more details on RICE and site integration.

1.0.8 Partnerships and comparative advantage

The Global Rice Science Partnership (GRiSP) was launched in 2010 and provided, for the first time, a single strategic plan and unique global partnership platform for impact-oriented rice research for development. At a global scale, GRiSP acts as an overarching umbrella and “organizing principle” for rice research for development. The CGIAR Research Program on rice was synonymous with GRiSP in the first phase CRPs. In the second phase, RICE will be the main CGIAR program contribution to a larger GRiSP.[7] The 2015 IEA evaluation of GRiSP noted that “GRiSP will require many years to develop a truly integrative and collaborative global rice science partnership” (p xiv). Thus, RICE will build on and continue the first phase of the CRP on rice. Recommendation 7 of the IEA evaluation states that “The rapid acceleration of rice research worldwide over the past 15 years is an opportunity for GRISP to develop new partnerships with ARIs. GRISP should enrich its portfolio of new frontier and discovery research projects in partnership with ARIs with the objective of exploring new concepts and tools to achieve its goals”. New partnerships with ARIs will be continuously explored; details are presented in each FP description.

Annex 2 outlines the overall RICE CRP partnership strategy and its underlying principles; a complete listing of all current partners of GRiSP is on the GRiSP website. RICE continues to be led by the same institutes that lead GRiSP: IRRI, the lead institute, AfricaRice, and CIAT; and three other leading agricultural agencies with an international mandate and a large research portfolio on rice: Centre de Cooperation lnternationale en Recherche Agronomique pour le Développement (Cirad), L'lnstitut de Recherche pour le Développement (IRD), and the Japan International Research Center for Agricultural Sciences (JIRCAS). Together, these six centers align and bring to the table consortia, networks, platforms, programs, and collaborative projects with some 900 partners from government, nongovernment, public, private, and civil society sectors, about equally divided among three categories—discovery research, proof of concept, and scaling-up.

The comparative advantage of RICE to pursue its goals and objectives (section 1.0.2) is that virtually all potential alternative suppliers worldwide have already become partners under GRiSP. In upstream research, for example, worldwide partnerships include the C4 Rice Consortium, the International Rice Informatics Consortium, or the OryzaSNP Consortium (www.oryzasnp.org). More examples are given in Annex 2. At the downstream (development) end of the R4D continuum, GRiSP now has active partnerships with well over 100 civil society organizations in over 20 countries. This advantage encompasses all the R&D activities that RICE will undertake toward achieving its IDOs and sub-IDOs. Further, RICE will benefit greatly from GRiSP experiences in developing and managing the many partnerships and activities.

The 2012 CGIAR survey on partnerships by CRPs reported that 82% of the respondents were satisfied with their GRiSP partnership (Globescan 2013). Research outcomes and expertise were the two indicators in which GRiSP performed strongest, with global expertise and innovation being the top two performing dimensions. Open-ended comments about GRiSP were generally positive, with both staff and management being praised. Respondents described it as one of the best rice research programs in the world.

[7] See bottom IEA evaluation report, p xiv

1.0.9 Evidence of demand and stakeholder commitment

Demand for research and development investment in the rice sector is explicitly identified in national rice development strategies (NRDS) of most countries that RICE targets. In Africa, NRDS have been developed under the Coalition for African Rice Development (CARD) with support from AfricaRice. These NRDS reflect national priorities and targets and are also aligned with overarching development frameworks such as the Comprehensive Africa Agriculture Development Program (CAADP). As of November 2014, NRDS have been validated in 22 African countries. Both AfricaRice and IRRI are members of the steering committee of CARD and have ensured that priorities identified in the NRDS are taken up in RICE. AfricaRice is an autonomous intergovernmental association of 25 African member countries. Its objectives, strategies, and research activities are aligned with those of its member states. Each year, the meeting of AfricaRice's national experts (composed of NARES directors general of the 25 member countries) is an important mechanism for the alignment of work plans with national priorities and programs.

In 2014, the Council for Partnership on Rice Research in Asia (CORRA) and GRiSP conducted two multicountry workshops to make a systematic inventory of and describe NRDS for 13 countries in Asia (Bangladesh, Cambodia, India, Indonesia, Iran, Lao PDR, Malaysia, Myanmar, Nepal, the Philippines, Sri Lanka, Thailand, and Vietnam). In these workshops, discussions focused on five topics: (1) relevance of the current GRiSP IDOs to countries and coverage in their NRDS, (2) commonalities among country strategies, (3) quantitative targets with a timeline for country development outcomes, (4) the logical link between country rice-sector development goals and research objectives, and (5) impact pathways from country rice research to product development to development outcomes. In addition, several bilateral country-IRRI/GRiSP workshops were organized to develop joint objectives and work plans such as with India, Indonesia, Myanmar, the Philippines, Thailand, and Vietnam. In 2015, feedback from CORRA on the RICE pre-proposal was used to develop the full RICE proposal, which was again shared for comment from CORRA members in 2016.

In Latin America and the Caribbean, CIAT partners with the Latin American Fund for Irrigated Rice (FLAR) to identify member country priorities and R&D needs, and to develop appropriate response options. As of 2012, FLAR comprised 27 institutions from both the private and public sector, from 17 countries and CIAT. In 2014, GRiSP and FLAR organized three consultation workshops—in Uruguay, Colombia, and Panama, respectively, to discuss R&D priorities and to validate and adapt GRiSP IDOs and indicators. Some 20 indicators were identified for monitoring at the national level by the national partners. Prioritized research topics of FLAR countries focus on rice breeding, agronomy and water harvesting, and hybrid rice development, and are incorporated in RICE.

Regionally, GRiSP has received support from major regional fora and economic communities that have a stake in the development of the rice sector; RICE will continue to build on this. In 2011, the 33rd meeting of the ASEAN Ministers on Agriculture and Forestry communicated that it "supported the Global Rice Science Partnership (GRiSP) … as it represents an important expansion and development of 2008's ASEAN Rice Action Plan." In 2014, they endorsed a proposal for a program to "Secure Global Food Security by Building a New Generation of ASEAN Rice Scientists" within GRiSP.

The CGARD3 and the CGIAR site integration processes are playing an important role in further

development of stakeholder interactions. Throughout 2014-early 2016, the GRiSP program partners conducted many workshops and stakeholder engagements with the public (NARES, NGOs, academia) and private sector to develop the content of the RICE proposal, including national dialogues, thematic workshops, regional and global workshops and dialogues, and academic fora (follow embedded hyperlinks for examples).

1.0.10 Capacity development

CapDev role in impact pathway			
Capacity development plays a crucial role in strengthening the enabling environmental along the whole impact pathway of RICE, from upstream research to large-scale delivery and adoption, see Annex 3. In many target countries of RICE, the cohort of scientists is aging and the need for investments in individual science capacity (upstream in the impact pathway) development is high. The same applies to farmers and other value-chain actors who need training and retooling to become modern business entrepreneurs, especially women and youth (downstream in the impact pathway). RICE partners require institutional development on capacity in gender research and transformative changes, modern research methods, (downstream in the impact pathway); monitoring, learning and evaluation (midstream in the impact pathway); partnership skills, innovation, and scaling (downstream in the impact pathway) - to name a few.			
2. Strategic CapDev actions (see CapDev Framework)			3 Please indicate any Indicators- from CapDev Indicators document or other - that could be used to track progress and contribution to CapDev sub-IDOs
Intensity of implementation of chosen elements (indicate High [H], Medium [M], Low [L]) Note- it is expected that no more than 3-4 elements would be implemented at High intensity		Give an indication of how chosen elements will be implemented (Note: more space available for full plan in Annex)	
Capacity needs assessment and intervention strategy design	L	At start of program, then monitoring and adaption during implementation	Proportion of participants targeted in Capacity Needs Assessments whose CapDev needs were met
Design and delivery of innovative learning materials and approaches	M	Modern ICT tools, hands-on training, cost-effective training delivery mechanisms	No. of partner organizations who use materials and approaches No. of people trained (disaggregated by gender) Cost effectiveness of materials and approaches
Develop CRPs and Centers' partnering capacities	H	Learning alliances and other multistakeholder platforms for impact acceleration with equity	No. of collaborations (e.g., joint research, training/workshops conducted jointly, shared funding arrangements, common membership of multistakeholder platforms) with partner organizations No. of research outputs resulting from partnerships that are successfully scaled-out
Developing future research leaders through fellowships	M	Degree training, vocational training, on-the-job training, exchange visits, scholarships	No. of fellowship places provided (disaggregated by gender)
Gender-sensitive approaches throughout capacity development	H	Gender targets, development of gender-specific training, gender-differentiated outcomes	Gender disaggregation on training and CapDev event statistics No. of effective partnerships that allow inclusion of gender-sensitive approaches in scaling-out
Institutional	H	Policy dialogues/workshops and capacity	No. of policy decisions taken based on

<table>
<tr><td>strengthening</td><td></td><td>of decision makers to use R&D outputs</td><td colspan="3">engagement and information dissemination by RICE</td></tr>
<tr><td>Monitoring and evaluation of capacity development</td><td>M</td><td>Monitoring CapDev outcomes, sub-IDOs, milestones, indicators; learning and feedback</td><td colspan="3">Frequency with which CapDev indicators are released and reported</td></tr>
<tr><td>Organizational development</td><td>M</td><td>Participatory R&D; Learning alliances, and local innovation platforms for impact acceleration with equity</td><td colspan="3">No. and extent of action plans of local multistakeholder platforms implemented

No. of research initiatives with evidence of direct response to demand of communities and development partners</td></tr>
<tr><td>Research on capacity development</td><td>L</td><td>-</td><td colspan="3"></td></tr>
<tr><td>Capacity to innovate</td><td>H</td><td>Learning alliances and innovation platforms with equity</td><td colspan="3">No. and extent of action plans of local multistakeholder platforms implemented

No. of research initiatives with evidence of direct response to demand of communities and development partners</td></tr>
<tr><td colspan="6">4. Budget and resource allocation (The CRP should demonstrate that budgets allocated for CapDev have a credible share of the total CRP budget (e.g. totaling around 10% although amounts may vary in individual Flagship budgets).
IMPORTANT: Please indicate in Table C of the Performance Indicator Matrix the investments of each FP on the Capacity Development sub-IDOs</td></tr>
<tr><td>Budget for CRP:</td><td colspan="5">14% (11,757,283 $/year on average)</td></tr>
<tr><td>Budget for Flagships/other:</td><td>FP1: 20% (3,062,829 $/year)</td><td>FP2: 10% (369,935 $/year)</td><td>FP3: 15% (3,604,212 $/year)</td><td>FP4: 5% (569,359 $/year)</td><td>FP5: 15% (4,150,945 $/year)</td></tr>
</table>

1.0.11 Program management and governance

The 2015 IEA evaluation of GRiSP concluded that "…GRiSP is well governed and managed in a complex environment. In most cases, application of the principle of subsidiarity to decentralize decision making and implementation to the centers is working well for reducing duplication and transaction costs" (IEA evaluation report, p xiii). It recommended that "GRiSP should review and clarify the roles and expectations of its non-CGIAR partners (JIRCAS, IRD and CIRAD) in governance, management and research implementation" (recommendation 13, p xvii). The 2014 review by the IEA of the CGIAR Research Programs Governance and Management (Robinson et al 2014) concluded that in GRiSP, the Program Planning and Management Team (PPMT) acted as a true management team (p 37) and rated the GRiSP Oversight Committee as having high independence (p 44). The 2013 internal audit of implementation and management of CGIAR Research Programs at IRRI headquarters gave the overall implementation and management of the CRPs, including GRiSP, the highest rating possible (Internal Audit 2013). In line with those findings, the management and governance structures of RICE will build on and strengthen the successful model of GRiSP.

RICE will be managed by the same PPMT that manages GRiSP. It is chaired by a program director and has a representative from senior management of each coordinating partner: the deputy director general of AfricaRice, the deputy director general for research of IRRI, director levels at CIAT, IRD, and JIRCAS, and senior researcher at Cirad. This high-level representation in CRP management facilitates effective management of RICE by—and within—the coordinating partners as these members are in a

position to implement decisions made by the PPMT. The desirability of having the nonCGIAR centers Cirad, IRD, and JIRCAS present in the management team (IEA recommendation 13) was confirmed during extensive discussions on the scope and structure of RICE. In addition, the chair of the gender committee will be a member of the (new) PPMT. The PPMT will be supported by a small Program Planning and Management Unit, consisting of 0.2 secretary and one full-time program assistant. The program director will be the main point of contact for RICE with the future CGIAR Systems Office (e.g., reporting).

As in the current GRiSP, the PPMT will oversee a gender committee; a monitoring, evaluation, and learning (MEL) committee; and a communication committee, with senior representatives from each of the coordinating partners. The work plans and budgets of these committees are fully integrated into specific clusters of activities in the relevant FPs. The chairs of these committees provide advice and guidance to the PPMT (as is currently done in GRiSP). The chair of the MEL committee is also the leader of the CoA (1.6) in FP1 with the same name (Monitoring, evaluation, and learning). Also, the chair is RICE's representative in the cross-CRP MEL community of practice, leads evaluations and the annual review of theories of change across the FP portfolio, guides RICE's reflection and learning processes, and reports back on progress to the PPMT and the Independent Steering Committee (ISC). The chair of the gender committee is also the leader of CoA1.2 on gender and youth research in FP1 and RICE's representative in the CGIAR gender and diversity network. Further, the chair guides gender-related activities across the FP portfolio and reports back on progress to the PPMT and the ISC. The chair of the communication committee is also RICE's representative on the CGIAR communications community of practice and works with the program director and the PPMT to develop and execute communication strategies.

The PPMT will oversee and guide the team of FP leaders, who will coordinate activities within their FPs across the participating centers and institutes. They are empowered by a dedicated coordination budget, while 20−40% of their salaries will be provided from the CRP management budget for this function. The 2015 IEA evaluation of GRiSP recommended that "Management structures could be improved by distributing leadership across GRiSP according to expertise*,..."* (IEA report, p xiv). In line with that recommendation (and with recommendation 13 to clarify roles of nonCGIAR partners in management), not all FPs and clusters of activity will be led by the lead center. IRRI will coordinate FPs 1, 2, and 5; CIAT and IRRI will co-coordinate FP4; and AfricaRice will coordinate FP 3.[8] The composition of the PPMT and of the teams of principal investigators of the flagship projects, including CVs of their leaders, is given in Annex 8. In line with IEA recommendation 13, the roles of nonCGIAR partners in research implementation have been made explicit. Non-CGIAR participating centers lead specific clusters of activity and coordinators in those institutes will be appointed and have a separate coordination budget. Cirad will contribute policy research to the cluster of activities "Foresight and targeting" (CoA1.1), "farm diversification" for upland rice and inland valleys (part of CoA3.3), "global phenotyping" (CoA4.2), "precision biotech breeding" (CoA5.2), and "new rice varieties for upland rice" (part of CoA5.5). IRD will co-lead (with JIRCAS) the cluster of activities on "biotic rice-plant interactions" (COA4.3) and will co-lead with Cirad the "Big Data integration platform" (CoA4.5). JIRCAS will specifically contribute its expertise on "precision breeding" (CoA5.2), problem soils and nutrient efficiency (CoA4.3),

[8] The still relatively large share in flagship project coordination by IRRI is justified by the huge share of rice in Asia versus Africa and Latin America and because IRRI is the globally recognized lead agency for international rice R&D in Asia. The distribution of flagship project coordinators was unanimously supported by all six lead centers of RICE.

food processing (CoA2.4), rice blast disease (CoA5.4), and climate change (CoA3.3).

Monitoring, evaluation, and learning (ME&L) are important functions of program management. In RICE, these functions are part of its results-based management framework and are explained in detail in Annex 6, including budget information.

Governance is provided by the Board of the lead center, IRRI, and by the ISC built on the current GRiSP Oversight Committee. The ISC of RICE will continue to have a significant representation of external experts and be chaired by an independent external expert. Center representation draws on the boards of participating centers, while the DGs of IRRI and AfricaRice are members *ex officio*. The roles and responsibilities of the ISC will be in line with those spelled out in the guidelines in the call for proposals. The 2015 IEA evaluation of GRiSP recommended that "Governance practices could be improved at the level of the Oversight Committee by better communication with stakeholders about the processes for stakeholder input to strategic priority setting for GRiSP, and by the use of coordinated external evaluations of specific research Themes across GRiSP" (Recommendation 11, p xvii). This recommendation has been passed on to the GRiSP Oversight Committee, and advice has been solicited to feed into the TOR of the new ISC of RICE.

1.0.12 Intellectual asset management

RICE regards the results and outputs of research and development activities as international public goods and is committed to their widespread diffusion and use and to achieving the maximum possible access, scale, and scope of impact from them for the benefit of poor farmers and consumers in developing countries. It recognizes that progress toward its goals and objectives relies on having a wide range of partners, including farmers; NARES; advanced research institutes; civil society organizations; governments; national, regional, and international organizations; and the private sector, including small and medium-size enterprises. In line with the CGIAR Principles on the Management of Intellectual Assets and their Implementation Guidelines, RICE recognizes that careful management of intellectual assets (IA) is a prerequisite for effective development and delivery of RICE's international public goods. The RICE strategy for management of intellectual assets (Annex 10) should be read in conjunction with its strategy on open access and data management (Annex 9). Ownership, custody, and management of IA rest with the RICE CGIAR centers producing them (with their partners). AfricaRice, CIAT, and IRRI are led by institutional IA and intellectual property policies that are in line with those of the CGIAR. The RICE CGIAR centers will manage their IA with integrity, fairness, equity, responsibility, and accountability, wherever they operate.

1.0.13 Open access management

RICE's research and information products are international public goods. RICE is committed to their widespread diffusion and use to ultimately achieve a positive, equitable, and lasting impact on the livelihoods of the world's poor rice farmers and consumers. RICE acknowledges the value of its information products, including research data, and considers that widespread sharing of these products will produce scientific, economic, and social benefits. Hence, in line with the CGIAR Open Access and Data Management Policy and its Implementation Guidelines, RICE strives to make final versions of its

information products openly and freely accessible for use and reuse by others. The RICE strategy for open-access management of data and information products (Annex 9) should be read in conjunction with its strategy on intellectual assets management (Annex 10). RICE data and information products include experimental research data; publications (peer-reviewed journal articles, reports and other papers, books and book chapters); research methodologies, models, tools, and computer software; and dissemination and training products (video, audio, images, fact-sheets, guidelines, and manuals).

1.0.14 Communication strategy

Good communication along the whole impact pathway is critical for RICE to deliver its development impacts. Building on the proposed six elements of a communication strategy,[9] RICE will:

communicate and engage with partners in all FPs through collaborative and participatory approaches to R&D and convening various networks, CGIAR communication and knowledge management community of practice, platforms, and consortia, using tools as above;

promote learning and sharing of information to improve communications and collaboration, in general by active engagement in the CGIAR communication and knowledge management community of practice and, more internally in RICE through the learning and feedback mechanisms in CoA1.6 of FP1; and

engage with actors on the ground to scale-out technologies and practices, through the development of multistakeholder platforms and scaling-out activities in FP1 (CoAs 1.3 and 1.4), using tools such as participatory impact pathway mapping (PIPA), stakeholder and outcome mapping, and problem tree definition and analysis;

communicate about the program, the science, results, and progress, using an array of tools such as a dedicated RICE website, specific project websites, newsletters, media briefs, radio and TV interviews, podcasts, and blogs—applying principles of subsidiarity with centers' communication strategies and tools to reduce costs and increase efficiency;

engage in policy dialogue to scale-up results, through its engagement with numerous national and regional bodies, and through developing and communicating results of policy analyses in FP1 (using tools such as policy briefs, media releases, forums, and ministerial roundtables);

make CRP information and resources open and accessible, as detailed in the RICE open-access and intellectual asset management strategies (sections 1.0.12 and 1.0.13; Annexes 9 and 10).

More detailed information on RICE's communication strategy is provided in Annex 13.

1.0.15 Risk management

RICE will continue the implementation of a formal risk management procedure initiated under GRiSP.
It applies the principle of subsidiarity to risk management by the RICE CGIAR centers for reducing duplication and transaction costs. For example, the following risks are all captured by CGIAR center risk management strategies and not duplicated in RICE: insufficient (in terms of quality and quantity) physical and human infrastructure; external threats and hazards such as earthquakes, typhoons, civil

[9] As per 2nd Call Full Proposal Guidance, p 33–36.

unrest, war; CGIAR center reputation; and lack of fiduciary accountability for projects. Following international best practices in the field, GRiSP maintains a risk register that records risks and their management that pertain to the program as a whole and that complements the risk registers of the GRiSP-participating CGIAR institutes. With IRRI being the lead center for GRiSP, the GRiSP risk register follows IRRI protocols and procedures for risk management and approval processes, and becomes part of the IRRI institutional risk register. IRRI's risk management strategy complies with the Risk Management Standard BS 31100:2011, Risk Management – Code of practice and guidance for the implementation of BS ISO 31000. The steps in GRiSP risk management follow:

1. Risks are registered in a matrix of likelihood (high, medium, low) by impact/consequences (high, medium, low). The risk register is updated annually by the GRiSP Program Planning and Management Team (PPMT), between October and December each year.
2. The GRiSP director and GRiSP PPMT are the owners of all risks identified in the GRiSP risk register.
3. The risk register will each year be presented for endorsement to the GRiSP Oversight Committee in its annual meeting.
4. After endorsement, the GRiSP register will be submitted to IRRI's Risk Management and Quality Assurance (RMQA) committee and be included in its overall risk management portfolio; the risk of managing GRiSP will be summarized as one of IRRI's key risks to enhance visibility.
5. As part of IRRI's overall risk register, the IRRI Board of Trustees will explicitly sign off on the GRiSP register component when signing off on the overall IRRI risk register.

Risks and their mitigation options are given in relation to impact pathways and theories of change (section 2.x.1.3) in each FP description. In Table 4, 23 key risks identified to date are summarized, together with their proposed mitigation strategies.

Table 4: Management of RICE risks

Area	Risk	Risk Management Approach	Risk holder(s)	Control
1. Assets				
1.01	Loss of physical assets	Lead center and partner centers have a risk management plan and a business continuity plan in place	Center Boards of Trustees	Center risk management plans and center business continuity plans
1.02	Loss of information assets	Lead center and partner centers have appropriate on- and off-site back-up systems and IT security systems and expertise	Center heads of ICT	Center risk management plans, center business continuity plans, Research Data Management Policies
1.03	Loss of intellectual assets	RICE intellectual asset management policy in line with CGIAR and center intellectual asset management policies	RICE program director; Center Boards of Trustees	RICE intellectual asset management strategy (Annex 10), and center IP policies
1.04	Loss of staff; staff safety	Attractive remuneration and work place at lead and partner centers; security information during travels	Relevant center DDG/heads of HR and Operations	Center risk management plans and center business continuity plans Center HR policies and procedures; international travel security system, medical, and repatriation arrangements
2. Compliance and failure to meet obligations				
2.01	RICE fails to meet contractual obligations with the CGIAR Systems Office	Timing and quality of critical RICE management documents (work plans, reports, budgets, template agreements) produced by the RICE and its FP management teams are overseen by the RICE Independent Steering Committee, which reports to the Board of Trustees of the RICE lead centre	RICE Independent Steering Committee, Board of Trustees of the RICE lead centre	RICE documents (work plans, reports, budgets) and RICE monitoring, evaluation and learning system (Annex 6)
2.02	Participating centers, subcontractors, and consultants fail to meet contractual obligations with the lead center	Work plans, reporting, and disbursement schedule in place and monitored for all participating centers, subcontractors, and consultants. Divergences from schedule brought to attention of the RICE management team, corrective action is taken	RICE management team, Board of Trustees of the RICE lead centre	Outcome and milestone-based work plans and contracts; RICE monitoring, evaluation and learning system (Annex 6)
2.03	Legal/compliance issues with CGIAR intellectual assets management principles and policies	RICE intellectual asset management policies in line with CGIAR and center intellectual asset management policies	RICE management team; Center Boards of Trustees	RICE intellectual asset management strategy (Annex 10) Center Board of Trustees certification reports on the management of intellectual assets

2.04	Compliance and legal claims cause liability (including Inappropriate use of funds)	Lead and participating center policies and procedures; quality of legal/IP personnel; internal and external audits; insurance.	Boards of Trustees of lead and participating centers	Lead and participating center policies and procedures; annual center compliance statements to CGIAR; internal and external audit reports.
3. Governance, and program and flagship project management				
3.01	Ineffective governance, conflict of interest between lead and participating centers and RICE	Independent Steering Committee with adequate independent members and clear terms of reference	Lead center Board of Trustees	Minutes of RICE Independent Steering Committee meetings
3.02	Ineffective RICE program director	International competitive recruitment of RICE director; clear terms of reference	Lead center director general, RICE Independent Steering Committee	Annual performance evaluations, including inputs from independent steering committee; 360° input from participating centers and stakeholders to performance evaluation of RICE director
3.03	RICE management team insufficiently empowered to manage for results	RICE management team includes high-level line managers (deputy director generals, directors) of lead and participating centers; flagship project leaders empowered to manage by results within their centers	RICE director, RICE Independent Steering Committee	Annual performance evaluations; RICE results-based management framework (Annex 6)
3.04	Ineffective team interactions due to decentralized posting	RICE management team with clear terms of references; calendar of physical and virtual meetings in place; clear work plans	RICE director	Results-based management framework (Annex 6)
3.05	Friction among RICE partners	RICE program and flagship projects management team operates fairly and transparently; RICE conflict resolution policy	RICE director; Independent Steering Committee; Lead center board of trustees	Program management meeting minutes; Independent Steering Committee minutes; RICE-related minutes lead center board of trustees meetings
4. General RICE nonperformance				
4.01	Women insufficiently benefit from development outcomes and impacts, and gender inequity is maintained or enhanced	A strong gender assessment CoA that identifies constraints to full and justly-rewarded participation of women in the rice sector and in rice value chains, and that identifies entry points for improvement and empowerment of women. All FPs take note of concerns, needs, and requirements of both men and women beneficiaries in technology development and dissemination. See section 1.0.10, FP descriptions (sections 2.x.1.2–6) and Annex 4 for more details.	RICE management team; center management teams	RICE baseline data, progress indicators, adoption data, and impacts are fully gender disaggregated; results-based management framework (Annex 6)
4.02	Lack of partner capacity for innovation, ability to take up and deliver research results, and ability to engage in cutting-edge	Capacity development is taken up along the whole impact pathway in all FPs, following the CGIAR capacity development strategy and its ten steps of implementation. Special attention is paid to	RICE management team; center management teams	Work plans, annual reports; results-based management framework (Annex 6)

	science	institutional capacity development through skills training on innovation systems, development and maintenance of multistakeholder platforms, and hands-on on joint R&D activities. Scholarships are awarded to train young scientists to become experts in their field and science leaders of the future. See Annex 3 and section 2.x.1.10 in each FP description (sections 2.x.1.2–6) for more details.		
4.03	Insufficient connection with cutting-edge new scientific developments to develop new science-based technologies and other solutions to the SRF grand challenges and SLOs	Actively establish collaboration with advanced research institutes across the globe. See Annex 2 and section 2.x.1.8 in each FP description (sections 2.x.1.2–6) for more details.	RICE management team; center management teams	RICE partnership arrangements (including subcontractors and consultants)
4.04	Not able to deliver outcomes and impacts at scale	Actively establish collaboration with scaling and development partners at key action sites, at target country level, and elsewhere where impact can be accelerated. Develop multistakeholder platforms aimed at delivery of development goals (specifically in CoA 1.3). Strengthen or develop (where nonexistent) seed systems through CoA 1.4. See Annex 2 and section 2.x.1.8 in each FP description (sections 2.x.1.2–6) for more details. Investments in institutional capacity development among partners, especially on capacity to innovate and deliver outcomes and impacts.	RICE management team; center management teams	RICE partnership arrangements (including subcontractors and consultants); work plans, annual reports; results-based management framework (Annex 6)
4.05	Full potential for outcomes and impact is not realized because RICE operates in isolation from other CRPs and from country development strategies	Extensively engage with other CRPs in thematic collaboration and in site integration at key RICE action sites in CGIAR priority countries and RICE target countries. Develop projects that involve several CRPs/centers such as CSISA. See Annex 7 for more details. Engage with national partners through rice sector development (policy) dialogues and consultations; see section 1.0.9 for summary of mechanisms to do so.	RICE management team	CGIAR site integration plans; RICE work plans, annual reports; results-based management framework (Annex 6)
4.06	Delivery of outcomes and impact is hindered by insufficient learning and feedback loops within RICE – leading to static impact pathways and theories of change	Implementation of a results-based management strategy with a state-of-the art monitoring, evaluation, and learning system. Each FP will regularly assess progress, reflect on learning, assess risk and effectiveness of mitigation actions, and update impact pathways and theories of change accordingly. See Annex 6 for details	RICE management team	RICE results-based management framework (Annex 6)

4.07	Development of new products is hindered by inability to access proprietary or patented technologies	Development and implementation of an active intellectual asset management strategy; see 0.s 1.12 and 1.0.13, Annex 10, and subsection 11 in each FP description (sections 2.x.1.2–6) for more details.	RICE management team; center management teams	RICE work plans, annual reports; contracts with partners, subcontractors, and consultants (including PPP)
4.08	Full potential for outcomes and impact is not realized because of restricted access to data, information, and products and services generated by RICE	Development and implementation of an active open access and data management strategy; see section 1.13, Annex 9, and subsection 11 in each FP description (sections 2.x.1.2–6) for more details.	RICE management team; center management teams	Center-managed open access data bases
4.09	Full potential for outcomes and impact is not realized because of insufficient communication	Development and implementation of a broad communication strategy, and mainstreaming of good communication practices across the impact pathway in all of RICE's FPs and other activities; see section 1.0.14 and Annex 13	RICE management team; center management teams	Annual work plans and reports that include communication results; RICE results-based management framework (Annex 6)
5. Financial				
5.01	Insufficient budget (including W1,2, W3, and bilateral) to deliver outcomes	Maintain a modular set of outcomes and milestones to adjust to budget fluctuations; aggressive fund raising; renegotiate outcomes with donors	RICE director; lead and participating center DGs	Budgets as uploaded in the Financial System

1.1 CRP Budget Narrative

1.1.1 General Information

CRP Name	CGIAR research program on rice-based agri-food systems, RICE
CRP Lead Center	International Rice Research Institute

1.1.2 Summary

Annual and total budget of RICE; in US$.

Flagship Name	2017	2018	2019	2020	2021	2022	Total
Flagship project 1: Accelerating impact and equity	14,202,524	14,654,190	15,123,063	15,609,843	16,115,259	16,640,072	92,344,950
Flagship project 2: Upgrading rice value chains	3,469,041	3,593,153	3,690,261	3,813,079	3,896,221	4,005,405	22,467,159
Flagship project 3: Sustainable farming systems	22,320,205	22,946,451	23,636,742	24,350,965	25,081,872	25,832,253	144,168,488
Flagship project 4: Global Rice Array	10,683,196	10,976,858	11,289,840	11,639,445	11,984,806	12,343,845	68,917,990
Flagship project 5: New rice varieties	25,881,376	26,609,119	27,402,741	28,221,621	29,086,019	29,982,516	167,183,392
Management & Support Cost	1,951,622	2,049,203	2,151,663	2,259,246	2,372,209	2,490,819	13,274,762
Strategic Competitive Research Grant (*)	0	0	0	0	0	0	0
	78,507,964	80,828,973	83,294,310	85,894,198	88,536,385	91,294,911	508,356,741

*: Strategic competitive research grants are included as a mechanism in the uplift budget.

Cost drivers, planned activities, and targets

Major cost drivers are personnel (scientists who conduct research and development activities), international travel (RICE is a global program, operating in Africa, Asia, Latin America and the Caribbean, Europe, and project coordination and implementation requires a relatively large investment in long-distance travel), and operational research activities. All planned activities are described in the RICE proposal text – especially sections 1.0.4 (gender; see also Annex 4), 6 (flagship projects), 7 (Cross CRP collaboration and site integration; see also Annex 7), 10 (capacity development; see also Annex 3), 12-13 (intellectual asset and data management; see also Annexes 9-10). Further details on activities are provided in each flagship project description, especially sections 1.0.6 (clusters of activity), 1.0.8 (climate change), 1.0.9 (gender), 1.0.10 (capacity development), and 1.0.11 (intellectual asset and data management). In summary, the following typical activities are major cost drivers in the five flagship projects:

- FP1: collection of survey data (involving travel, local expenses in country such as translators, enumerators, vehicle rental, local partners), and analyses and reporting of survey data (CoAs 1.2, 1.5, 1.6). Other activities include development and use of the results-based management system and of the monitoring, evaluation and learning system

(CoA 1.6); developing and use of foresight, supply-demand, and ex-ante impact assessment models (CoA1.1); developing and sustaining multistakeholder platforms at action sites (CoAs 1.4 and 1.5); developing partnership arrangements for scaling out (CoAs 1.4 and 1.5); adoption studies, including the conduct of randomized control trials (CoA1.5);

- <u>FP2</u>: collection of survey data among partners (consumers, millers, processors, traders, farmers, input suppliers) along the rice value chain (involving travel, local expenses in country such as translators, enumerators, vehicle rental, local partners), and analyses and reporting of survey data (CoA2.1 and 2.2). Other activities include the development and conduct of investment games (CoA2.1); the development, testing, and dissemination of improved postharvest equipment and practices such as baling of straw and husk, improved dryers and storage facilities (CoA2.3); development, testing, and dissemination of improved processing equipment and practices for rice grain and rice byproduct materials, such as parboiling, briquetting and peleting of straw and husk; research into novel product development (CoA2.4)
- <u>FP3</u>: collection of survey data among farmers at key action sites (involving travel, local expenses in country such as translators, enumerators, vehicle rental, local partners), and analyses and reporting of survey data (CoA3.1); the development and use of simulation models for crop growth, farming systems, greenhouse gas emissions (CoAs 3.1 and 3.2); the conduct of experiments in greenhouses, on stations, and on-farm (CoAs 3.2 and 3.3); farmer-participatory experimentation on new farming systems and crop management practices (CoAs 3.2 and 3.3); development and measurement of quantitative and qualitative multi-dimensional sustainability parameters (CoA 3.2); development, testing, and dissemination of improved equipment and machinery, such as mechanized land leveling, seeding, transplanting, combine-harvesting (CoA3.2)
- <u>FP4</u>: establishment and maintenance of high-quality field-experimental sites under the global rice array (CoA4.1); the development and application of simulation models for crop growth (CoA 4.1); the conduct of experiments at the global rice array sites and the collection of phenotyping data, including the development, testing, and use of modern sensors (CoAs 4.1 and 4.2); collection, analysis, and reporting of plant and soil biome samples (CoA4.3); collection of plant samples, determination of genetic make-up, genetic and genome-wide analysis (CoA44.); development and use of a big data platform that makes (open) accessible all collected genotypic, phenotypic, and environmental data, analysis tools, and analyses conducted (CoA4.5)
- <u>FP5</u>: establishment and maintenance of high-quality experimental trials throughput the breeding pipeline (greenhouse, screenhouse, open field trials; multi-location evaluation trials) (CoAs 5.3-5.6); Conduct of participatory variety selection trials (CoAs 5.3-5.4); conduct of sensory evaluation panels (CoA5.5); collection and analysis of phenotypic (plant characteristics) and genotypic data (DNA samples) (CoAs 5.3-5.6); collection of plant samples, determination of genetic make-up, genetic and genomic analysis, development of markers and of novel breeding tools and software (CoAs5.1 and 5.2); Laboratory experiments to determine grain quality properties and derive genetic traits (CoA5.5); making (open) accessible all collected genotypic, phenotypic, and environmental data, analysis tools, and analyses conducted (all CoAs)
- <u>Cross-cutting</u>: workshops; stakeholder consultations; development of communication materials (papers, flyers, brochures, websites, video, etc); partnership development; development and support of learning alliances; partner capacity development for research, innovation, and delivery; (open access) data management – see section 1.0.4 below.

The targets of RICE (broken down by target country), and their associated costs - are presented in Table A of the Performance Information Matrix. The costs are estimates, as the various outcomes

and targets are all mutually related and feed into each other as explained in the RICE impact pathways (section 1.0.3 of the RICE description and of each flagship project). For example the targets 'no. people assisted out of poverty' and 'no. people assisted out of hunger' is a direct consequence of the target 'no. farmers adopting new technologies'. Though most flagship projects (FP) contribute to most of the targets, FPs 4 and 5 (and their budgets) specifically contribute to 'increase in genetic gain' and 'no. of people consuming high Zn-rice'; and FP3 to 'no. of women consuming adequate number of food groups', '5% increase in water and nitrogen use efficiency', and 'reduction in greenhouse gas emissions'. FP1 contributes to scaling out and ensuring that large numbers of beneficiaries are reached with new varieties, technologies and services. At a more detailed level, sub-IDOs are given in Table C of the Performance Information Matrix, and outcomes and their associated costs in Table B of the Performance Information Matrix. Section 2.x.1.2 of each flagship project description lists all the outcomes, sub-IDOs, and IDOs that the flagship project delivers.

Funding level rationale
The main funding priority (as per resources allocation) is given to genetic enhancement, and farming systems, where the biggest comparative advantages of RICE are. The contribution of new crop varieties to improving food security and reducing poverty is one of the best documented outcomes of international agricultural research, especially for crops such as rice and wheat (Evenson and Gollin 2003, Fan et al 2005, Raitzer and Kelley 2008, Renkow and Byerlee 2010). Genetic crop improvement is one of the pillars of the CGIAR and it features prominently in the SRF. Yields still need to increase to keep up with increasing global demand for rice, and increasing genetic gain is one of the two main ways to increase yields - the other being improved agronomy/crop husbandry to close yield gaps as addressed in FP3. Adaptation to climate change and mitigation of greenhouse gases is a major 'societal grand challenge (SRF)' addressed by FP3.

Risk to spending as planned
The RICE CRP is an 'umbrella program', consisting of five 'umbrella flagship projects', which include up to 100-125 bilateral grants any given year. Hence, the RICE budget is dictated by the collective investments that donors want to make through W1/2, W3, bilateral, and 'others means'. The investment levels are unpredictable: 1) the W1-3 donors can not commit to 6-year funding obligations and the W1-3 investments into the CGIAR fluctuate substantially each year, and 2) 70-80% of the budget is contributed to by bilateral projects, the majority of which still need be developed and secured. Hence, the likelihood that budgets are obtained —and spent— as targeted, decreases as the CRP progresses in time. Each year, updates on investment expectations and budgets will be developed, and spending managed accordingly. At the level of bilateral projects, spending risk is managed by project leaders following procedures spelled out in project contracts. For W1-3, spending risk is managed by flagship project leaders and the RICE program Planning and Management Team. Project leaders get regular updates on actual spending rate through OCS, and are required to make project adjustments if under- or overspending occurs beyond the (donor-) accepted range (usually 10% of line items).

Country level activities
Table A of the Performance Information Matrix indicates the investments made for target country beneficiaries. The RICE budget supports a range of in-country activities, mostly centered around 'action sites', based on local partnerships in villages to districts where new technologies are developed, evaluated, improved, and disseminated in a highly participatory mode. Action sites also include laboratories, breeding locations (e.g., multi-environment trials), or experimental platforms. Although RICE will work in many countries, key action sites will be located in Africa (Burundi, Côte d'Ivoire, Madagascar, Mali, Nigeria, Senegal, and Tanzania); Asia (Bangladesh, Cambodia, (Eastern) India, Indonesia, Myanmar, the Philippines, and Vietnam); and Latin America (Colombia, Nicaragua,

and Peru). Typical activities at action sites include: collection of survey data; developing and sustaining multistakeholder platforms; developing partnership arrangements for scaling out; adoption studies, including the lay-out of randomized control trials; the development, testing, and dissemination of improved postharvest equipment and practices such as baling of straw and husk, improved dryers and storage facilities; development, testing, and dissemination of improved processing equipment and practices for rice grain and rice byproduct materials, such as parboiling, briquetting and peleting of straw and husk; the conduct of agronomic experiments in greenhouses, on stations, and on-farm; farmer-participatory experimentation on new farming systems and crop management practices; development, testing, and dissemination of improved equipment and machinery, such as mechanized land leveling, seeding, transplanting, combine-harvesting; establishment and maintenance of high-quality field-experimental sites under the global rice array; establishment and maintenance of high-quality breeding trials throughput the breeding pipeline (greenhouse, screen house, open field trials; multi-location evaluation trials); conduct of participatory variety selection trials; conduct of sensory evaluation panels; workshops; stakeholder consultations; development and support of learning alliances; partner capacity development for research, innovation, and delivery. For more details, see Annex 7 on 'Collaboration with other CRPs and site integration'.

1.1.3 CRP Funding Plan

Annual and total budget of RICE, by source of funding; in US$.

Funding Needed	2017	2018	2019	2020	2021	2022	Total
W1+W2	16,351,621	16,723,477	17,077,961	17,487,936	17,855,174	18,260,203	103,756,375
W3	34,209,036	35,204,861	36,218,989	37,281,692	38,354,894	39,472,204	220,741,678
Bilateral	27,947,305	28,900,633	29,997,358	31,124,569	32,326,316	33,562,502	183,858,687
Other Sources	0	0	0	0	0	0	0
Total	78,507,962	80,828,971	83,294,308	85,894,197	88,536,384	91,294,909	508,356,731

Funding Secured	2017	2018	2019	2020	2021	2022	Total
W1+W2(Assumed Secured)	16,351,621	16,723,477	17,077,961	17,487,936	17,855,174	18,260,203	103,756,375
W3	21,577,233	15,332,406	1,568,547	1,646,601	1,731,093	1,818,416	43,674,299
Bilateral	13,634,172	14,880,901	15,813,674	16,461,234	17,136,853	17,841,804	95,768,640
Other Sources	0	0	0	0	0	0	0
Total	51,563,026	46,936,784	34,460,182	35,595,771	36,723,120	37,920,423	243,199,306

Funding Gap	2017	2018	2019	2020	2021	2022	Total
W1+W2	0	0	0	0	0	0	0
W3	-12,631,803	-19,872,454	-34,650,441	-35,635,090	-36,623,800	-37,653,787	-177,067,379
Bilateral	-14,313,132	-14,019,732	-14,183,684	-14,663,335	-15,189,463	-15,720,697	-88,090,046
Other Sources	0	0	0	0	0	0	0
Total	-26,944,935	-33,892,186	-48,834,125	-50,298,425	-51,813,263	-53,374,484	-265,157,418

As seen from the Tables, considerable effort is required to raise the investments needed to accomplish the goals, objectives, and targets of RICE, both for W1-3 and for bilateral grants. With a donor-imposed cap of 30% on W1,2 contribution, most effort will be directed at bilateral grant acquisition. However, there will remain considerable uncertainty on actual donor investments. Hence, RICE developed a value proposition based on three levels of donor investments: a low investment scenario, a medium investment (presented here), and a high investment– with W1,2

contributions of 20-30% (see section 1.0.2 ‘Goals objectives, targets). For each investment scenario, the value proposition of RICE is elaborated in terms of contributions to the CGIAR SLO targets. Outcomes and milestones for the low and high investment levels will be prepared in a modular way, so that RICE can adapt to any actual investment level and respond with associated budget adjustments.

1.1.4 CRP Management and Support Costs

COST COMPONENT	AMOUNT US$							COMMENT
	2017	2018	2019	2020	2021	2022	6-year Total	
A. Basic components as defined in the guidance document; subtotal.	**1,426,662**	1,497,953	1,572,851	1,651,493	1,734,068	1,820,771	**9,703,758**	
A.1 Management fee charged by the lead center to handle CRP finance and administrative matters (finance, accounting, reporting, contracts management, legal, HR, IT, communication-if handled by lead center)	358,949	376,896	395,741	415,528	436,305	458,120	2,441,540	
A.2 Combines three of the basic components to protect confidentiality of staff salaries – the sum total of these three component should be reported as a single amount: • CRP director including related cost – benefits and on-cost if customary (computer, vehicle lease and office space) based on percentage time allocation • Infrastructure and general and administrative charges if CRP leader is not located at the Lead Center • Financial and administrative support based on time allocation	287,673	302,057	317,159	333,017	349,668	367,152	1,956,727	Program Management Unit staff: 1 CRP director, 1 program assistant, 0.2 secretary. All management staff are based at the lead center.

A.3 Flagship project leader and regional coordinators only if a significant percentage time (>50%) is dedicated to managerial activities.	0	0	0	0	0	0	0	Management time of FP leaders is less than 50% and is incorporated into FP budgets
A.4 CRP Management committee and related costs	100,000	105,000	110,250	115,763	121,551	127,628	680,191	Annual workshops with CRP management team and FP leaders to evaluate (review impact pathways and theories of change) and plan work; 3-4 annual CRP management team meetings
A.5 Independent steering committee and related costs	80,000	84,000	88,200	92,610	97,241	102,103	544,153	1-2 meetings per year
A.6 Communication activity related specifically to CRP communication and webpage (not if handled by lead center)	300,000	315,000	330,750	347,288	364,652	382,884	2,040,574	Rice Today, website, central communication costs, information content, participation in CGIAR communication community of practice
A.7 CRP internal audit by the CGIAR internal audit unit, or its future equivalent in the new system governance structure	0	0	0	0	0	0	0	At time of writing, audit arrangements within the CGIAR are still under debate by the System Management Board
A.8 CRP internal and external reviews (e.g. CCEEs and other evaluations and reviews), as well as impact assessments	300,000	315,000	330,750	347,288	364,652	382,884	2,040,574	See Table A6.2 in Annex 6 for details on proposed reviews
B. CRP-level cross-cutting components not mentioned in the guidance document; subtotal	**525,000**	551,250	578,813	607,753	638,141	670,048	**3,571,004**	
B.1 CRP special events (e.g. CRP-wide program meetings)	375,000	393,750	413,438	434,109	455,815	478,606	2,550,717	Various workshops at CRP level, by flagship projects, for site integration, cross-flagship projects, cross-CRP for CGIAR collaboration, etc.
B.2 CRP leadership meetings (e.g. country coordinators, flagship	150,000	157,500	165,375	173,644	182,326	191,442	1,020,287	Extensive travel to and within Africa, Asia, Europe, Latin America and the

project leaders, cross-cutting coordinators)								Caribbean, USA - by Program Management Unit and FP leaders (or designated staff); participation in meetings organized by System Office and other CGIAR entities; participation in conferences, workshops, etc.
B.3 CRP M&E coordination and systems (not including external evaluations and impact assessments)	0	0	0	0	0	0	0	These costs are included in Cluster of Activity on M&E 1.6 of FP1
B.4 CRP communications, open access, IP assets, KMIS (including lead centre staff budgeted as direct costs not allowed under A.6 above)	0	0	0	0	0	0	0	OA and IA budgets are indicated in Annexes 9 and 10, respectively; these costs are included in the FPs.
B.5 CRP capacity development coordination	0	0	0	0	0	0	0	Central costs for capacity development are included in Cluster of Activity 1.3 of FP1
B.6 CRP gender and youth coordination	0	0	0	0	0	0	0	These costs are included in Cluster of Activity Gender & Youth 1.2 of FP1
B.7 CRP site integration support.	0	0	0	0	0	0	0	Included in B.1
B.8 Other	0	0	0	0	0	0	0	
C. Total budget for management and support costs	**1,951,622**	2,049,203	2,151,663	2,259,246	2,372,209	2,490,819	**13,274,762**	
C.1 W1,2	1,951,622	2,049,203	2,151,663	2,259,246	2,372,209	2,490,819	13,274,762	
C.1 Bilateral projects	0	0	0	0	0	0	0	All bilateral projects are incorporated into FPs

All costs related to impact assessment, and to monitoring, evaluation and learning (ME&L), are included in the budgets of clusters of activity 1.5 and 1.6, respectively, of FP1; a summary is given below while table A.3 of Annex 6 provides full budget details and explanation of cost items.

COST COMPONENT	AMOUNT US$							COMMENT
	2017	2018	2019	2020	2021	2022	6-year Total	
Impact assessment								
Under the MSC budget								
Under the Competitive Grants Fund								
Under flagship budgets	2,418,721	2,497,740	2,579,834	2,665,130	2,753,765	2,845,875	15,761,067	About 16% W1,2 and 50% W3
TOTAL	**2,418,721**	**2,497,740**	**2,579,834**	**2,665,130**	**2,753,765**	**2,845,875**	**15,761,067**	
ME&L								
Under the MSC budget								
Under the Competitive Grants Fund								
Under flagship budgets	3,181,483	3,277,847	3,377,811	3,481,517	3,589,116.	3,700,765	20,608,542	About 16% W1,2 and 50% W3
TOTAL	**3,181,483**	**3,277,847**	**3,377,811**	**3,481,517**	**3,589,116**	**3,700,765**	**20,608,542**	

1.1.5 CRP Financial management principles

FP W1,2 allocation process

From any W1,2 investment in RICE, first the management cost is taken 'from the top' – after any adjustment caused by funding fluctuations. The remainder is allocated to participating centers based on a fixed percentage (reviewed regularly by the RICE management team and the Independent Steering Committee to ensure relevance maintained), derived from needs for investment on a continental basis (Africa, Asia, Latin America and the Caribbean). Continental investment needs were derived from an assessment of geographic importance of rice in relation to food security, poverty, and the environment, and to expected impacts on the SRF SLO targets. Each center distributed its W1,2 allocation over the five flagship projects, bearing in mind the relative importance of investments in flagship projects (see 'funding level rationale' under section 1.0.1 above) and the (expected) investments through W3, bilateral grants, and 'other means'. RICE aims to retain maximum flexibility in allocation of W1,2 funds to respond to emerging needs and opportunities in the coming six years and to developments in bilateral grants, and following principles of results-based management (see Annex 6)- hence, variances may be more than 10%/year per FP or per budget line item.

Budget ownership

Flagship project leaders will track and report on use of W1,2 funds within their FP, and on FP results in general. They will annually review progress, update impact pathways and theories of change (if needed), and propose adjustments to the W1,2 budgets to the RICE program Planning and Management Team (PPMT) for approval. The PPMT tracks the use of W1,2 funds across all FPs, and adjusts allocations based on the expected level of W1,2 investments (following the regular updates in the CGIAR Financial Plan issued by the System Office).

Variance and center budgets

See above under 'FP W1,2 allocation process'.

Capital investments

Capital investments are expected over the duration of RICE for the upgrading of existing equipment or the purchase of new ones, specifically for laboratories, experimental platforms, computing power and software. The Global Rice Array sites and the phenotyping platforms will build as much as possible on existing infrastructure, but investments will be required in new equipment such as sensors, drones, spectrometers, etc. The modernization of the rice breeding programs requires investments in specialized machinery such as transplanters, seeding drills, and seed sorters that can handle small volumes of (diverse) seed. New equipment is required to study grain quality parameters in the laboratory. Open access management of large volumes of data and information requires storage, back up, and open-source enabling software (see Annex 9 to the RICE proposal for details). As the scope for capital investments through bilateral projects is limited or restricted, an annual allocation for capital equipment is set aside from W1,2 sources as well. Priorities for capital investments will be determined on an annual basis.

1.1.6 Budgeted Costs for certain Key Activities

The following are average costs over 6 the years of the CRP, in US$.

RICE	Cost/year	Key activities
Gender	9,878,968	Development of an overarching gender strategy, R&D framework, and gender outscaling activities. Gender analysis along the value chain; developing business models for women entrepreneurs; targeting technology development for women users especially in postharvest, processing and marketing operations. Developing business models for women entrepreneurs in rice production; targeting technology development for women farmers to reduce drudgery and enhance their labor productivity; targeting development of crop and farm management options to women farmers in stress-probe environments; enhancing resilience of women farmers to climate change and other shocks; capacity development. Targeting development of new rice varieties to needs of women farmers and women consumers, especially taking health, nutrition, and other grain quality parameters into consideration; involving women in evaluation (PVS, sensory panels) of new rice lines; enhancing resilience of women farmers to climate change and other shocks; capacity development. See details in section 2.x.1.9 of the FP description, and section 1.0.4 of the main RICE description, and Annex 4 on gender
Youth	3,698,990	Developing business models for young entrepreneurs in rice production and along the rice value chain, including inputs suppliers (eg., machinery manufacturers, contract service providers); targeting technology (ICT) development for young people, such as cell-phone based advisory services. See details in section 1.0.5 of the main RICE description, and Annex 5 on youth
Capacity development	11,757,283	Individual education and training activities, and institutional development; capacity development of research, development, and scaling partners; strengthens capacity to innovate across partners in rice production and the input supply and service industry. See details in section 2.x.1.10 of the FP descriptions, section 1.0.10 of the main RICE description, and Annex 3 of the main RICE description
Impact assessment	2,626,845	All RICE impact assessments are carried out under CoA 1.5 of FP1
Intellectual asset management	1,231,526	Professional intellectual asset management services are provided throughout RICE and estimated to be around 1%, see Annex 10 to main RICE proposal for details
Open access and data management	11,103,170	Processing, validating, curation and quality control of collected data from surveys and experiments; data storage; making data accessible through standardized ontologies and descriptions; maintaining databases, websites, and other data delivery mechanisms. See section 2.x.1.11 of the FP description and Annex 9 of the main RICE description with details on cost items
Communication	7,640,815	Engages in policy dialogue to scale up results, through engagement with national and regional bodies as listed in section 1.0.9 of the main RICE proposal, and through developing and communicating results of policy analyses, using tools such as policy briefs, media releases, fora and

		ministerial roundtables); communicates with actors on the ground to scale out technologies and practices, through the development of multi-stakeholder platforms and scaling out activities, using tools such as participatory impact pathway mapping (PIPA), stakeholder and outcome mapping, problem tree definition and analysis; develops and communicates information and content to about RICE in general, its science, results, and progress; communicates and engages with partners through collaborative and participatory approaches to R&D and convening various networks, communities of practice, platforms, and consortia; promotes learning and sharing of information to improve communication and collaboration, through learning and feedback mechanisms. Development of journal papers, manuals, technical reports, and other communications media such as video, audio, websites, etc. Participation in conferences, workshops, forums, stakeholder meetings, etc.

1.1.7 Other: use of W1,2 funds

Although contributing only between 20 and 30% to the total RICE investment, W1,2 funds play a crucial role in providing the 'glue' or 'backbone' to the whole CRP. W1,2 funds are used to invest in new research and development directions along the impact pathway, from upstream research to downstream development of business models and multistakeholder partnerships for innovation an scaling out. The W1,2 investments cover both the product development component of the impact pathway and the enabling environment, e.g. through capacity development and partnership building. The long-term nature of W1,2 funding is also crucial in providing continuity to research, and to invest in new research that will deliver results in 5-10 years time only. It complements a set of bilateral grant projects that are usually of shorter duration, that focus on a smaller set of activities and outcomes, and often are limited to research and development activities further down the impact pathway, such as validation and delivery of already proven technologies. Box 1 gives details of the use of W1,2 funds in RICE and in its five FPs. The Tables B-C of the Performance Indicator Matrix give the contribution of W1,2 to the delivery of FP1's outcomes and sub-IDOs in financial terms.

The GRiSP CRP (2011-20) initially operated on an annual W1,2 budget of 30-35 million $ and invested 1.5-2 million $/year in upstream research through competitive grants. In the base funding scenario, the W1,2 funds for RICE are expected to be between 40-60% of the GRiSP level, and investments in upstream research are routed (including commissioning) through the RICE partners. In the uplift budget, RICE will again invest W1,2 funds through competitive grants.

Box 1. Use of W1,2 funds in RICE and its five FPs.

RICE overall
W1,2 funds are used to invest in new research and development directions along the impact pathway, from upstream research to downstream development of business models and multistakeholder partnerships for innovation an scaling out. The W1,2 investments cover both the product development component of the impact pathway and the enabling environment, e.g. through capacity development and partnership building. The long-term nature of W1,2 funding is also crucial in providing continuity to research, and to invest in new research that will deliver results in 5-10 years time only. It complements a set of bilateral grant projects that are usually of shorter duration, that focus on a smaller set of activities and outcomes, and often are limited to research and development activities further down the impact pathway, such as validation and delivery of already proven technologies. Particular use of W1,2 funds includes: • Gender research and gender mainstreaming in the research and development continuum (see section 1.0.4 and Annex 4 of the RICE description) • Capacity development along the impact pathway, through scholarships, partnership development, and institutional capacity strengthening (see section 2.x.1.10 of the FP descriptions, and Annex 3 of the RICE proposal) • Strengthening results-based management and 'monitoring, learning, and evaluation' through the development and application of a performance information and management system (MIS), the conduct of adoption and impact assessment studies, and the commissioning of external reviews and evaluations (mainly through FP1) • Targeted research into new areas of the SRF and into supporting areas for the SDGs, especially health and nutrition (through improved nutritious quality of rice grains, farm diversification) and climate change (adaptation and mitigation). • Support for CGIAR 'site integration' through co-investments with other CRPs at selected action sites in key 'site integration countries'. • Startup research in new areas such as market analysis, value chains, diversified farming systems, Big data, and the Global Rice Array
Flagship project 1
W1,2 funding is critical to the success of FP1. It is used specifically to support the cross-cutting functions of FP1 such as adoption and impact studies; monitoring, evaluation and learning; and gender and youth studies. It is used to develop the gender and youth strategies, and to conduct mission-critical research in these areas. W1,2 fund are also invested in developing and supporting multistakeholder and scaling partnerships needed to bring RICE's products and services to scale and reach millions of beneficiaries. Whereas bilateral grants are used to scale out specific technologies (such as the STRASA project for delivery of stress-tolerant rice varieties in CoA1.4), the W1.2 funds are used to conduct research on scaling methodologies and derive general lessons on applicability of the various scaling models. In impact assessment studies, W1,2 is specifically used to support the development and use of advanced techniques such as randomized control trials. W1,2 furthermore play a crucial role in developing and applying the RICE results-based management and monitoring, evaluation and learning systems. Activities are also funded to support individual and institutional capacity development.

Flagship project 2
Being a new FP (compared with GRiSP) with relatively few bilateral projects, W1,2 funding is critical to the success of FP2. W1,2 funds are used for strategic market and value chain research. Identified entry points for improvement are explored in a limited set of action sites, and, when successful, further developed and scaled out through the acquisition of bilateral project grants. Similarly, prototype technologies for improved postharvest operations, processing, or novel products are developed and tested at small scale using W1,2 funding, and scaled out when additional funds become available. W1,2 funds are also used to ensure that the gender dimension of FP2 are addressed (see also section 2.2.1.9 of the FP2 description).
Flagship project 3
W1,2 funding is used for strategic research into the new area (compared to GRiSP) of diversified farming systems, and to support the development of new management technologies. This use of W1,2 funding complements a set of bilateral projects that are more development oriented and that engage more in downstream technology validation, adaptation, and dissemination. W1,2 funding supports a few key action sites and partnerships where – together with other CRPs (see Annex 7 on linkages with other CRPs and site integration) - rice farming is expanded into other crops, animals, or trees. This will contribute to the process of CGIAR 'site integration' through co-investments with other CRPs in key 'site integration countries'. Capacity development activities are funded by W1,2 through scholarships and on-site participatory research and development activities. W1,2 funds are also used to ensure that the gender dimension of FP3 are addressed (see also section 2.3.1.9 of the FP3 description).
Flagship project 4
Being a new FP (compared with GRiSP) with relatively few bilateral projects, W1,2 funding is critical to the success of FP4. W1,2 funds are used to 'kick-start' the establishment of the Global Rice Array at a few key sites, building on the multi environment [breeding] trials (MET) and the phenotyping network established under GRiSP. Upstream research will be supported on the development of a (open access) Big Data integration platform (connecting to the CGIAR Big data Platform) and the exploitation of its content for the discovery of genomic associations.
Flagship project 5
W1,2 funding is used for strategic upstream research into the development of novel rice varieties (gene discovery, harnessing rice diversity, developing tools and methods of precision breeding, grain quality for health and nutrition) and to support modernization of breeding programs to accelerate the increase in genetic gain (in collaboration with the CGIAR Genetic Gain Platform). This use of W1,2 funding complements a relatively large set of bilateral projects that are more development oriented and that engage more in downstream variety testing and delivery. W1,2 funding also supports activities at key action sites on mainstreaming gender issues in the breeding pipeline, through participatory variety selection and sensory taste panels involving women. Capacity development activities funded by W1,2 aim at institutional strengthening of partners to engage in upstream research and to modernize local/national breeding pipelines.

2. Flagship Projects

2.1 Flagship project 1: Accelerating impact and equity

2.1.1 Flagship Project Narrative

2.1.1.1 Rationale, scope

The ongoing structural transformations in many countries require donors and governments to develop investment plans based on future development scenarios. This means that high-quality information is needed on such issues as changing consumer preferences, farmers' technology needs, drivers of change in rice ecosystems, yields, input use, rice markets, and prices. Such information is also needed to guide and prioritize research within RICE. Further, data are needed for effective monitoring and evaluation, and to draw lessons to feed back into the research cycle. In addition, in the absence of market feedback, publicly funded rice research requires systematic analysis of expected impacts so as to justify, prioritize, and target future investments.

To support decision making by these donors and governments, RICE as a research in development program requires a strong framework for adaptive management of its research agenda in response to changes in the rice sector, emerging needs and opportunities among beneficiaries, and feedback and learning loops based on documented results. Continuous foresight is needed to identify and monitor current and emerging drivers of change in a rapidly evolving rice sector, and to make the case for further investment.

Women make significant contributions to rice farming, processing, and marketing, but still face many barriers and inequality in access to and control over resources such as land, capital, and credit as well as access to agricultural inputs, improved technologies, and marketing services. Youth unemployment has recently emerged as a crisis in agriculture-based economies of low-income countries; the creation of job opportunities for young people in agriculture is important to reduce poverty and unemployment. Enhancing gender equity and inclusion of youth in the rice sector requires systematic situation analyses and crafting of policies and programs that will strengthen women's access to resources and services and create meaningful employment opportunities for youth. Moreover, understanding gender-related issues is prerequisite to developing and disseminating new technologies by RICE that specifically target the reduction of gender inequities. This requires good-quality information on gender-disaggregated socioeconomic and biophysical characteristics of rice production and consumption.

To realize the intended benefits of RICE among the tens of millions of targeted beneficiaries, the results of its research and development activities need to be brought to scale and answer the needs of various actors in the rice sector. This requires the development and support of collective innovation mechanisms and strategic partnerships for scaling-out, strengthening the capacity of R&D partners, and management and communication of existing and new knowledge. The design and conduct of research at the action sites of RICE will need to be informed by the perceptions of rice value-chain actors and gender and youth needs in a farming systems context, in order to deliver impact and equity at scale. The capacity of rice R&D organizations needs to be strengthened so that they fully involve value-chain and farming systems stakeholders in the research process, build on

local knowledge and expertise, and empower women and employ youth. Effective and efficient knowledge exchange mechanisms and partnerships for large-scale outreach and dissemination will need to be identified and implemented early to accelerate the adoption of innovative research products and services.

Most of the intended benefits from RICE derive from millions of farmers adopting improved rice technologies, especially new rice varieties. Hence, the existence of well-functioning seed delivery systems is a specific and critical enabling factor for the success of RICE. However, in most countries in Africa and the hinterlands of Asia and Latin America and the Caribbean, seed distribution systems are poorly developed or nonexistent. It is crucially important to improve seed delivery systems and catalyze their formation where nonexistent, to ensure timely delivery of sufficient quantities of quality seed of improved varieties to millions of farmers.

Finally, to complete the R&D loop, research managers within RICE need accurate information on the impact of their research, so that their efforts can be targeted at the most promising options.

Annex 11 gives a schematic overview of FP1's contribution to the 10 grand challenges of the SRF. FP1 addresses most of the grand challenges that RICE addresses as a whole, since much of its work guides and evaluates the activities in the other FPs. However, effects of competition for land and climate change will be addressed specifically in its foresight and scenario studies and through impact assessments of CRP-derived technologies. CoAs 1.3 and 1.4 specifically address the grand challenge "New entrepreneurial and job opportunities are emerging."

2.1.1.2 Objectives and targets

FP1 provides an overarching framework for guidance and feedback to all the RICE FPs, to promote and accelerate large-scale delivery and intended outcomes and impacts. FP1 undertakes foresight, policy analyses, gender and youth studies, technology targeting, fostering innovative mechanisms and partnerships for scaling-out, monitoring, and evaluation of progress, and ex-ante and ex-post impact assessments across the CRP. It helps all other FPs develop well-targeted and demand-driven products and delivery approaches. At the same time, FP1 serves the broad community of stakeholders in the rice sector by filling a general demand for up-to-date information. The focus is primarily on synthesizing and making available accurate science-based information to policymakers, donors, scientists, agricultural professionals, farmers, and the general public. FP1 provides baseline data and information against which these actors can assess the success or impact of previous interventions and plan new ones through ex-post and ex-ante assessments of projects, technologies, and policies.

FP1 will deliver the following research outcomes to selected sub-IDOs, IDOs, SLOs, and cross-cutting issues of the SRF (see also the performance indicators matrix):

FP1 research outcome	Sub-IDO	IDO	SLO or cross-cutting issue
Foresight analyses and priority setting used by RICE and partner scientists to develop and target technology options	Increased capacity for innovation in partner research organizations	National partners and beneficiaries enabled	Capacity development
Improved role in decision making by women and youth in rice value chains as evidenced by empowerment measures at key action sites	Improved capacity of women and young people to participate in decision-making	Equity and inclusion achieved	Gender and youth
Well functioning multistakeholder platforms for innovation at six action sites (Bangladesh, India, Nepal; Nigeria, Senegal, Tanzania)	Increased capacity for innovation in partner development organizations and in poor and vulnerable communities	National partners and beneficiaries enabled	Capacity development
New cadre of young, well-trained scientists (30% women) engaged in rice research	Enhanced individual capacity in partner research organizations through training and exchange	National partners and beneficiaries enabled	Capacity development
Effective public and private delivery systems for seeds of improved rice varieties in six countries (Bangladesh, India, Nepal; Nigeria, Senegal, Tanzania)	Increased capacity of beneficiaries to adopt research outputs	Enabling environment improved	Policies and institutions
Impacts and adoption of RICE technologies assessed	Increased capacity of beneficiaries to adopt research outputs	Enabling environment improved	Policies and institutions
Functional and effective results-based management system for RICE and its partners	Increased capacity for innovation in partner research organizations	National partners and beneficiaries enabled	Capacity development

2.1.1.3 Impact pathway and theory of change (for each individual FP)

Fig. 1.1 presents the impact pathway and theory of change, with risks and associated enabling actions for the whole of FP1.

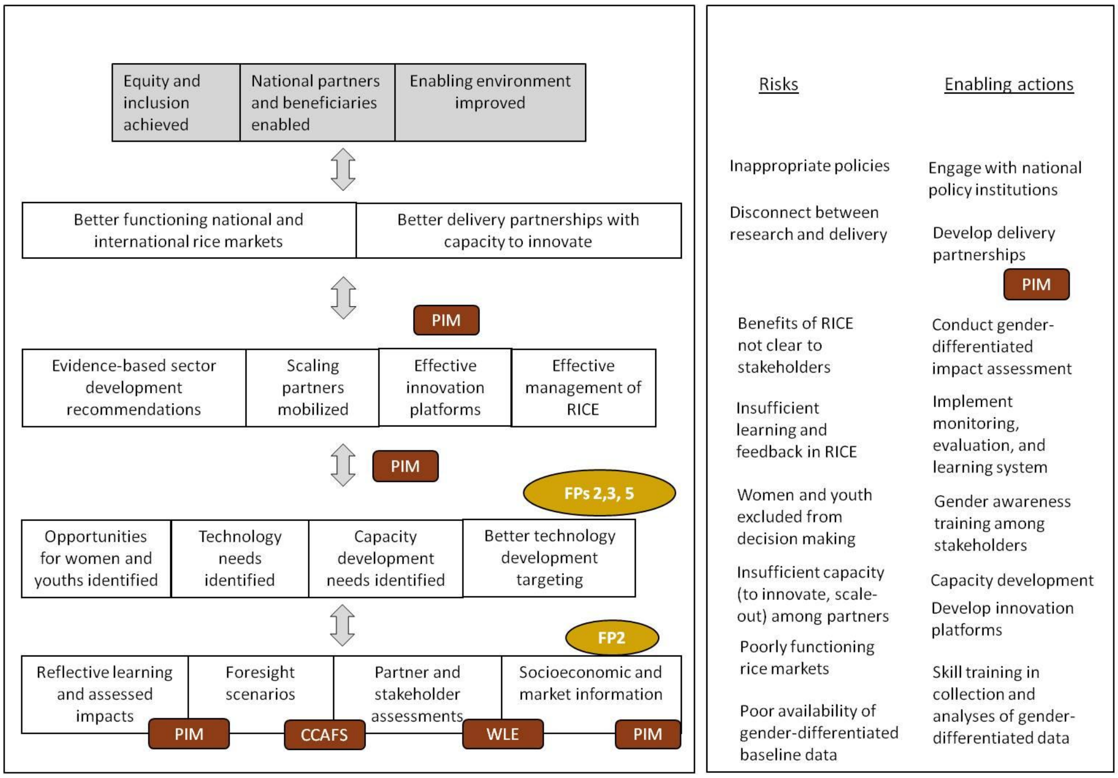

Fig. 1.1. Impact pathway (left) and theory of change (right) of FP1. Grey boxes are IDOs, ovals (with FP x) refer to links with other FPs, and the dark boxes refer to links with other CRPs (see Annex 12 for abbreviations).

FP1 conducts many of the enabling actions that support the impact pathway and theory of change of the whole RICE CRP. Foresight and priority-setting activities are the basis of evidence-based decision making by program/project management and senior research leaders in allocating resources where they have the greatest impact potential. The gender-disaggregated findings of socioeconomic analyses of farm households on technology needs of farmers, technology performance in farmers' fields, and adoption constraints are expected to improve product development and the formulation of supportive policies for their scaling-out and adoption. Addressing social considerations with a focus on women and youth is expected to lead to policies and technological changes that promote gender equality in access to productive resources and opportunities that will contribute to household food and nutrition security.

A central element of the theory of change is the establishment or strengthening at action sites of multistakeholder platforms[10]—mechanisms that allow interactions along the rice value chain and/or within a particular farming systems environment among stakeholders who share a common goal to improve mutual understanding, create trust, define roles, and engage in joint action within a value chain (FP2) and/or farming systems (FP3) context. A learning alliance is a multistakeholder platform that places special emphasis on capturing learnings from joint development and implementation of solutions and interventions in repetitive, progressive learning cycles (Lundy et al 2005). Another form of multistakeholder platform is the innovation platform, which provides a space for learning and change (Homann-Kee Tui et al 2013). It comprises a group of individuals (who often

[10] According to ISPC (2015), multistakeholder platforms 'concern structured alliances of stakeholders from public, private and civil society sectors. These include companies, policy makers, researchers, a variety of forms of NGOs, development agencies, interest groups and stakeholders from local, national, regional and international governance regimes. The key feature is the dissimilarity of partners'.

represent organizations) with different backgrounds and interests: farmers, traders, food processors, researchers, government officials etc. The members come together to diagnose problems, identify opportunities, and find ways to achieve their goals. They may design and implement activities or coordinate activities by individual members.

To reach millions of beneficiaries, partnerships will be forged for capacity development and scaling-out beyond the action sites.

Real-time data on rice production, the medium-term outlook, and quantitative assessment of domestic and trade policies will help national policymakers to effectively forecast and mitigate problems in the sector. In particular, policy measures such as export bans, import restrictions/quotas, and input subsidies are often subject to controversial debate on national food security. FP1 research will help to mitigate situations like the 2008 global rice price spike by engaging rice traders and government agencies in more appropriate market and policy responses. However, much relies on the presence and quality of data. Engagement of national partners will be sought to collect, verify, and take ownership of national and subnational data.

2.1.1.4 Science quality

FP1 will collect and analyze vast amounts of cross-sectional and panel data and GIS/remote-sensing data across the rice sector in different countries and along whole rice value chains using state-of-the-art tools and methodologies. The information will be used to provide critical feedback to all other RICE FPs, allowing them to develop well-targeted, demand-driven products and delivery approaches for varieties, management systems, and other information that actors along the rice value chain really need. For farm households, such data include information on farm characteristics, resource base, labor use, income levels, farmers' perceptions on technology needs, technology adoption patterns and constraints, and farm-level effects of technologies. The farm household data will be geo-referenced and disaggregated by gender to identify any changing roles of women and youth. All household data will be collected using computer-assisted personal interviewing, in which completed questionnaires are immediately sent to the main server to allow continuous checking of data collection and quality.

Spatial analysis will involve mapping and monitoring the biophysical and socioeconomic characteristics of rice-producing areas using remote-sensing technology and GIS for effective technology targeting. The use of remote sensing to track technology adoption and real-time monitoring of rice production (including crop losses due to extreme weather such as flood and drought), will be supplemented with survey data to improve accuracy, timeliness, and cost-effectiveness of the estimates.

The in-house foresight and policy simulation integrated platform, using the rice growth model ORYZA2000 and the IRRI Global Rice Econometric Model, will be linked to IFPRI's IMPACT modeling framework to measure the impacts of potential technologies and policies nationally, regionally, and globally. 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 and policymakers will be provided through qualitative evaluation during early adoption. The adoption survey data will be combined with DNA fingerprinting of collected rice seed samples to cross-validate survey results. To enhance the scientific quality and rigor of impact assessment, advanced methods will be used, including randomized control trials,

conditional and marginal treatment effects, experimental auctions, and other experimental methods to elicit information from farmers and other value-chain actors. FP1 will combine quantitative and participatory impact-evaluation methods. The quantitative part focuses on the new marginal treatment effect (MTE) framework that accounts for selection of both observables and unobservables and creates a unified framework to generate various parameters of interest.

The leader of FP1 is an experienced economist in the rice sector and has leadership skills in research-for-development projects and programs obtained in GRiSP. The FP1 core team (see section 2.1.1.12 [FP1 management] and CVs in Annex 8) consists of a well-balanced mix of senior scientists and young professionals

The IEA review of GRiSP noted that, although the GRiSP social sciences produced some outstanding work with some excellent examples of high-quality science, quality overall was variable (IEA report, p 32). Too much of the work was too descriptive, too disciplinary, or published in working papers, reports, and mediocre journals rather than in first-call journals. In line with their recommendations (IEA report, p xvi and 32), FP1 management will foster more interdisciplinary research with biophysical scientists (especially in FP3 and FP5, through joint situation analyses, need and opportunity assessments, and technology evaluations). It will also foster strong partnerships with both public and private ARIs to bring in fresh and novel social science tools, such as through collaboration with the University of California-Berkeley on randomized control trials; Purdue University, University of Mississippi, and North Carolina State University for joint analysis of farm household survey data in gaining insight into poverty dynamics, food security, technology adoption, and impact; the University of Arkansas on the development and application of the multicountry econometric model; and Sarmap for remote sensing technology and software (see also section 2.1.1.7 on partnerships).

Finally, FP1 management will encourage jointly authored (among CRP centers and ARIs), high-quality publications similar to a recently published article (Yamano et al 2016) on the adoption and impact of international rice research technologies, co-authored by social scientists from IRRI, AfricaRice, and CIAT (IEA review recommendation #2, IEA report, p xvi). Already in recent years, the FP1 core team has published in top tier disciplinary and interdisciplinary journals, including the American Economic Review, Food Security Report, Proceedings of the National Academy of Sciences, Agricultural Economics, World Development, Food Policy, Applied Economic Perspective and Policy, Plos One, Australian Journal of Agricultural Economics, Agricultural Systems, Field Crop Research, Remote Sensing, Land Use Policy, Global Food Security, Food Security, Global Environmental Change, and Mitigation and Adaptation Strategies for Global Change. One paper was the best journal paper in Agricultural Economics in 2014 (Balagtas et al 2014).

2.1.1.5 Lessons learnt and unintended consequences

FP1 builds on Theme 5 (Technology evaluations, targeting, and policy options for enhanced impact) and Theme 6 (Supporting the role of the global rice sector) of GRiSP. A major lesson learned was that a strong conceptual and analytical framework should be developed to underpin this work, and that this work should play a stronger role in CRP internal guidance and monitoring, evaluation, and learning (MEL). Hence, this role has been strengthened and two new CoAs have been added to strengthen the MEL (CoA1.6) and impact assessment (CoA1.5) activities. In particular, capturing learning on progress toward development outcomes and feeding this back into the research progress of the other FPs are major improvements over GRiSP. Also new are the analyses of youth

mobilization in the rice sector; CoA1.2 includes the development of a youth strategy for the whole of RICE. Section 2.1.1.9 summarizes some of the specific GRiSP lessons learned on gender and how FP1 will improve on them in RICE.

Through its activities on program monitoring and evaluation and impact assessments, FP1 aims to address unintended consequences of RICE on any development outcome or SLO. Repeated household surveys and analyses of national survey data will reveal impacts on such issues as household food security, poverty, gender equity, youth employment, and natural resources. Such information will be fed back into the research planning cycle of the RICE FPs through CoA1.6. A particular potential unintended consequence is that RICE technologies do not respond to the needs of women or socially disadvantaged groups in society, or do not bring them benefits. Hence, FP1 will disaggregate (by gender, age, and social groups) and monitor technology adoption data, conduct gender studies to develop technologies that address women's needs, and engage in technology dissemination approaches that target women and socially disadvantaged groups. Another risk of unintended consequences arising from these actions is that traditional power structures become threatened to the extent that development objectives are obstructed. Through close collaboration with project partners and monitoring the success of multistakeholder platforms, especially learning alliances, FP1 will signal such risks and develop mitigation strategies such as additional awareness raising and developing and demonstrating win-win situations. Under special conditions, partners with special skills such as conflict resolution may be needed.

2.1.1.6 Clusters of activity (CoA)

1.1 Foresight and targeting

Foresight analyses combine qualitative methods such as national and regional policy dialogues and stakeholder consultations, and quantitative methods. In CoA1.1, qualitative assessments will be carried out in strong collaboration with national planning activities such as through policy dialogues and contributions to the development of national rice sector development strategies, especially in sub-Saharan Africa and Asia. For example, in collaboration with REPAD (Réseau de Recherche pour l'Appui au Développement de l'Afrique), CoA1.1 has begun to assess the impact of the common external tariff on the development of the rice sector in West African countries.

Quantitative modeling approaches will be used to conduct dynamic supply-and-demand analyses under different socioeconomic and environmental scenarios. An integrated model, combining a global rice supply-and-demand econometric model with a crop growth simulation model (developed in collaboration with PIM/IFPRI) will be used to assess the changes in technology and policy development that are needed to meet the challenges to global food security, poverty, climate change, and natural resource degradation. The econometric model describes the behavior of the world rice market and how it is linked with other agricultural and nonagricultural inputs and products. It includes 33 major rice-producing, rice-consuming, and rice-trading countries/regions. Its linkage with the crop growth simulation model allows yield estimation to be endogenized in the system. The integrated model will further be linked to a satellite-based rice monitoring system to provide seasonal forecasts of rice area, yield, production, price, and predictions of crop loss caused by extreme weather events such as floods, droughts, and tropical cyclones.

Together with survey data and tools such as GIS, the above models will be used to characterize and map market segments and target environments for technologies that other RICE FPs will develop—such as new varieties, crop management technologies, farming systems, and

postharvest technologies. Information obtained from participatory, structured, and quantitative priority-setting exercises will be fed into the model to obtain estimates of economic, health, and environmental benefits per dollar of investment in potential research areas. Components of this analysis include mapping of rice agroecosystems, assessment of current and projected yield gaps under future climatic conditions, and disaggregation of yield gaps into efficiency gaps, gender gaps, abiotic yield limitations, and biotic yield reductions for particular agroecosystems and countries.

1.2 Gender and youth for inclusive development

CoA1.2 identifies the constraints and gender- and age-specific needs and opportunities for women and youth in rice-based systems and rice value chains. The findings from gender and youth research will provide important feedback to RICE FPs 2–5 for the design of gender- and youth-sensitive technologies and for the implementation of gender- and youth-inclusive actions to accelerate impacts of these technologies.

CoA1.2 focuses on developing strategies for the equitable inclusion of men, women, and youth in the rice sector and identifying income-generating opportunities for women and youth in rice-based agricultural systems. The major activities of this cluster are identifying opportunities, needs, and constraints of women and youth to contribute to and benefit from the development and dissemination of improved rice technologies, diversified farming systems, and sustainable natural resource management practices. This cluster also identifies gender- and age-differentiated impacts of rice-related technologies and the changing role of women and youth in rice farming. Capacity development programs will be designed for women and youth. Innovative business models (e.g., agricultural service provider and seed entrepreneur) for women and youth will be developed and tested in selected countries of Asia and Africa. Opportunities are described in more detail in the other FPs. Finally, CoA1.2 will assess the impacts of new technologies, training, and business models on youth and women's empowerment by evaluating their decision-making power and access to and control over assets comparing pre- and post-intervention scenarios. Findings will be provided as feedback to project leaders, national partners, and donors for gender- and age-inclusive agricultural policy decisions.

1.3 Collective innovation and scaling-out

Fig. 1.2 presents a detailed impact pathway and theory of change for CoA 1.3. Accelerating the adoption of rice products and services resulting from research depends first on full and equitable participation of key stakeholders in research activities at the action sites to ensure that products and services that are developed are inclusive and demand driven. CoA1.3 will bring the voice of poor and vulnerable communities to the development partners that directly interface with them. It will strengthen the capacity of RICE research and development partners for innovation at action sites by developing innovation platforms and building on local knowledge and iterative cycles of collective planning, action, and learning. The capacity of rice value-chain actors at the action sites to generate innovations will be strengthened. CoA1.3 will develop a proactive and inclusive approach to opportunities for youth employment and women's empowerment during technology development, and prioritize innovations that help more marginal farmers, ethnic groups, and women to capture a significant (if not disproportional) fraction of the benefits.

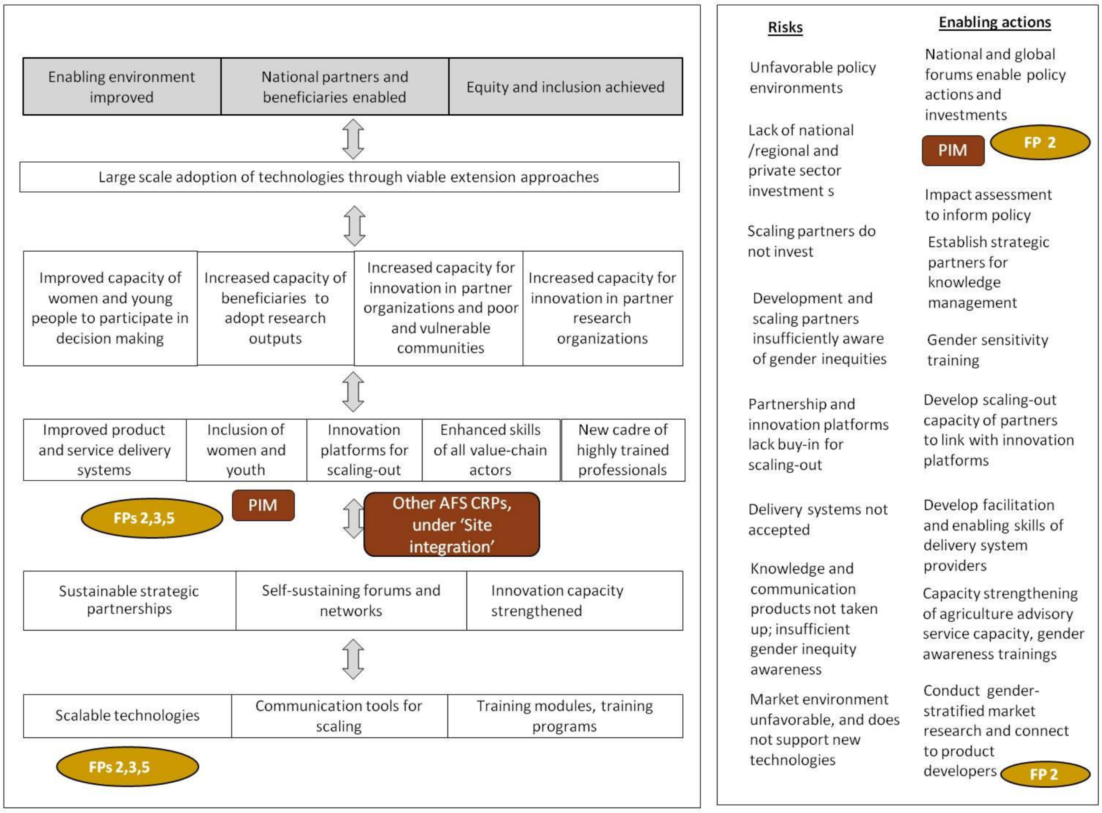

Fig. 1.2. Impact pathway (left) and theory of change (right) of CoA 1.3 of FP1. Grey boxes are IDOs, ovals (with FP x) refer to links with other FPs, and the dark boxes refer to links with other CRPs (see Annex 12 for abbreviations).

CoA1.3 will also establish, maintain, and expand partnerships with major scaling partners from the public and private sector to scale-out RICE technologies and services (developed in FPs 2–5) to reach millions of beneficiaries beyond the action sites. Scaling partners include national extension services; national research, technology, agricultural, and rural development ministries; the private sector (e.g., seed industry and machinery providers); international development and donor agencies (e.g., international development banks); and NGOs such as Catholic Relief Services, Bangladesh Rural Advancement Committee, and Digital Green. Such partnerships will build on the lessons learned and the principles and technologies derived from research at the action sites. Hence, CoA1.3 promotes linkages between multistakeholder platforms at action sites and scaling partners. In return, the scaling partners will provide RICE with information on the performance of these innovations and gender-disaggregated data on their uptake by target beneficiaries. Successful scaling-out of RICE technologies and services also requires that policymakers and decision makers create and maintain a favorable policy environment. Hence, CoA1.3 links with the policy activities of CoA1.1.

CoA1.3 will conduct research to rigorously assess the cost-efficiency, effectiveness, and inclusiveness of the various scaling models used by RICE and its development partners. Case studies will include seed systems for effective delivery of new varieties (link with CoA1.4), agricultural machinery systems (link with FP2 and FP3), rice management decision support (link with FP3), and business models and capacity strengthening approaches. The outcome of this research will be the enhanced ability to select best-fit scaling approaches for impact at scale, in particular targeting women and youth.

1.4 Seed delivery systems

This CoA will strengthen seed delivery systems, and catalyze their formation where nonexistent, to ensure timely delivery of sufficient quantities of quality seed of improved varieties to millions of farmers. Enabling actions will include developing good understanding of the gaps in seed delivery, strengthening the capacity of partners along the seed chain, and strengthening linkages with national seed systems, community seed growers, input dealers, and private seed companies. Effective communication strategies will be employed along the demand-supply chain to provide adequate seed of different categories to relevant partners. The role of the private sector, NGOs, and other seed producers will be emphasized and strengthened to sustain seed multiplication and delivery. New entrepreneurships will be sought, particularly among youth and women's groups, to engage in good-quality seed multiplication and marketing, especially in remote or inaccessible areas. Special attention will be paid to including women farmers among the beneficiaries of the seed of improved rice varieties.

1.5 Adoption and impact assessment

Ex-post impact assessment will be conducted when RICE research products are close to their peak of adoption. Results will be fed back into technology development, targeting, and scaling-out in CoA 1.3 and CoA1.4, and other FPs. These studies will focus on estimating the realized economic, social, and environmental benefits of adoption of RICE products. The studies will be designed to allow the disaggregation of impact results for men, women, and youth so as to assess how RICE outcomes have led to changes in the CGIAR SLOs such as food security, poverty, and environmental footprints for each actor. Most ex-post impact studies in the CGIAR so far have focused on results of adoption of improved varieties; impacts from the adoption of improved natural resource management (NRM) and postharvest technologies have been less documented. Difficulties in defining NRM technologies and practices, measuring noneconomic returns, and measuring long-term benefits have inclined social scientists to focus on genetic contributions.

Therefore, in addition to impact assessments of novel genetic resources, CoA1.5 will focus on evaluating NRM and postharvest technologies and practices. The proposed studies include resources conservation technologies (e.g., smart-valley, alternate wetting and drying, and One-Must Do and Five Reduction), improved farming equipment (mechanical weeder), institutional innovations (contractual arrangements), decision support innovation (RiceAdvice and Crop Manager) and postharvest innovations (parboiling system and ASI thresher). Impact surveys will take into account estimation of household (both male and female led) and aggregate (country-wide and mega-growing environment) parameters.

To obtain reliable impact estimates, evaluation studies need to employ rigorous evaluation methods. Often, it is useful to have baseline data to identify changes over time with and without new technology. In CoA1.5, the ex-post impact assessment methodology will combine both quantitative and qualitative participatory impact-evaluation methods. The quantitative component uses a design that integrates both randomized control trials and observational study methods, based on the potential outcomes framework, but the focus will be on the new marginal treatment effect (MTE) framework. Unlike traditional approaches such as propensity score matching, the MTE framework accounts for selection on both observables and unobservables and creates a unified framework to generate parameters of interest. Surplus analyses will be used to estimate the total benefits of RICE varieties at the aggregated level. Impact evaluation specialists will work closely with scientists who are familiar with new technologies and practices to establish baselines and control

treatments for later impact evaluations. Data will be collected and analyzed using an automated web-based application (Mlax) developed by AfricaRice (www.mlax.org) and other computer-assisted personal interview systems (e.g., Surveybe).

1.6 Monitoring, evaluation, and learning

A results-based management system prototyped under GRiSP will be further developed and used to track progress of RICE toward its development outcomes (Annex 6). This system will be interoperable with center-specific MEL systems that are already in place. Special emphasis will be placed on tracking gender-disaggregated process indicators and providing feedback on gender-specific RICE targets. A functional and well-articulated MEL system is essential to manage for results. CoA1.6 will be responsible for leading the RICE results framework and developing and implementing tools to measure IDOs and sub-IDOs. The MEL system of RICE will track, monitor, and evaluate progress and provide reflective learning across the FPs. The system will help design impact pathways and theories of change, guide the FPs through analysis of critical feedback loops, and use the results to adapt the impact pathways and theories of change in a continuous learning cycle. It will also derive key lessons for program/project management and decision making. The results of the MEL system generate knowledge for scaling-out RICE products and services. Finally, the MEL system will be used for reporting and to show accountability to donors and stakeholders. The backbone of the system consists of repeated household surveys at RICE key action sites, supplemented with focus group discussions and spatial analyses.

2.1.1.7 Partnerships

Partnership building and strengthening are at the heart of CoAs 1.3 and 1.4, which will also improve the capacity of the other RICE FPs to collaborate with farmer organizations, private-sector and civil society partners, and national and regional rice development projects. It will build on local knowledge and expertise, thereby empowering women and mobilizing youth. Specifically for value-chain analysis and upgrading, FP1 will partner with PIM to adopt a common framework, which will be applied jointly at specific action sites in target countries.

Collection and analysis of the data needed to achieve the goals of FP1 require partnerships across a wide spectrum of advanced institutions within and outside the CGIAR. Special emphasis will be placed on strengthening capacity in national partner institutes to carry out policy work related to the seed sector, input supply and availability, and the labor market. Such capacity will be mobilized to support technology development, adoption, and dissemination. A consultative framework and mechanism of information sharing will be adopted with various stakeholders (NARES and NGO staff, national agricultural statistical service staff, rice stakeholder organizations, policy analysts, and donors). To enhance the quality of its science, FP2 will expand its partnerships, particularly with other CGIAR centers, ARIs, and universities (IEA review recommendation #2, IEA report, p xvi).

FP1 has a comparative advantage for rice sector research because its research portfolio naturally connects through many entry points to rice agri-food value chains. Although the private sector increasingly addresses mechanization and postharvest problems, it usually engages only in areas that have short- to medium-term market potential. The comparative advantage of FP1 further rests in its international mandate, which facilitates exchange among countries and can thus improve rice sector efficiency at regional and global scale.

Some major partners and their roles are:

Discovery	Proof of concept/Scaling-out
IFPRI, International Crops Research Institute for the Semi-Arid Tropics, University of California-Berkeley, Purdue University, University of Mississippi, North Carolina State University, University of Arkansas, London School of Economics, Alliance of the International Center for development-oriented Research in Agriculture (ICRA), Center for Development Innovation (CDI) of the Wageningen University research group, the Royal Tropical Institute (KIT), and Sarmap.	Numerous NARES partner institutes in Africa, Asia, and Latin America. NARES researchers are normally given the responsibility of data collection, analysis, report writing, and publication at the national/state level for all studies in their respective countries. NARES institutes also disseminate results in national scientific and policy forums. Scaling partners include national extension services; national research, technology, agricultural, and rural development ministries; private sector (e.g., seed industry and machinery providers); international development and donor agencies (e.g., international development banks); and NGOs such as Catholic Relief Services and the Bangladesh Rural Advancement Committee.

2.1.1.8 Climate change

The long-term data collected in this FP will be used to assess the effects of climate change on yield and provide insight into the coping mechanisms adopted by farmers to adapt to its effects. Foresight and ex-ante assessment of potential technologies will be conducted under different climate scenarios, using the integrated economic and crop modeling framework to measure potential impacts. CoA1.6 describes the MEL process that uses climate change impact and other assessments in a continuous learning cycle for program/project management.

2.1.1.9 Gender

Rice farming and value chains everywhere are changing rapidly, with major implications for the role of women in decision making, labor specialization, and postharvest management. With appropriate technological and institutional support, rice farming could offer equal opportunity employment for women and men. The IEA evaluators of GRiSP concluded (IEA report, p 59) that GRiSP, specifically through its W1/W2 funding, played a central role in sensitizing and training its participating centers' staff and partners in gender analysis. GRiSP successfully involved women as target beneficiaries in its activities for scaling-out technologies despite cultural barriers imposed in some societies. However, the evaluators also noted that GRiSP was less successful in incorporating gender as an integral part of research planning and technology design, and recommended that GRiSP should do more in-depth analysis to understand opportunities and constraints of women in rice farming and value chains in order to better address the effectiveness and equity impacts of its research and technology delivery (Recommendation #9, p xvii). Hence, gender research has been embedded as a specific CoA in FP1 to pay particular attention to gender issues upstream in the research-delivery pipeline, to conduct in-depth research on the role of women in rice farming and value chains, and to guide planning of research that explicitly incorporates gender dimensions in the early stage of technology design in the other FPs of RICE. It also contributes to gender aspects of ex-ante and ex-post impact assessments. Further details are provided in the description of CoA1.2.

2.1.1.10 Capacity development

Capacity development in FP1 incorporates most of the nine elements of the CGIAR Capacity Development Framework. Lessons from GRiSP have shown that the element "Needs assessments and promising interventions" requires expert facilitation of innovation processes for successful technology development and dissemination. In turn, successful facilitation requires interdisciplinary and gender competences, as well as business development skills. Hence, CoA1.3 supports the development of skilled facilitators in RICE institutions and in partner R&D organizations. These facilitators will also be trained in gender-sensitive approaches so that they will be able to recognize gender gaps in access to improved technologies and technical knowledge, and to identify gender-disaggregated constraints and opportunities. CoA1.3 will also develop capacity enhancement programs to address gender concerns in the whole R&D process; to train women on all aspects of production, processing, and farm management; and to train grassroots women farmers and other actors in the rice value chain. Concrete outputs will include training material, people trained on women and youth aspects in value-chain development and products, and advisory services that work for women and youth.

In ex-ante and ex-post impact assessment (CoA1.5), emphasis will be on institutional capacity development in advanced tools and methods through close interaction with national partners. Specifically, training is to be provided on analytical forecasting and modeling tools, remote sensing, GIS, and the conduct of surveys and other data collection techniques. Capacity to apply these tools at the institutional level will be prioritized.

2.1.1.11 Intellectual asset and open access management

FP1 follows the RICE policies and strategies on intellectual asset management, open access, and data management (Annexes 9, 10), which are in line with the CGIAR Principles on the Management of Intellectual Assets and their Implementation Guidelines, and with the CGIAR Open Access and Data Management Policy and its Implementation Guidelines. FP1 intellectual assets relate to statistical data, survey data, models, tools, methodologies, training and information dissemination products in various forms (digital, written video, audio, manuals, pamphlets, posters, and PowerPoint presentations: Rice Knowledge Bank, RiceHub, Rice videos Africa, and Rice videos Asia), and policy briefs, reports, and publications. Data on national rice sector statistics are made available through the World Rice Statistics. Gender-disaggregated household and other survey data are made open access and are distributed through the online sites Farm Household Survey data and AfricaRice Research data. As a policy, these data are made available within 12 months after curation and quality control or 6 months after publication. Surveys are conducted in accordance with the highest ethical standards; the RICE CGIAR centers are committed to protecting the rights, dignity, health, safety, and privacy of research subjects when collecting data. Informed consent from study participants shall be obtained at the outset of any survey or interview. Personal data collected with respect to farmers or other stakeholders will be processed fairly and lawfully and, in particular, will not be made public. The structural econometric model of the global rice sector developed at IRRI is publicly available (Jamora et al 2010, IRRI 2012, Hoang 2014). The rice model ORYZA2000 is fully documented, maintained, and downloadable with tutorials. CoA1.6 will maintain a web-based performance management system that catalogues RICE outputs, outcomes, IDO indicators and underlying data, and reports and other knowledge products.

2.1.1.12 FP management

FP1 is led by Dr. Sam Mohanty, head of social science division of IRRI. Each CoA is co-led by a team of senior scientists (focal persons) consisting of one or more representatives from each center. Annex 8 presents the list of senior scientists and a set of selected curricula vitae.

CoA 1.2 is led by a RICE expert who coordinates the RICE gender team and participates in the CGIAR gender network. CoA 1.6 is led by RICE's M&E expert, who coordinates the RICE MEL team and participates in the CGIAR Monitoring, Evaluation & Learning community of practice (MELCOP), and IEA's evaluation community of practice. Both the gender and M&E expert participate in the extended RICE management team.

2.1.2 Flagship Budget Narrative

2.1.2.1 General Information

CRP Name	CGIAR research program on rice-based agri-food systems, RICE
CRP Lead Center	International Rice Research Institute
Flagship Name	Accelerating impact and equity
Center location of Flagship Leader	Los Baños, Philippines

2.1.2.2 Summary

Total flagship project budget summary by sources of funding (US$).

Funding Needed	2017	2018	2019	2020	2021	2022	Total
W1+W2	2,366,483	2,408,701	2,452,508	2,497,971	2,545,156	2,594,133	14,864,954
W3	7,160,100	7,364,881	7,575,919	7,793,407	8,017,546	8,248,538	46,160,393
Bilateral	4,675,940	4,880,607	5,094,635	5,318,463	5,552,556	5,797,399	31,319,602
Other Sources							0
Total	14,202,523	14,654,189	15,123,062	15,609,841	16,115,258	16,640,070	92,344,943

Funding Secured	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Assumed Secured)	2,366,483	2,408,701	2,452,508	2,497,971	2,545,156	2,594,133	14,864,954
W3	4,752,015	3,263,051	0	0	0	0	8,015,066
Bilateral	4,311,827	4,130,534	3,549,481	3,726,955	3,913,303	4,108,968	23,741,070
Other Sources							0
Total	11,430,325	9,802,286	6,001,989	6,224,926	6,458,459	6,703,101	46,621,086

Funding Gap	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC	-2,408,085	-4,101,830	-7,575,919	-7,793,407	-8,017,546	-8,248,538	-38,145,327

Members)							
Bilateral (Fundraising)	-364,112	-750,073	-1,545,153	-1,591,507	-1,639,253	-1,688,431	-7,578,532
Other Sources (Fundraising)	0	0	0	0	0	0	0
Total	-2,772,198	-4,851,903	-9,121,073	-9,384,916	-9,656,799	-9,936,969	-45,723,859

Total flagship project budget summary by natural classification (US$).

	2017	2018	2019	2020	2021	2022	Total
Personnel	6,229,536	6,446,118	6,670,692	6,903,572	7,145,086	7,395,576	40,790,583
Travel	1,539,562	1,584,023	1,630,235	1,678,272	1,728,209	1,780,127	9,940,429
Capital Equipment	0	0	0	0	0	0	0
Other Supplies and Services	4,680,234	4,814,841	4,954,757	5,100,207	5,251,422	5,408,645	30,210,107
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	62,860	64,344	65,872	67,445	69,066	70,736	400,326
Indirect Cost	1,690,330	1,744,862	1,801,504	1,860,344	1,921,473	1,984,986	11,003,502
Total	14,202,522	14,654,188	15,123,060	15,609,840	16,115,256	16,640,070	92,344,936

Total flagship project budget summary by participating partners (US$).

	2017	2018	2019	2020	2021	2022	Total
IRRI	9,906,429	10,174,189	10,449,982	10,734,049	11,026,639	11,328,005	63,619,295
Africa Rice	4,146,095	4,325,457	4,513,788	4,711,535	4,919,170	5,137,186	27,753,233
CIAT	150,000	154,542	159,291	164,257	169,450	174,879	972,421
Total	14,202,524	14,654,188	15,123,061	15,609,841	16,115,257	16,640,070	92,344,941

Explanations of these costs in relation to the planned 2022 outcomes

Flagship project 1 is composed of 6 clusters of activity as described in the FP1 narrative section 2.1.1.6. Each cluster of activity delivers one or more outcomes each (with a related set of milestones), as listed in the Performance Indicator Matrix, Tables B-D. The required investment (budget) for each outcome is listed in Table B of the Performance Indicator Matrix. The Clusters of activities (CoA) and their outcomes are:

FP1	Cluster of Activity	Outcomes
1.1	Foresight and targeting	Foresight analyses and priority setting used by RICE and partner scientists to develop and target technology options
1.2	Gender and youth	Improved role in decision making by women and youth in rice value chains as evidenced by empowerment measures at key action sites
1.3	Collective innovation for scaling out	Well functioning multistakeholder platforms for innovation at six action sites (Bangladesh, India, Nepal; Nigeria, Senegal, Tanzania)
		New cadre of young, well-trained scientists - 30% women - engaged in rice research
1.4	Seed delivery systems	Effective public and private delivery systems for seeds of improved rice varieties in six countries (Bangladesh, India, Nepal; Nigeria, Senegal, Tanzania)
1.5	Benefits and impact	Impacts and adoption of RICE technologies assessed

	assessment	
1.6	Monitoring, evaluation, and learning	Functional and effective results-based management system for RICE and its partners

Besides the above outcomes, each cluster of activity contributes to various capacity development actions. The budget of each cluster of activities depends on the type of activities, and involves typically the collection of survey data (involving travel, local expenses in country such as translators, enumerators, vehicle rental, local partners), and analyses and reporting of survey data (CoAs 1.2, 1.5, 1.6). Other activities include development and use of the results-based management system and of the monitoring, evaluation and learning system (CoA 1.6); developing and use of foresight, supply-demand, and ex-ante impact assessment models (CoA1.1); developing and sustaining multistakeholder platforms at action sites (CoAs 1.4 and 1.5); developing partnership arrangements for scaling out (CoAs 1.4 and 1.5); adoption studies, including the conduct of randomized control trials (CoA1.5); workshops; stakeholder consultations; partner capacity development for research, innovation, and delivery; publications; communication; (open access) data management (all CoAs) – see section 2.1.2.5 below.

Risk to spending as planned

The RICE FPs are 'umbrella projects', which include a large number of bilateral projects any given year. Hence, the FP budgets are dictated by the collective investments that donors want to make through W1/2, W3, bilateral, and 'others means'. The investment levels are unpredictable: 1) the W1-3 donors can not commit to 6-year funding obligations and the W1-3 investments into the CGIAR fluctuate substantially each year, and 2) 70-80% of the budget is contributed to by bilateral projects, the majority of which still need be developed and secured. Hence, the likelihood that budgets are obtained - and spent - exactly as targeted, decreases as the CRP progresses in time. Each year, updates on investments expectations and budgets will be developed, and spending managed accordingly. At the level of bilateral projects, spending risk is managed by project leaders following procedures spelled out in project contracts. For W1-3, spending risk is managed by flagship project leaders. Project leaders get regular updates on actual spending rate through OCS, and are required to make project adjustments if under- or overspending occurs beyond the (donor-) accepted range (usually 10% of line items).

2.1.2.3 Additional explanations for certain accounting categories

Benefits

Benefits are separated out and include pension, housing, vehicle, home leave, medical insurance, and education allowances

Other supplies and services

Costs related to the collection of survey data, conduct of interviews, and other methods of collecting socio-economic data involving local expenses in country such as recruitment of translators, enumerators, vehicle rental, local partner costs, laptops for data entry);

- Software for the development and use of simulation models, supply-demand models, and ex-ante impact assessment models; the results-based management system; the monitoring, evaluation and learning system;
- Costs related to the development and sustenance of multistakeholder platforms at action sites, and for the development of partnership arrangements for scaling out (partner costs, workshop costs, stakeholder consultations, meetings);
- Conduct of adoption studies, including the conduct of randomized control trials;
- Various others: workshops; partner capacity development (training materials, training course costs, costs for on-the-job training, survey costs for capacity needs); publications; communication costs; various small office supplies.

Costs for the above vary by continent and country (eg, costs in Africa being higher than in Asia), and local budgets are developed in accordance with local costs in detail prior to conduct of any activity.

2.1.2.4 Other Sources of Funding for this Project

1. Aggressively seek additional funding from bilateral sources. 2. All RICE FPs have a modular set of outcomes and activities related to various levels of donor investment: with fluctuations in donor investment, budgets, activities, outcomes and milestones can easily be adjusted accordingly. 3. Seek new partnerships based on self-funding principles (in kind contributions included) that can contribute to outcomes that are underfunded

2.1.2.5 Budgeted Costs for certain Key Activities

Estimated average annual costs (over 6 years) for key activities (US$).

	Annual cost (US$)	Please describe main key activities for the applicable categories below, as described in the guidance for full proposal
Gender	2,909,779	This FP houses the overarching gender strategy, R&D, and gender outscaling activities for the whole of RICE. See details in section 2.1.1.5 of the FP1 description, description of CoA 1.2 of FP1, section 1.0.4 on gender of the main RICE description, and Annex 4 of the main RICE description on gender
Youth (only for those who have relevant set of activities in this area)	1,531,415	This FP houses the overarching youth strategy, R&D, and youth outscaling activities for the whole of RICE. See details in description of CoA 1.2 of FP1, section 1.0.5 on youth of the main RICE description, and Annex 5 of the main RICE description on youth
Capacity development	3,062,830	This FP coordinates education and training activities across all other FPs; engages in institutional development, capacity development of research, development, and scaling partners; strengthens capacity to innovate across all partners; strengthens capacity of rice farmers to cope with climate change and other shocks through outscaling of RICE technologies. See details in section 2.1.1.10 of the FP description, section 1.0.10 of the main RICE description, and Annex 3 of the main RICE description
Impact assessment	2,626,845	CoA1.5 conducts impact assessment activities for the whole of RICE. See description CoA 1.5 of FP1
Intellectual asset management	229,712	Professional intellectual asset management services are provided throughout RICE and estimated to be around 1%, see Annex 10 to main RICE proposal for details

Open access and data management	1,990,839	Processing, validating, curation and quality control of collected data from surveys and experiments; data storage; making data accessible through standardized ontologies and descriptions; maintaining databases, websites, and other data delivery mechanisms. See section 2.1.1.11 of the FP description and Annex 9 of the main RICE description with details on cost items
Communication	1,531,415	Engages in policy dialogue to scale up results, through engagement with national and regional bodies as listed in 1.0.9 of the main RICE proposal, and through developing and communicating results of policy analyses, using tools such as policy briefs, media releases, fora and ministerial roundtables); communicates with actors on the ground to scale out technologies and practices, through the development of multi-stakeholder platforms and scaling out activities, using tools such as participatory impact pathway mapping (PIPA), stakeholder and outcome mapping, problem tree definition and analysis; communicates and engages with partners through collaborative and participatory approaches to R&D and convening various networks, communities of practice, platforms, and consortia; promotes learning and sharing of information to improve communication and collaboration, through learning and feedback mechanisms. Development of journal papers, manuals, technical reports, and other communications media such as video, audio, websites, etc. Participation in conferences, workshops, forums, stakeholder meetings, etc.

2.1.2.6 Other

W1,2 funding is critical to the success of FP1. It is used specifically to support the cross-cutting functions of FP1 such as adoption and impact studies; monitoring, evaluation and learning; and gender and youth studies. It is used to develop the gender and youth strategies, and to conduct mission-critical research in these areas. W1,2 fund are also invested in developing and supporting multistakeholder and scaling partnerships needed to bring RICE's products and services to scale and reach millions of beneficiaries. Whereas bilateral grants are used to scale out specific technologies (such as the STRASA project for delivery of stress-tolerant rice varieties in CoA1.4), the W1.2 funds are used to conduct research on scaling methodologies and derive general lessons on applicability of the various scaling models. In impact assessment studies, W1,2 is specifically used to support the development and use of advanced techniques such as randomized control trials. W1,2 furthermore play a crucial role in developing and applying the RICE results-based management and monitoring, evaluation and learning systems. Activities are also funded to support individual and institutional capacity development. The Tables B-C of the Performance Indicator Matrix indicate the contribution of W1,2 to the delivery of FP1's outcomes and sub-IDOs in financial terms.

2.1.3 Flagship Uplift Budget

Total uplift budget for six years for flagship project 1: Accelerating impact and equity.

Outcome Description	Amount needed (US$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
National systems use CRP-presented assessments of impacts of policy measures (free trade, domestic, variety release, import/export, WTO-related) to inform national policies	9,000,000	30	0	70	0

Novel tools used for large-scale adoption studies of improved rice technologies, e.g. remote sensing and DNA fingerprinting	9,000,000	30	0	70	0
Extensive network of women and rural development organizations that scale out RICE technologies that target women and marginalized groups	9,000,000	30	0	70	0

2.2 Flagship project 2: Upgrading rice value chains

2.2.1 Flagship Project Narrative

2.2.1.1 Rationale, scope

The food security debate has often focused on farm output, while ignoring broader developments in the food system. The main focus has been on own-demand for food among rural populations, while urban food economy came to dominate national food economies (Reardon et al 2014). Food security in urbanized economies needs well-functioning food value chains that link production in rural areas and hinterlands to consumption in big, urban consumption zones. A sustainable food value chain is defined as "the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources" (FAO 2014, p 6). The implication is that food value chains must be sustainable, not only from an economic point of view, but also from a social and environmental perspective.

International food markets increasingly pay attention to the way food is produced, such as inclusiveness (e.g., fair trade) and environmental footprint (e.g., organic, carbon neutral). Increasingly stringent production standards may challenge traditional food value chains at first, but they provide economic opportunities for poor farmers to capture value and tap into high-quality markets. Gender equity and inclusion of youth are crucial components of long-term social sustainability; food value chains provide more entry points for gender and youth-inclusive development than farming can offer. Food production is extremely vulnerable to climate change, but efficient, inclusive, and environment-friendly food value chains can minimize this vulnerability and increase resilience (Biggs et al 2015). Women play an important role in rice value chains as they significantly contribute to rice farming, processing, and marketing. However, they still face many barriers and inequality in access to and control over resources such as land, capital, and credit as well as access to agricultural inputs, improved technologies, and marketing services. Youth unemployment has recently emerged as a crisis in agriculture-based economies of low-income countries; the creation of job opportunities for young people in agriculture is important to reduce poverty and unemployment.

Rice value chains are rapidly changing in many parts of the world. Future rice value chains will be the result of ongoing profound transformations, which are well advanced in Latin America, rapidly occurring in Asia, and now emerging in Africa (Demont 2013, Reardon et al 2014). The drivers for the current transformative changes of rice value chains are two-fold (Reardon and Timmer 2014). First, rapid urbanization is occurring in Asia. Future rice value chains will attempt to tap into growing market opportunities by tailoring their products to the increasingly demanding taste of urban consumers, who spend more on food per person than rural consumers, although food represents a lower share in their total expenditures. Second, urbanization leads to increasing incomes and triggers changes in life style that increase the opportunity cost of cooking time. Increasing income increases the desire for a diverse diet (Bennett 1954), leading to higher amounts and shares of (1) nongrains (meat, fish, dairy, fruit, and vegetables) and animal-feed grains, (2) processed products, and (3) prepared foods bought away from home (Reardon et al 2014, Tschirley et al 2015). Although rice consumption per capita has stabilized in most Asian countries, it is still rising in Bangladesh,

rapidly rising in Africa, and declining in more advanced countries (Rutsaert et al 2013, Reardon and Timmer 2014). Future rice value chains will tap into these growing market opportunities by adding value to products through processing, quality upgrading, and through diversification of rice varieties, products and by-products, and new market channels.

Except for Latin America, rice value chains are traditionally characterized by high physical and quality losses, food safety issues, limited coordination between actors, lack of incentives for quality and product differentiation, and fragmented supply dominated by smallholders with low bargaining power and limited access to finance, services, and infrastructure. Although in parts of Asia this picture is changing (Reardon et al 2014), it is still dominant in most of Asia and sub-Saharan Africa (Demont 2013). Improvements in such value chains can contribute to reduced losses, enhanced value capture by their participants, and improved quality and variety of products for consumers. Ultimately, such improvements contribute to the SLOs of the CGIAR—reduced poverty, increased nutrition and health, and more sustainable use of natural resources.

2.2.1.2 Objectives and targets

FP2 comprises a portfolio of upgrading strategies that can make rice value chains more responsive to emerging market opportunities and more sustainable from an economic, social, and environmental point of view. Value-chain upgrading is defined here as “a set of strategic and innovative actions and investments aiming at improving the performance (competitiveness) of a value chain” (Demont and Ndour 2015, p 70).

The upgrading strategies of FP2 are related to five areas of intervention in the value chain: product, process, function, channel, and intersectoral upgrading (Table 2.1). These areas of intervention are addressed through four CoAs, which each act through multiple entry points on the rice-based agri-food value chain (Fig. 2.1). Through value-chain analysis and market research, FP2 will identify constraints and opportunities for value-chain upgrading and elicit product, process, and technology upgrading needs and preferences of value-chain stakeholders (consumers, retailers, distributors, processors, traders, and farmers). Detailed gender-disaggregated analysis of needs, preferences, constraints, and opportunities along age/generation groups of value-chain stakeholders will enable identification of value-chain upgrading strategies that are gender-inclusive and maximize opportunities for youth.

Particular attention will be given to the identification of those parts of the value chain where economic growth can be spurred through positive feedback loops (or “growth loops,” FAO 2014) triggered by inclusion of youth. For example, as productivity of farm labor increases and as more value is added further downstream, wages in the rice value chain will increase, but at the same time less labor will be required in rice farming. Upgrading strategies developed by FP2 will identify job opportunities for released farming labor, e.g., in service provision and further downstream in the rice value chain, where most value is added; also in nonrice value chains and through self-employment. Attraction of youth to these related sectors will have positive feedback on the value chain through productivity increase, value adding, and salary income increase.

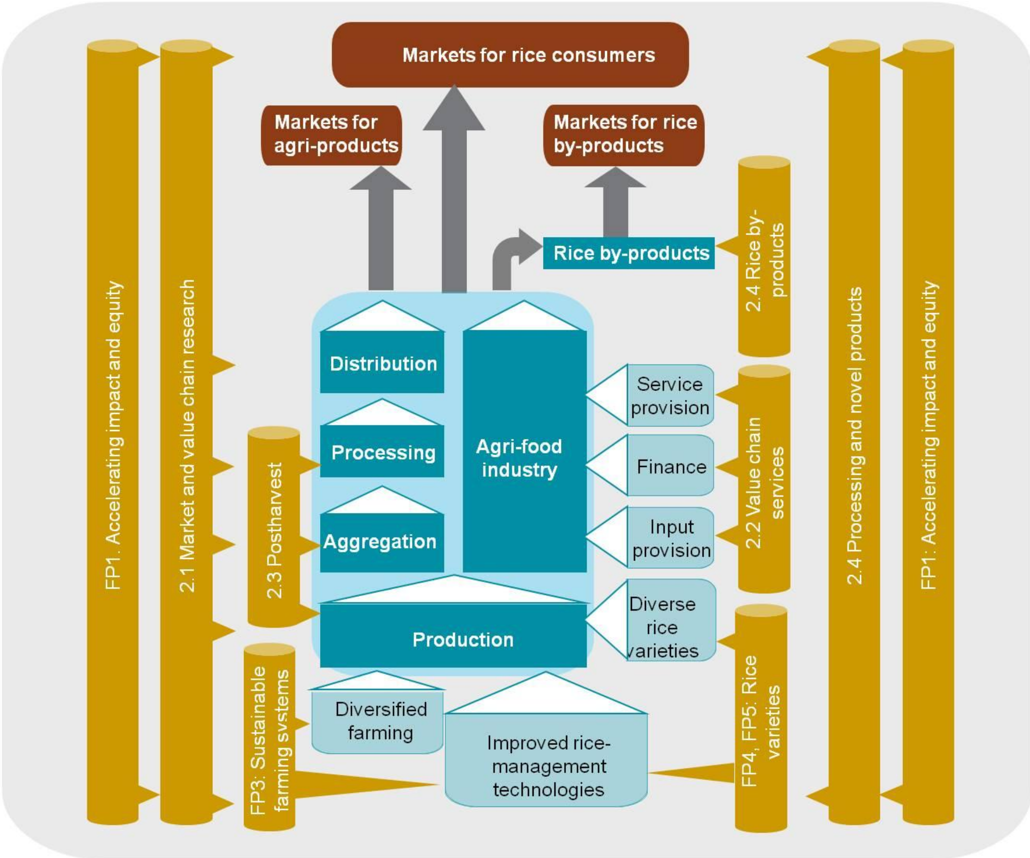

Fig. 2.1. Entry points for flagship project 2 in the rice-based agri-food value chain (adapted from FAO 2014).

Rice value chains supply specific markets or market segments. As a result, they can exceed regional and national boundaries, while coexisting with other rice and nonrice value chains within a food system. Therefore, upgrading strategies will be value-chain specific in that they are connected to particular market or market segments and/or specific production hubs. The ongoing transformations of rice value chains are occurring in waves that are correlated with initial levels of income and development and degree of openness and market liberalization (Reardon and Timmer 2014). Therefore, through its international mandate and connection to many entry points along rice value chains, RICE FP2 is in a unique position for studying the dynamics of rice value-chain development. Lessons learned in the dynamic zones, where rice value chains are adapting to rapid structural transformations (Reardon et al 2014) will help anticipating and triggering similar developments in less-developed hinterlands and tailoring strategies to upgrade emerging rice value chains for the benefit of poor men and women farmers, workers, and consumers.

Table 2.1. Linkage between cluster of activities and area of intervention.

	Area of upgrading interventions				
Cluster of activities	Product	Process	Function	Channel	Intersectoral
2.1 Value chain and market research	x		x	x	
2.2 Value chain services and finance			x		
2.3 Improved postharvest systems	x	x	x		
2.4 Processing and novel products	x	x	x	x	x

FP2 will deliver the following research outcomes to selected sub-IDOs, IDOs, SLOs, and cross-cutting issues of the SRF (see also the performance indicators matrix; the milestones in Table D explain the time course for these outcomes):

FP2 research outcome	Sub-IDO	IDO	SLO or cross-cutting issue
Diversified enterprise opportunities through upgraded value chains at six action sites (Indonesia, Myanmar, Vietnam; Cote d'Ivoire, Nigeria, Tanzania)	Diversified enterprise opportunities	Increased income and employment	Reduced poverty
Income by value-chain actors increased by 10% at six action sites through improved access to financial and other services (Indonesia, Myanmar, Vietnam; Cote d'Ivoire, Nigeria, Tanzania)	Improved access to financial and other services	Enhanced smallholder market access	Reduced poverty
Income by value-chain actors increased by 15% through adoption of at least one of the postharvest or value addition practices or technologies at six action sites (Bangladesh, Cambodia, Indonesia; Benin, Cote d'Ivoire, Nigeria)	Reduced pre- and postharvest losses	Increased productivity	Reduced poverty
Functional value chains for improved processing and novel products from rice at six action sites (Bangladesh, Cambodia, Indonesia; Benin, Cote d'Ivoire, Nigeria)	Increased value capture by producers	Increased income and employment	Reduced poverty
Increased capacity for innovation in partner research organizations along the rice value chain	Increased capacity for innovation in partner research organizations	National partners and beneficiaries enabled	Capacity development

The milestones in Table D of the performance indicators matrix explain the time course for these outcomes. Annex 11 gives a schematic overview of FP2's contribution to the 10 grand challenges of the SRF. FP2 will directly contribute to the reduction of postharvest losses (CoA2.3) and to the mitigation of climate change through reduction of losses (CoA2.3) and improved by-product management practices (CoA2.4), which contribute to reducing GHG emissions. Sustainability analysis, including life-cycle analysis, will be conducted for different management options to minimize the environmental footprint; the use of by-products to produce energy contributes to carbon-neutral energy production, and the incorporation of carbonized by-products in the soil contributes to carbon sequestration. Food safety issues in the rice value chain tackled by FP2 will include agrochemical residues from production and storage, pollutants from processing (e.g., from dryers with direct heating), and mycotoxins. FP2 will contribute to new entrepreneurial and job opportunities in two ways. First, the development of business models and planning activities will facilitate the transformation of smallholders into small-scale entrepreneurs. Second, support to manufacturing, dissemination, after-sales service providers, and business model development for mechanized machinery services and postharvest operations will help generate new jobs.

2.2.1.3 Impact pathway and theory of change (for each individual FP)

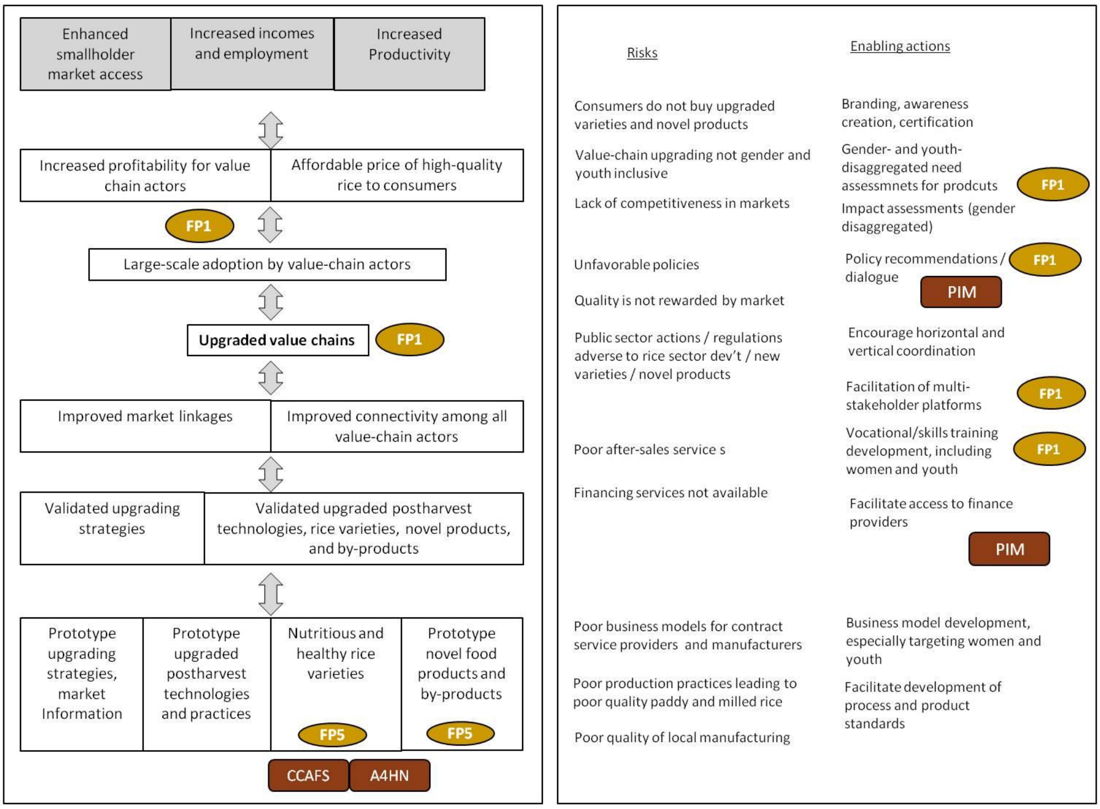

Fig. 2.2. Impact pathway (left) and theory of change (right) of FP2. Grey boxes are IDOs, ovals (with FP x) refer to links with other FPs, and the dark boxes refer to links with other CRPs (see Annex 12 for abbreviations).

Fig. 2.2 presents the impact pathway and theory of change of FP2, with risks and associated enabling actions (see also section 2.2.1.5 on 'unintended consequences'). Tangible outputs of the FP that move along the impact pathway will be locally produced or imported "hardware" products such as postharvest and mechanization equipment and seeds, and "software" products such as strategies for value-chain upgrading, extension and marketing, market information, improved market linkages, and institutional innovations. These products will be used by public and private actors for upgrading rice value chains at producer, trader, processor, wholesaler, and retailer levels. Rice value-chain upgrading requires a farm-to-plate approach.

Poor production practices at farm level, leading to poor quality of paddy and milled rice, are a major risk for the success of value-chain upgrading. This risk will be mitigated through facilitation of the development of process and product standards. However, value-chain upgrading also requires behavioral change in end-markets. To minimize the risk of end-users rejecting the upgraded products, processes, and technologies, detailed market research will be conducted to generate segmented market information on product, process, and technology upgrading needs and preferences, and opportunities and constraints for value-chain upgrading of consumers and value-chain stakeholders. To mitigate the risk of proposing value-chain upgrading strategies that are not gender and youth inclusive, market information will be segmented among gender and age/generation groups and will enable development of inclusive value-chain upgrading strategies, which will be validated with value-chain stakeholders. New markets and market segments will be

identified as well as opportunities for triggering growth loops through inclusion of youth, following the gender and youth strategies developed in FP1. Gender inclusiveness of value-chain upgrading strategies will then be monitored and evaluated through gender-disaggregated impact assessments.

Inclusive value-chain upgrading strategies reduce or mitigate gender barriers and inequality in access to and control over resources such as land, capital, and credit as well as access to agricultural inputs, improved technologies, and marketing services. This requires a dynamic value-chain perspective. Some barriers and inequalities cannot be reduced in the short and medium term within a particular stage of the rice value chain, but may be overcome through improvement in another stage. For example, African women's lack of access to basic farming production factors like land can be mitigated by investing in marketing skills and entrepreneurship such that they can capture market opportunities further down the rice value chain. Capacity development in downstream (postharvest) activities may extend their set of options and increase their intra-household bargaining power, which may result—in the long run—in increased access to basic farming production factors. Thus, barriers and constraints will not necessarily be tackled in FP2 at the stage where they occur, but may require a dynamic value-chain perspective. Further, value-chain upgrading does not always need to be technological (product or process upgrading). It is often a matter of changing (functional upgrading) or reinforcing (empowerment) the roles of actors within the chain through capacity development. Therefore, capacity development will be a central focus of the value-chain upgrading strategies proposed.

In terms of the enabling environment, FP2 will identify upgrading needs and research priorities in terms of processes (new or upgraded postharvest technologies and management options) and products (e.g., by-products and varieties with new quality traits), and engage with public and private partners and innovative end users in participatory technology verification. This will involve several adaptation/verification cycles at the RICE action sites, which will also be used to develop processes and materials for dissemination (link to FP1), and to verify compliance with value-chain upgrading needs. The value-chain upgrading strategies developed by FP2 will include specific gender and youth strategies, which will be developed in cooperation with FP1 and based on the segmented market information collected.

Achieving the objectives of FP2 will also require that favorable policies be in place, especially concerning labor, land use, mechanization, and trade; hence, a link will be established with FP1 and PIM. Through policy dialogue, the risk of public sector actions having an adverse effect on rice sector development will be mitigated. Furthermore, the private sector will be encouraged to invest in upgrading the components of the value chain. Value-chain upgrading in a particular situation will be coordinated among components/actors to avoid bottlenecks in any one part of the chain that will discourage investment in other parts. Lack of competitiveness in supporting markets and poor quality of local manufacturing are major risks in value-chain upgrading. Therefore, scaling-out and large-scale adoption will be supported by strategies developed in FP1 to strengthen the various technical, financial, and capacity development-related service providers. Business models for both the provision of machinery services and the delivery of equipment will be developed and piloted to support this process. These service providers will be enabled to provide better, demand-driven services based on the identified upgrading needs.

2.2.1.4 Science quality

The inefficiencies of rice value chains in developing countries are well documented (e.g., Demont 2013, Reardon et al 2014). Lacking is a comprehensive framework for action research on value-chain upgrading that can tackle these inefficiencies. A thorough understanding of market demand and governance structures in rice value chains and their enabling environment is necessary before any upgrading strategy can be designed and successfully implemented. CoA 2.1 will partner with FP1 and the PIM CRP to adopt a common framework for value-chain analysis, which will be conducted jointly in target countries. CoA2.1 feeds into the other CoAs by providing a consistent framework for the assessment of consumers' and value-chain stakeholders' priorities among value-chain upgrading strategies. In collaboration with partners, CoA 2.1 will develop optimal portfolios of upgrading strategies tailored to the needs of consumers and value-chain stakeholders in selected countries and action sites. Comparing rice value chains within or between countries and action sites will then provide profound insights on the dynamics and sustainability implications of value-chain development. These will enable fine-tuning and sequencing of upgrading strategies for maximum impact.

The activities under FP2 will consist of a mix of all five types of upgrading (Table 2.1). This portfolio approach to value-chain upgrading is novel in itself. An additional novelty is that it will develop these activities by linking to the market in two directions. On the one hand, it will learn from the market (passive market link), by surveying and compiling current consumer preferences and assessing the market value of existing rice products, processes, and technologies. FP2 will hence provide market feedback to FP3 and FP5. For example, quality-oriented market demand for rice products will be segmented—by income classes, consumption zones, and regions based on the profiling of mega-varieties with respect to quality parameters—in order to derive strategies to restructure breeding programs (FP5) toward a focus on increased quality. On the other hand, FP2 will develop strategies for steering the market (active market link) by assessing under which conditions consumers are willing to accept and pay for upgraded and new intrinsic quality traits, including nutritious and health attributes developed by FP5 (product upgrading). Product upgrading may also include research on how extrinsic cues like packaging, labeling, branding, and information (awareness campaigns) can be deployed to strengthen emerging value chains by convincing consumers on the benefits the products. Analogously to the way FP3 will study rice production from a broader farming systems perspective, FP2 will embed demand for rice quality traits in a wider food systems framework.

FP2 will adopt a similar bi-directional approach upstream for value-chain stakeholders (including farmers). Stakeholder preferences will be assessed (learning from the market) to support product (e.g., rice varieties), process (e.g., technologies) and functional (e.g., institutional arrangements) upgrading strategies, which will be subsequently tested in the value chain (steering the market). Functional upgrading will receive particular attention (all CoAs include this area). Governance structures and institutional arrangements between actors will be assessed and compared with regard to their performance in terms of financial and technical viability, capacity to produce rice that can compete with other sources, and impact on farmer empowerment, job creation (e.g., for youth), and equity. Since many of the upgrading strategies will require behavioral change by consumers or value-chain stakeholders (active market link), CoA 2.1 will heavily draw on experimental methodologies borrowed from behavioral economics, in addition to commonly used survey-based data collection techniques. FP2 will not only generate market feedback to FP5, but also

to FP3, where upgrading is typically focused on processes (e.g., sustainable production practices). FP2 will assess current demand for process upgrading and determine under which conditions the market or value-chain stakeholders are willing to adopt, finance, or support those upgrading activities.

The value-chain perspective of FP2 is ideal for addressing sustainability concerns. The first question is how to embed sustainability in the rice value chain. To answer this question, CoA 2.1 will partner with the Sustainable Rice Platform (SRP) (UNEP/IRRI) and FP3 to develop and pilot market-based incentive mechanisms for the adoption of sustainable production standards throughout rice-based, agri-food value chains (process upgrading). Entry points that will be considered are (1) policy (FP1), (2) consumers (e.g., product upgrading through labeling and certification combined with channel upgrading toward new markets and market outlets for certified-sustainable rice), and (3) governance structures in rice-based agri-food value chains (e.g., combining process and functional upgrading by internalizing sustainable production standards in the value chain through contract farming). Second, gender and youth inclusiveness—two important components of social sustainability—will be addressed on a case-by-case basis. CoA 2.1 will partner with FP1 to identify and implement the optimal portfolios of upgrading strategies that maximize gender and youth inclusiveness in the rice value chain, based on gender and youth-disaggregated market data and focused research on constraints, opportunities, and policy options for deploying gender and youth in value-chain growth engines.

The quality of science will be high because FP2 brings together accomplished and relevant scientists and leverages knowledge from other ARIs, the private sector, and national partners. The leader of FP2 is an experienced agricultural economist in value-chain and market research, and has leadership skills in research-for-development projects and programs obtained in GRiSP. In 2008, he initiated an innovative program on experimental value-chain research at AfricaRice which led to a segmented policy framework for rice value-chain upgrading in Africa (Demont 2013). This novel program was highly commended by the IEA review of GRiSP (IEA report, pp 30, 41, 42, 56). In 2013, he joined IRRI where he is further developing this innovative program. The FP2 core team (see section 2.2.1.12, FP management, and CVs in Annex 8) consists of a well-balanced mix of senior scientists and young professionals with expertise in various fields of social sciences.

2.2.1.5 Lessons learnt and unintended consequences

FP2 is new, but CoAs 2.3 and 2.4 build on activities begun in Theme 4 of GRiSP (Extracting more value from rice harvests through improved quality, processing, market systems, and new products). In GRiSP, these activities were rather disconnected, but in FP2, they have been fitted into an overall framework of value-chain analysis and upgrading. CoA2.1 provides an overall assessment of the strengths and weaknesses of rice value chains, identifies entry points for improvement, and uses these results to guide the research in CoAs 2.3 and 2.4. Since the inception of GRiSP, markets have evolved rapidly, especially in Asia (Masters et al 2013, Reardon et al 2014), and the scope and opportunities for high-quality and specialty rice as well as for rice by-products have increased markedly. Compared to GRiSP, FP2 of RICE will conduct more market research and invest more in connecting farmers to markets and linking actors in the whole rice value chain.

Commonly, value capture concentrates on the higher end of the value chain; thus, the added value introduced by FP2 may not benefit the intended beneficiaries such as small farmers at the base of the value chain. In collaboration with FP1, especially CoA1.1 and CoA1.5, and through its

own surveys and market analyses, FP2 will monitor where in the value chain added value accrues, and will exert influence to ensure that the poor (small farmers and other actors) benefit most. It also participates in the Sustainable Rice Platform in which socioeconomic and biophysical sustainability is explicitly mainstreamed in rice value chains by the involvement of private (input suppliers, traders, and food industry), public, and NGO value-chain partners.

2.2.1.6 Clusters of activity (CoA)

2.1 Value-chain and market research

CoA2.1 will analyze rice value chains and explore intervention points for upgrading that will contribute to the overall increase in livelihoods of its actors. For this, it will partner with PIM to adopt a common framework across PIM and RICE, which will be applied jointly at specific action sites in target countries. The CoA will assess the status quo and explore how different upgrading strategies will benefit the various actors along the value chain. Surveys of urban consumers and other value-chain actors, including millers, traders, and retailers in major rice-consuming countries, will be conducted to assess preferences for current rice products, processes, and technologies and to identify upgrading priorities using the "stacked survey" method that includes a full, structured questionnaire at every part of the value chain (Reardon et al 2014). So far, consumer surveys have been conducted in 24 cities in South and Southeast Asian countries and stacked value-chain surveys have been conducted in 16 sites in 5 countries. This information will be fed into rice-breeding priorities for targeted product development. Particular attention will be given to market segmentation among gender and age/generation groups. This will provide market feedback to the upgrading strategies developed in the other CoAs of FP2, process upgrading in FP3 (e.g., sustainable production practices), and product upgrading in FP5 (e.g., development of new rice varieties).

Next, in collaboration with partners, optimal upgrading strategies will be designed and tailored to the specific needs at the action sites and in target countries. These strategies will be tested in the field and scenarios formulated as to how end markets can be influenced to catalyze the upgrading process (demand-pull strategy). In most cases, research in several areas of intervention will be needed to effectively upgrade a whole value chain. For example, the development of high-quality rice (product upgrading) may also require investment in (1) process upgrading (e.g., improved color sorting), (2) functional upgrading (e.g., horizontal coordination among farmers to harmonize varietal choice and vertical coordination by the agri-food industry through contract farming and marketing) to ensure the purity of the product throughout the value chain, (3) channel upgrading to enable sellers to tap into new markets for new or specialty rice products, (4) possibly upgrading extrinsic quality attributes (packaging, labeling, and information) that accompany the product, and (5) subsequent consumer awareness campaigns on the benefits of the new product to steer the market and generate demand (facilitated by FP1).

To improve the sustainability of rice value chains, market-based incentive mechanisms for the adoption of sustainability standards throughout the chain will be developed and tested. Public governance through policy and regulation has been traditionally used to encourage ("carrot" approach) sustainable practices and discourage ("stick" approach) unsustainable practices. Use of chemicals has been regulated and some chemicals that are harmful to the environment have been banned by governments. In addition to nonmarket mechanisms such as policy and regulation, FP2 will conduct research on market-based mechanisms. A first example is *embodying* sustainability in rice products through product upgrading, labeling, and certification and capturing consumer

premiums for sustainably produced rice in product markets. A second example is *internalizing* sustainability in the rice value chain through private governance (e.g., vertical coordination and contract farming). These incentive mechanisms provide different entry points for making rice value chains sustainable (Fig. 2.1). Depending on the stage of development of the value chain and the purchasing power of the consumer, a different mix of mechanisms and concomitant upgrading strategies will be needed to render the rice value chain sustainable.

The gender- and youth-disaggregated market data on needs, preferences, constraints, and opportunities for product, process, and technology upgrading will enable formulating an optimal portfolio of upgrading strategies that is gender inclusive and deploys youth to the maximum extent possible in its growth loops.

2.2 Value-chain services and finance

Major constraints to the adoption of improved postproduction technologies in rice value chains are often caused by a lack of financial services for those actors willing to make the required investments. Value-chain finance offers an opportunity to expand the opportunities of value-chain actors and to consolidate linkages among participants in the chain. Poor or nonexistent equipment supply chains, weak after-sales services, and lack or poor quality of local manufacturing also constrain adoption.

This CoA will develop methodologies and tools for strengthening these essential support services. Baseline studies and multistakeholder platforms involving public and private actors will set the scene for conceptualizing, piloting, and disseminating interventions in three areas. First, value-chain actors will be linked to finance services and the upgrading of finance schemes will be facilitated (e.g., inventory credit for farmers can allow them to obtain higher prices for their products in the off-season). Second, business models will be developed for postharvest technology use by individual farmers or farmers' groups, for contract service provision, for integrated postharvest operations, and for the delivery of equipment. Third, industrial extension activities such as training and technology transfer to local manufacturers will help to strengthen supply chains and last-mile delivery of new equipment. Vocational training courses will be developed in after-sales services and in operating machinery to provide postharvest services.

CoA2.2 will also analyze policy conditions that affect the new business models that emerge in the transforming rice sector (in collaboration with PIM). Models will be developed and applied that deal with minimizing transaction costs in rice value chains, mechanized service provider businesses, land lending and renting, and water markets.

2.3 Improved postharvest systems

CoA2.3 will improve postharvest practices to reduce losses, improve processing, and develop novel rice products to increase value adding to farmers and other value-chain actors. Needs and opportunity assessments (together with FP1) of region-specific processing practices and facilities will lead to development of new technologies and innovations, technical assistance, and capacity building. Based on the assessment results, CoA2.3 will develop, test, and promote scalable technologies and equipment. Options will be evaluated in a value-chain context with respect to sustainability using life-cycle assessments, energy balances, and socioeconomic considerations.

To reduce losses, CoA2.3 will focus on improved threshers, mills, dryers, processing, and grain storage, addressing specifically the problems of insect proliferation and mycotoxin accumulation. Where women are involved in such activities, improvement options will increase their productivity and income, and COA2.3 will actively support women with appropriate training. CoA2.3

will also deliver entrepreneurial opportunities for women such as improved parboiling systems at the small and medium scale in Africa.

Lack of access to markets with price premiums for better quality often constrains the improvement of postharvest value chains. Hence, CoA2.3 will develop and pilot village business models for postharvest and processing activities. These will include new market linkages that enable farmers to add value from market-driven production and processing and from selling to premium markets. This activity will contribute to new employment opportunities specifically for women (and women's groups, especially in Africa) and youth. CoA2.3 will also develop methodologies and tools for strengthening postharvest support services such as for new equipment that has to be financed, produced, distributed, and maintained.

Together with FP1, CoA2.3 will contribute to innovation platforms and learning alliances that facilitate repeated learning cycles. They will initiate and verify the postharvest improvements and then progress toward strengthening support and finance services, markets, and market linkages among farmers and other value-chain actors. Industrial extension activities such as training and technology transfer to local manufacturers will be facilitated to support last-mile delivery. Vocational training courses with certification will be developed for after-sales services and for operating machinery.

2.4 Rice processing and novel products

Several routes for value adding through improved processing and novel rice products will be explored. CoA2.4 will test fortification of milled rice with essential minerals and vitamins to alleviate prevailing deficiencies, especially for women and their children. Furthermore, CoA2.4 will develop new rice-based products with slower digestibility through processing, including rice pasta, and products from broken rice through wet-milling. Women will also have greater access to nutritious food, which will help reduce malnutrition in women and children.

New uses of rice by-products such as straw, husk, and bran can contribute to value adding in value chains and to the mitigation of climate change. Despite many prohibitions, burning of rice straw is still widespread (in some regions, up to 80% of all straw is burned), causing air pollution and subsequent health problems, and adding to the greenhouse effect. Alternative uses of straw and husk include energy production and use as mushroom substrate, animal fodder, and construction material. In collaboration with partners outside the rice sector, component technologies will be developed and evaluated, including baling, compressing into briquettes or pellets, and carbonization of straw and husk for carbon sequestration or, in combination with composting, for use as soil conditioner. The feasibility, both technical and economic, of oil extraction from rice bran and of bio-refineries for straw and husk will also be assessed.

All options will be assessed in a value-chain context with respect to sustainability using life-cycle assessments, energy balances, and socioeconomic considerations.

2.2.1.7 Partnerships

FP2 will build on relevant partnerships established under GRiSP (specifically GRiSP flagship project 4). An inventory of partners is provided in Table 2.2.

Table 2.2. FP2 partners.

	Discovery	Proof of concept	Scaling-out
2.1 Value-chain and market research	• IFPRI-PIM • Wageningen University • FAO • University of Kentucky • University of Arkansas	• NGOs (Rice Inc., Philippines; UTZ Certified, Netherlands; VECO, West Africa • Sustainable Rice Platform (SRP)/UNEP • Value chain stakeholders (farmers, processors, agri-business, exporters and importers)	• Ministries • NARES • CORRA (Asia) • CARD (Africa) • Regional Economic Communities (ECOWAS, WAEMU, CEMAC) • JIRCAS • Policy (including market) Task Force • (Africa)
2.2 Value-chain services	• IFPRI-PIM • Wageningen University • FAO	• Don Bosco Technical School, Battambang, Cambodia • Royal University of Agriculture • Pioneer Agrobiz Co. Ltd. • Private manufacturers • Value chain stakeholders (farmers, processors, agri-business, exporters and importers)	• Royal University of Agriculture • Ministry of Agriculture, Forestry, and Fisheries • ACLEDA Bank, Cambodia
2.3 Improved postharvest systems	• CLAAS, Germany • Hohenheim University	• Sub-Institute of Agricultural Engineering and Postharvest • Philippine Rice Research Institute • Nong Lam University, Vietnam • Trimble, Australia • GrainPro, Inc., Subic, Philippines • Don Bosco Technical School, Battambang, Cambodia • LEHNER Agrar GmbH, Germany • Kellogg's • Hohenheim University, Germany • Balai Pengkajian Teknologi Pertanian (Assessment Institute for Agricultural Technology), Indonesia • Processing and Value Addition Task Force (Africa) • Mechanization Task Force (Africa) • Value-chain stakeholders	• Ministry of Agriculture and Rural Development • Ministry of Agriculture, Forestry, and Fisheries • Ministry of Agriculture and Irrigation • Indonesia Center for Rice Research • Department of Agriculture, Myanmar • Processing and Value Addition Task Force (Africa) • Policy (including market) Task Force (Africa) • Mechanization Task Force (Africa)

		(farmers, processors, agri-business, exporters and importers)	
2.4 Rice processing and novel products	• University clusters (Arkansas, Aarhus, Netherlands; Metabolomics Centre, Max Planck Institute, Golm) • U.S. Department of Agriculture (US$A), Stuttgart • Establishment of grain quality excellence cluster (international public-private partnership) • University of Milan, Italy • US$A-ARS, New Orleans, LA • Purdue University, IN • Enertime, Puteaux, France • Sustainable Rice Platform • Hohenheim University, Germany • CSIR-FRI, Ghana •	• Philippine Rice Research Institute (PhilRice) • Indian Council of Agricultural Research • Ministry of Agriculture and Rural Development (MARD), Vietnam • IFRPD, Thailand • University of Milan, Italy • US$A-ARS, New Orleans, LA • Universities and research institutes • Tyndell Centre, Manchester University, United Kingdom • Newcastle University, United Kingdom • Nong Lam University, Vietnam • Sub-Institute of Agricultural Engineering and Postharvest, Vietnam • Can Tho University, Vietnam • Hohenheim University, Germany • An Giang Plant Protection Joint Stock Company • CSIR-FRI, Ghana • Value-chain stakeholders (farmers, processors, agri-business, exporters and importers)	• PhilRice • Indian Rice Research Institute • Value-chain stakeholders (farmers, processors, agri-business, exporters) • Ministry of Agriculture and Rural Development, Vietnam • PhilRice • Processing and Value Addition Task Force (Africa)

FP2 has a comparative advantage for value-chain research because its research portfolio naturally connects through many entry points to the rice agri-food value chain (Fig. 2.1). Although the private sector increasingly addresses mechanization and postharvest problems, it usually engages only in areas that have short- to medium-term market potential. The comparative advantage of FP2 further rests in its international mandate, which facilitates exchange across countries and can thus accelerate value-chain upgrading by learning from other countries that are on similar or advanced trajectories. FP2 also has a comparative advantage in the inclusion of gender and youth issues in its value-chain perspective. Addressing gender and youth concerns within a single stage of the value chain may be difficult, but upgrading may create opportunities for their inclusion elsewhere in the chain.

2.2.1.8 Climate change

Since rice value chains are rooted in the environment, stakeholders implicitly need to make a trade-off between two opposing demands. On the one hand, consumers demand rice products with certain consumption characteristics (grain quality, aroma, food safety, origin, etc.), while the environment demands rice varieties with certain growing characteristics (tolerance for abiotic and biotic stresses, maturity, etc.) or management practices (irrigation, alternate wetting and drying, etc.). Rice value chains reconcile these two opposing demands. Developing efficient food value chains has been advanced by the World Bank (2008) as a priority policy objective in support of sustainable growth and poverty reduction in developing countries. Value chains are built on cooperation rather than adversarial business relationships; their members recognize that they must create a win-win situation whereby they all benefit financially and are all part of the information sharing and decision-making process. Hence, by linking producers to consumers through a shared objective, value chains present a more sustainable approach to consumption and production than segmented and adversarial production chains (Demont 2010). The working hypothesis of FP2 is that efficient rice value chains can more efficiently mitigate the vulnerability of rice production to climate change than mitigation at farm level alone (Biggs et al 2015). Increased vertical coordination between actors will ultimately increase the long-term competitiveness of rice value chains with simultaneous effects on reduced poverty and increased resilience to climate change.

2.2.1.9 Gender

Gender and youth will drive the research conducted in FP2 and the concomitant value-chain upgrading strategies that will be developed. Gender-disaggregated data collection on needs, preferences, constraints, and opportunities for product, process, and technology upgrading in rice value chains ensures that optimal upgrading portfolios will be gender inclusive. Gender will be approached at the value-chain level. Gender inequity cannot be addressed at only a single stage of the value chain; there are many entry points along the value chain for gender-inclusive development. In Africa, for example, women tend to have limited access to land and tend to specialize in postharvest activities and marketing. In such cases, value-chain upgrading strategies should focus on empowering women to become more entrepreneurial in those activities through mechanization of postharvest operations, capacity development in business and marketing, and product (quality, branding, and labeling) and channel upgrading (connecting women's businesses to new markets and market segments).

A dynamic value-chain perspective is required to develop inclusive value-chain upgrading strategies that reduce or mitigate gender barriers and inequality in access to and control over resources such as land, capital, and credit as well as access to agricultural inputs, improved technologies, and marketing services. Capacity development will be a central component of these upgrading strategies because of their potential impact on changing (functional upgrading) or reinforcing (empowerment) the roles of actors in the rice value chain.

2.2.1.10 Capacity development

The overall capacity development strategy of RICE is given in Annex 3. In FP2, individual capacity development will focus on participatory and on-the-job training of partners from the public and private sector as well as service providers. Partners will participate in piloting business models and selected first-adopter value-chain actors will participate in technology and management piloting and verification activities.

At the institutional level, capacity-development measures will focus on creating an enabling environment and improving the capacity of national partners in developing curricula for academic and vocational training. These activities will target organizational and institutional changes such as assisting with the joint use of technologies, organization of service provision, and the institutional changes required, for example, for the certification of equipment.

2.2.1.11 Intellectual asset and open access management

FP2 follows the RICE policies and strategies on intellectual asset management, open access, and data management (Annexes 9 and 10), in line with the CGIAR Principles on the Management of Intellectual Assets and their Implementation Guidelines, and with the CGIAR Open Access and Data Management Policy and its Implementation Guidelines. Its intellectual assets relate mostly to survey data, models, and written knowledge products such as policy briefs, reports, and publications. Gender-disaggregated survey data are made open access and are distributed through the online sites Farm Household Survey data and AfricaRice Research data. As a policy, these data are made available within 6 months after curation and quality control. Surveys are conducted in accordance with the highest ethical standards; the RICE CGIAR centers are committed to protecting the rights, dignity, health, safety, and privacy of research subjects, and the integrity of the environment when collecting data. Informed consent from study participants will be obtained at the outset of any survey or interview. Personal data collected will be processed fairly and lawfully and, in particular, will not be made public.

2.2.1.12 FP management

FP2 is led by Dr. Matty Demont, senior social scientist at IRRI. Each CoA is co-led by a team of senior scientists (focal persons) consisting of one or more representatives from each center. Annex 8 presents the list of senior scientists and a set of selected curricula vitae.

2.2.2 Flagship Budget Narrative

2.2.2.1 General Information

CRP Name	CGIAR research program on rice-based agri-food systems, RICE
CRP Lead Center	International Rice Research Institute
Flagship Name	Upgrading rice value chains
Center location of Flagship Leader	Los Baños, Philippines

2.2.2.2 Summary

Total flagship project budget summary by sources of funding (US$).

Funding Needed	2017	2018	2019	2020	2021	2022	Total
W1+W2	1,281,283	1,324,196	1,346,130	1,384,317	1,392,561	1,417,128	8,145,614
W3	1,026,631	1,064,899	1,095,292	1,133,407	1,159,982	1,194,397	6,674,608
Bilateral	1,161,126	1,204,058	1,248,839	1,295,356	1,343,678	1,393,880	7,646,937
Other Sources							0
Total	3,469,040	3,593,151	3,690,259	3,813,078	3,896,219	4,005,404	22,467,151

Funding Secured	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Assumed Secured)	1,281,283	1,324,196	1,346,130	1,384,317	1,392,561	1,417,128	8,145,614
W3	198,004	207,034	218,338	228,881	242,487	255,380	1,350,124
Bilateral	716,996	743,506	771,158	799,882	829,721	860,721	4,721,984
Other Sources							0
Total	2,196,283	2,274,735	2,335,625	2,413,079	2,464,768	2,533,229	14,217,719

Funding Gap	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	-828,627	-857,865	-876,954	-904,526	-917,495	-939,017	-5,324,484
Bilateral (Fundraising)	-444,130	-460,552	-477,681	-495,474	-513,957	-533,159	-2,924,953
Other Sources (Fundraising)	0	0	0	0	0	0	0
Total	-1,272,758	-1,318,417	-1,354,635	-1,400,000	-1,431,452	-1,472,176	-8,249,437

Total flagship project budget summary by natural classification (US$).

	2017	2018	2019	2020	2021	2022	Total
Personnel	1,352,202	1,425,454	1,476,581	1,529,660	1,584,771	1,641,996	9,010,665
Travel	224,104	227,903	231,851	235,953	240,215	244,646	1,404,675
Capital Equipment	62,377	31,896	33,490	54,165	36,923	38,769	257,623
Other Supplies and Services	1,126,284	1,159,065	1,181,834	1,205,583	1,230,355	1,256,197	7,159,319

CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	313,937	347,429	353,828	360,466	367,353	374,499	2,117,515
Indirect Cost	390,134	401,403	412,674	427,249	436,600	449,296	2,517,359
Total	3,469,038	3,593,150	3,690,258	3,813,076	3,896,217	4,005,403	22,467,142

Total flagship project budget summary by participating partners (US$).

	2017	2018	2019	2020	2021	2022	Total
IRRI	2,120,927	2,169,070	2,218,847	2,270,117	2,322,925	2,377,316	13,479,205
Africa Rice	1,348,113	1,424,081	1,471,413	1,542,962	1,573,296	1,628,088	8,987,954
Total	3,469,040	3,593,151	3,690,260	3,813,079	3,896,219	4,005,404	22,467,153

Explanations of these costs in relation to the planned 2022 outcomes

Flagship project 2 is composed of 4 clusters of activity as described in the FP2 narrative section 2.2.1.6. Each cluster of activity delivers one or more outcomes each (with a related set of milestones), as listed in the Performance Indicator Matrix, Tables B-D. The required investment (budget) for each outcome is listed in Table B of the Performance Indicator Matrix. The Clusters of activities (CoA) and their outcomes are:

FP2	Cluster of activity	Outcome
2.1	Value chain upgrading and policy	Diversified enterprise opportunities through upgraded value chains at six action sites (Indonesia, Myanmar, Vietnam; Cote d'Ivoire, Nigeria, Tanzania)
2.2	Value chain services	Income by value-chain actors increased by 10% at six action sites through improved access to financial and other services (Indonesia, Myanmar, Vietnam; Cote d'Ivoire, Nigeria, Tanzania)
2.3	Improved postharvest systems	Income by value-chain actors increased by 15% through adoption of at least one of the postharvest or value addition practices or technologies at six action sites (Bangladesh, Cambodia, Indonesia; Benin, Cote d'Ivoire, Nigeria)
2.4	Rice processing and novel products	Functional value chains for improved processing and novel products from rice at six action sites (Bangladesh, Cambodia, Indonesia; Benin, Cote d'Ivoire, Nigeria)

Besides the above outcomes, each cluster of activity contributes to various capacity development actions, captured in a joint outcome "Increased capacity for innovation in partner research organizations along the rice value chain". The budget of each cluster of activities depends on the type of activities, and involves typically the collection of survey data among partners (consumers, millers, processors, traders, farmers, input suppliers) along the rice value chain (involving travel, local expenses in country such as translators, enumerators, vehicle rental, local partners), and analyses and reporting of survey data (CoA2.1 and 2.2). Other activities include the development and conduct of investment games (CoA2.1); the development, testing, and dissemination of improved postharvest equipment and practices such as baling of straw and husk, improved dryers and storage facilities (CoA2.3); development, testing, and dissemination of improved processing equipment and practices for rice grain and rice byproduct materials, such as parboiling, briquetting and peleting of straw and husk; research into novel product development (CoA2.4); workshops; stakeholder consultations; development of communication materials (papers, flyers, brochures, websites, video, etc); partnership development; development and support of learning alliances;

partner capacity development for research, innovation, and delivery; communication (open access) data management (all CoAs)– see section 2.2.2.5 below.

Risk to spending as planned
The RICE FPs are 'umbrella projects', which include a large number of bilateral projects any given year. Hence, the FP budgets are dictated by the collective investments that donors want to make through W1/2, W3, bilateral, and 'others means'. The investment levels are unpredictable: 1) the W1-3 donors can not commit to 6-year funding obligations and the W1-3 investments into the CGIAR fluctuate substantially each year, and 2) 70-80% of the budget is contributed to by bilateral projects, the majority of which still need be developed and secured. Hence, the likelihood that budgets are obtained - and spent - exactly as targeted, decreases as the CRP progresses in time. Each year, updates on investments expectations and budgets will be developed, and spending managed accordingly. At the level of bilateral projects, spending risk is managed by project leaders following procedures spelled out in project contracts. For W1-3, spending risk is managed by flagship project leaders. Project leaders get regular updates on actual spending rate through OCS, and are required to make project adjustments if under- or overspending occurs beyond the (donor-) accepted range (usually 10% of line items).

2.2.2.3 Additional explanations for certain accounting categories

Benefits
Benefits are separated out and include pension, housing, vehicle, home leave, medical insurance, and education allowances.

Other supplies and services

- Costs related to the collection of survey data, conduct of interviews, and other methods of collecting socio-economic data (e.g., investment games) involving local expenses in country such as recruitment of translators, enumerators, vehicle rental, local partner costs, laptops for data entry);
- Various software
- Costs related to the development and sustenance of learning alliances at action sites (partner costs, workshop costs, stakeholder consultations, meetings);
- Cost for development of prototype improved postharvest equipment such as dryers, milling machines, quality determination kits;
- Cost for development of prototype improved/novel processing equipment (eg., parboiling, grain fortification, balers, pellet machines) and novel products;
- Various others: workshops; partner capacity development (training materials, training course costs, costs for on-the-job training, survey costs for capacity needs); publications; communication costs; various small office supplies.

Costs for the above vary by continent and country (e.g., costs in Africa being higher than in Asia), and local budgets are developed in accordance with local costs in detail prior to conduct of any activity.

2.2.2.4 Other Sources of Funding for this Project

1. Aggressively seek additional funding from bilateral sources. 2. All RICE FPs have a modular set of outcomes and activities related to various levels of donor investment: with fluctuations in donor investment, budgets, activities, outcomes and milestones can easily be adjusted accordingly. 3. Seek new partnerships based on self-funding principles (in kind contributions included) that can contribute to outcomes that are underfunded

2.2.2.5 Budgeted Costs for certain Key Activities

Estimated average annual costs (over 6 years) for key activities (US$).

	Annual cost (US$)	**Please describe main key activities for the applicable categories below, as described in the guidance for full proposal**
Gender	369,935	Gender analysis along the value chain; developing business models for women entrepreneurs; targeting technology development for women users especially in postharvest, processing and marketing operations. See details in section 2.2.2.5 of the FP description, and section 1.0.4 of the main RICE description, and Annex 4 on gender
Youth (only for those who have relevant set of activities in this area)	184,968	Developing business models for young entrepreneurs in the rice value chain; targeting technology (ICT) development for young people. See details in section 1.0.5 of the main RICE description, and Annex 5 on youth
Capacity development	369,935	This FP engages in individual education and training activities and in institutional development; capacity development of research, development, and scaling partners; strengthens capacity to innovate across all partners. See details in section 2.2.1.10 of the FP description, section 1.0.10 of the main RICE description, and Annex 3 of the main RICE description
Impact assessment	-	All RICE impact assessments are carried out under CoA 1.5 of FP1
Intellectual asset management	55,490	Professional intellectual asset management services are provided throughout RICE and estimated to be around 1%, see Annex 10 to main RICE proposal for details
Open access and data management	369,935	Processing, validating, curation and quality control of collected data from surveys and experiments; data storage; making data accessible through standardized ontologies and descriptions; maintaining databases, websites, and other data delivery mechanisms. See section 2.2.1.11 of the FP description and Annex 9 of the main RICE description with details on cost items

Communication	369,935	Engages in dialogue to scale up results, through engagement with national and regional bodies as listed in section 1.0.9 of the main RICE proposal, using tools such as media releases, fora and ministerial roundtables; engages with actors on the ground to scale out technologies and practices, through the participation of multi-stakeholder platforms and scaling out activities (convened in CoAs 1.3 and 1.4), using tools such as participatory impact pathway mapping (PIPA), stakeholder and outcome mapping, problem tree definition and analysis; contributes information and content to overall communicate about the program, the science, results and progress; communicates and engages with partners through collaborative and participatory approaches to R&D and convening various networks, community of practice, platforms, and consortia; promotes learning and sharing of information to improve communications and collaboration. Development of journal papers, manuals, technical reports, and other communications media such as video, audio, websites, etc. Participation in conferences, workshops, forums, stakeholder meetings, etc.

2.2.2.6 Other

Being a new FP (compared with GRiSP) with relatively few bilateral projects, W1,2 funding is critical to the success of FP2. W1,2 funds are used for strategic market and value chain research. Identified entry points for improvement are explored in a limited set of action sites, and, when successful, further developed and scaled out through the acquisition of bilateral project grants. Similarly, prototype technologies for improved postharvest operations, processing, or novel products are developed and tested at small scale using W1,2 funding, and scaled out when additional funds become available. W1,2 funds are also used to ensure that the gender dimension of FP2 are addressed (see also section 2.2.1.9 of the FP2 description). The Tables B-C of the Performance Indicator Matrix indicate the contribution of W1,2 to the delivery of FP2's outcomes and sub-IDOs in financial terms.

2.2.3 Flagship Uplift Budget

Total uplift budget for six years for flagship project 2: Upgrading rice value chains.

Outcome Description	Amount Needed (US$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Improved access by women and poor farmers to high-value markets through better functioning value chains	9,000,000	30	0	70	0
Full suite of improved postharvest technologies (threshing, drying, milling, storage, processing) to reduce losses in the value chain with 10-15%	9,000,000	30	0	70	0
Proof of concept for value chains using rice byproducts, such as straw and husk, that generate additional income for farmers (energy generation, mushroom cultivation, soil amendment, etc)	9,000,000	30	0	70	0

2.3 Flagship project 3: Sustainable farming systems

2.3.1 Flagship Project Narrative

2.3.1.1 Rationale, scope

Some 400 million of the world's poor are associated with rice-based farming systems, and improving their livelihoods is one of the top priorities of RICE. These poor farmers provide surplus food to feed the increasing numbers of urban residents, many of whom are also poor and spend a large proportion of their income to buy rice. Hence, improved livelihoods of smallholder farmers should go hand-in-hand with securing the supply of safe, nutritious, and affordable rice to poor consumers. This combination broadens the scope of RICE to include large farms such as those found in the Southern Cone of Latin America, which make an important contribution to the global rice supply.

With increasing scarcity and degradation of natural resources, exacerbated by the effects of climate change, sustainable and ecological intensification is a key to increasing farm productivity at the rate needed to feed an increasing population. As the production of rice contributes to the emission of GHGs, sustainable intensification should include options to reduce such emissions.

Although gender roles and responsibilities are dynamic and can change over time depending on emerging factors such as shifts from subsistence to commercialized rice production, increasing mechanization, male out-migration, and other driving forces, female farmers play important roles in production. As family labor, women are often involved in rice farming activities that are mostly performed manually such as sowing, transplanting, weeding, harvesting, and threshing. However, women generally face difficulties performing these roles because of their lack of access to technical knowledge and technologies that can reduce their drudgery and labor bottlenecks, and provide additional income. Women also have household and care responsibilities. Reducing women's time in farm activities by enhancing their access to technologies will improve women's well-being by allowing them sufficient time for leisure or to engage in other income-generating activities. Smallholder women farmers are affected by the consequences of climate variability and other shocks with very little means to cope or adapt. Finally, women and children may suffer from malnutrition due to lack of access to and information about nutritious diets.

RICE considers farm diversification – through the introduction of nonrice crops (including fruits, vegetables, pulses, legumes), or the inclusion of trees, livestock or fish – as a major avenue to improving farmers' livelihoods and nutritional diversification. Hence, FP3 will develop and deliver diversified farming systems and improved crop management technologies to sustainably intensify rice-based farming systems, while minimizing their environmental footprint and adapting them to climate change. Modifying the production characteristics for the rice crop is often the lynch pin change required to enable change across the entire system - eg the use of short duration rice varieties, or getting fertilizer and water management in the rice crop, is critical to enabling the success of the following crop and indeed the farming system. Crop and farm diversification will offer women increased income-generating opportunities and improved nutrition security. New mechanization options are expected to increase women's labor productivity and reduce their drudgery. This will free women's time that can be used for enhancing their income through other on- or off-farm activities. Consequently, women will gain greater control over income that they can

invest for their families' well-being, including maternal health, children's education, and food and nutrition security.

FP3 develops its approaches, technologies, and farming systems in five RICE mega-rice-growing environments: mega-deltas and coastal zones, irrigated systems, rainfed lowlands, uplands, and inland valleys (see Table 3 for details). Through its place-bound mode of operation, FP3 is the main entry point for site integration with other CRPs. FP3 comprises three CoAs that make up a cycle from research to impact. Systems approaches will guide the research activities. Using a strong gender focus, CoA3.1 analyzes existing farming systems and identifies intervention points for innovations. Results are fed into CoAs 3.2 and 3.3 that develop and test prototype sustainable intensification and diversification options for rice production and harvest operations (postharvest operations are covered by FP2). Participatory testing and delivery of prototype options with farmers, partners, and intermediate users at key action sites in target environments will provide the critical feedback and reflective learning in the process of technology development.

Annex 11 shows a schematic overview of FP3's contribution to the grand challenges of the SRF: competition for land, soil degradation, overdrawn and polluted water supplies, new entrepreneurial and job opportunities for women and youth, climate change, and diverse agri-food systems and diets.

2.3.1.2 Objectives and targets

FP3 will develop and deliver improved crop management technologies and harvest practices, and intensified and diversified farming systems to (1) improve male and female farmers' and other value chain actors' livelihoods, (2) increase the sustainability and reduce the environmental footprint of rice-based farming systems and rice value chains, and (3) improve the nutritional status of malnourished, predominantly rice consumers (particularly women and children).

FP3 will deliver the following research outcomes to selected sub-IDOs, IDOs, SLOs, and cross-cutting issues of the SRF (see also the performance indicators matrix):

FP3 research outcome	Sub-IDO	IDO	SLO or cross-cutting issue
Improved management practices that reduce yield gap by 10-15% developed and disseminated at eight action sites (Nigeria, Senegal, Tanzania, Madagascar, Vietnam, Indonesia, Bangladesh, Myanmar)	Closed yield gaps through improved agronomic and animal husbandry practices	Increased productivity	Reduced poverty Improved food and nutrition security for health
Improved management practices that increase input use efficiency by 5% developed and disseminated at eight action sites (Nigeria, Senegal, Tanzania, Madagascar, Vietnam, Indonesia, Bangladesh, Myanmar)	More efficient use of inputs Enhanced conservation of habitats and resources More productive and equitable management of natural resources	Increased incomes and employment Natural capital enhanced and protected, especially from climate change Enhanced benefits from ecosystem goods and services	Reduced poverty Improved natural resource systems and ecosystem services

Options to diversity rice farms with other crops, animals, or trees developed and disseminated at six action sites (Cote d'Ivoire, Madagascar, Tanzania, India, Bangladesh, Myanmar) (together with other CRPs)	Increased livelihood opportunities	Increased income and employment	Reduced poverty
Diversified on-farm diets sourced through diversified farming systems at four action sites (Cote d'Ivoire, Madagascar, Bangladesh, Myanmar) (together with other CRPs)	Increased access to diverse nutrient rich food	Improved diets for poor and vulnerable people	Improved food and nutrition security for health
Improved rice management practices that reduce GHG by 5% disseminated at three action sites (Bangladesh, Philippines, Vietnam)	Reduced net GHG emissions from agriculture, forests and others forms of land use	More sustainably managed agroecosystems Mitigation and adaptation achieved	Improved natural resource systems and ecosystem services Climate change
Results of completed farming systems analyses used to focus development activities on key opportunities for adapting to climate risks at eight action sites (Nigeria, Senegal, Tanzania, Madagascar, Vietnam, Indonesia, Bangladesh, Myanmar)	Enhanced capacity to deal with climate risks and extremes	Mitigation and adaptation achieved	Climate change
Value chain actors including farmers and service providers using new mechanization options designed to increase women's labor productivity at seven action sites (Nigeria, Senegal, Tanzania, Vietnam, Indonesia, Bangladesh, Myanmar)	Technologies that reduce women's labor and energy expenditure developed and disseminated	Equity and inclusion	Gender and youth
Increased capacity for innovation on sustainable farming systems in partner research organizations	Increased capacity for innovation in partner research organizations	National partners and beneficiaries enabled	Capacity development

Among RICE target countries, FP3 focuses on actions sites in Côte d'Ivoire, Madagascar, Nigeria, Senegal, and Tanzania (in Africa); and Bangladesh, India, Indonesia, Myanmar, the Philippines, and Vietnam (in Asia). These countries were selected based on potential impact from rice research, country and partners' support, and donor interest. Five of these countries (Nigeria, Tanzania, Bangladesh, India, and Vietnam) were selected by the CGIAR Consortium for concerted site integration across CRPs.

2.3.1.3 Impact pathway and theory of change (for each individual FP)

Fig. 3.1 presents the impact pathway and theory of change, with risks and associated enabling actions of FP3. The three CoAs ensure that a pipeline of products and services (crop management technologies, novel cropping and farming systems, and mechanization equipment) is developed that benefits male and female farmers and other value-chain actors at the key action sites of RICE. Adoption of these products and services should enhance farmers' and other value-chain actors' livelihoods, gender equity, and the sustainability of natural resources and ecosystem services. Risks

for poor farmers' adoption of products and services include lack of market incentives, limited access to credit and input suppliers, high expense of equipment for individual farmers, weak manufacturers and workshops for machineries, limited dissemination of products by scaling partners, supportive policies not in place, and major trade-offs among productivity, livelihood, and the environment (Fig. 3.1). Enabling actions to realize the benefits may include partnership development, capacity development, policy advocacy, engagement with market actors, facilitating linkages to finance services, business model development in collaboration with other FPs, and development of appropriate products and services in this FP (see enabling actions in Fig. 3.1). The development of products and services will be underpinned by needs and opportunity assessments and results from market surveys, technology targeting, gender and youth analyses, and ex-ante impact assessments from FPs 1 and 2. Assessments will involve social scientists to help provide in-depth understanding of farmers' demand, labor, food and nutrition security, and risk constraints; mechanization in household decisions; and gender dimensions that are critical for designing products and services. Multistakeholder innovation platforms (linked with FP1), in which public and private sectors with strong inclusion of women and youth will be involved, will be used to identify opportunities for achieving common goals.

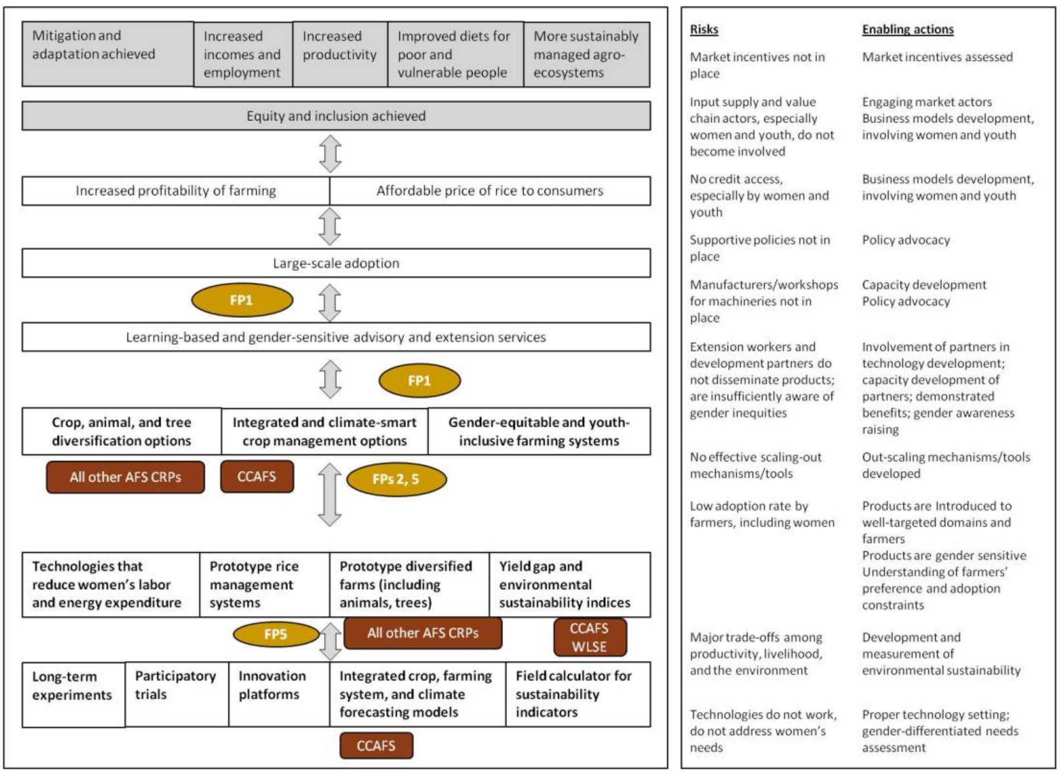

Fig. 3.1. Impact pathway (left) and theory of change (right) of FP1. Grey boxes are IDOs, ovals (with FP x) refer to links with other FPs, and the dark boxes refer to links with other CRPs (see Annex 12 for abbreviations).

A main feature of improving the enabling environment for development outcomes is the highly participatory and gender-inclusive way in which products and services will be developed, tested, adapted, and disseminated through multistakeholder innovation platforms and learning alliances (see Annex 2 for definitions). Feedback loops will be maintained throughout the impact pathway and result in site-specific versions that are continuously updated through incorporation of reflective learning.

To avoid poor adoption rate by female farmers and to provide new income-generating opportunities for them, special attention will be paid to gender equity and women's empowerment through the development and dissemination of gender-sensitive technologies and know-how that particularly respond to women's constraints, needs, and preferences, and through targeted inclusion of women in capacity development. Enabling actions in RICE such as training, development of scaling-out mechanisms, multistakeholder platforms that can strengthen linkages among value-chain actors, financial services, business model development, and market incentives, will improve women's access to resources, technologies, and know-how, which will contribute to increased productivity, reduced labor input, and increased food and nutrition security.

Increasing productivity and production leads to increased marketable surplus, thus enabling women to have a greater income and increased purchasing power to buy quality food, ensuring their roles in guarding household food security and health, especially of young children. They may also have more time to invest in other income-generating activities and for collecting water and sanitation practices, which will lead to improved health outcomes. Obviously, care must be taken with the introduction of labor-saving technologies that women workers are not deprived of their means of income and that alternative use of their time really constitutes an improvement in welfare.

Together with FP1, FP3 will develop training and dissemination materials such as videos, posters, leaflets, manuals, and training curricula for enhancing large-scale adoption. RICE recognizes that nearly all farmers are connected to markets and input suppliers through many intricate value chains. Hence, FP3 will maintain a strong link with FP2 to ensure that solutions respond to market demand, new market opportunities are exploited, links to input suppliers and service providers are strengthened, new entrepreneurial opportunities are exploited, and access to credit is facilitated. Links with FPs 1 and 2 will enable supportive policies to be designed and put in place that allow innovative farmers and other value-chain actors, including the private sector, to engage in, and benefit from, new market incentives.

Scaling-out and large-scale adoption will be supported by FP1 to strengthen the various technical, financial, and capacity development-related service providers. In collaboration with FP2, business models for the provision of agricultural advisory and machinery services and the delivery of equipment will be developed and piloted to support this process. These service providers will be enabled to provide better, demand-driven services based on the identified upgrading needs.

2.3.1.4 Science quality

FP3 will build on the approach of GRiSP to promote integrated research for developing demand-driven technologies with consideration of farmers' perspectives, including gender issues. In GRiSP, agronomy research focused on rice technologies at the plot/field level such as nutrient, water, or pest management options, with little consideration for the whole farming system that includes other crops, livestock, fish, or trees for improving whole-farm productivity, income, and diet diversity. Social learning is integrated in some agronomy work in Asian rice systems, but more effort is required. Development of new technologies and farming systems requires novel transdisciplinary research and partnership approaches in FP3, and will be based on needs and opportunity assessments, market surveys, technology targeting, gender and youth analyses, and ex-ante impact assessments from FPs 1 and 2. These assessments will be taken with involvement of social scientists (FPs 1 and 2), which will help provide in-depth understanding of farmers' demand, labor, and risk

constraints; mechanization in household decisions; and gender dimensions that are critical for designing technologies. Technologies will be co-designed with farmers and other value-chain actors through innovation platforms and learning alliances and will be intensively evaluated for their efficacy and potential for poverty reduction so that the technologies will be readily adopted.

FP3 will use and develop systems analysis approaches throughout the product pipeline. Integrated farming systems approaches will be supported by the development and use of multidisciplinary and participatory diagnostics, site analyses, and technology assessments; and through the use of such tools as simulation analysis (e.g., ORYZA2000 for rice, APSIM and DSSAT for crop rotations) and decision-support systems (e.g., Crop Manager, RiceAdvice, WeRise—integrated seasonal weather forecasting and associated crop management advice, and PRACT—a tool for designing conservation agriculture systems). Development and delivery of decision-support tools will be major achievements in FPs 3 and 6. FP3 builds on GRiSP tools and will upgrade these based on farmers' and users' feedback, and critical assessment of these tools (as noted in the IEA report, p 41).

Socioeconomic and biophysical considerations will be integrated and trade-offs or win-win situations using alternative technologies and farming systems will be made explicit. Objective assessments of these trade-offs will be enabled through further development of the Field Calculator that simultaneously assesses economic and biophysical aspects of alternative management options. New metrics for socioeconomic and environmental sustainability will be designed and scaled-up together with the Sustainable Rice Platform and WLE.

RICE considers crop and farm diversification as a major avenue to improving farmers' livelihoods and will evaluate other staple crops (maize, wheat, and potatoes), pulses, vegetables, fish, livestock, and trees as diversification options in rice-based farming systems in collaboration with other agri-food system CRPs as well as other partners such as AVRDC. Its focus will not only be at field level, but also at farm and/or community level, especially for land and water management. Whole-farm productivity, income, and diet diversity as well as environmental sustainability will be assessed to make sure that there is no major trade-off among them.

The leader of FP3 is experienced in agronomy and has leadership skills obtained in both GRiSP and AfricaRice research-for-development projects and programs. The FP3 core team (see section 2.3.1.12 and CVs in Annex 8) consists of senior scientists with a wide range of expertise (soil management, pest management, water management, cropping systems, crop models, climate change, and mechanization). Additional skills on needs and opportunity assessments, technology targeting, gender analyses, and participatory delivery will be drawn from collaboration with FPs 1 and 2.

GRiSP Theme 3 (equivalent to FP3) performed well in terms of scientific publications, with 18 of the top 50 most-cited publications in GRiSP since 2011 being on agronomy and crop management (IEA report, p 30). The RICE FP3 will continue to emphasize high-quality journal papers and, as per IEA review recommendation (IEA report, p 31), FP3 senior scientists will mentor junior colleagues, especially those at the lower end of the H-index scale and in Africa. To ensure quality of publications in peer-review journals and to reduce publications with no or very low impact factors, FP3 management will carefully monitor publication records annually and share publication guidelines among FP3 partners (IEA report, p 28-32). Also, FP3 management will encourage stronger research collaboration among RICE core partners and with partners in ARIs for further improving the overall quality of the scientific output through jointly authored, high-quality publications (IEA review recommendation #2, IEA report, p xvi; see also section 2.3.1.7 on partnerships). FP3 management

will strengthen interdisciplinary research in collaboration with management of the other RICE FPs. Special attention will be paid to joint research in social science and gender aspects. Finally, in FP3, joint PhD scholarships will be pursued with ARIs such as Wageningen University that have strength in farming systems analyses and agricultural innovation systems. Two science partners—University of Leeds and NIAES—will strengthen climate-related research through use of state-of-the-art crop-climate modeling and novel micro-climate assessment methodologies. AVDRC will be a key partner for rice-vegetable systems.

2.3.1.5 Lessons learnt and unintended consequences

In GRiSP, much of the location-specific work on improved crop management was organized around hubs, or key action sites, and carried out in close partnership with national programs. The selection of technologies for adaptive testing and dissemination should be based on participatory diagnostics, but, as the IEA review of GRiSP identified (IEA report, p 21), "too many resources were allocated to routine baseline descriptive data collection to characterize sites, with little analysis to understand household decision making on technology and natural resource management. This was partly due to donor-driven development projects too eager to see quick results (uptake and impact) on the ground. Also, insufficient resources were invested to understand opportunities and constraints of women in rice farming and value chains in order to better address the effectiveness and equity impacts of GRiSP research and technology delivery" (IEA report, p 59-61). Hence, in RICE, FP3 includes a specific CoA (3.1) to conduct multidisciplinary, participatory diagnostics and in-depth site analyses on issues of gender, nutrition security, risk, labor markets, farmers' needs and opportunities, and mechanization in household decisions (IEA recommendation #2, p 22).

Also, as suggested by the IEA GRiSP reviewers (IEA report, p 19), FP3 will invest more resources (especially W1 and W2) in exploratory and upstream research and less in downstream delivery projects, which will become more appropriate for GRiSP scaling-out partners (through FP1). Another lesson learned is that too many of GRiSP R&D activities remained disciplinary in nature. FP3 will focus its work on specific action sites where, through multistakeholder platforms and participatory approaches, it will join hands with other FPs to develop interdisciplinary and holistic solutions that fit site-specific contexts (IEA report, p 22).

FP3 will develop and deliver a wide range of technologies to promote gender equity, close yield gaps, improve productivity, enhance food and nutrition security, reduce production risks, adapt to climate change, increase farmers' livelihoods, and reduce degradation of natural resources and ecosystems. To account for potential trade-offs and develop win-win situations, various measures of both socioeconomic and environmental sustainability will be designed and collected. FP3 participates in the Sustainable Rice Platform in which multidimensional sustainability criteria are developed and mainstreamed in rice production and rice value chains. FP3 will also serves as the link point with WLE's ESA flagship project that will develop scalable sustainability indicators for RICE interventions, building on 2015 GRISP/WLE collaboration on assessing trade-offs in rice production systems.

Particular attention will be paid to potential unintended consequences for women when new technologies are introduced. For example, labor-saving technologies such as mechanized crop establishment may alleviate the plight of women by removing the need for backbreaking manual transplanting, but it may also deprive them of their jobs and hence their income. However, women might gain additional benefits from alternative value-adding opportunities or contract service

provision. FP3 will closely monitor—and find ways to remedy—negative impacts and foster positive outcomes in close collaboration with FP1. Through its hands-on collaboration with local partners in innovation platforms and learning alliances, FP3 will closely monitor any other unintended consequences of its R&D activities.

2.3.1.6 Clusters of activity (CoA)

3.1. Farming systems analysis

Farming systems analysis will be the entry point for identifying opportunities for diversification and intensification for improving farmers' livelihoods (e.g., crop rotation, opportunities for livestock or fish, and improved crop management). CoA3.1 uses diagnostic surveys, participatory needs assessment, and simulation analysis tools (e.g., ORYZA2000 for rice, and APSIM and DSSAT for crop rotation). Analyses will encompass environmental, socioeconomic, and biophysical aspects such as environmental sustainability, resilience and capacity to adapt to shocks, and current and future climate risk. In collaboration with CCAFS, FP3 will assess future climate risk using the climate change scenarios and climate impact methodologies that are developed in CCAFS. CoA3.1 will build on information generated by FP1 through its foresight analyses and ex-ante and ex-post impact assessments. Linked with FP1, the analyses made in this CoA will also include gender issues to guide the development of R&D frameworks to deliver technologies designed to increase women's labor productivity, reduce their drudgery, and improve their nutrition security.

Through the process of site integration, CoA3.1 will organize joint workshops with other CRPs that have a significant presence in similar geographic areas to develop a common understanding of needs and opportunities for collaboration efforts. Such activities will foster ideas for collective action that will be further teased out in joint next steps (e.g., joint analysis using existing data, joint experiments, thematic workshops, and sharing facilities) and formulations of joint grant proposals. Joint PhD scholarships will be pursued with advanced research universities that have strength in farming systems analyses. Some of these PhD scholarships will be co-funded with other CRPs (see Annex 7). As female agronomists are very few in sub-Saharan Africa and Asia, female candidates will be given priority.

In collaboration with the Sustainable Rice Platform, CoA 3.1 will develop, validate, and scale-up multidimensional sustainability indicators, building on the socioeconomic and biophysical sustainability criteria and field calculator developed in GRiSP. The indicators developed in this CoA will be used by CoAs 3.2 and 3.3.

3.2. Intensification and mechanization

Innovative technologies to improve rice farming will be designed based on the analyses from CoA3.1, as well as on yield gap assessments, process-based knowledge derived from ongoing long-term rice trials (>50 years in Asia and >20 years in Africa), and gender analyses (together with FP1). CoA3.1 starts with technologies developed in GRiSP (e.g., Crop Manager, RiceAdvice, alternate wetting and drying, and weeder), and novel technologies as they emerge from the pipeline.

Options for mechanization will be developed in response to labor shortages and to improve labor productivity and agricultural income. Examples are mechanical transplanters, direct-seeding equipment, mechanical weeders, and harvesting machinery (combined harvester-thresher). Attention will be paid to options that free women from backbreaking activities such as transplanting and weeding. Where women remain involved in such activities, mechanization will increase their productivity and income and CoA3.2 will actively support them with appropriate training. However,

where the introduction of mechanization introduces the risk that women are deprived of their source of income, CoA3.2 will facilitate the development of alternative job opportunities. Together with FP1, CoA3.2 will link with partner organizations that foster women's development such as NGOs and women's self-help groups. CoA3.2 will also develop or upgrade ICT tools, on-farm advisory services, and machinery options that could be attractive to youth who want to start a rice business or extension service (thus contributing to youth employment; see also Annex 5).

Component technologies such as options for improved management of soils, water, and pests; mechanization options; and new varieties (link with FP5) will be grouped into integrated management practices, which will be co-developed and tested with farmers, with a strong inclusion of women and youth and other stakeholders organized in multistakeholder platforms at key action sites. Experiences of farmers and local partners will provide critical feedback to the process of technology development and lead to reflective learning and adaptation of impact pathways and theories of change (jointly with FP1). Together with FP1, experimental results will be combined with simulation tools to identify target domains that are suitable for adoption of the selected technologies.

Further, CoA3.2 will develop specific technologies to reduce GHG emissions from rice fields at key action sites and assess GHG emissions under improved technologies such as adapted tillage, water-saving technologies (e.g., alternate wetting and drying), straw and residue management with composting and charring, and fertilization strategies. Indicators developed in CoA3.1 will help assess synergies or trade-offs among other dimensions of sustainability. This CoA is a co-investment with the CCAFS CRP through sharing of staff, resources, and experimental sites (see framework for GRiSP-CCAFS cooperation). Jointly with CCAFS, climate-smart agricultural practices will be defined, fine-tuned, and scaled-up in rice production.

3.3. Farm diversification

In collaboration with other AFS CRPs and with centers such as AVRDC, other staple crops (maize, wheat, potatoes), pulses, vegetables, fruits, fish, livestock, and trees will be evaluated as diversification options in rice-based farming systems. The opportunity of farm diversification to diversify on-farm diets will be an important focus. The hypothesis that the on-farm availability of diverse food items will enhance dietary diversity among farmers and rural communities will be tested through dietary surveys. Novel systems options will be co-developed and tested with farmers, with strong inclusion of women and youth and other stakeholders organized in multistakeholder platforms at key action sites. The development of prototype systems will be based on the analyses of CoA3.1, novel technologies from CoA3.2, experiences from long-term rice-based cropping system trials, and in-depth understanding of local cropping/farming systems, farmers' demands, diets, labor and risk constraints, household decision mechanisms, and critical gender dimensions. Mechanization dimensions will expand from a rice focus in CoA3.2 to whole farm operations and farming system optimization. Examples are the use of machinery for multiple crops, and the opportunities that mechanization of one crop offers for changes in whole farm cropping patterns (see below).

Diversified cropping systems may take many forms depending on local conditions. For example, in parts of Bangladesh where water saving is required, crops that use less irrigation than boro rice, such as wheat, maize, and sunflower, are being introduced. The introduction of early-maturing rice varieties in two-rice crop systems has been shown to give farmers an extra month between seasons, allowing a third crop such as maize or mustard that can provide farmers with an extra US$ 600−700/ha (CSISA 2014). Double- or triple-cropped systems combining stress-tolerant

rice and maize varieties with new breeds of fish have been shown to double the production of both rice and fish (CSISA 2014). Rice-lentil-mungbean systems produce rice-equivalent yield of 41% more than two-rice (aman-boro) crop systems, and are five times more profitable (Sirajul Islam et al 2015).

Newly-introduced systems create many new connections and networks into the rice-based system, each requiring its own (sub)set of interventions such as market research and postharvest and distribution activities, in order to optimize benefits to producers and consumers. CoA3.3 assesses the consequences of the introduction of new systems on livelihoods, labor productivity, diet diversity, and gender equity and empowerment parameters. The interactions between the crops, trees, or animals (livestock and fish) and the generalized rice-based value chain are envisaged as interconnecting value chains, such that the performance of any one crop/tree/animal affects the performance of the whole. While complex systems and their interactions are beyond the scope of RICE, opportunities for their analyses will be explored with other agri-food system CRPs and PIM through the process of site integration. The aim is to jointly develop a coherent approach to address complex webs of agri-food systems.

2.3.1.7 Partnerships

The CGIAR centers have strong partnerships with regional organizations and NARES, and have long experience in collaborative R&D on the topics of FP3. In Africa, AfricaRice leads research networks on the Africa-wide Rice Agronomy Task Force and the Africa-wide Rice Mechanization Task Force. Through these networks, technologies are introduced, validated, and disseminated. In Asia, IRRI leads cross-country partnerships through research consortia such as the Consortium for Unfavorable Rice Environments (CURE) and the Irrigated Rice Research Consortium (IRRC). In Latin America and the Caribbean, CIAT does not engage in agronomy research itself, but facilitates cross-country knowledge sharing and transfer through the Latin American Fund for Irrigated Rice (FLAR).

International public goods (IPGs) include simulation analysis tools, decision-support systems (e.g., Crop Manager, RiceAdvice, and Field Calculator), options for diversified farming systems, improved crop management technologies and machinery, and indicators for environmental sustainability. Generic IPGs will be adapted and developed into site-specific technologies and practices that fit local contexts.

The CGIAR centers and their partners have developed innovative research areas in GRiSP, which provide a solid foundation for RICE. Comparative advantages of CGIAR centers compared to other R&D providers are their international mandate, their extensive and diverse partner networks, the unique long-term and strategic NRM studies that are in place (e.g., IRRI long-term experiment ongoing since 1961; nutrient management studies with omission plots with national partners, 1995–2015), the close association of germplasm development and NRM, and their ability to adopt, validate, and transfer technologies across countries.

Some major partners and their roles are:

Discovery	Proof of concept	Scaling out
To enhance the quality of its science, FP3 will particularly expand partnerships with ARIs and universities (IEA review recommendation #2, IEA report, p xvi) such as CSIRO, Wageningen	NARES (e.g., PhilRice, VAAS, ICAR, BRRI, AIAT, NCRI, ISRA, and FOFIFA), development agencies (e.g., AGRA, CoARI, GIZ, SNV, and Syngenta Foundation), local universities (e.g., UPLB, Yezin	Regional organizations (e.g., ECOWAS), NARES (e.g., BRRI, VAAS, ICAR, ICRR, AIAT, and WAAPP), Latin American Fund for Irrigated Rice (FLAR), national organizations (e.g., SAED),

University, University of Leeds, AVRDC, and NIAES. CSIRO and Wageningen University will specifically strengthen RICE in systems analysis such as crop simulation models and farming systems analysis	Agricultural University in Myanmar, and Royal University of Agriculture in Cambodia), private companies (e.g., OCP), NGOs (e.g., CRS, BRAC, and Don Bosco), and value-chain stakeholders (farmers, processors, agri-business, exporters, and importers) are partners at the pilot study level. FP3 will undertake joint R&D activities such as surveys, participatory technology testing, and development of innovation platforms and learning alliances at action sites.	development agencies (e.g., AGRA, CoARI, GIZ, and Syngenta Foundation), NGOs (e.g., CRS and BRAC), private companies (e.g., Hanigha Nigeria Limited), Notore Chemical Industries Plc, and value-chain stakeholders (farmers, processors, agri-business, and exporters) are partners for scaling-up, which will also involve other value-chain actors' organizations and business communities (e.g., input suppliers and markets).

2.3.1.8 Climate change

Rice is among the most vulnerable crops to changing climates because of its importance in low-lying production areas such as mega-deltas and coastal zones. Women rice farmers are generally more threatened than their male counterparts by climate change, having far less capacity than males to cope or adapt (Mehar, 2014). Rice-farming areas are also substantial producers of the GHG methane, and climate-smart management practices are needed for both adaptation and mitigation along the rice value chain. FP3 will develop integrated management practices combining climate-smart varieties (from FP5) with climate-smart management technologies (e.g., water, nutrient, and residue management). Scaling-out of climate-smart technologies will be done with FP1 and in strong collaboration with CCAFS. Weather forecasting will be combined with climate-smart management practices into climate-informed advisories.

For reducing GHG emissions, specific management and technologies such as improved water management options, technologies to reduce the emissions and pollution from open field burning, and more energy-efficient machines will be developed and delivered in collaboration with CCAFS.

2.3.1.9 Gender

Based on demand and needs from women in rice farming (in collaboration with FP1), and in collaboration with them, FP3 will develop and deliver integrated management options and sustainable farming systems designed to increase productivity, income, and diet diversity of women farmers. Options that can reduce/eliminate women's drudgery, reduce health risks, and free their time will be a special focus, including mechanical transplanters, direct-seeding equipment, mechanical weeders and/or the use of herbicides, harvesting machinery (combine harvester-thresher), and mechanical threshers. On-farm participatory testing will explicitly involve women farmers to ensure that technology development addresses their specific needs and concerns.

To avoid biased adoption by male and female farmers and to reduce the gender gap, FP3 will collaborate with FP1 and with the CGIAR gender network in PIM to enhance gender-equitable access to its developed products and services, gender-inclusive rural extension and advisory systems, other services including financial services, and agricultural training programs. As the introduction of mechanization might displace women in certain farm operations and deprive them of current incomes, FP3 facilitates the introduction and expansion of new income-generating opportunities.

Mechanization can also provide new value-adding options for youth, and therefore can renew interest among youth for a career in agriculture. In collaboration with FP2, FP3 will ensure that business models for mechanization activities are gender inclusive and will provide appropriate capacity development, e.g., on the operational and financial aspects of business models to women. Finally, FP3 researchers and their partners (public and private sector, NARES, NGOs, etc.) will be sensitized by gender specialists in RICE to the gender aspects of their work. FP3 scientists will improve their understanding of gender roles and cultural contexts, and will engage women farmers and other women actors along the rice value chain for technology testing and dissemination.

2.3.1.10 Capacity development

The overall capacity development strategy of RICE is given in Annex 3. Five of the nine elements of the CGIAR Capacity Development Framework (CapDev) are specifically addressed in FP3. In the element "Developing future research leaders through fellowships," FP3, together with FP1, will have a scholarship program for PhD research, especially for women. A clear focus in Africa is to develop capacity in systems analysis, including crop simulation modeling and farming systems analysis. For the element "Organizational development," FP3 will focus on enhancing NARES research and research management capacity, and capacity development of partners and extension systems for scaling-out technologies.

"Capacity needs assessment and intervention strategy design" will focus on creating an enabling environment and improving the capacity of national partners in developing curricula for academic and skills training, in particular for mechanization. These activities will target organizational and institutional changes such as assisting the joint use of technologies, service provision, and institutional changes required. Individual capacity development will focus on participatory and on-the-job training of partners from the public and private sector as well as service providers. Women will be given priority. Through the multistakeholder approach using learning alliances, FP3 will also engage in "Design and delivery of innovative learning materials and approaches" in close cooperation with FP1. FP3 will also work with FP1 on "Gender-sensitive approaches for capacity development," in particular for mechanization interventions.

2.3.1.11 Intellectual asset and open access management

FP3 follows the RICE policies and strategies on intellectual asset management, open access, and data management (Annexes 9 and 10) in line with the CGIAR Principles on the Management of Intellectual Assets and their Implementation Guidelines, and with the CGIAR Open Access and Data Management Policy and its Implementation Guidelines. FP3 intellectual assets/research data include agronomic data and databases; data analysis tools; computer and other IT software such as simulation models and advisory systems; crop management options; blueprints for machinery (in rice production); video, audio, and images; peer-reviewed journal articles; reports and other papers; and books and book chapters. Data will be made accessible through various websites, e.g., AfricaRice Data Repository and Dataverse. Agronomic knowledge, information on management practices, training materials, and dissemination products will be made available at Rice Knowledge Bank, RiceHub, Rice videos Africa, and Rice videos Asia. The rice model ORYZA2000 is fully documented, maintained, and downloadable with tutorials. Data are made available within 12 months after curation and quality control or 6 months after journal publication of analyses. Personal data

collected with respect to farmers or other stakeholders will be processed fairly and lawfully and, in particular, shall not be made public.

2.3.1.12 FP management

FP3 is led by Kazuki Saito from AfricaRice. Each CoA is co-led by a team of senior scientists (focal persons) consisting of one or more representatives from each center. Annex 8 presents the list of senior scientists and a set of selected curricula vitae.

FP3 leader Kazuki Saito will coordinate activities in FP3 across the participating centers and institutes. AfricaRice and IRRI will work on all the CoAs. CIAT will facilitate knowledge sharing with and within Latin America and the Caribbean in conjunction with FP1. Cirad will contribute to CoA 3.3. JIRCAS will contribute to CoA 3.2. Cirad and JIRCAS will focus on target countries in sub-Saharan Africa. David Johnson (IRRI) will coordinate all CoAs in Asia. Patrice Autfray (Cirad) and Satoshi Tobita (JIRCAS) will co-lead CoAs 3.3 and 3.2 in Africa, respectively, and Kazuki Saito (AfricaRice) will lead the other CoAs in Africa. These senior staff (focal points) will be responsible for planning, monitoring, and evaluating activities across CoAs within each center or institute. The FP3 leader and focal points will organize workshops using the FP3 leader's coordination budget. Also, they will facilitate communication across the participating centers and institutes to enhance information and knowledge sharing. Reiner Wassmann is focal point for CCAFS in IRRI and will also facilitate collaboration between CCAFS and RICE.

2.3.2 Flagship Budget Narrative

2.3.2.1 General Information

CRP Name	CGIAR research program on rice-based agri-food systems, RICE
CRP Lead Center	International Rice Research Institute
Flagship Name	Sustainable farming systems
Center location of Flagship Leader	Cote d'Ivoire

2.3.2.2 Summary

Total flagship project budget summary by sources of funding (US$).

Funding Needed	2017	2018	2019	2020	2021	2022	Total
W1+W2	2,976,259	3,033,675	3,087,155	3,142,575	3,194,278	3,243,665	18,677,609
W3	4,365,423	4,498,667	4,634,324	4,775,010	4,918,529	5,065,640	28,257,597
Bilateral	14,978,521	15,414,108	15,915,262	16,433,377	16,969,063	17,522,947	97,233,281
Other Sources							0
Total	22,320,203	22,946,450	23,636,741	24,350,962	25,081,870	25,832,252	144,168,478

Funding Secured	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Assumed	2,976,259	3,033,675	3,087,155	3,142,575	3,194,278	3,243,665	18,677,609

Secured)							
W3	2,536,280	2,024,979	859,950	902,947	948,094	995,499	8,267,750
Bilateral	4,287,440	6,051,769	8,029,140	8,297,307	8,574,886	8,862,224	44,102,768
Other Sources							0
Total	9,799,979	11,110,423	11,976,245	12,342,829	12,717,258	13,101,388	71,048,122

Funding Gap	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	-1,829,144	-2,473,689	-3,774,375	-3,872,063	-3,970,435	-4,070,141	-19,989,846
Bilateral (Fundraising)	-10,691,082	-9,362,338	-7,886,122	-8,136,070	-8,394,178	-8,660,723	-53,130,513
Other Sources (Fundraising)	0	0	0	0	0	0	0
Total	-12,520,225	-11,836,027	-11,660,497	-12,008,134	-12,364,613	-12,730,864	-73,120,359

Total flagship project budget summary by natural classification (US$).

	2017	2018	2019	2020	2021	2022	Total
Personnel	9,505,484	9,829,010	10,164,159	10,511,376	10,871,125	11,243,887	62,125,044
Travel	588,936	606,418	620,362	634,783	649,700	665,129	3,765,330
Capital Equipment	275,191	207,575	217,954	228,852	252,794	252,309	1,434,676
Other Supplies and Services	6,619,118	6,818,777	6,989,962	7,166,727	7,349,260	7,537,759	42,481,606
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	2,950,371	3,039,042	3,123,756	3,211,100	3,278,658	3,371,516	18,974,444
Indirect Cost	2,381,102	2,445,626	2,520,547	2,598,124	2,680,332	2,761,651	15,387,385
Total	22,320,202	22,946,448	23,636,740	24,350,962	25,081,869	25,832,251	144,168,472

Total flagship project budget summary by participating partners (US$).

	2017	2018	2019	2020	2021	2022	Total
IRRI	18,545,128	19,009,708	19,538,888	20,083,942	20,645,349	21,223,597	119,046,614
Africa Rice	3,775,076	3,936,742	4,097,854	4,267,022	4,436,523	4,608,655	25,121,873
Total	22,320,204	22,946,450	23,636,742	24,350,964	25,081,872	25,832,252	144,168,484

Explanations of these costs in relation to the planned 2022 outcomes

Flagship project 3 is composed of 3 clusters of activity as described in the FP3 narrative section 2.3.1.6. Each cluster of activity delivers one or more outcomes each (with a related set of milestones), as listed in the Performance Indicator Matrix, Tables B-D. The required investment (budget) for each outcome is listed in Table B of the Performance Indicator Matrix. The Clusters of activities (CoA) and their outcomes are:

FP3	Sustainable farming systems	Outcomes
3.1	Farming systems analysis	Results of completed farming systems analyses used to focus development activities on key opportunities for adapting to climate risks at eight action sites (Nigeria, Senegal, Tanzania, Madagascar, Vietnam, Indonesia, Bangladesh, Myanmar)
3.2	Intensification and mechanization	Improved management practices that reduce yield gap by 10-15% developed and disseminated at eight action sites (Nigeria, Senegal, Tanzania, Madagascar, Vietnam, Indonesia, Bangladesh, Myanmar)
		Improved management practices that increase input use efficiency by 5% developed and disseminated at eight action sites (Nigeria, Senegal, Tanzania, Madagascar, Vietnam, Indonesia, Bangladesh, Myanmar)
		Value chain actors including farmers and service providers using new mechanization options designed to increase women's labor productivity at seven action sites (Nigeria, Senegal, Tanzania, Vietnam, Indonesia, Bangladesh, Myanmar)
		Improved rice management practices that reduce GHG by 5% disseminated at three action sites (Bangladesh, Philippines, Vietnam)
3.3	Farm diversification	Options to diversity rice farms with other crops, animals, or trees developed and disseminated at six action sites (Cote d'Ivoire, Madagascar, Tanzania, India, Bangladesh, Myanmar) (together with other CRPs)
		Diversified on-farm diets sourced through diversified farming systems at four action sites (Cote d'Ivoire, Madagascar, Bangladesh, Myanmar) (together with other CRPs)

Besides the above outcomes, each cluster of activity contributes to various capacity development actions, captured in a joint outcome "Increased capacity for innovation on sustainable farming systems in partner research organizations". The budget of each cluster of activities depends on the type of activities, and involves typically the collection of survey data among farmers at key action sites (involving travel, local expenses in country such as translators, enumerators, vehicle rental, local partners), and analyses and reporting of survey data (CoA3.1); the development and use of simulation models for crop growth, farming systems, greenhouse gas emissions (CoAs 3.1 and 3.2); the conduct of experiments in greenhouses, on stations, and on-farm (CoAs 3.2 and 3.3); farmer-participatory experimentation on new farming systems and crop management practices (CoAs 3.2 and 3.3); development and measurement of quantitative and qualitative multi-dimensional sustainability parameters (CoA 3.2); development, testing, and dissemination of improved equipment and machinery, such as mechanized land leveling, seeding, transplanting, combine-harvesting (CoA3.2); workshops; stakeholder consultations; development of communication materials (papers, flyers, brochures, websites, video, etc); partnership development; development and support of learning alliances and multistakeholder platforms; partner capacity development for research, innovation, and delivery; communication; (open access) data management (all CoAs)– see section 2.3.2.5 below.

Risk to spending as planned

The RICE FPs are 'umbrella projects', which include a large number of bilateral projects any given year. Hence, the FP budgets are dictated by the collective investments that donors want to make through W1/2, W3, bilateral, and 'others means'. The investment levels are unpredictable: 1) the W1-3 donors can not commit to 6-year funding obligations and the W1-3 investments into the CGIAR fluctuate substantially each year, and 2) 70-80% of the budget is contributed to by bilateral projects,

the majority of which still need be developed and secured. Hence, the likelihood that budgets are obtained - and spent - exactly as targeted, decreases as the CRP progresses in time. Each year, updates on investments expectations and budgets will be developed, and spending managed accordingly. At the level of bilateral projects, spending risk is managed by project leaders following procedures spelled out in project contracts. For W1-3, spending risk is managed by flagship project leaders. Project leaders get regular updates on actual spending rate through OCS, and are required to make project adjustments if under- or overspending occurs beyond the (donor-) accepted range (usually 10% of line items).

2.3.2.3 Additional explanations for certain accounting categories

Benefits
Benefits are separated out and include pension, housing, vehicle, home leave, medical insurance, and education allowances.

Other supplies and services

- Costs related to the collection of survey data among farmers at key action sites, involving local expenses in country such as recruitment of translators, enumerators, vehicle rental, local partner costs, laptops for data entry);
- Various software for development and application of crop growth simulation models;
- Costs related to the development and sustenance of multistakeholder platforms and learning alliances at key action sites (partner costs, workshop costs, stakeholder consultations, meetings);
- Cost for development of prototype improved machines and equipment for rice production, such as laser levers, combine-harvesters, improved direct-seeding and transplanting machines;
- Cost for establishment of weather station (if nonexistent) and measurement of weather data: radiation, temperature, wind speed, humidity, pan evaporation, sunshine hours
- Costs for agronomic field trials (greenhouse, on station, on farm) and on-farm participatory experiments, including experimental diversified farms: land rental; seeds, agrochemicals, irrigation water, plastic sheets; plant and soil sampling; harvesting; sample processing (small supplies such as paper bags, strings, labels, markers); bar coding; tablets for data entry; use of small equipment such as leaf area meter, SPAD meter, radiometer, soil moisture tensiometers, irrigation water measurement devices, piezometers, penetrometer, etc;
- Cost for sample processing: laboratory analysis: plant chemical analyses; soil and water chemistry; soil physics;
- Cost for greenhouse gas emissions (equipment, chemicals);
- Various others: workshops; partner capacity development (training materials, training course costs, costs for on-the-job training, survey costs for capacity needs); publications (leaflets, journal papers, videos, brochures, websites, audio materials); communication costs; various small office supplies.

Costs for the above vary by continent and country (e.g., costs in Africa being higher than in Asia), and local budgets are developed in accordance with local costs in detail prior to conduct of any activity.

2.3.2.4 Other Sources of Funding for this Project

1. Aggressively seek additional funding from bilateral sources. 2. All RICE FPs have a modular set of outcomes and activities related to various levels of donor investment: with fluctuations in donor investment, budgets, activities, outcomes and milestones can easily be adjusted accordingly. 3. Seek new partnerships based on self-funding principles (in kind contributions included) that can contribute outcomes that are underfunded.

2.3.2.5 Budgeted Costs for certain Key Activities

Estimated average annual costs (over 6 years) for key activities (US$).

	Annual cost (US$)	**Please describe main key activities for the applicable categories below, as described in the guidance for full proposal**
Gender	3,604,212	Developing business models for women entrepreneurs in rice production; targeting technology development for women farmers to reduce drudgery and enhance their labor productivity; targeting development of crop and farm management options to women farmers in stress-probe environments; enhancing resilience of women farmers to climate change and other shocks; capacity development. See details in section 2.3.1.9 of the FP description, and section 1.0.4 of the main RICE description, and Annex 4 on gender
Youth (only for those who have relevant set of activities in this area)	1,201,404	Developing business models for young entrepreneurs in rice production and among inputs suppliers (e.g., machinery manufacturers, contract service providers); targeting technology (ICT) development for young people, such as cell-phone based advisory services. See details in section 1.0.5 of the main RICE description, and Annex 5 on youth
Capacity development	3,604,212	This FP engages in individual education and training activities and in institutional development; capacity development of research, development, and scaling partners; strengthens capacity to innovate across all partners in rice production and the input supply and service industry. See details in section 2.3.1.10 of the FP description, section 1.0.10 of the main RICE description, and Annex 3 of the main RICE description
Impact assessment	-	All RICE impact assessments are carried out under CoA 1.5 of FP1
Intellectual asset management	360,421	Professional intellectual asset management services are provided throughout RICE and estimated to be around 1%, see Annex 10 to main RICE proposal for details
Open access and data management	2,883,370	Processing, validating, curation and quality control of collected data from surveys and experiments; data storage; making data accessible through standardized ontologies and descriptions; maintaining databases, websites, and other data delivery mechanisms. See section 2.3.1.11 of the FP description and Annex 9 of the main RICE description with details on cost items

Communication	2,402,808	Engages in dialogue to scale up results, through engagement with national and regional bodies as listed in section 1.0.9 of the main RICE proposal, using tools such as media releases, fora and ministerial roundtables; engages with actors on the ground to scale out technologies and practices, through the participation of multi-stakeholder platforms and scaling out activities (convened in CoAs 1.3 and 1.4), using tools such as participatory impact pathway mapping (PIPA), stakeholder and outcome mapping, problem tree definition and analysis; contributes information and content to overall communicate about the program, the science, results and progress; communicates and engages with partners through collaborative and participatory approaches to R&D and convening various networks, community of practice, platforms, and consortia; promotes learning and sharing of information to improve communications and collaboration. Development of journal papers, manuals, technical reports, and other communications media such as video, audio, websites, etc. Participation in conferences, workshops, forums, stakeholder meetings, etc.

2.3.2.6 Other

In FP3, W1,2 funding is used for strategic research into the new area (compared to GRiSP) of diversified farming systems, and to support the development of new management technologies. This use of W1,2 funding complements a set of bilateral projects that are more development oriented and that engage more in downstream technology validation, adaptation, and dissemination. W1,2 funding supports a few key action sites and partnerships where – together with other CRPs (see annex 7 on linkages with other CRPs and site integration) - rice farming is expanded into other crops, animals, or trees. This will contribute to the process of CGIAR 'site integration' through co-investments with other CRPs in key 'site integration countries'. Capacity development activities are funded by W1,2 through scholarships and on-site participatory research and development activities. W1,2 funds are also used to ensure that the gender dimension of FP3 are addressed (see also section 9 of the FP3 description). The Tables B-C of the Performance Indicator Matrix indicate the contribution of W1,2 to the delivery of FP3's outcomes and sub-IDOs in financial terms.

2.3.3 Flagship Uplift Budget

Total uplift budget for six years for flagship project 3: Sustainable farming systems.

Outcome Description	Amount Needed (US$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Framework to identify opportunities to strengthen resilience of women and the poor to climate risks and others shocks (together with other CRPs)	9,000,000	30	0	70	0
Enhanced benefits to the marginalized and poor derived from eco-system services provided by rice landscapes (with WLE)	9,000,000	30	0	70	0
Increased livelihoods of the poor through improvement management of coastal zones in mega deltas of Bangladesh, Guinea, India, Myanmar, Sierra Leone, and Vietnam (with Fish, WLE)	9,000,000	30	0	70	0

2.4 Flagship Project 4: Global Rice Array

2.4.1 Flagship Project Narrative

2.4.1.1 Rationale, scope

Climate variability explains around 33% of rice yield variation globally (Ray et al 2015). Current rice yields are projected to decline with climate change, for example, by 45% for zones in sub-Saharan Africa (Adhikari et al 2015). To meet the challenges of climate change, new rice varieties are needed that are adapted to projected future climates, including the consequences for pest and disease pressures. This calls for accelerating the discovery of new genes and traits and optimizing the use of genetic diversity under different environments and climate scenarios. A clear understanding of the complexity of interactions between genotypes (G), environments (E), and crop management (M) is necessary. The E factor includes weather, soils, and pest and disease patterns. Conventional methods to quantify G × E interactions rely on a limited number of multienvironment evaluations of breeding materials. With the exception of a few large multinational companies, there is no systematic strategy to exploit G × E × M to enhance crop performance in major cereals. A significant investment in understanding the environments under climatic change and discovering adaptive traits and genes and their E- and M-dependent expression is much needed to accelerate genetic gain in breeding.

Advances in genomics and high-throughput phenotyping tools provide a unique opportunity to discover new genes targeted at each G × E × M relationship. Germplasm can now be sequenced at low cost to reveal genetic diversity in fine molecular detail. GIS allows the integration of geographic information with environment and crop data. Missing are multienvironment and multitrait phenotypic data to rapidly discover gene-phenotype relationships and their G × E × M dependency that determines crop performance in diverse environments.

A main goal of FP4 is to provide rice breeders worldwide with the phenomics, genomics, and environmental information, as well as target ideotypes, in order to generate better adapted varieties at a faster rate. A Global Rice Array will be established consisting of high-throughput (HTP) field phenotyping sites to evaluate genetic populations, including diversity panels, mapping, and breeding populations. Complementary HTP platforms will be used for precision phenotyping of physiological, biochemical, and architectural traits. Smaller but diverse "diagnostic" populations at different sites of the Global Rice Array will also serve as biological "antennae" to characterize and diagnose the diversity and dynamics of a changing climate "through the eye of the crop." This "sensing" of the effects of climate variability on rice crops globally will provide useful information to policymakers, agronomists, and scientists studying the impacts of climate change.

Crop models such as ORYZA2000 will be used to analyze and extrapolate data from the Global Rice Array in predicting the effects of climate variability and change on the rice crop. Conversely, crop models will help translate the phenotypic diversity and factor responses into ideotypes adapted to changing environments. In-depth research on G × E × M effects on gene/trait expression will reveal genetic networks that condition adaptive traits, providing genomic markers that are effective across major rice production environments.

The data will be integrated in a Big Data user-friendly platform to allow data mining and use by the global community. FP4 products will increase the efficiency and efficacy of the breeding programs of FP5.

The Global Rice Array will engage many partners in phenotyping and gene discovery for both common and site-specific traits using genotyped genetic populations. Partners will include NARES, ARIs, and the private sector as appropriate. FP4 will collaborative strongly with CCAFS, which will provide downscaled climate change scenarios for the sites of the Global Rice Array and link FP4 rice efforts with those on other crops.

Annex 11 gives a schematic overview of FP4's contribution to the 10 grand challenges of the SRF. In particular, evidence of climate change/variation effects on rice crops, and concepts to improve their adaptation (see section 2.3.1.8, Climate change) will support national and regional decision making toward mitigating the risk and impact of climate change on rice-based production systems.

2.4.1.2 Objectives and targets

The production constraints associated with environmental changes and the current yield ceiling for improved rice varieties are global and a challenge to all rice improvement programs. Generating genomics and phenomics data resources for multiple environments and climatic conditions, and understanding the genetic control of crop adaptation/performance constitute a strategic bottleneck. The large dataset generated by the Global Rice Array of FP4 will be open to benefit public rice breeding and provide the information needed to tailor the use of rice diversity to meet future needs. Moreover, the Global Rice Array will involve rice improvement and research programs from all major rice-growing environments across the globe, including international and national institutions from the public and private sector.

FP4 intends to accelerate gene and trait discovery in order to help optimize the use of genetic diversity under different climate scenarios. It will use knowledge from partners worldwide, including CCAFS, to select climate change sentinel sites in key rice production environments across the globe and assess the impact of climatic variation on rice crops. The use of populations of diverse genetic background as biological antennae to sense the environment under different climate scenarios will provide a head start in developing climate-smart technologies in FP3 and FP5. FP4 will collaborate closely with CCAFS to make use of predictive tools such the analogue approach (Rameris et al 2011) to identify adaptive germplasm for different locations. At a regional level, the rice array will enhance preparedness for deploying adapted technologies based on good knowledge of specific features of future rice production environments.

FP4 will collaborate extensively with NARES to capture local knowledge and expertise. Each phenotyping site will serve as a research capacity development site for young rice scientists, both men and women, in NARES and equip them with skills in modern breeding, phenotyping, computational science, and informatics. Phenotyping, genotyping, and climatic data will be integrated in a rice data hub publicly available and connected to other Big Data platforms.

FP4 will deliver the following research outcomes to selected sub-IDOs, IDOs, SLOs, and cross-cutting issues of the SRF (see also the performance indicators matrix):

FP4 research outcome	Sub-IDO	IDO	SLO or cross-cutting issue
Predicted global rice production risks used to guide development and targeting of climate change-adapted technologies at least for the most vulnerable rice agroecosystems	Enhanced adaptive capacity to climate risks	More sustainably managed agroecosystems	Improved natural resource systems and ecosystem services
A functional global phenotyping network composed of 30% non-CRP partners (including self-sponsored), and genetic donors (>10) and ideotypes (2-4) adopted by breeding programs to develop climate-smart rice varieties	Enhanced genetic gain	Increased productivity	Reduced poverty Improved food and nutrition security for health
Characterized pathogen populations and diversity used to predict varietal deployment for at least 3 major rice diseases	Enhanced capacity to deal with climatic risks and extremes	Mitigation and adaptation achieved [to climate change]	Climate change
At least 5 major QTLs/genes that are stable across environment and management, for all rice mega-environments, integrated in the respective varietal development pipelines	Enhanced genetic gain	Increased productivity	Reduced poverty Improved food and nutrition security for health
A functional rice data hub providing open access phenotypic and genotypic information and data analysis tools for users worldwide	Increased conservation and use of genetic resources	Increased productivity	Reduced poverty Improved food and nutrition security for health
Increased capacity for innovation in pre-breeding and Big Data in partner research organizations	Increased capacity for innovation in partner research organizations	National partners and beneficiaries enabled	Capacity development

2.4.1.3 Impact pathway and theory of change

Fig. 4.1 presents the impact pathway and theory of change, with assumptions, risks, and associated enabling actions of FP4. Impact is generated on food security, productivity, producers, and environmental resilience. It will be achieved through better adapted germplasm (via FP5) and improved regional/national mitigation strategies (via FPs 1, 2, and 5). Anticipated risks are mainly related to (1) the efficiency and timeliness of the various interdependent actions in FP4 and FP5, (2) effective coordination and choices in methodology, (3) potentially inaccurate predictions of representative sites and ideotypes, (4) weak testing network deficient in environmental characterization, (5) inadequate agronomic and breeding capacity at action sites, and (6) selected sites not being representative of key constraints and climate change.

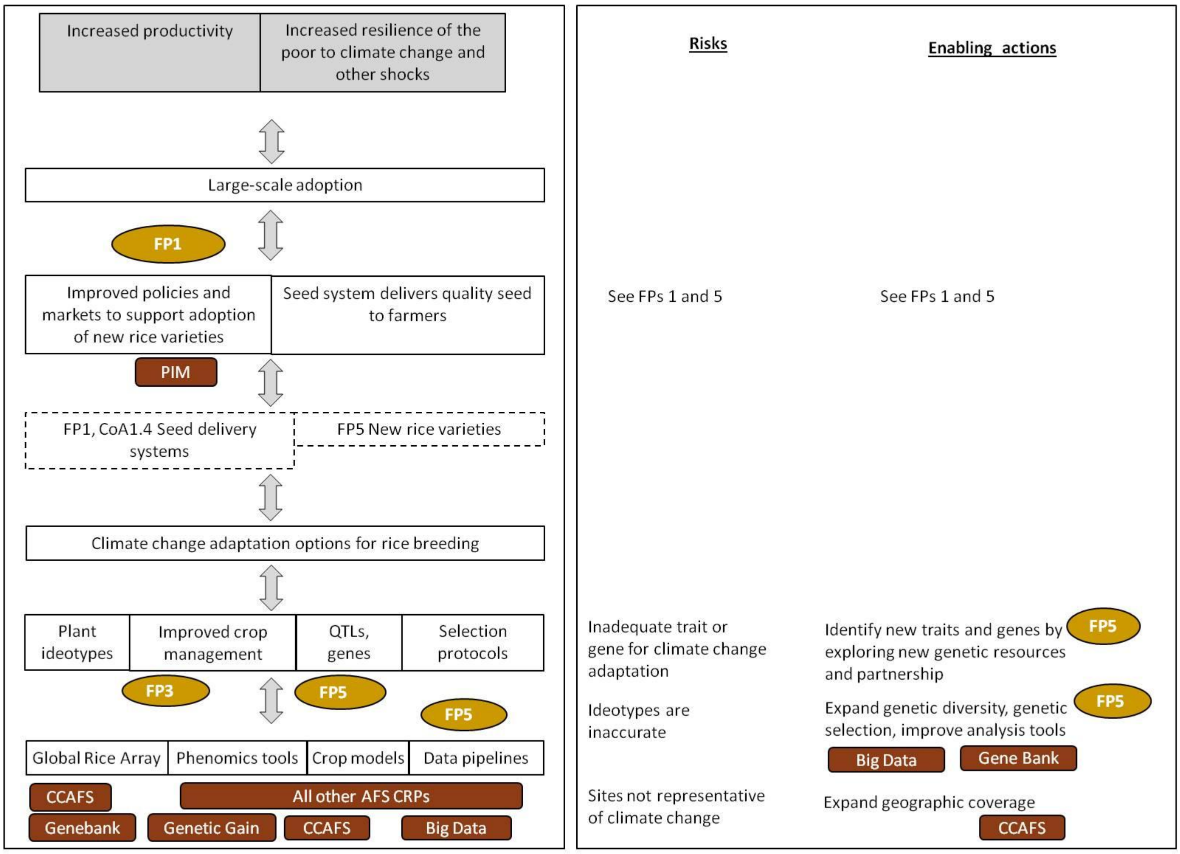

Fig. 4.1. Impact pathway (left) and theory of change (right) of FP4. Grey boxes are IDOs, ovals (with FP x) refer to links with other FPs, and the dark boxes refer to links with other CRPs (see Annex 12 for abbreviations).

Within FP4, achieving targets will depend on (1) good trait expression at selected sites; (2) easy germplasm exchange across countries and availability of sufficient seed; (3) existing genomic data and efficient genome-wide association studies (GWAS) pipelines; (4) availability of robust prediction models for the rice crop, pathogens, and future climate scenarios; and (5) a well-structured database and rapid data-analysis pipelines for large datasets. The enabling actions will include upgrading agronomic and breeding capacity as well as data handling, and regular re-analysis of the Global Rice Array sites using additional data in consultation with CCAFS. Use of consistent metadata and agri-semantics in the Big Data platform will allow efficient contextual searches, including links between genetic, environmental, and gender aspects, enabling highly targeted use of the data. Although breeders will be the most frequent direct users of FP4 outputs, agronomists, economists, and policymakers will also benefit from such outputs as risk and impact maps.

2.4.1.4 Science quality

The revolution in knowledge and methodology in genomics and informatics has opened up vast opportunities for accelerated and more effective crop improvement. However, optimizing the use of genetic diversity under different environments and climatic conditions remains a major challenge in plant breeding. Large-scale phenotyping in multiple environments offers tremendous power to understand the complex interactions among G × E × M. Such knowledge is critical for the identification of combinations of genes and traits that are adaptive to changing climatic regimes. By exposing a common set of genetic populations to a range of climate conditions, FP4 will reveal the

genetic networks that condition adaptive traits across major rice production environments. The diagnostic genetic populations placed in different locations serve as "biological antennae" assessing the response of genetic resources to climate change in a much shortened timeframe, thus enabling better preparation for future climatic scenarios.

FP4 will provide a large store of genetic potential for rice improvement. State-of-the-art HTP phenomics technology will be deployed and partners will be trained to exploit the data resources to empower many breeding programs worldwide.

The novelty of the proposed project comes from the integration of the best advances in several disciplines. The new genetic resources underpinning the Rice Array are specially designed to have high genetic diversity for sensing the environment. The range of scientific expertise assembled has the depth and scope needed, covering genetics, breeding, physiology, crop modeling, GIS, and computational science. The team involved in the project has a track record of publishing on genetic resources, large-scale phenotyping, crop modeling, and GIS applications. These attributes ensure a high probability of success in implementing the work plan.

As recommended by the IEA review of the science quality of GRiSP (recommendation #2, IEA report, p xvi), FP4 management will foster strong research collaboration with partners in ARIs (see section 2.4.1.7 on partnerships). FP4 will aim for jointly authored, high-quality publications in high-quality international journals.

2.4.1.5 Lessons learnt and unintended consequences

FP4 and the establishment of a Global Rice Array are completely new; however, the project builds on elements and learning from GRiSP Theme 1 (Harnessing genetic diversity to chart new productivity, quality, and health horizons). In particular, the existing global phenotyping network of GRiSP has provided valuable lessons: (1) ensure that populations are genotyped before engaging many partners in costly phenotyping efforts; (2) take phenotyping/GWAS closer to the breeding process by giving sufficient emphasis to recombinant populations (as opposed to gene discovery in exotic accessions, which is complementary); (3) ensure timely availability of data infrastructure and tools to avoid a backlog, which could cause disorder; and (4) ensure that the implementation of crucial actions, in terms of timeliness for the Global Rice Array, is controlled by network management to avoid potential disruptions to the collective workflow. FP4 will develop a Big Data platform based on the work of the International Rice Informatics Consortium (IRIC) created under GRiSP.

FP4 mainly engages in upstream research, and its (intended or unintended) consequences for the CGIAR SLOs are mostly realized through FP5, which takes up and uses the outputs and outcomes of FP4. A specific risk of unintended consequences is that FP4 genetic or trait discoveries are not widely shared and thus do not reach a large number of beneficiaries (e.g., breeders in national programs). To minimize this risk, FP4 will be as inclusive as possible by partnering with diverse stakeholders, who will define their needs in terms of phenotyping and target traits.

2.4.1.6 Clusters of activity (CoA)

FP4 will establish field sites using GIS, climatic analogue tools (Ramírez-Villegas et al 2011), FP1 mapping data, and extensive consultation with NARES partners and CCAFS. Phenotyping of reference genetic populations and local breeding materials will be conducted at each site. Through FP4,

investment will be made to upgrade phenotyping capacity by improving infrastructure and the technical skills of researchers, and by deploying phenotyping systems.

Through GWAS, the phenotyping and genotyping data will be analyzed to discover new genes underlying traits relevant to adaptation. FP4 will use the Global Rice Array sites as regional observatories for pathogen populations of major diseases. The pathogen population data will provide a guide to effective deployment of disease-resistant varieties.

A data integration platform will be established to store and analyze the large dataset generated from genotyping and phenotyping. The project will provide support and provide incentives to key site operators to ensure that high-quality data are collected. The potential benefits of the dataset should attract participation of many national programs. For countries with large breeding programs, FP4 will mobilize financial support from national governments. Together, the outputs of the CoAs will be channeled to FP5 where varietal development will be accelerated through new understanding of the adaptive traits and the interactions of G x E x M. Especially the understanding of G x E x M interactions is critical to the improvement of rice based systems - because G x E x M interactions for rice (e.g. direct seeded short duration varieties) are critical for complex rotations. The genetics required for the rice components of such systems will be dissected in FP4.

4.1 Establishing a worldwide field laboratory

CoA4.1 establishes the Global Rice Array, a physical array (network) of field laboratories and trial sites, characterizes and monitors the environments (e.g., through “antenna” experiments), conducts crop/pathogen trials, and develops models to quantify and map the impact of abiotic/biotic factors on yield. The scale and scope of phenotyping will depend on the function of a site within the network and on breeders’ requirements for regional or global data.

Sites will be selected based on geographic location, climatic pattern, local rice production systems, and infrastructure criteria such as proximity to breeding and laboratory facilities. As much as possible, marginal/low-lying areas that are usually left to women rice producers will be captured in the Global Rice Array. Existing trial sites of IRRI, AfricaRice, and CIAT and of other CRPs, notably CCAFS, will be included as appropriate. Linking with CCAFS, site selection will be guided by both current and future climates using such approaches as the analog-site principle (Ramírez-Villegas et al 2011) and the Target Prone Environment principle).

Besides the analog site analysis, CoA4.1 will work with CCAFS on areas of mutual interest. CCAFS has expertise on past, present, and future environments and their impact on yield, as well as on characterizing breeding programs’ target populations of environments. CoA4.1 will use the data to identify priority constraints and traits, define extrapolation domains, and design ideotypes to feed into FP5. Risk, climate impact, and varietal performance maps generated by CoA4.1 in collaboration with CCAFS will be provided to agronomists, economists, and policymakers (through FP3 and FP1).

The key products of this CoA will be (1) a Global Rice Array consisting of equipped and well-characterized field laboratories and trial sites, (2) information on yield potential and biotic/abiotic factor contributions to yield variability by environment and varietal type, and (3) risk management database and maps for policymakers.

4.2 Global phenotyping

Phenotyping, in the sense of measuring trait expression in large populations, is a necessary step for gene discovery, marker development, and breeding. In GRiSP, a Global Rice Phenotyping Network

was established to characterize subspecies diversity for yield potential and abiotic-stress-related traits in different environments. GWAS led to the identification of many putative genes/alleles that breeders can potentially use. Building on this, as well as on available genome sequences and SNP maps, a new concept for global phenotyping will be implemented in CoA4.2. It will integrate environmental characterization, gene discovery, and marker development and validation.

In the initial stage of CoA4.2, phenotyping capability will be increased to enable each site to measure a common set of agronomic traits from the reference populations. These include measurements of plant growth and yield-related traits. Response to environmental stresses will be measured at sites where stresses are present. Depending on the locations and local capability, additional phenotyping methods will be implemented. For selected sites, HTP phenotyping in the field will be implemented using tractor-based and drone-based technologies. At sites with laboratory capability, a HTP, low-cost, analytical pipeline, based on Fourier transform infrared spectroscopy technology for rice tissue and grain chemistry (including nutrition and consumer health aspects), will be deployed. This will help expand the scope of phenotyping to traits that were previously too costly to screen or characterize genetically. The phenotypic data collected from field and laboratory at multiple sites will provide an assessment of the response of rice diversity to specific environmental and climatic conditions.

The genetic populations to be phenotyped will include (1) subsets of the 3,000 rice genomes already sequenced, (2) the PRAY panel that was characterized in the GRiSP New Frontier Project, (3) nested association mapping (NAM) populations produced by CIAT and AfricaRice, and (4) multiparent advanced generation intercross (MAGIC) populations produced at IRRI. The NAM populations were developed from 20 diverse crosses (4,000 lines total). NAM is a powerful design that allows ultra-fine mapping of QTLs. The NAM populations are being sequenced under FP5. The MAGIC populations were derived from 16 founder elite parents and recombined by intercrossing to generate high genotypic diversity (Bandillo et al 2013).

An important feature of these populations is that they represent genetic diversity from both landrace and elite varieties. Further, these populations have been densely genotyped and are ready for phenotype-genotype association analysis. Additional training populations designed for genomic selection in FP5 can be evaluated in selected sites. Besides these genetic populations, CoA4.2 will encourage NARES partners to put their elite breeding populations in the same site to enable comparative analysis.

The phenotypic information on trait diversity and variable expression obtained from the Global Rice Array will be used to predict better-adapted ideotypes. This will make use of rice growth models to simulate trait-trait and G × E × M interactions, including morphological traits. Ideotypes, in terms of specific trait combinations that improve resilience and yield, will be proposed as guidance to breeders.

An important aspect of this CoA is the speed of data acquisition, analysis, and sharing to accelerate data transfer from phenotyping to breeders and geneticists, as well as the rapid shuttling of populations and data between phenotyping, GWAS (CoA4.4), and breeding (FP5). Through partly automated data acquisition and data processing (CoA4.5), users will have timely access to multisite results. The Global Rice Array will actively engage NARES and other partners to participate when appropriate with their own sites or facilities, and with joint methodology development and technology transfer.

4.3 Genetics of rice plant interaction with the biotic environment

Rice is susceptible to many fungal, bacterial, and viral diseases. Because of climate change and changing production systems, previously minor diseases such as sheath blight and false smut have become new threats. The dynamic nature of host-pathogen interaction requires a constant search for diverse resistance mechanisms and deployment strategies to manage disease epidemics.

The impact of rice disease depends largely on pathogen population diversity, climatic conditions, and the genetic background of varieties. The interactions between pathogens, host, and environment (including cultural practices) will ultimately determine the effectiveness and durability of resistance. The Global Rice Array offers the opportunity to develop a long-term observatory of disease impacts on representative sets of genetic diversity. CoA4.3 includes pathogen monitoring at key breeding sites, characterizing the pathogen virulence spectrum and genetic diversity, and hot-spot screening of breeding material for new resistance. Results of CoA4.3 will feed into FP5 for breeding new varieties with enhanced resistance to diseases.

There is growing evidence that soil microbiomes can improve plant health. In collaboration with the University of California-Davis, initial experiments are being designed to compare microbiomes under different cropping environments at IRRI. The Global Rice Array can provide a range of diverse sites for examining the potential of microbiomes in sustaining rice production.

4.4 Discovery of genomic associations

Since all phenotypic information delivered by CoA4.2 will be on populations that have been genotyped by either re-sequencing or genotyping-by-sequencing, QTLs can be readily identified by GWAS. Most available QTLs for rice have unknown environment interactions. CoA4.4 will therefore combine QTL discovery with characterization of the stability of their effects (G × E and G × E × M) across the Global Rice Array sites.

CoA4.4 will apply GWAS methods to identify trait-loci associations and will build linear mixed models and apply machine-learning techniques for predicting phenotypes from genotypes and environment. Improved GWAS pipelines and tools will be used to conduct multienvironment and multitrait analyses to identify QTLs and underlying candidate genes. Confidence in these discoveries will be strengthened by the G × E and G × E × M information on their effects.

Cross-species searches for synteny and gene function will further strengthen them (engaging other CRPs). This information will be fed into FP5 for further validation (e.g., on different genetic backgrounds), marker development, and use in breeding. Meta-analysis of multiple gene-trait associations will be conducted to identify co-localizations and to explore potential cross-adaptations, which may be physiological or controlled by a network of genes of particular interest for breeding.

In the GRiSP New Frontier Project, the PRAY panel was characterized in different locations and GWAS were undertaken. Data analysis pipelines and tools developed in CoAs 4.4 and 4.5 can be trained on these datasets and be rapidly validated. Consolidated genetic associations in the PRAY panel can then quickly move to gene discovery and marker development in FP5 while the other populations are progressively moving in the phenotyping and GWAS pipelines.

4.5 Big Data integration platform

A large amount of data has been generated by GRiSP and will continue to be generated by RICE through the work of FPs 4 and 5. A cross-cutting Big Data platform is essential to connect the different FPs. Specifically, FP4 needs a platform for fast genotypic-phenotypic analysis and generation of markers for breeding in FP5.

CoA4.5 will create a Big Data integration platform to integrate such data as well as create linkages to databases of other CRPs and the proposed Genetic Gain Platform. The Big Data integration platform will provide an efficient mechanism for data sharing and communication not only within RICE but also with other rice researchers and the plant research community in general.

The development of the Big Data platform will build on the work of IRIC, in which many research institutions from the public and private sector already participate, for example, Cirad, University of Arizona, University of Queensland, The Genome Analysis Center, and Bayer Crop Science. The Big Data platform will expand such partnerships.

The platform will support the Global Rice Array by integrating the following activities:

(1) *Automated phenotyping data capturing*. This activity will result in building a new or adopting an existing tool for mobile devices to ensure accurate, easy, and quick processing of phenotypic data collection, minimize errors in data collection, and provide initial quality control on the data.

(2) *Data storage*. Phenotypic data have a complex structure, which should be properly reflected in the relational database. Data curation will adopt existing crop, trait, and other ontologies. Data structures for genotyping and sequencing data with gene ontologies have already been developed and will be used in this project. CoA4.5 will establish sufficient storage space for digital images.

(3) *Data analysis*. CoA4.5 will apply statistical description analysis to the phenotypic data to ensure data quality and to identify outliers. It will also apply methods of quantitative genetics to estimate environmental and genetic contributions to the phenotypes.

(4) *Data sharing*. All data from this project will be publicly available and CoA4.5 will develop user-friendly web interfaces for browsing, searching, and downloading the results.

2.4.1.7 Partnerships

RICE is uniquely positioned to lead a global program using well-characterized genetic populations, multiple locations, and different agronomic practices (G × E × M) as a platform for discovering new traits needed for climate change adaptation. Most of its partners can be categorized as partners at the discovery research level. Following the IEA review recommendations of GRiSP to "encourage and incentivize stronger research collaboration with partners in advanced research institutes for further improving the overall quality of the scientific output" (IEA review recommendation #2, IEA report, p xvi), FP4 will partner with such ARIs as Cornell University, University of Arizona, University of Queensland, The Genome Analysis Center, and Bayer Crop Science. In addition, NARES partners are involved, especially through the establishment of the Global Rice Array. The rice phenotyping network of GRiSP already involves many partners from Africa, Asia, Australia, Europe, Latin America, and the US, each of which brings in a particular expertise. RICE will aim to expand this network with additional partners from countries that have a large investment in rice research, such as China, India, Indonesia, and Vietnam. RICE will continue GRiSP's coordination of a global rice modeling team (part of AgMIP: Agricultural Model Intercomparison Program) and will use the rice simulation model ORYZA2000. This model is integrated in the DSSAT (Decision-Support Systems for Agrotechnology Transfer) suite that is used in CCAFS and PIM, connecting the crop modeling work of these CRPs with RICE.

The comparative advantage of RICE (as opposed to actions of individual centers) resides in (1) distributing research that surpasses an individual center's capacity, (2) gaining access to the necessary range of environments globally, and (3) using increased power of analysis resulting from the large amount of data on any given panel of genotypes.

2.4.1.8 Climate change

Climate change is central to FP4. Existing climate variability will be used to identify proxy (analog) sites for future conditions. By combining the RICE rice growth model with climate prediction models generated by CCAFS, FP4 will evaluate the resilience of breeding materials (FP5) and develop ideotype concepts. These will guide breeding strategies for adaptation to anticipated climate change, particularly where current varieties are poorly adapted. The identification of traits (associated genes) related to nutrient- and water-use efficiency will contribute to the development of rice varieties with reduced needs for these inputs and that can be grown under management systems with reduced emissions of GHGs (in collaboration with FP3 and FP5).

2.4.1.9 Gender

FP4 will follow the overall gender strategy of RICE (Annex 4), and will have the following specific elements:

- FP4 will strive for gender balance in the leadership roles at flagship project and CoA levels.
- FP4 is uniquely positioned to train a new generation of scientists equipped with the skills set needed in modern plant breeding and agronomy. To promote women's careers in plant sciences, FP4 will actively recruit female candidates to participate in training courses and degree programs (MS and PhD) with affiliated universities.
- FP4 will facilitate the development of climate-resilient varieties in FP5 and will work closely with FP5 to target traits that can benefit women such as drought tolerance, labor-saving, cooking and eating quality.
- By making its data an open resource, FP4 ensures that all rice stakeholders independently of their age and sex are given an equal right to access and use the data.

2.4.1.10 Capacity development

The overall capacity development strategy of RICE is given in Annex 3. FP4 will specifically strengthen research capacity in its partner organizations. The Global Rice Array sites are well suited for practical training sites. These sites will act as focal points to develop locally adapted technologies, providing technical support, and demonstrating technology to partners and adopters. As they emerge, new research methodologies will be shared with NARES and other CRPs through workshops, short-term training, and degree training. Sandwich/joint training programs with ARIs will be favored whenever possible to tap into expertise available outside RICE.

In a gap analysis of capacity, GRiSP identified important areas for capacity development, including bioinformatics to ensure an intelligent use of tools for GWAS; genotyping-by-sequencing; genetic mapping; new phenotyping methods for disease scoring; remote sensing; instrumentation; development of sound experimental protocols; experimental error tracking; data management; and modeling to accurately account for G x E x M and climate change.

Phenotyping sites hosted by NARES partners will provide ideal locations for training in these areas. Training will be on the use of measurement equipment, including climate stations and diagnostics kits; and data collection, management, and analysis. FP4 will explore sandwich programs with universities for training PhD and MS students to enable them to work in each of the five CoAs.

Active interactions with stakeholders—breeders, geneticists-physiologists, and other users—will be crucial for application of Global Rice Array results.

2.4.1.11 Intellectual asset and open access management

FP4 follows the RICE policies and strategies on intellectual asset management, open access, and data management (Annexes 9 and 10), which are in line with the CGIAR Principles on the Management of Intellectual Assets and their Implementation Guidelines, and with the CGIAR Open Access and Data Management Policy and its Implementation Guidelines. FP4 intellectual assets/research data include (1) readily accessible data on novel genes/alleles for rice adaptation and productivity in different environments and future climates, along with donor materials and selection tools for them; (2) knowledge of environment profiles, risk factors associated with climate change scenarios, and varietal adaptation; (3) ideotype concepts as blueprints for breeding strategies; and (4) a public database for phenomics, genomics, environment profiles, and trait−G × E × M interactions.

Data are made widely and publicly accessible through various pertinent and dedicated websites such as the International Rice Information System (providing access to structured information on rice germplasm pedigrees, field evaluations, structural and functional genomic data—including links to external plant databases and environmental [GIS] data), and the Rice SNP-Seek Database (providing genotype, phenotype, and variety information based on the 3,000 Rice Genomes Project). FP4 will develop public-/private-sector partner agreements for the use of discovered genes/materials in order to ultimately reach as many farmers and national breeding programs as possible. Access to data and germplasm will be guided by customized Material Transfer Agreements and specific collaborative agreements.

2.4.1.12 FP management

FP4 is a network of partners, in particular NARES. Thus, management of the project must involve stakeholders who participate in the Global Rice Array. The essential elements of a management plan for FP4 will include the FP leaders Dr. Camilla Rebolledo (CIAT) and Dr. Hei Leung (IRRI), and formation of an inclusive committee for developing governance mechanisms that will include representatives of different institutes and network stakeholders and users such as breeders, geneticists, and Big Data managers. The committee will nominate leaders for individual CoAs and will develop consensus and recommend activities matching the common interests of the network. Each CoA is co-led by a team of senior scientists (focal persons) consisting of one or more representatives from each center. Annex 8 presents the list of senior scientists and a set of selected curricula vitae.

The FP4 coordinator and management team will organize workshops, using the FP4 leader's coordination budget. Also, the team will facilitate communication across the participating centers and institutes to enhance information and knowledge sharing. Developing an integrated platform with collaborating groups from different organizations requires regular communication, using commonly accepted tools for project management and common source control repositories (for example, BitBucket).

2.4.2 Flagship Budget Narrative

2.4.2.1 General Information

CRP Name	CGIAR research program on rice-based agri-food systems, RICE
CRP Lead Center	International Rice Research Institute
Flagship Name	Global Rice Array
Center location of Flagship Leader	Colombia/Philippines

2.4.2.2 Summary

Total flagship project budget summary by sources of funding (US$).

Funding Needed	2017	2018	2019	2020	2021	2022	Total
W1+W2	3,334,146	3,385,824	3,443,641	3,521,753	3,589,556	3,660,043	20,934,964
W3	5,113,691	5,259,161	5,411,035	5,574,397	5,738,744	5,908,762	33,005,790
Bilateral	2,235,360	2,331,873	2,435,163	2,543,295	2,656,504	2,775,041	14,977,236
Other Sources							0
Total	10,683,196	10,976,858	11,289,840	11,639,445	11,984,806	12,343,845	68,917,990

Funding Secured	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Assumed Secured)	3,334,145	3,385,824	3,443,641	3,521,753	3,589,557	3,660,043	20,934,964
W3	3,075,652	2,273,515	490,260	514,773	540,512	567,537	7,462,249
Bilateral	1,103,802	939,694	578,812	607,753	638,141	670,048	4,538,251
Other Sources							0
Total	7,513,601	6,599,034	4,512,714	4,644,279	4,768,209	4,897,628	32,935,464

Funding Gap	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	-2,038,039	-2,985,645	-4,920,775	-5,059,624	-5,198,233	-5,341,225	-25,543,541
Bilateral (Fundraising)	-1,131,557	-1,392,179	-1,856,351	-1,935,542	-2,018,364	-2,104,993	-10,438,985
Other Sources (Fundraising)	0	0	0	0	0	0	0
Total	-3,169,594	-4,377,823	-6,777,125	-6,995,164	-7,216,595	-7,446,216	-35,982,517

Total flagship project budget summary by natural classification (US$).

	2017	2018	2019	2020	2021	2022	Total
Personnel	4,535,986	4,699,046	4,868,393	5,044,287	5,226,998	5,416,809	29,791,522
Travel	554,036	566,572	577,623	591,212	605,361	620,095	3,514,901
Capital	266,051	227,853	184,996	157,496	165,370	173,639	1,175,407

Equipment							
Other Supplies and Services	3,328,875	3,404,840	3,530,142	3,662,620	3,748,421	3,837,802	21,512,702
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	834,702	887,831	903,494	919,628	936,245	953,361	5,435,264
Indirect Cost	1,163,544	1,190,713	1,225,189	1,264,200	1,302,407	1,342,137	7,488,192
Total	10,683,194	10,976,855	11,289,837	11,639,443	11,984,802	12,343,843	68,917,974

Total flagship project budget summary by participating partners (US$).

	2017	2018	2019	2020	2021	2022	Total
IRRI	7,018,454	7,183,938	7,356,613	7,534,469	7,717,660	7,906,347	44,717,483
Africa Rice	1,896,235	1,950,219	2,012,569	2,102,406	2,178,502	2,258,401	12,398,333
CIAT	1,768,507	1,842,700	1,920,656	2,002,569	2,088,644	2,179,096	11,802,172
Total	10,683,196	10,976,857	11,289,838	11,639,444	11,984,804	12,343,844	68,917,983

Explanations of these costs in relation to the planned 2022 outcomes

Flagship project 4 is composed of 5 clusters of activity as described in the FP4 narrative section *2.4.1.*6. Each cluster of activity delivers one or more outcomes each (with a related set of milestones), as listed in the Performance Indicator Matrix, Tables B-D. The required investment (budget) for each outcome is listed in Table B of the Performance Indicator Matrix. The Clusters of activities (CoA) and their outcomes are:

FP4	Cluster of activity	Outcome
4.1	A worldwide field laboratory	Predicted global rice production risks used to guide development and targeting of climate change-adapted technologies at least for the most vulnerable rice agroecosystems
4.2	Global phenotyping	A functional global phenotyping network composed to 30% by non-CRP partners (including self-sponsored), and genetic donors (>10) and ideotypes (2-4) adopted by breeding programs to develop climate-SMART rice varieties
4.3	Biotic rice-plant interactions	Characterized pathogens populations and diversity used to predict varietal deployment for at least 3 major rice diseases
4.4	Discovery of genomic associations	At least 5 major QTLs/genes that are stable across environment and management, for all four mega rice environments, are integrated in the respective varietal development pipelines
4.5	Big Data integration platform	A functional rice data hub providing open access phenotypic and genotypic information and data analysis tools to global users

Besides the above outcomes, each cluster of activity contributes to various capacity development actions, captured in the joint outcome “Increased capacity for innovation in pre-breeding and Big Data in partner research organizations”. The budget of each cluster of activities depends on the type of activities, and involves typically the establishment and maintenance of high-quality field-experimental sites under the global rice array (CoA4.1); the development and application of simulation models for crop growth (CoA 4.1); the conduct of experiments at the global rice array sites and the collection of phenotyping data, including the development, testing, and use of modern sensors (CoAs 4.1 and 4.2); collection, analysis, and reporting of plant and soil biome samples (CoA4.3); collection of plant samples, determination of genetic make-up, genetic and genome-wide

analysis (CoA4.4); development and use of a big data platform that makes (open) accessible all collected genotypic, phenotypic, and environmental data, analysis tools, and analyses conducted (CoA4.5); workshops; stakeholder consultations; development of communication materials (papers, flyers, brochures, websites, video, etc); partnership development; partner capacity development for research, innovation, and delivery; communication; (open access) data mana*gement (all CoAs)– see section 2.4.2.5* below.

Risk to spending as planned

The RICE FPs are 'umbrella projects', which include a large number of bilateral projects any given year. Hence, the FP budgets are dictated by the collective investments that donors want to make through W1/2, W3, bilateral, and 'others means'. The investment levels are unpredictable: 1) the W1-3 donors can not commit to 6-year funding obligations and the W1-3 investments into the CGIAR fluctuate substantially each year, and 2) 70-80% of the budget is contributed to by bilateral projects, the majority of which still need be developed and secured. Hence, the likelihood that budgets are obtained - and spent - exactly as targeted, decreases as the CRP progresses in time. Each year, updates on investments expectations and budgets will be developed, and spending managed accordingly. At the level of bilateral projects, spending risk is managed by project leaders following procedures spelled out in project contracts. For W1-3, spending risk is managed by flagship project leaders. Project leaders get regular updates on actual spending rate through OCS, and are required to make project adjustments if under- or overspending occurs beyond the (donor-) accepted range (usually 10% of line items).

2.4.2.3 Additional explanations for certain accounting categories

Benefits

Benefits are separated out and include pension, housing, vehicle, home leave, medical insurance, and education allowances.

Other supplies and services

- Various software for development and application of crop growth simulation models and downscaled climate models;
- Costs for establishment and running of the Global Rice Array experimental sites and phenotyping platforms: seeds; agro-chemicals, irrigation water, plastic sheets, etc;
- Cost for establishment of weather station (if nonexistent) and measurement of weather data: radiometer, temperature, wind speed, humidity, pan evaporation, sunshine hours
- Cost for data collection: plant, soil, and water sampling; harvesting; sample processing (small supplies such as paper bags, strings, labels, markers); bar coding; tablets for data entry; small equipment for measurements such as SPAD meter, canopy analyzer, infrared sensors, soil moisture tensiometers; etc;
- Cost for laboratory analysis: plant chemical analyses; DNA extraction; genetic and genomic analyses; soil and water chemistry; soil physics;
- Cost for data analysis, data management (Big Data platform), and data publication (open access): computer software, computing platforms (cloud, rental),
- Various others: workshops; partner capacity development (training materials, training course costs, costs for on-the-job training, survey costs for capacity needs); publications

(leaflets, journal papers, brochures, websites); communication costs; various small office supplies.

Costs for the above vary by continent and country (e.g., costs in Africa being higher than in Asia), and local budgets are developed in accordance with local costs in detail prior to conduct of any activity.

2.4.2.4 Other Sources of Funding for this Project

1. Aggressively seek additional funding from bilateral sources. 2. All RICE FPs have a modular set of outcomes and activities related to various levels of donor investment: with fluctuations in donor investment, budgets, activities, outcomes and milestones can easily be adjusted accordingly. 3. Seek new partnerships based on self-funding principles (in kind contributions included) that can contribute to outcomes that are underfunded

2.4.2.5 Budgeted Costs for certain Key Activities

Estimated average annual costs (over 6 years) for key activities (US$).

	Annual cost (US$)	**Please describe main key activities for the applicable categories below, as described in the guidance for full proposal**
Gender	227,744	Mostly through training and capacity development of women researchers. See details in section 2.4.1.9 of the FP description, and section 1.0.4 of the main RICE description, and Annex 4 on gender
Youth (only for those who have relevant set of activities in this area)	227,744	Mostly through training and capacity development of young researchers. See details in section 1.0.5 of the main RICE description, and Annex 5 on youth
Capacity development	569,360	This FP engages in individual education and training activities and in institutional development (mainly on phenotyping, big data handling, modern genomic tools); capacity development of research partners. See details in section 2.4.1.10 of the FP description, section 1.0.10 of the main RICE description, and Annex 3 of the main RICE description
Impact assessment	-	All RICE impact assessments are carried out under CoA 1.5 of FP1
Intellectual asset management	170,808	Professional intellectual asset management services are provided throughout RICE and estimated to be around 1%, see Annex 10 to main RICE proposal for details
Open access and data management	1,708,079	Processing, validating, curation and quality control of collected data from surveys and experiments; data storage; making data accessible through standardized ontologies and descriptions; maintaining databases, websites, and other data delivery mechanisms. See section 2.4.1.11 of the FP description and Annex 9 of the main RICE description with details on cost items

Communication	569,360	Engages in dialogue to scale up results, through engagement with national and regional bodies as listed in section 1.0.9 of the main RICE proposal, using tools such as media releases, fora and ministerial roundtables; engages with actors on the ground to scale out technologies and practices, through the participation of multi-stakeholder platforms and scaling out activities (convened in CoAs 1.3 and 1.4), using tools such as participatory impact pathway mapping (PIPA), stakeholder and outcome mapping, problem tree definition and analysis; contributes information and content to overall communicate about the program, the science, results and progress; communicates and engages with partners through collaborative and participatory approaches to R&D and convening various networks, community of practice, platforms, and consortia; promotes learning and sharing of information to improve communications and collaboration. Development of journal papers, manuals, technical reports, and other communications media such as video, audio, websites, etc. Participation in conferences, workshops, forums, stakeholder meetings, etc.

2.4.2.6 Other

Being a new FP (compared with GRiSP) with relatively few bilateral projects, W1,2 funding is critical to the success of FP4. W1,2 funds are used to 'kick-start' the establishment of the Global Rice Array at a few key sites, building on the multi environment [breeding] trials (MET) and the phenotyping network established under GRiSP. Upstream research will be supported on the development of a (open access) Big Data integration platform (connecting the CGIAR Big data Platform) and the exploitation of its content for the discovery of genomic associations. The Tables B-C of the Performance Indicator Matrix indicate the contribution of W1,2 to the delivery of FP4's outcomes and sub-IDOs in financial terms.

2.4.3 Flagship Uplift Budget

Total uplift budget for six years for flagship project 4: Global rice array.

Outcome Description	Amount Needed (US$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other (%)
Global phenotyping network expanded to include 3-5 countries in each major-rice growing continent, and feeding information to all major rice breeding programs across the continents	9,000,000	30	0	70	0
Pathogen information of all major rice diseases across the continents feeding into variety resistance breeding of all major rice breeding programs globally	9,000,000	30	0	70	0
Rice phenotypic and genotypic information integrated with environmental and socio-economic Big Data open access available to global users	9,000,000	30	0	70	0

2.5 Flagship project 5: New rice varieties

2.5.1 Flagship Project Narrative

2.5.1.1 Rationale, scope

The contribution of new crop varieties to improving food security and reducing poverty is one of the best documented outcomes of international agricultural research, especially for crops such as rice and wheat (Evenson and Gollin 2003, Fan et al 2005, Raitzer and Kelley 2008, Renkow and Byerlee 2010). Genetic crop improvement is one of the pillars of the CGIAR and it features prominently in the SRF. In the rice sector, genetic crop improvement remains essential. Yields still need to increase to keep up with the increasing global demand for rice, and increasing genetic gain is one of the two main ways to increase yields (the other being improved agronomy/crop husbandry to close yield gaps, see FP3). Current annual rates of genetic gain of 0.8–1.0% need to increase to 1.5–2.0% to meet increased food demand in the future. Genetic gain includes raising intrinsic yield potential as well as increasing tolerance for, and resistance to, yield-limiting factors such as biotic and abiotic stresses. Stresses like drought, flooding, salinity, and adverse temperatures are already severe in many rice-growing environments, and will generally become more severe in the future because of climate change, which will also induce the emergence and spread of new pests and diseases. To respond to these challenges, a constant stream of new rice varieties with enhanced yield potential, yield stability, and multiple resistances to various stresses must be available to farmers.

Empirical research and socioeconomic analysis consistently shows feminization of rice farming in Asia, Africa, and South America because of rising off-farm wages and increased climatic stresses such as drought, flooding, and salinity. These two factors have led to a growing rate of male outmigration in small-scale farming households. As a result, farming responsibilities, particularly in unfavorable environments, are increasingly being taken care of by women farmers. Ironically, women farmers also suffer the most from food insecurity (Neha and Quisumbing 2013). Hence, specific needs and preferences of women farmers for particular rice varieties should be an important driver for the development of new varieties. Evidence also shows that women and children are more likely to be malnourished due to lack of access to nutritional food (Bhagowalia et al 2012). Since rice is widely consumed in the majority of low income-earning households in Asia, Africa, and South America, increasing the nutritional quality of rice will have a direct impact on women's and children's nutritional security. Finally, the purchase of rice by consumer households is dominated by women. Hence, their preferences are driving markets in relation to various quality aspects such as taste, cooking time, aroma, fluffiness, and stickiness.

Rice production has an environmental footprint, with the use of increasingly scarce water resources and the emission of GHGs being the most prominent factors. Breeding can play a mitigating role by developing varieties that perform well under management practices that reduce the use of scarce resources (e.g., water-saving) and the production of GHGs (methane-reducing technologies) or by developing varieties that intrinsically use fewer resources (such as water and nutrients) and inputs (pesticides).

The above needs for genetic improvement play out against the backdrop of rapid structural transformations in the rice sector such as increasing feminization that change the way rice is grown and that put new emphasis on quality and other market requirements (Mohanty 2014). Increasing labor scarcity is leading to the rapid adoption of mechanized direct seeding, which puts new

requirements on rice varieties such as early uniform emergence, early vigor, weed competitiveness, and lodging resistance. Demand for rice with special properties such as aroma and better nutrition is steadily growing. To meet these demands, grain quality characteristics need to be mainstreamed in all regular breeding programs to offer a variety of new products to rice consumers. Farm diversification requires rice varieties with shorter duration to expand the window of opportunity for growing additional crops each year to increase nutritional security and income, particularly for women farmers.

2.5.1.2 Objectives and targets

FP5 will speed up genetic gain for the development of improved and climate-resilient rice varieties to increase men and women farmers' income, reduce their vulnerability to climate change, and increase farmers' and other consumers' food and nutritional security. FP5 will focus on increased use of genetic variability (including genebank accessions), precision breeding, and innovative breeding tools to address yield stagnation, yield reduction by climate-related stress, yield reduction by biotic stress, and inclusion of nutritious and quality traits across all breeding activities. It will collaborate with the genetic gains platform in developing and using new prebreeding tools. Together with its partners and with FP1, FP5 will also strengthen dissemination and seed distribution networks of the improved varieties. Throughout, it will pay particular attention to needs and preferences of women farmers and of women rice purchasers in relation to rice varietal traits. Capacity development activities will support individual and institutional strengthening of FP5 partners on a range of topics, such as novel breeding tools, harnessing genetic diversity, modernization of breeding programs to accelerate genetic gain, and strengthening gender awareness.

FP5 will deliver the following research outcomes to selected sub-IDOs, IDOs, SLOs, and cross-cutting issues of the SRF (see also Tables A-D of the performance indicators matrix):

FP5 research outcome	Sub-IDO	IDO	SLO or cross-cutting issue
Rice diversity in rice gene banks used globally for identification of traits and discovery of new genes	Increased conservation and use of genetic resources	Increased productivity	Reduced poverty Improved food and nutrition security for health
Novel tools for precision biotech breeding based on genetic diversity shared open access and globally	Increased conservation and use of genetic resources	Increased productivity	Reduced poverty Improved food and nutrition security for health
New rice varieties resulting in 1.3 % genetic gain in intensive systems	Enhanced genetic gain	Increased productivity	Reduced poverty Improved food and nutrition security for health
Rice varieties with 20, 15, 10% reduction in yield loss caused by factors induced by climate change, in mega deltas, rainfed lowlands, and uplands, respectively	Enhanced capacity to deal with climatic risks and extremes	Mitigation and adaptation achieved [to climate change]	Climate change
High quality and high nutritious	Increased access to	Improved diets for	Improved food and

rice varieties that are preferred by men and women farmers and consumers	diverse nutrient-rich food	poor and vulnerable people	nutrition security for health
Prototype C4 rice lines with increased yield potential available	Increased conservation and use of genetic resources	Increased productivity	Reduced poverty Improved food and nutrition security for health
Increased capacity on modern rice breeding technologies in partner research organizations	Increased capacity for innovation in partner research organizations	National partners and beneficiaries enabled	Capacity development

Annex 11 gives an overview of FP5's contribution to the 10 grand challenges of the SRF. FP5 activities in climate change are described in section 2.5.1.8.

2.5.1.3 Impact pathway and theory of change

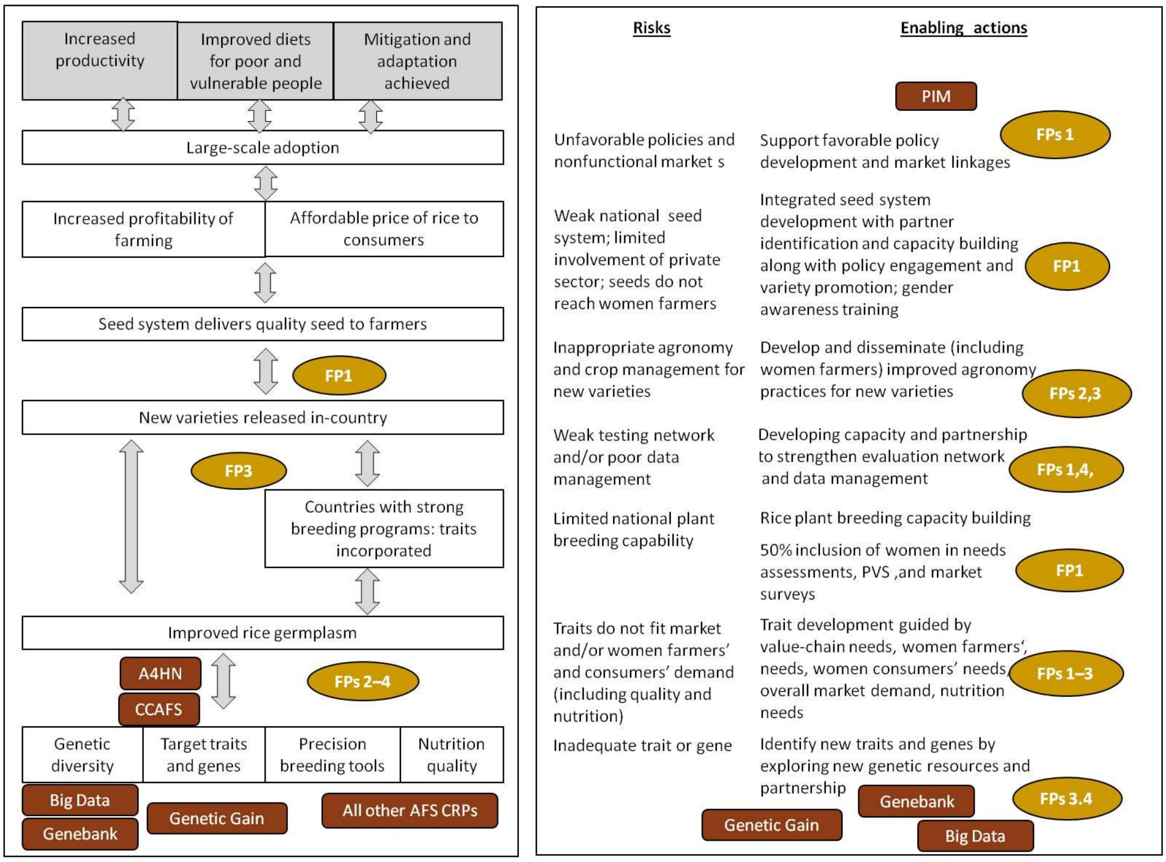

Fig. 5.1. Impact pathway (left) and theory of change (right) of FP5. Grey boxes are IDOs, ovals (with FP x) refer to links with other FPs, and the dark boxes refer to links with other CRPs (see Annex 12 for abbreviations).

Fig. 5.1 presents the impact pathway and theory of change, with risks and associated enabling actions of FP5. The logic flow of the impact pathway is that farmers obtain higher income from growing novel varieties that have higher yield (under stress and climate change), yield stability, resource-use efficiency, and/or added value by having quality traits that are in high (new) market demand. In order for this to happen at scale, desired traits need be identified, built into new varieties, and disseminated to and adopted by large numbers of farmers and value-chain actors (millers, processors, and traders). Support for large-scale delivery of new varieties through improved

seed distribution systems is undertaken in FP1, through CoA 1.4 ‘Seed delivery systems’, which is very closely linked with FP5. The specific targeting of women farmers will lead to increase in their income, which will have a multiplier effect on family food and nutrition security. With successful large-scale production and marketing of the new varieties, rice will remain affordable for net consumers (including small farmers), thus contributing to their food and nutrition security and reduction of their poverty status.

As Fig. 5.1 shows, assumptions and risks that can prevent achieving full impact range from inability to identify and produce the desired trait response to nonadoption by farmers and weak or remote seed release systems that prevent delivery of sufficient quality seed to end users.

To minimize the risk of not successfully identifying desired traits or of developing varieties that are not attractive to farmers, FP5 will use outcomes of FP2 in understanding value-chain demand (e.g., millers, processors, and traders) and market preferences of consumers, especially those of women. Such traits typically relate to shape and size of grains, head rice recovery, taste, aroma, texture, etc. Also together with FPs1 and 2, needs, preferences, and opportunities for specific varietal traits will be identified among men and women farmers in the target rice-growing environments. Such traits are typically related to yield potential; maturity and duration; tolerance for stresses such as drought, submergence, salinity, and problem soils; resistance to pests and diseases; and quality characteristics related to home consumption and markets. Especially important are traits related to climate change. Predictions of future climates are needed in order to develop climate-smart varieties (i.e., varieties adapted to climate-induced changes in weather, pests, diseases, and other environmental factors) specifically suited for RICE target environments. FP5 collaborates with FP4 and CCAFS to obtain maps of climate-change induced weather patterns and stresses, especially for mega-deltas and coastal regions predicted to be affected by sea level rise (increasing incidences of flooding and salinity intrusion). Similarly, accurate regional and location-specific predictions will be sought of increases in day and night temperature, shifts in cropping seasons and rainfall patterns, and occurrences of droughts. Consequences of climate change on geographic shifts in populations of insect pests and emergence of new insect-borne diseases and their interaction with abiotic stresses need to be better understood as the changes become more apparent.

After desired traits have been incorporated into novel germplasm, participatory approaches such as varietal selection and taste panels among farmers, including women, will reduce the risk that the varieties do not match demand and are not adopted. FP5 works with local partners in developing and releasing location-specific cultivars. It will invest in institutional capacity development to modernize local or national breeding programs to accelerate breeding cycles and the development and delivery of new varieties. Breeding networks involved in evaluating new material will be strengthened and monitored to ensure the collection of relevant high-quality data that are properly managed and analyzed.

To reduce the risk of failure to deliver seeds of new varieties to target farmers, FP5 will support FP1 in the development of partnerships to strengthen weak seed distribution systems and to develop them where they are nonexistent, e.g., through development of community seed banks. FP5 will also partner with an array of public, private, and civil society (NGO) partners depending on location-specific circumstances. Capacity development will play a large role. FP5 will work with FP1 nationally and regionally to influence changes in local policies and regulations to accelerate varietal release processes, and to align partners along the seed chain to ensure production and timely delivery of high-quality seeds. Improving varietal release guidelines, seed certification policies, and

seed system infrastructure, together with enabling environments for private-sector involvement, will accelerate delivery and shorten the time for outreach and varietal turnover.

To reduce the risk that women farmers and consumers insufficiently benefit from the new varieties, they are explicitly targeted in the identification of desired traits, in participatory variety selection processes, in preference and taste panels, and in outreach activities such as seed distribution, demonstrations, and training. Together with FP1, FP5 also invests in raising gender awareness among its research and development partners.

2.5.1.4 Science quality

FP5 will accelerate genetic gain by capitalizing on breeding material, knowledge, and tools developed during GRiSP. The global phenotyping network and associated phenotyping methodologies developed by FP4 will be intensively used for early evaluation of the breeding material in FP5. Rapid uptake of genotype-phenotype relationship information and prebreeding material produced in FP4 will be assisted by streamlining the use of conventional tools (such as marker-assisted gene introgression-pyramiding and rapid generation advancement) and by adapting and adopting some emerging concepts and technologies. These will include genomic selection and gene editing, and by hosting blue-sky research such as systems biology and C_4 rice. The ability to undertake large-scale phenotyping in multiple environments using the facilities developed in FP4 will be another asset for accelerating genetic gain.

The streamlining of conventional marker-assisted selection (MAS) will be achieved through the ongoing establishment of breeding-dedicated genotyping platforms of homogeneous and compatible characteristics across the three CGIAR centers. To take full advantage of the 3,000 sequenced genomes of rice, a few additional accessions will be sequenced to fill some gaps in the representation of rice genetic diversity.

To go beyond MAS for individual gene/QTL, a systems biology approach will be implemented for some traits heavily involved in resource-use efficiency (i.e., root development) or yield potential (i.e., panicle architecture) to identify relevant gene/allele networks that are targeted in the breeding programs. Allele mining, using the 3,000 genome data, will be systematically undertaken for major QTLs/genes identified in FP4, to detect/validate the most favorable haplotypes and/or the most compatible donors for the recipient breeding program. New breeding populations optimizing recombination rate and genetic resolution power (e.g., MAGIC) will be developed using the above-mentioned high performing and/or multipurpose donors.

Genomic selection, a promising and powerful methodology developed about 15 years ago to increase genetic gain in breeding, is aggressively implemented in private plant breeding companies. In FP5, the genomic selection concept will be applied to rice breeding. The development of a rice-specific breeding program simulator will help optimize the application of genomic selection and new breeding schemes to attain the highest genetic gain per unit resource and time.

FP5 will continue GRiSP's efforts in mastering gene editing tools based on Cas9/CRISPR technology and will use them for validation of candidate gene function. FP5 will also explore their use for targeted upgrading of popular varieties and as a complementary tool in breeding programs. FP5 will also use genotyping platforms and analytical pipelines that are being developed in the CGIAR centers and cross-CRP partnerships such as the Genetic Gains platform and the Genomic and Open-source Breeding Informatics Initiative (GOBII) to accelerate genetic gain. Lastly, FP5 will continue the quest for a major breakthrough in genetic gain by working on the long-term scientific

challenges of developing a rice plant with a C_4 photosynthetic engine and adapted anatomical attributes.

GRiSP FP3 performed well in terms of scientific publications, with 33 of the top 50 most-cited publications in GRiSP since 2011 being on molecular breeding, genomics, genetics, and physiology (IEA report, p 30). The RICE FP5 will continue to emphasize high-quality journal papers, and, as per IEA recommendation (IEA report, p 31), FP5 senior scientists will mentor junior colleagues, especially those at the lower end of the H-index scale and in Africa. To enhance the number of quality publications in peer-review journals and to reduce publications with no or very low impact factor, FP5 management will monitor publication output and encourage stronger research collaboration among RICE core partners and with partners in ARIs for improving the overall quality of scientific output through jointly authored, high-quality publications (IEA review recommendation #2, IEA report, p xvi). FP5 includes partnerships with prominent scientists in ARIs throughout the world (see section 2.5.1.7) to further augment the upstream research capacity of FP5 CGIAR centers and to access state-of-the-art technologies and bioinformatics support for handling and interpreting the massive amounts of data generated.

2.5.1.5 Lessons learnt and unintended consequences

FP5 builds on GRiSP FP1 (Harnessing genetic diversity to chart new productivity, quality, and health horizons) and FP2 (Accelerating the development, delivery and adoption of improved rice varieties). A key lesson is that the identification of desired traits should not be limited to needs assessment among farmers but should include preference assessments of all value-chain actors (millers, processors, and traders) and consumers. Otherwise, adoption of new varieties may be hindered because millers or traders will not buy the surplus for marketing. Another key lesson is that the structural transformations taking place in the rice sector are driving segmentation of rice markets, and that breeding programs need to be able to respond by rapidly developing targeted breeding pipelines.

A further lesson from GRiSP is the important role of women farmers, processors, sellers, and consumers, especially in less favorable areas. Through linkages with FPs 1 and 2, special attention will be paid to women's preferences and needs through targeted inclusion of women (50%) in needs and opportunity assessments, participatory varietal selection, sensory preference panels, and market research. In CoAs 5.3–5.5, special attention will be paid to ensuring that women farmers receive new varieties that match their needs through, among others, collaboration with women's farming groups and specialized NGOs, and, in linkage with FP1, through raising awareness among other actors in seed delivery systems.

Trade-offs may exist among the traits of new varieties. For example, tolerance for abiotic stresses such as drought or submergence may come at the expense of yield potential under nonstress conditions (leading to a trade-off in yield level and yield stability). Similarly, positive or negative interaction may exist between seedling stage tolerance for salinity and submergence. These trade-offs will be minimized, or as much as possible removed altogether, during the breeding process, but if they persist, farmers will be made aware of them and guided in the proper use of the new varieties.

Another potential unintended consequence is that improved varieties may preferentially reach the better-off farmers as happened in the early years of the Green Revolution. Together with

FP1, FP5 will strengthen seed delivery systems to benefit poorer farmers, especially women farmers who live in marginal areas with most risk of climatic stresses. Partners in seed distribution networks will be sensitized to gender inequalities and village and community seed systems will be strengthened by training women on the effective and efficient management and multiplication of seeds. Impact assessments conducted in FP1 will show how new varieties are contributing to improve farmers' income and well-being and to women's empowerment (i.e., women's control over the increased income). Gender-differentiated adoption studies will identify adoption rates and diffusion paths under different dissemination models in different environments.

The introduction of high-yielding varieties may induce farmers to overuse inputs such as fertilizers or pesticides, as recorded on occasion with hybrid rice. Such unintended consequences of new varieties that are introduced in farming systems will be monitored through FP5 together with FP3 and addressed through training and capacity development on proper management of the new varieties.

2.5.1.6 Clusters of activity (CoA)

CoAs 5.1 and 5.2 engage in so-called prebreeding activities, the outputs of which feed into CoAs 5.3 and 5.4 that will develop novel varieties for intensive and irrigated, and unfavorable rainfed ecosystems, respectively. CoA5.5 will develop grain quality traits and novel food products that also feed back into the development of new varieties in CoAs 5.3 and 5.4. CoA5.6 focuses exclusively on the development of C_4 rice, with links to CoAs 5.1 and 5.2, and potential spin-off to CoA5.3 in the breaking of existing yield barriers.

Breeding efforts will focus on accelerating genetic gain by improving key steps in the breeding process such as increasing the accuracy of selection using molecular markers in routine selection, reducing the generation interval from cross to cross, increasing population size using mechanization and automation, and taking advantage of multienvironment trials (METs) for wide testing. Breeding lines developed in CoAs 5.3 and 5.4 will be evaluated by METs for adaptation, yield in the target environment, tolerance for climatic stresses, resistance to pests and diseases, and grain quality. The evaluation of breeding lines will have strong linkages with national variety testing programs of different countries. Participatory varietal selection (PVS) and sensory evaluation (with FP 2) will be carried out prior to releasing varieties meeting the national quality requirement as well as rice farmers' demands. In PVS as well as in sensory evaluation, participants will include at least 50% women to ensure the breeding program captures traits preferred by women. Promising breeding lines will be made available to other institutions through INGER.

5.1 Harnessing rice diversity

Intensive use will be made of the 3,000 sequenced genomes of rice for allele mining and identification of multipurpose donors while maintaining the long-term aim of sequencing new sets of accessions from different subgroups of *O. sativa*, *O. glaberrima*, and wild relatives. The methodology used for diversity analysis using sequence data will be also updated. The 3,000 genome resource will also be used for QTL and gene discovery for traits needed by breeders. Donors identified in initial screening in the Global Rice Array developed in FP4 will be validated through targeted phenotyping in hot-spot sites or in controlled conditions. A plant-systems biology approach will be used to identify key genes and gene networks for adaptation and resource-use efficiency such as root development, and yield potential-related traits such as panicle architecture. The gene

discovery approach will include multiscale physiological description and modeling of developmental processes, forward and reverse genetics, functional analyses, modeling of regulatory gene networks, and integrative functional modeling. Knowledge of the genotype-phenotype relationships and of the best donors for target traits will be incorporated into breeding programs through MAS within dedicated breeding populations that have a high level of recombination and genetic resolution power (MAGIC). The exploration and use of rice diversity will be underpinned by effective conservation and management of rice accessions maintained in genebanks. Conservation research to improve the understanding of seed physiology and longevity will be critical to ensure the sustained use of this invaluable resource.

5.2 Precision breeding

A breeding scheme for yield potential and tolerance for major abiotic stresses (such as drought, submergence, salinity, and extreme temperatures) will be progressively adapted to allow the application of genomic selection concepts. The first steps will include proof of concept for efficiency of genomic selection in population breeding, and the use of large diversity panels to predict the breeding value in the progeny of bi-parental crosses. A breeding program simulator will be developed that helps optimize the breeding scheme for faster and cheaper genetic gain than at present.

Tools for precision genome editing such as site-directed nucleases will be used to induce small mutations in loci of interest, to replace alleles, and to insert genetic material at specific sites. This will enable the rapid validation of candidate genes and the efficient introduction and/or fixing of known traits or new alleles into elite material without linkage drag. Diagnostic markers will be used to develop markers for QTLs and genes for different traits. SNP assays will be designed and used to introduce genes and haplotypes for traits required in specific ecosystems and regions. QTLs identified in GRiSP, RICE FP4, and this CoA will be fine-mapped; candidate genes will be identified and functionally validated to develop gene-based markers. Marker-assisted breeding in CoAs 5.3 and 5.4 will then use these markers to pyramid sets of alleles desired for a particular ecosystem into popular varieties and elite lines to develop new varieties. CoA5.2 will also use genotyping platforms and analytical pipelines that will be developed in the Genetic Gains Platform and GOBII.

5.3 Intensive systems

CoA5.3 aims to produce new high-yielding and stable varieties for the intensive rice environments; such varieties will respond to the challenge of climate change, have resistance to pests and diseases, and have desirable quality characteristics responding to the needs of farmers, value-chain actors, and consumers. Building on progress made in GRiSP, breeding efforts will focus on accelerating genetic gain by improving key steps in the breeding process such as increasing the accuracy of selection using molecular markers in routine selection, reducing the generation interval between crosses, increasing population size using mechanization and automation, and taking advantage of multienvironment trials for comprehensive testing. Using the information from CoA5.1 and precise breeding techniques from CoA5.2, this CoA will use new germplasm resources: genes for more grains per panicle, higher panicle branching, more tillers, higher percent grain setting, taller plants, and sturdier stem than in existing varieties. Based on improved understanding of underlying genetic and physiological mechanisms, and using novel modeling approaches, appropriate combinations of traits will be determined to achieve increased genetic gain.

In temperate regions where yields of japonica varieties are generally high, existing cultivars need improvement for resistance to insects and diseases, tolerance for extreme temperatures, and better grain quality traits. Precision breeding techniques will allow overcoming barriers and sterility problems in crosses between indica and japonica varieties. New traits such as high biomass production, nonstructural carbohydrate accumulation and translocation, lodging resistance, tolerance for cold and heat, low solar radiation, and anaerobic germination will be combined.

Mechanized dry direct-seeded rice is an emerging technology replacing manual transplanted rice in areas affected by labor shortages. Suitable varieties will be developed with such traits as early and uniform emergence, early vigor, weed suppression, roots with increased nutrient uptake, lodging resistance, and water-use efficiency. Root plasticity traits that allow rice to have better access to nutrients, flexibility for establishment whether transplanted or dry direct seeded, and better adaptation to cycles of aerobic-anaerobic soil conditions, will provide flexibility to farmers to adapt crop establishment methods according to weather conditions and seasonal labor availability.

5.4 Unfavorable ecosystems

Drought, submergence, salt, extreme high and low temperature, low soil fertility, iron toxicity, low solar radiation, and high disease pressure, individually or in different combinations are among the most serious factors that reduce rice yields in unfavorable rice-growing environments. Droughts are increasing in severity and often alternate with periods of uncontrolled flooding. Many mega-deltas are increasingly affected by floods and salinity intrusion, while incidences of pests and diseases like blast, bacterial blight, and brown planthoppers remain rampant. CoA5.4 will develop novel varieties that combine tolerance for multiple abiotic and biotic stresses using recent (GRiSP) and new discoveries of donors/genes for anaerobic germination, stagnant flooding, salinity, and drought, together with genes for resistance to prevalent pests and diseases. Many of the traditional varieties grown in unfavorable ecosystems possess excellent grain and cooking quality traits. FP5.4 will collaborate with FP5.5 to capture such quality traits and embed them in the new varieties.

Potential donors with traits of interest (identified in FP4 and validated in CoA5.1) and the main relevant QTLs/genes will set the base for the introgression of key traits. Breeding lines will be developed using new breeding technologies (CoA5.2) to gain efficiency and hasten line development. MAS with donors/QTLs/genes that have tolerance for drought, submergence, salinity, high and low temperature, and iron toxicity, coupled with genes for improved nutrient-use efficiency and resistance to relevant biotic stresses will help develop rice varieties with higher and more stable yield in unfavorable rice-growing conditions. Inclusion of MAS in the breeding scheme will result in faster genetic gains by accelerating the breeding cycle through (1) rapid generation advancement, (2) gene introgression, and (3) population breeding. Genomic selection combined with breeding simulations will enable the development of appropriate ideotypes for drought-prone rainfed lowlands and uplands that in turn will contribute to increased rice production in the less favorable ecosystems.

5.5 Grain quality and nutrition

RICE will continue the development of rice with high content of micronutrients, especially zinc, as undertaken in GRiSP and in collaboration with A4NH through HarvestPlus. The development of high-zinc rice is a joint investment with A4NH whereas RICE mainstreams traits for high nutrient content in rice grains throughout its breeding programs.

In market-driven product development (see FP2), associating multiple parameters of grain quality (as proxy traits) can enable breeders to tailor new varieties according to consumer demand. Sensory evaluation has seen limited routine use in rice improvement programs because it is low in throughput, yet it is an integral component of food product development as it captures attributes that routine quality evaluation assays leave out, and it measures consumer preferences. CoA5.5 will use sensory evaluation platforms and novel holistic tools for grain quality traits to capture men and women consumers' preferences for premium quality (organoleptic properties) of cooked rice. Phenotypic assessments of grain quality preferences through metabolic signatures for aroma and taste, and identification of diagnostic markers (using the 3,000 sequenced genomes of rice) for medium-quality and premium-quality rice will be undertaken with emphasis on consumer preferences. Value-added rice products will be generated from specialty rice varieties developed in the categories of (1) healthy and nutritious rice in terms of high levels of micronutrients, high fiber, slow digestibility, and low glycemic index; (2) best cooking quality; and (3) best keeping quality after processing. These will be used to derive processed rice products suitable for the agroindustry in FP2.

5.6 C_4 rice

CoA5.6 focuses on C_4 rice activities, part of a global C_4 rice consortium of GRiSP that attempts to introduce the C_4 photosynthetic pathway into rice, with the aim of achieving 25−50% increase in rice yield while greatly reducing water and nitrogen inputs, increasing profitability and reducing environmental footprint. The technology is widely applicable to other C_3 crops such as wheat and soybean and thus has benefits across a wide range of CRPs. C_4 photosynthesis research involves the construction of transgenic lines with multiple transporter genes via gene stacking, and crossing those transgenes with lines containing the C_4 biochemical pathway produced in GRISP to develop transgenic lines with increased C_4 photosynthetic flux. Genes will also be transferred into rice to alter leaf anatomy and provide the necessary structure to support C_4 photosynthesis (e.g., vein density and bundle sheath cells). An important component of CoA5.6 is the training of a new generation of young scientists at the cutting edge of molecular and genetic science.

2.5.1.7 Partnerships

FP5 will engage in strong partnerships throughout the variety development pipeline. At discovery research level, FP5 will involve partnership research at ARIs across the globe on genomics, system biology, gene and gene network identification, and their use in precision breeding. Specifically with ARIs in China and India, FP5 will develop strong research partnerships on C_4 rice, germplasm sequencing, gene identification, population development, and trait development. At proof-of-concept level, FP5 will partner with ARIs on genomic selection, marker-assisted breeding, trait development, design QTL pyramiding, and association mapping. For scaling-out, FP5 will partner with NARES on evaluation of lines, PVS, sensory evaluation, and varietal release. The CGIAR institutes associated with FP5 are aware of strong NARES in many rice-growing countries. With those NARES, FP5 will partner more on trait development, marker development for traits, precision breeding tools, standardization, and refinement and use of genomic selection strategies in rice.

A strong comparative advantage of this FP is the 40−50 years of experience in rice breeding of the CGIAR centers AfricaRice, CIAT, and IRRI, including their worldwide partnership networks that cover all the major rice-growing environments, their global breeding efforts, and their ability to integrate knowledge produced by the international community working on rice as a model plant.

The CGIAR centers of FP5 are unique in their ability to facilitate the exchange of germplasm across national borders, assuring phytosanitary health and meeting regulatory norms in an increasingly restrictive global situation. They lead global and regional varietal evaluation networks, such as MET in Asia with more than 50 partners, the Africa-wide Rice Breeding Task Force with 29 national partners, and CIAT/FLAR with partners from 17 countries in Latin America. These networks provide a unique global partnership for developing and sharing new rice germplasm that responds to both global and local challenges. Equally relevant is the expertise of Cirad, JIRCA, and IRD with system biology, genomic selection approaches, gene identification, and integration of modeling with breeding programs.

Through IRRI, AfricaRice, and CIAT, GRiSP has pioneered the transformation of rice breeding programs by the conversion of breeding activities into market- and product-oriented trait and variety development pipelines, acceleration of selection using rapid generation advancement, and development and use of HTP, genotyping, and information management platforms. FP5 continues and expands this program, and will transfer its model to NARES partners.

Some major partners and their roles are:

Discovery	Proof of concept	Scaling out
BGI-Shenzhen, ACIAR, CSIRO, US$A, Cornell University, Duke University, Max Planck, University of Cambridge, University of Oxford, University of Sheffield, University of Nottingham, University of Toronto, Washington State University, University of Dusseldorf, Shanghai Institute of Biological Sciences, Australian National University, Academia Sinica (Taiwan), Simon Fraser University, National Institute of Agrobiological Sciences (NIAS, Japan), INRA (France), University of Milano, University of Aberdeen, Yale University, University of Tokyo, Embrapa, National Agriculture and Food Research Organization (NARO, Japan), Department of Biotechnology (India), and Chinese Academy of Agricultural Sciences	Indian Council of Agricultural Research, Bangladesh Rice Research Institute, FLAR partners in Latin America, Africa-wide Rice Breeding Task Force (29 NARES in Africa), CRA (Italy), Embrapa, HRDC in Asia and Latin America, UPLB, PhilRice, MARD (Vietnam), MARDI (Malaysia), RDA (Republic of Korea). Central Rice Research Institute (India), Indian Institute of Rice Research, Chinese Academy of Agricultural Sciences	DARE, NSP, and agricultural universities from India; Nepal Agricultural Research Council; Cambodian Agricultural Research and Development Institute; CARP (Sri Lanka); DOA (Thailand); PARC (Pakistan); PhilRice and PCAARRD (Philippines); MAF (Laos); MOAI (Myanmar); GSDM (Madagascar); Consejo Mexicano del Arroz (México); Genarroz (Dominican Republic); ANAR (Nicaragua); Senumisa (Costa Rica); Fedagpa, Secosa, and Conagro (Panamá); Iancarina, DANAC, Aproscello, Asoportuguesa, INIA, and Fundarroz (Venezuela); GRDB (Guyana); Aceituno, CORPOICA, SEMSA, and Fedearroz (Colombia); INIAP (Ecuador); CIAT/FENCA and CAISY (Bolivia); INIA-ACA (Uruguay); INIA (Chile); IRGA (Brazil; INTA, Copra, and Adecoagro (Argentina); DICTA APHRA ANAMH (Honduras); ICTA (Guatemala); El Potrero Farm (Peru); FEPRODES and UNIS (Senegal); Syngenta Seed, Notore Seed, Value Seed, and Lumiere Seed (Nigeria); Neema Agricole Du Faso (Burkina Faso); and FASSOKABA (Mali)

2.5.1.8 Climate change

The main grand challenge that FP5 addresses is climate change. New rice varieties will be developed and delivered with tolerance for stresses induced or exacerbated by changing and increasingly variable climates: variable water availability (drought and flooding), extreme temperatures, salinization, and the emergence and spread of new pests and diseases. The use of such varieties will increase and stabilize yields, reduce yield failures and yield reductions, and increase the resilience and adaptive capacity of farmers to climatic (and climate-induced) shocks. Also, the development and delivery of short-duration varieties will facilitate the diversification of farming systems, thus further increasing farmers' resilience and livelihood opportunities. The development of water-efficient varieties will contribute to the conservation of water as a natural resource.

2.5.1.9 Gender

FP5 aims to improve women farmers' livelihoods and family food security through the development and targeted delivery of stress-tolerant, short duration, and high-yielding rice varieties adapted to climate-change. Short-duration varieties will allow women to intensify the cropping pattern (and improve their nutritional security) by cultivating other crops such as legumes. High-yielding varieties will improve women-led households' food security and help them earn extra income. The development of varieties with improved productivity in unfavorable environments, either as a result of better stress tolerance or higher water-use and nutrient-use efficiency, will deliver further benefit to women farmers who are less likely to have access to resources like water, fertilizers, and phytosanitary products. Since rice is widely consumed in the majority of low-income earning households, increasing the nutritional quality of rice will have a direct impact on women's and children's nutritional security.

Together with FP2, attention will be given to the development of new rice varieties that specifically take women farmers' and women consumers' preferences into account, using two complementary activities. First, ex-ante preference analysis techniques such as investment games will be used to identify the needs of women farmers and consumers. Second, ex-post preference analysis such as PVS and sensory evaluation will be conducted to identify the most preferred varieties in terms of cooking time and specific organoleptic characteristics. A target of 30-50% women will be included in these assessments. Together with FP1, new varieties will be disseminated using women-centric delivery approaches, including women's organizations and self-help groups, pioneered under GRiSP (Women at the heart of technology delivery). FP1 will train women in seed management and multiplication to enhance their sustained access to seed of improved varieties.

2.5.1.10 Capacity development

The overall capacity development strategy of RICE is given in Annex 3. In FP5, specific actions are undertaken related to the following four steps of the CGIAR Capacity Development Framework*:* Develop future research leaders, Research, Institutional strengthening, and Gender-sensitive approaches. Partners' breeding capacity will be strengthened through training of young breeders (the future research leaders—including at least 50% women) on advanced breeding tools and techniques, including molecular approaches and plant biology. This will be achieved through annual training programs at each of the CRP institutes or in their respective countries, on-the-job training in project activities, and through open online courses on rice genetics and breeding. FP5 and FP1 will

also provide training on seed systems, directly or through training of trainers, to a larger array of stakeholders, including at least 50% women participants. Institutional capacity of NARES partners will be developed in transforming rice breeding programs to accelerate genetic gain, using experiences in this area under GRiSP. Women farmers and (aspiring) young entrepreneurs are especially targeted for capacity development in seed delivery, for example, through training on community seed banks, seed health, and marketing. Women farmers will also be trained on variety evaluation through participation in participatory varietal selection.

2.5.1.11 Intellectual asset and open access management

FP5 follows RICE policies and strategies on intellectual asset management, open access, and data management (Annexes 9 and 10), in line with the CGIAR Principles on the Management of Intellectual Assets and their Implementation Guidelines, and with the CGIAR Open Access and Data Management Policy and its Implementation Guidelines. FP5 intellectual assets (research data, outputs) span the whole discovery research–delivery chain, from prebreeding products such as better characterized and exploited rice gene pools, new donors, genes of agronomic importance, advanced breeding tools and methodologies; to new genetic material with traits for stress tolerance, lines with high yield potential for intensive systems, and water- and resource-efficient varieties suitable for mechanized direct-seeded systems. Data will be widely and publicly accessible through pertinent and dedicated websites such as the International Rice Information System, (providing access to structured information on rice germplasm pedigrees, field evaluations, structural and functional genomic data—including links to external plant databases—and environmental (GIS) data) and the Rice SNP-Seed Database (providing genotype, phenotype, and variety information based on the 3,000 Rice Genomes Project). Through the International Rice Informatics Consortium (IRIC), FP5 will develop public/private-sector partner agreements for the use of discovered genes/materials to ultimately reach as many farmers and national breeding programs as possible. Access to data and germplasm will be guided by customized Material Transfer Agreements and specific collaborative and use agreements.

2.5.1.12 FP management

FP5 is led by Dr. Arvind Kumar, senior rice breeder IRRI. Each CoA is co-led by a team of senior scientists (focal persons) consisting of one or more representatives from each center. Annex 8 presents the list of senior scientists and a set of selected curricula vitae.

2.5.2 Flagship Budget Narrative

2.5.2.1 General Information

CRP Name	CGIAR research program on rice-based agri-food systems, RICE
CRP Lead Center	International Rice Research Institute
Flagship Name	New rice varieties
Center location of Flagship Leader	Philippines

2.5.2.2 Summary

Total flagship project budget summary by sources of funding (US$).

Funding Needed	2017	2018	2019	2020	2021	2022	Total
W1+W2	4,441,828	4,521,878	4,596,864	4,682,073	4,761,412	4,854,414	27,858,471
W3	16,543,190	17,017,252	17,502,418	18,005,470	18,520,091	19,054,867	106,643,290
Bilateral	4,896,357	5,069,987	5,303,458	5,534,077	5,804,514	6,073,234	32,681,630
Other Sources							0
Total	25,881,375	26,609,117	27,402,740	28,221,620	29,086,017	29,982,515	167,183,384

Funding Secured	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Assumed Secured)	4,441,828	4,521,878	4,596,864	4,682,073	4,761,413	4,854,415	27,858,471
W3	11,015,282	7,563,827	0	0	0	0	18,579,109
Bilateral	3,214,106	3,015,397	2,885,082	3,029,336	3,180,803	3,339,843	18,664,567
Other Sources							0
Total	18,671,217	15,101,102	7,481,946	7,711,409	7,942,215	8,194,258	65,102,147

Funding Gap	2017	2018	2019	2020	2021	2022	Total
W1+W2 (Required from SO)	0	0	0	0	0	0	0
W3 (Required from FC Members)	-5,527,909	-9,453,426	-17,502,418	-18,005,470	-18,520,091	-19,054,867	-88,064,181
Bilateral (Fundraising)	-1,682,251	-2,054,591	-2,418,377	-2,504,742	-2,623,712	-2,733,391	-14,017,064
Other Sources (Fundraising)	0	0	0	0	0	0	0
Total	-7,210,160	-11,508,016	-19,920,795	-20,510,212	-21,143,803	-21,788,258	-102,081,245

Total flagship project budget summary by natural classification (US$).

	2017	2018	2019	2020	2021	2022	Total
Personnel	11,222,716	11,609,560	12,010,542	12,426,213	12,857,144	13,303,932	73,430,108
Travel	571,672	586,381	611,588	637,310	653,567	670,377	3,730,897
Capital Equipment	267,691	277,575	267,954	258,852	240,294	252,309	1,564,676
Other Supplies and Services	7,621,240	7,820,955	8,028,102	8,230,340	8,465,927	8,697,256	48,863,822
CGIAR collaborations	0	0	0	0	0	0	0
Non CGIAR Collaborations	3,490,325	3,525,196	3,609,910	3,707,254	3,817,312	3,910,170	22,060,169
Indirect Cost	2,707,730	2,789,449	2,874,642	2,961,650	3,051,772	3,148,469	17,533,715
Total	25,881,374	26,609,116	27,402,738	28,221,619	29,086,016	29,982,513	167,183,376

Total flagship project budget summary by participating partners (US$).

	2017	2018	2019	2020	2021	2022	Total
IRRI	19,798,529	20,270,113	20,806,505	21,358,989	21,928,048	22,514,178	126,676,363
Africa Rice	3,543,449	3,705,342	3,863,829	4,040,816	4,213,727	4,410,508	23,777,672
CIAT	2,539,397	2,633,663	2,732,406	2,821,815	2,944,243	3,057,828	16,729,355
Total	25,881,375	26,609,118	27,402,740	28,221,620	29,086,017	29,982,514	167,183,384

Explanations of these costs in relation to the planned 2022 outcomes

Flagship project 5 is composed of 6 clusters of activity as described in the FP5 narrative section *2.5.1.*6. Each cluster of activity delivers one or more outcomes each (with a related set of milestones), as listed in the Performance Indicator Matrix, Tables B-D. The required investment (budget) for each outcome is listed in Table B of the Performance Indicator Matrix. The Clusters of activities (CoA) and their outcomes are:

FP5	New rice varieties	Outcomes
5.1	Harnessing rice diversity	Rice diversity in rice gene banks used globally for identification of traits and discovery of new genes
5.2	Precision breeding	Novel tools for precision biotech breeding based on genetic diversity shared open access and globally
5.3	Intensive systems	New rice varieties resulting in 1.3 % genetic gain in intensive systems
5.4	Unfavorable ecosystems	Rice varieties with 20, 15, 10% reduction in yield loss caused by factors induced by climate change, in mega deltas, rainfed lowlands, and uplands, respectively
5.5	Rice grain quality and nutrition	High quality and high nutritious rice varieties that are preferred by men and women farmers and consumers
5.6	C_4 rice	Prototype C4 rice lines with increased yield potential available

Besides the above outcomes, each cluster of activity contributes to various capacity development actions, captured in the joint outcome “Increased capacity on modern rice breeding technologies in partner research organizations”. The budget of each cluster of activities depends on the type of activities, and involves typically the establishment and maintenance of high-quality experimental trials throughput the breeding pipeline (greenhouse, screenhouse, open field trials; multi-location evaluation trials) (CoAs 5.3-5.6); Conduct of participatory variety selection trials (CoAs 5.3-5.4); conduct of sensory evaluation panels (CoA5.5); collection and analysis of phenotypic (plant characteristics) and genotypic data (DNA samples) (CoAs 5.3-5.6); collection of plant samples, determination of genetic make-up, genetic and genomic analysis, development of markers and of novel breeding tools and software (CoAs5.1 and 5.2); Laboratory experiments to determine grain quality properties and derive genetic traits (CoA5.5); making (open) accessible all collected genotypic, phenotypic, and environmental data, analysis tools, and analyses conducted (all CoAs); workshops; stakeholder consultations; development of communication materials (papers, flyers, brochures, websites, video, etc); partnership development; partner capacity development for research, innovation, and delivery; communication; (open access) data management (all CoAs)– see section 2.5.2.5 below.

Risk to spending as planned

The RICE FPs are ‘umbrella projects’, which include a large number of bilateral projects any given year. Hence, the FP budgets are dictated by the collective investments that donors want to make through W1/2, W3, bilateral, and ‘others means’. The investment levels are unpredictable: 1) the W1-3 donors can not commit to 6-year funding obligations and the W1-3 investments into the CGIAR

fluctuate substantially each year, and 2) 70-80% of the budget is contributed to by bilateral projects, the majority of which still need be developed and secured. Hence, the likelihood that budgets are obtained - and spent - exactly as targeted, decreases as the CRP progresses in time. Each year, updates on investments expectations and budgets will be developed, and spending managed accordingly. At the level of bilateral projects, spending risk is managed by project leaders following procedures spelled out in project contracts. For W1-3, spending risk is managed by flagship project leaders. Project leaders get regular updates on actual spending rate through OCS, and are required to make project adjustments if under- or overspending occurs beyond the (donor-) accepted range (usually 10% of line items).

2.5.2.3 Additional explanations for certain accounting categories

Benefits

Benefits are separated out and include pension, housing, vehicle, home leave, medical insurance, and education allowances.

Other supplies and services

- Costs for establishment and running of the breeding trials: land rental; seeds; agro-chemicals, irrigation water, plastic sheets, etc;
- Cost for establishment and measurement of weather data: radiometer, temperature, wind speed, humidity, pan evaporation, sunshine hours
- Cost for data collection: plant and soil sampling; harvesting; sample processing (small supplies such as paper bags, strings, labels, markers); bar coding; tablets for data entry; etc;
- Cost for laboratory analysis: DNA extraction; genetic and genomic analyses; grain quality analyses
- Cost for data analysis: computer software, computing platforms (cloud, rental)
- Cost for 'breeding': making crosses, developing near-isogenic parental lines, developing nested association mapping populations, etc (various small materials and supplies involved, such as trays, trolleys, labels, pens, markers, bar codes, stickers, paper bags, etc);
- Cost for data and material sharing among partners, such as seed shipments, quarantine costs, health and sanitation processes and checks, etc
- Costs for participatory variety selection and sensory panels, involving local expenses in country such as recruitment of translators, enumerators, vehicle rental, local partner costs, laptops for data entry;
- Various others: workshops; partner capacity development (training materials, training course costs, costs for on-the-job training, survey costs for capacity needs); publications (leaflets, journal papers, brochures, websites); communication costs; various small office supplies.

Costs for the above vary by continent and country (eg, costs in Africa being higher than in Asia), and local budgets are developed in accordance with local costs in detail prior to conduct of any activity.

2.5.2.4 Other Sources of Funding for this Project

1. Aggressively seek additional funding from bilateral sources. 2. All RICE FPs have a modular set of outcomes and activities related to various levels of donor investment: with fluctuations in donor investment, budgets, activities, outcomes and milestones can easily be adjusted accordingly. 3. Seek new partnerships based on self-funding principles (in kind contributions included) that can contribute to outcomes that are underfunded

2.5.2.5 Budgeted Costs for certain Key Activities

Estimated average annual costs (over 6 years) for key activities (US$).

	Annual cost (US$)	**Please describe main key activities for the applicable categories below, as described in the guidance for full proposal**
Gender	2,767,297	Targeting development of new rice varieties to needs of women farmers and women consumers, especially taking health, nutrition, and other grain quality parameters into consideration; involving women in evaluation (PVS, sensory panels) of new rice lines; enhancing resilience of women farmers to climate change and other shocks; capacity development. See details in section 2.5.1.9 of the FP description, and section 1.0.4 of the main RICE description, and Annex 4 on gender
Youth (only for those who have relevant set of activities in this area)	553,459	Mostly through training and capacity development of young researchers. See details in section 1.0.5 of the main RICE description, and Annex 5 on youth
Capacity development	4,150,946	This FP engages in individual education and training activities and in institutional development (mainly on genotyping, modern breeding and genomic tools; modernizing breeding programs; accelerating genetic gain); capacity development of research partners. See details in section 2.5.1.10 of the FP description, section 1.0.10 of the main RICE description, and Annex 3 of the main RICE description
Impact assessment	-	All RICE impact assessments are carried out under CoA 1.5 of FP1
Intellectual asset management	415,095	Professional intellectual asset management services are provided throughout RICE and estimated to be around 1%, see Annex 10 to main RICE proposal for details
Open access and data management	4,150,946	Processing, validating, curation and quality control of collected data from surveys and experiments; data storage; making data accessible through standardized ontologies and descriptions; maintaining databases, websites, and other data delivery mechanisms. See section 2.5.1.11 of the FP description and Annex 9 of the main RICE description with details on cost items

Communication	2,767,297	Engages in dialogue to scale up results, through engagement with national and regional bodies as listed in section 1.0.9 of the main RICE proposal, using tools such as media releases, fora and ministerial roundtables; engages with actors on the ground to scale out technologies and practices, through the participation of multi-stakeholder platforms and scaling out activities (convened in CoAs 1.3 and 1.4), using tools such as participatory impact pathway mapping (PIPA), stakeholder and outcome mapping, problem tree definition and analysis; contributes information and content to overall communicate about the program, the science, results and progress; communicates and engages with partners through collaborative and participatory approaches to R&D and convening various networks, community of practice, platforms, and consortia; promotes learning and sharing of information to improve communications and collaboration. Development of journal papers, manuals, technical reports, and other communications media such as video, audio, websites, etc. Participation in conferences, workshops, forums, stakeholder meetings, etc.

2.5.2.6 Other

In FP5, W1,2 funding is used for strategic upstream research into the development of novel rice varieties (gene discovery, harnessing rice diversity, developing tools and methods of precision breeding, grain quality for health and nutrition) and to support modernization of breeding programs to accelerate the increase in genetic gain (in collaboration with the CGIAR Genetic Gain Platform). This use of W1,2 funding complements a relatively large set of bilateral projects that are more development oriented and that engage more in downstream variety testing and delivery. W1,2 funding also supports activities at key action sites on mainstreaming gender issues in the breeding pipeline, through participatory variety selection and sensory taste panels involving women. Capacity development activities funded by W1,2 aim at institutional strengthening of partners to engage in upstream research and to modernize local/national breeding pipelines. The Tables B-C of the Performance Indicator Matrix indicate the contribution of W1,2 to the delivery of FP5's outcomes and sub-IDOs in financial terms.

2.5.3 Flagship Uplift Budget

Total uplift budget for six years for flagship project 5: New rice varieties.

Outcome Description	Amount Needed (US$)	W1 + W2 (%)	W3 (%)	Bilateral (%)	Other(%)
Rice varieties with 1.5 % genetic gain across the mega-rice-growing environments	9,000,000	30	0	70	0
10% increased (compared with base budget) use of rice genetic diversity through genotype sequencing of additional 2 K panel and gene identification	9,000,000	30	0	70	0
Healthy rice varieties released with low glycemic index and slow digestibility	9,000,000	30	0	70	0