CGIAR Generation Challenge Programme (GCP)

Transition strategy
2011–2013

May 2010

Generation
Cultivating Plant Diversity for the Resource-Poor

In partnership with GCP Consortium members:

AfricaRice ■ African Centre for Gene Technologies ■ Agropolis ■ Bioversity ■ CIAT ■ CIP CIMMYT ■ Chinese Academy of Agricultural Sciences ■ Cornell University ■ EMBRAPA ■ Indian Council of Agricultural Research ■ ICARDA ■ ICRISAT ■ IITA ■ IRRI ■ John Innes Centre ■ NIAS ■ Wageningen University and Research Centre

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Acronyms and abbreviations

ACGT	African Centre for Gene Technologies, South Africa
AfricaRice	Africa Rice Center
Alt_{SB}	marker diagnostic for aluminium tolerance
ARI(s)	advanced research institute(s)
BC_1 etc	backcross 1, etc
BC_1F_4	F4 progenies derived from BC_1
BCNAM	backcross nested association mapping
BecA	Biosciences Eastern and Central Africa
Bioversity	Bioversity International
CAAS	Chinese Academy of Agricultural Sciences
CAAS	Chinese Academy of Agricultural Sciences
CBSD	cassava brown streak disease
CC	Consortium Committee
CG	*abbreviation for* 'CGIAR'
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture)
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (the International Maize and Wheat Improvement Center)
CIP	Centro Internacional de la Papa (International Potato Centre)
CLCs	Crop Lead Centres
CMD	cassava mosaic disease
CoP	community of practice
DFID	Department for International Development, United Kingdom
DT	Drought-tolerant *or* drought tolerance
EB	(GCP) Executive Board
EC	European Commission
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
EPMR	External Programme and Management Review
F_1, F_2, etc	1^{st} filial generation, 2^{nd} filial generation, etc
GCP	Generation Challenge Programme of the CGIAR
GIB Service	Genomics and Integrated Breeding Service
GIS	geographic information system(s)
GRSS	Genetic Resources Support Service
GSS	Genotyping Support Service
IBP	Integrated Breeding Platform
ICAR	Indian Council of Agricultural Research
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communication Technology
IER	Institut d'économie rurale, Mali
IITA	International Institute of Tropical Agriculture

IP	intellectual property
IRRI	International Rice Research Institute
IT	information technology
LAC	Latin America and the Caribbean
M&E	monitoring and evaluation
MAB	marker-assisted breeding
MABC	marker-assisted backcrossing
MAGIC	multiparent advanced generation inter-cross
MARS	marker-assisted recurrent selection
MAS	marker-assisted selection
MBP	Molecular Breeding Platform
NARS	national agricultural research system(s)
NIAS	National Institute of Agrobiological Sciences, Tsukuba, Japan
P	phosphorus
PDC	Product Delivery Coordinator
PDL	Product Delivery Leader
PI	Principal Investigator
Pup1	marker diagnostic for phosphorus uptake
QTL(s)	quantitative trait locus (loci)
R&D	research and development
RYMV	rice yellow mottle virus
SA	South Asia
SEA	Southeast Asia
SiMAC	Scientific and Management Advisory Committee (of the IBP)
SMEs	small- and medium-scale enterprises
SP	Subprogramme
SPL	Subprogramme Leader
SSA	sub-Saharan Africa
TLI	Tropical Legumes I Project
TLII	Tropical Legumes II Project
WUR	Wageningen University and Research Centre, The Netherlands

1 Executive summary

The Generation Challenge Programme (GCP) was created by the CGIAR in 2003 as a time-bound 10-year programme with the objective to explore plant genetic diversity and apply advanced genomics and comparative biology to advance the breeding of the main staple crops grown by resource-poor farmers in drought-prone and other harsh environments.

GCP is committed to close by the end of 2013, and this transition strategy summarises the GCP workplan for the period until then, and the plan for efficient and sustainable integration of GCP activities in the context of the ongoing CGIAR reform and the formation of the Megaprogrammes (MPs).

The GCP network and partnerships established in Phase I (2004–2008) has brought together a diverse array of applied research teams and scientists from developing and developed countries, CGIAR Centres and universities to stimulate interest and set the stage for successful genomic research and molecular breeding in the developing world. This exceptional partnership is to be further nurtured during Phase II to establish a broad research-for-development network with diverse and extensive capabilities, to support molecular breeding. GCP Consortium members support this strategy on the assumption that the Programme will remain a coherent entity until 2013, and in the hope that the model GCP has cultivated can be emulated in the different post-reform programmes and services.

As recommended by a 2007 external review, GCP’s workplan for Phase II is building on a set of focused research components and an integrated service component. While the research components aim to demonstrate – through selected use cases – that modern and integrated breeding approaches can have a significant impact on crop productivity in developing countries, the service component is conceived as a vehicle for dissemination of knowledge and technology, enabling broad access to and proactive distribution of crop genetic stocks and breeding material; molecular, genomics and informatics technology and information; cost-effective high-throughput laboratory services; and capacity building programmes.

GCP has a focused research agenda up to 2013 which includes eight research components that are crop-, trait- and region-specific. These research activities will be embedded and described in each of the six crop megaprogramme proposals under Theme 3, and integrated in respective logframes. GCP will monitor these eight research projects, in collaboration with scientists from the respective crop megaprogrammes, until the end of current contractual obligations to GCP grant recipients. Research activities extended beyond GCP’s lifetime shall be managed by the megaprogrammes in keeping with their respective strategies.

Working with different partners, on different crops, in different ecoregions, GCP is uniquely positioned within the CGIAR to draw important cross-cutting lessons to inform molecular breeding in varied circumstances. These lessons will be amongst the most valuable outcomes of the Programme as it closes in 2013.

The development of a demand-driven Genomics and Integrated Breeding (GIB) Service component builds on and expands an ongoing Integrated Breeding Platform initiative, and will be driven by a well-defined set of 14 use cases conducted in the different crop

MPs under Theme 3. The Service should be operational as an integrated pipeline by 2012, at which time it will be open to a broader set of users within and outside of the CG system. The operational and governance framework of this service after 2013 will be discussed and defined with partners during this transition.

GCP governance shall remain unchanged during the transition period, with CIMMYT remaining as Host Agent.

For the Generation Challenge Programme to achieve its overall objectives at the end of its 10-year life cycle, building on previous investments[1] and achievements,[2] and meet its contractual obligations to grant recipients, it needs to secure USD10 million per year for the next three years. Those funds will be additional to an annual income of USD5m that the Bill & Melinda Gates Foundation will provide until 2013.

2 Background and rationale

Food security in the developing world is one of the greatest global challenges, exacerbated by the global financial crisis and climate change. Growth in scientific knowledge and innovation, and advances in information and communication technology (ICT) over the past two decades have jointly provided new tools, avenues and resources to address food security. The global agricultural research agenda must take advantage of this progress to enhance the agricultural knowledge base and provide innovative solutions.

Biological sciences are now extremely 'data-rich'. This quantitative nature of modern biology demands closer collaboration between biologists and informaticians, as well as strong partnerships across sectors and disciplines between developing and developed country researchers. The concurrent revolutions in genomics, molecular biology and information technology offer unprecedented opportunities to enhance breeding programmes. Consequently molecular characterisation, accurate phenotyping, analytical tools and overarching information systems must be integrated with breeding workflows combining pedigree, phenotypic, genotypic and adaptation data for better predictions on the performance of different genotypes in different environments.

Integrated breeding hastens genetic gain by combining phenotypic selection with cost-effective, precise, and faster molecular breeding methods. However, though molecular breeding approaches have proven to be of great benefit to the private sector, they have had limited impact in the public sector and in small private enterprises. The reasons for this vary, but include: lack of personnel, inadequate high-throughput capacity, unreliable phenotyping practices and protocols, inadequate infrastructure, poor information systems and adaptable analysis tools, and insufficient resources. This has slowed development of new cultivars and compromised food security. Availability of services to overcome these bottlenecks becomes imperative for the breeding effort projected under Theme 3.

2.1 GCP research themes

GCP brings together diverse interdisciplinary teams to harness the power of the collective. GCP projects are mainly undertaken by partners, with GCP serving as an enabler and mediator. The activities, achievements, and products reported here are the results of the cumulative efforts by these partners.

[1] http://www.generationcp.org/UserFiles2/File/Comms-docs/Brochures/GCP-Phase-I-to-Phase-II_Sep09_Final_Web-layout.pdf

[2] http://www.generationcp.org/UserFiles2/File/Research/Transit-strategy/Impacts-Phase-I-GCP.pdf

In Phase I, GCP identified the most promising research interventions and ideal partnerships that delivered significant products to improve genetic research and crop breeding. In Phase II, the focus is on applying genomic tools in selected developing-country breeding programmes – with a view to demonstrating that molecular breeding can increase genetic gains when improving germplasm for adaptation to target environments in developing countries. The eight research components geared towards this, presented in Section 6.2, will be integrated into Theme 3. Target crops include cassava, maize, pulses, rice, sorghum and wheat. An additional research theme aims to demonstrate the value of comparative genomics in exploiting genetic resources.

2.2 Partnerships and access to products

The 2008 External Programme and Management Review (EPMR) report noted: "*Many of the platforms, developed or improved by GCP, are embedded in CGIAR centers or key partners. The full impact of GCP products will require that these platforms are durable beyond GCP and are accessible by CGIAR centers, NARS and some ARIs, and down-stream breeding programs and seed distribution networks*." GCP is a broad network of diverse partners drawn from developing and developed countries, advanced research institutes, country agricultural research programmes, and the private sector – exemplifying the partnership goal of the ongoing CGIAR reform. This network links basic science with applied research, creating an interactive community of crop researchers at both the global and the regional levels.

2.3 Genomics and Integrated Breeding Service

GCP recently launched the Integrated Breeding Platform (IBP) mainly funded by the Bill & Melinda Gates Foundation, with additional funds from the UK Department for International Development (DFID) and the European Commission. IBP is to serve as a one-stop shop providing access to modern tools, applications, and services for integrated breeding.

During the transition period, the IBP will evolve into the Genomics and Integrated Breeding Service (GIB Service), incorporating services for genomic research. It will nurture existing GCP partnerships, extend the network of users and providers working to improve crop breeding in developing countries, and ensure that genomic and genetic resources developed in Phase I are made available for broad use. The Service will be demand-driven, critical for adoption and uptake, and will address the needs of ongoing genomic and breeding activities in the GCP research themes and in other use cases.

The transition will provide opportunity to establish communities of practice (CoPs) that are discipline- and commodity-oriented. These will be essential to drive the development and operation of the GIB Service from a user perspective, and ensure its sustainability. An efficient user-friendly GIB Service established under the stewardship of a set of 14 use cases (managed by GCP, by CGIAR Centres and by non-CGIAR institutes) can have significant impact on breeding in developing countries. An example is the development of submergence-tolerant rice cultivars through marker-assisted backcrossing, a project led by the International Rice Research Institute (IRRI). The introgression of the *Sub-1* gene from FR13A (the world's most flood-tolerant variety) into widely grown varieties like Swarna improved yields in more than 15 million hectares of rainfed lowland rice in South and Southeast Asia. Similarly, a recent economic study of molecular breeding of rice for tolerance to salty and low phosphorous soils in Bangladesh, India, Indonesia and The Philippines, indicated that the method would save between two and three years compared to conventional selection, resulting in significant incremental benefits in the range of

USD 50 to 500 million. Additional information on this is available at:
http://www.generationcp.org/sp5_impact/sp5main

Given its history of effective network development, GCP is well positioned to coordinate the development and implementation of this service component. The proposed GIB Service could develop into a key asset for the Centres, NARS and other partners in agricultural research, by facilitating access to resources and information they generate, and building on best practice and proven operational systems developed by the Centres.

3 Vision, Mission and Objectives

GCP's Vision: ***A future where plant breeders have the tools to breed crops for marginal environments with greater efficiency and accuracy for the benefit of resource-poor farmers and their families***

GCP provides access to and enhances the use of genetic diversity and advanced plant science to improve crops for greater food security in the developing world

The overall objectives of the Programme are to:

- *Provide access to and promote the use of genetic diversity in plant improvement programmes.*
- *Develop a public platform of genetic and genomic resources and tools, and support a global community that can use them.*
- *Generate and apply knowledge across crops, and demonstrate the potential of comparative genomics to impact plant improvement programmes.*
- *Use genetic diversity and advanced science to develop products for plant breeding programmes to improve the livelihoods of resource-poor farmers in marginal, drought-prone environments.*

4 Vision of success

By 2020, genomic-based breeding approaches conducted within Theme 3 crop megaprogrammes in partnership with NARS and the local private seed sector will have a significant impact on breeding practices in developing countries. Specifically, crop productivity will significantly increase, due to the uptake and application of modern breeding techniques and the availability of genomic and genetic resources through the network and services of the GIB Service.

5 Product delivery and impact

Each GCP project is designed with embedded product Delivery Plans and clear impact indicators. The project impact pathway is thus identified and articulated at project inception. These plans are jointly conceived with product users, taking into account local priorities. Product design and development are thus driven by relevance to, and feedback from, users and stakeholders in CGIAR Centres, NARS, developing country institutes, universities and other research institutions, and SMEs.

The spectrum of GCP products is broad, and research activities supported by GCP aim to deliver products for breeders in the short and long term. These products are deployed along the entire GCP research pipeline – from characterisation of genetic diversity up to molecular breeding – and therefore include genetic and genomic resources, genes for target traits, markers, new enabling tools and technologies, methodologies and learning materials, and ultimately, improved germplasm.

The GCP Product Delivery Leader (PDL) evaluates and catalogues each product, and oversees product quality, packaging, promotion, distribution and access. Distribution would be through the GIB Service and other channels, to facilitate transfer to and adoption by an expanding set of users. Adoption shall be measured through the impact indicators in Box 1 below.

Box 1. Impact indicators

Short-term (monitored over time)

1. Number of requests for the different products available through the service (eg, germplasm, molecular markers, IT and data analysis tools, protocols, training materials)
2. Number of support requests received from NARS and SMEs (eg. planning a breeding project, informatics, data management, data analysis, genotyping, training, IP)
3. Number of first-time and returning users for the different high-throughput genomics and breeding services
4. Number of datasets published through Crop Lead Centre databases
5. Number of researchers that join established CoPs
6. Number of researchers obtaining a graduate degree while engaged in GCP research components
7. Number and description of new genomic resources generated through the 8 research components and accessible through the GIB Service
8. Number of gene-linked or gene-based markers generated through the 8 research components and accessible through the GIB Service
9. At least five new gene-linked markers used in developing-country breeding programmes to improve maize, rice, and sorghum for acid soils in Africa, and Latin America and for phosphorus-deficient soils in Asia

Long-term (monitored over time)

10. Number of lines with new alleles from genetic stocks distributed by Centres through the GIB Service
11. Number of operational molecular breeding programmes in developing countries, in both the public and private sectors
12. Number and membership dynamics of active crop CoPs
13. Number of improved crop varieties released by national programme partners developed using molecular breeding
14. Acreage under crop varieties produced using molecular breeding
15. Yield increases in a given ecoregion and time period attributable to crop varieties from molecular breeding programmes
16. Number of farm households with enhanced livelihoods attributable to increased crop productivity due to improved varieties from molecular breeding programmes

6 Activity portfolio

This section describes the organisation and nature of the different activities in the GCP workplan for 2011–2013. The Programme logframe, attached as Appendix A, is divided into a service component with four modules and eight Research Theme components. All the activities are supported by proposals. Service and research component summaries are presented in Appendix B.

6.1 Genomics and Integrated Breeding Service

Over the next three years, we propose to develop and deploy a sustainable Genomics and Integrated Breeding Service (GIB Service) as a one-stop-shop for information, decision modelling and analytical tools, and related services to design, conduct and analyse genomic and molecular breeding experiments. This service will enable research and breeding programmes, in the public and private sectors in developing countries, to accelerate crop variety development. Initially, a limited set of services and data management tools and applications is developed to address the needs of 14 genomic and use case breeding projects serving as proofs-of-concept for the Integrated Breeding

Platform project. The IBP will be the foundation of the GIB Service that will incorporate four additional elements: a Network for Agricultural Genomics, a Research Informatics Network, Regional Hubs for genomics and molecular breeding, and Product Delivery and Impact Evaluation.

The design and scope of this project is challenging and requires the close collaboration and goodwill of an array of partners, as explained below. Scientists involved in 14 use cases will work in close collaboration with developers and data managers, to prioritise the development of and define the most appropriate structure for the different modules of the service.

It will be important to define Centre roles and responsibilities in key areas and operations of the GIB Service – including germplasm distribution, tool development and data management, roles which would be revised periodically. Roles and responsibilities will be further refined when drawing up the terms of reference for Crop Lead Centres in the context of the Service. For example, the Genotyping Resource Support Service will be a portal for users to access genetic stocks and pre-breeding material, but the responsibility for seed conservation, quality control and distribution will be borne by Centres and NARS genebanks. Access to those genetic resources would be coordinated with ongoing efforts led by Bioversity and the Global Crop Diversity Trust, in facilitating access to genebank accessions (by both CGIAR and national programmes) through a single web portal (GENESYS).

To support genomic research and molecular breeding projects to be conducted in crop MPs under Theme 3, the Genomics and Integrated Breeding Service will establish four activity modules listed below, and described in the logframe and appendix B.

1. Module 1: Communication and access to services
2. Module 2: Genomics and Molecular Breeding Informatics service for crop MPS and partners
3. Module 3: Services and support for genomics research and breeding projects
4. Module 4: Service communities and product delivery

6.2 Research Theme components

GCP Phase I was defined by exploration and discovery. In Phase II, and particularly from 2010, the GCP research portfolio comprises of eight components – seven crop components and one component on comparative genomics. Each of the seven crop components focuses on a single crop, primarily addressing improvement of drought tolerance in selected countries (Box 2) within GCP's priority farming systems.[3] The comparative genomics component covers rice, sorghum and maize, and leverages knowledge from model species or crops to facilitate gene discovery.

These eight components will together guide the development of the service modules described above – based on the needs of their respective projects. The degree of success of these projects by 2013 will be a good indicator of the efficiency of the service.

[3] http://www.generationcp.org/gen.php?da=08128238#gcp_target-crops

Box 2. Research Theme target countries

Cassava	Chickpeas	Cowpeas	Maize	Rice	Sorghum	Wheat	Comparative genomics
Nigeria Tanzania	Ethiopia India	Burkina Faso Senegal	China India Indonesia Thailand	Burkina Faso Mali Nigeria	Ethiopia Mali	China India	Indonesia Kenya Zambia

GCP Research projects within specific crop themes will be firmly embedded in respective crop MPs in Theme 3. All Centres concerned have agreed that GCP research activities will be included in their programme proposals, and integrated into their logframes. While these activities will be included in the commodity workplans, they will remain under GCP management until 2013 when GCP's contractual obligations to grant recipients end. Below is the list of these research projects and the specific crop megaprogramme into which they will be integrated. A brief description of project rationale and activities is in Appendix B.

6.2.1: Improving drought tolerance in rice for Africa
affiliated crop megaprogramme: Rice-based production system
6.2.2: Drought-tolerant maize for Asia
affiliated crop megaprogramme: Maize-based production system
6.2.3: Improving drought tolerance in wheat for Asia
affiliated crop megaprogramme: Wheat-based production system
6.2.4: Improving tropical legumes productivity for marginal environments in sub-Saharan Africa and India
affiliated crop megaprogramme: Pulses and legumes
6.2.5: Improving cassava yield in Africa's drought-prone environments
affiliated crop megaprogramme: Roots and tubers, bananas and plantains
6.2.6: Improving drought tolerance in sorghum for Africa
affiliated crop megaprogramme: Sorghum, millet and barley
6.2.7: Yield improvement of sorghum in Africa through MARS
affiliated crop megaprogramme: Sorghum, millet and barley
6.2.8: Comparative genomics to improve cereal yields in high-aluminium and low-phosphorous soils
affiliated crop megaprogrammes: i)Rice-based production system, ii)Maize-based production system, and iii) Sorghum, millet and barley

A cross-cutting comparison of molecular breeding efficiency for different crops, working with different kinds of partners, will be an important output of GCP Phase II. To enable this comparison, the research components should be conducted under a comparable management system and the GCP should remain a coherent entity until 2013.

6.3 More use cases of the GIB Service

All the research activities listed above are use cases supported by GCP funds. Additional use cases financed from other sources that are just as important in driving the development and implementation of the GIB Service include:

1. Drought-tolerant **maize** for Africa
   Led by CIMMYT and supported by the Bill & Melinda Gates Foundation
2. Stress-tolerant **rice** for poor farmers in Africa and South Asia
   Led by IRRI and supported by the Bill & Melinda Gates Foundation
3. Green Super **Rice** for poor farmers of Africa and Asia
   Led by CAAS and supported by the Bill & Melinda Gates Foundation
4. Molecular marker technologies for faster **wheat** breeding in India

Led by the Plant Breeding Institute, University of Sidney, and supported by the Australian Centre for Agricultural Research

5. Durable Rust Resistance in **Wheat**
   Led by Cornell University in collaboration with CIMMYT and supported by the Bill & Melinda Gates Foundation

6.4 Capacity building

The objective of capacity building in GCP is to bridge gaps that prevent research advances from being applied in projects targeting resource poor farmers.

In the context of the GIB Service, a suite of Support Services is designed to facilitate access to and promote adoption of molecular markers and corresponding modern breeding approaches. These services include, among others, the *Genotyping Support Service*, specifically addressing new users of molecular technologies in developing countries, and the *Phenotyping Sites and Protocols* that supports the enhancement of local infrastructure at selected locations. Training courses and workshops, with emphasis on data analysis, learning materials and technical backstopping are also offered. GCP will complement the capacity-building efforts of CGIAR Centres, since Centre best practice will be the foundation for extending molecular breeding to a larger clientele. GCP will work with partners to establish communities of practice (CoPs) focused on data management and molecular breeding. These CoPs promote knowledge-sharing and encourage one-on-one technical support.

Secondly, since NARS are active partners and lead some of the activities in the Research Themes, human resource and infrastructure development are an integral part of project activities involving them, helping build their capacity in molecular breeding. Capacity development is realised through hands-on training embedded in the research activities and through exposure to the latest advances in technology, and support to postgraduate faculty and fellowships in two regional training institutes in Africa.

7 Partnerships

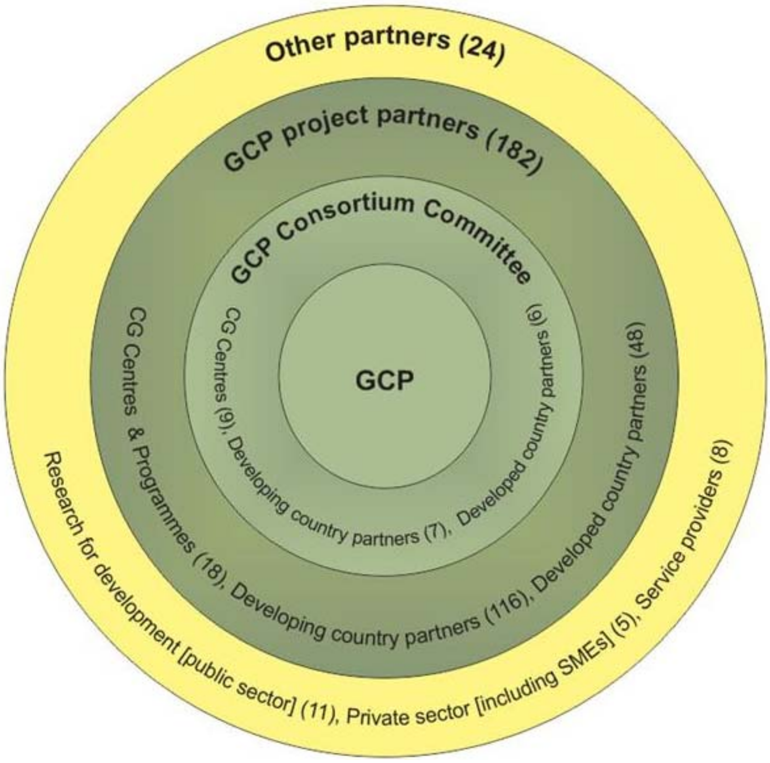
GCP does not have an independent legal persona but is premised on a Consortium Agreement – a legal document binding the 18 CGIAR Centres, developed country institutes and developing country institutes who constitute the Consortium, with four provisional members pending their formal signing of the Agreement (see Figure 1).

This transition strategy has the support of the Consortium members, with formal support letters.

The role of Consortium members has evolved over time, from leaders to partners and mentors. The current research portfolio clearly reflects this shift, with developed country institutes becoming mentors and the CGIAR Centres active supporting partners, while developing-country partners are increasingly leading projects. The appropriations of the GCP budget mirror this changing trend (see Section 13 and Chart 1).

GCP has built partnerships that link discovery science with applied research through a broad network of plant scientists from diverse backgrounds, working in international and national agricultural research – at CGIAR Centres, in academia, and in regional and national research programmes. A list of current GCP partners (over 200) is available at http://www.generationcp.org/gcppartners.php?da=0646141#nars.

Figure 1. The GCP Network in 2010: 200+ partners



As noted by GCP's 1st External Programme and Management Review (EPMR) "*GCP has developed an extensive consortium partnership and leveraged its resources to establish a broad network of R&D participants with extensive capability and capacity to support the GCP overall objectives.* The report concludes: "*Perhaps the most important value of GCP thus far, is the opportunities it has provided for people of diverse backgrounds to think collectively about solutions to complex problems and in the process to learn from one another*." GCP has pioneered what the CGIAR reform aims to achieve in partnerships, and the GIB Service will help sustain existing and new partnerships linking discovery science with applied research.

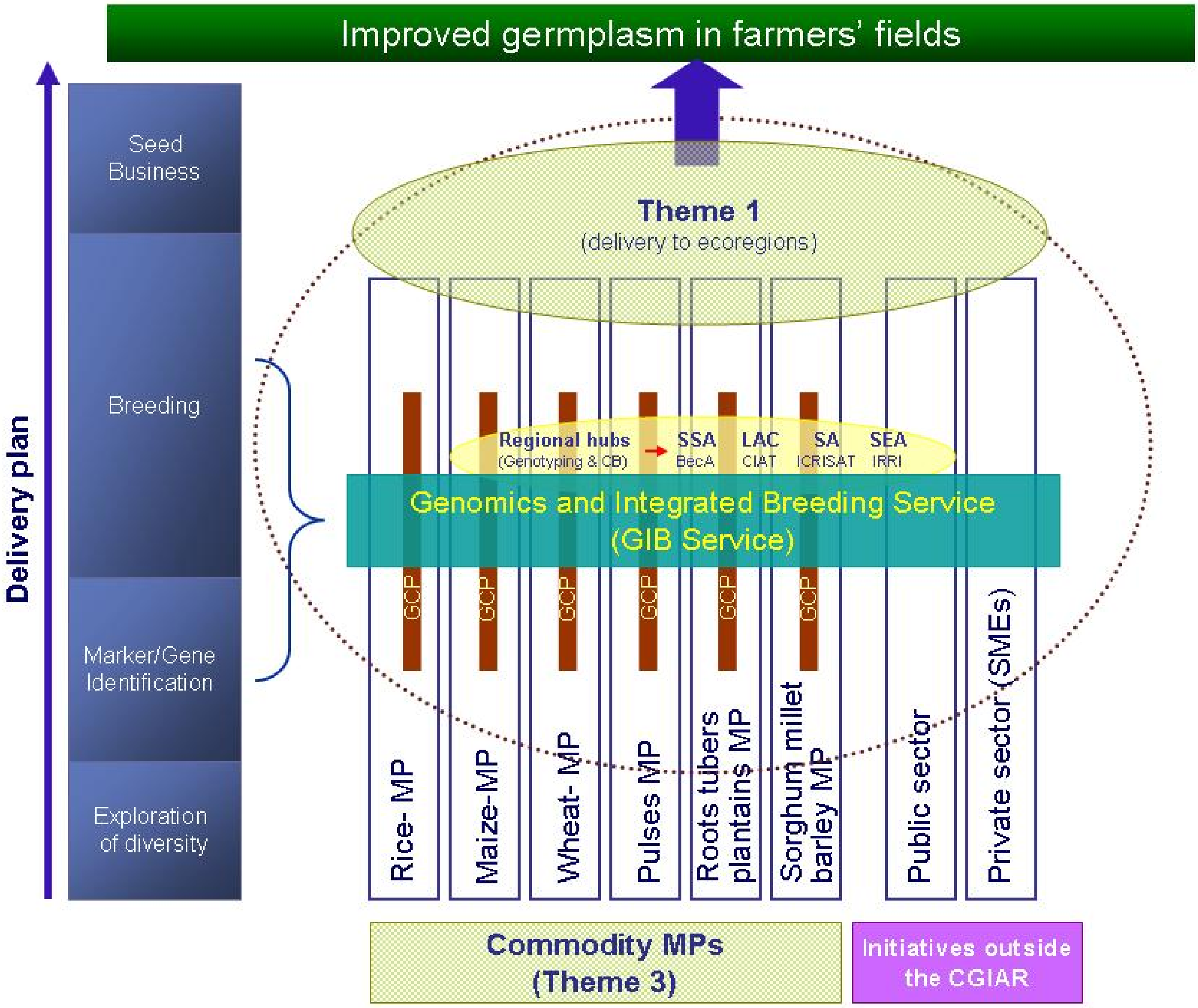
GCP projects thus bring together different partners who collectively achieve far more than any single institute working on its own. These partnerships have worked well, and there are numerous illustrations of this: in Phase I a joint partnership between scientists from EMBRAPA in Brazil and Cornell University in the United States successfully cloned the aluminium toxicity gene in sorghum. Elite alleles for this gene have been identified and introduced into Brazil's elite sorghum and are now been transferred to African germplasm in GCP Phase II.

GCP Consortium Committee members have expressed concern that the spirit of community and cross-fertilisation of diverse ideas that GCP has nurtured, should not be lost in the new GCIAR. The GCP Management Team commits to work with MP leaders to transfer this spirit into the Theme 3 crop megaprogrammes. This spirit will also be nurtured through the establishment of networks on genomics and informatics molecular breeding CoPs as envisioned for the GIB Service.

8 Integration with other CGIAR Consortium Themes

Activities included in the GCP workplan for 2011–2013 will be integrated into the new CGIAR organisational research framework that will emerge from the current reform (see Figure 2). For this transition period, GCP's home will be Theme 3, with some interaction with Theme 1. Though the GIB Service will initially focus on Theme 3 crop megaprogrammes, it could eventually extend to other commodities since it is designed to continue after GCP's 'sunset'. Indeed, one of the proposed regional hubs – BecA – already covers livestock, in addition to crops.

Figure 2. The GIB Service within the new CGIAR crop megaprogrammes.



Theme 1 will be critical in the delivery path of the GIB Service products, and of products from the eight GCP research components, for impact on crop productivity at the ecoregional level.

The GIB Service may also benefit the biofortification and food safety research in Theme 4. It may also link with Theme 7 by providing a portal for accessing GIS data for field experiment sites. Since weather and site characterisation data are strongly recommended for all experiments conducted through the GIB Service, such data collected for the crop megaprogrammes and made available through the GIB Service can also help scientists working in Theme 7 to identify homologous environments. Based on crop performance in this network of sites and considering the prediction of breeding requirements that will be generated in Theme 7, adjusted selection indices that anticipate the effects of climate change might be available through the GIB Service portal.

GCP has consulted with Centres involved in drafting crop proposals under Theme 3. It has been agreed that GCP research activities will be referred to in the 12-pagers of the crop megaprogrammes and in their respective logframes. The GIB Service will also be incorporated as a support service in each crop MP proposal.

9 Innovations

Major innovations for GCP Phase II will include:

- ✓ ***Access to diverse new tools and technologies though the GIB Service*** opening up new opportunities for agricultural research by offering a one-stop shop for a broad range of genomic and molecular breeding applications via a web portal. It includes access to quality high-throughput technologies at reduced concessionary costs, achieved by outsourcing to specialised commercial laboratories.
- ✓ ***Establishment of Communities of practice (CoPs) and capacity enhancement*** to facilitate information exchange and support the adoption and promotion of molecular breeding in a sustainable way, and to inform GIB Service development and evolution, so that it remains relevant to user needs.
- ✓ ***Crop Lead Centres*** for the coordinated management of crop information and data, with well-defined operational rules and quality criteria, building on their achievements and avoiding duplication. All Centres contacted have committed to this concept, and will take the leadership for coordinating data on their mandate crop(s).
- ✓ ***Molecular breeding proofs of concept*** in the public sector for crops like beans, cowpeas, chickpeas, rice, sorghum and wheat, led by breeders in developing country programmes (like the wheat project for India and China), or conducted in close collaboration with scientists from transnational companies, like the sorghum MARS project that includes the active participation of Syngenta scientists.
- ✓ ***Comparative genomics proofs of concept*** in the public sector demonstrating that by serving genomics and integrated breeding projects across a set of different crops, historically under-resourced crops will be able to access the same tools and resources that have greatly boosted research in common staple crops.

10 Governance, management and monitoring

10.1 Governance

Legally, GCP is a ‘partnership consortium’ (not an independent legal entity), established under the Amended Consortium Agreement, with three key governance bodies: the Consortium Committee, the Executive Board and the Host Agent.

The Consortium Committee (CC) comprises highly accomplished scientific leaders appointed by the Consortium Members. The CC provides expert scientific counsel to the Executive Board and the Management Team. It is the ultimate governance body. The seven-member Executive Board (EB) is the primary governance body, with full authority to oversee high-level management, approve budget and research strategy and evaluate Programme achievement. Since GCP’s inception, CIMMYT has been Host Agent, assuming GCP’s financial and legal liabilities, and providing operational support and services as defined in the Amended Host Agreement.

GCP’s governance will remain unchanged until 2013. The GCP governance model could inform the future governance of the themes in the new CGIAR.

10.2 Management

GCP is led by a Management Team consisting of a Director, four Subprogramme Leaders (SPLs) and a Product Delivery Leader. The SPLs lead, coordinate and monitor research and service activities in Genomics, Breeding, Crop Information, and Capacity-building and also serve as administrators and technical advisors to project Principal Investigators. The Product Delivery Leader implements the GCP product delivery strategy, aided by Product Delivery Coordinators (PDCs) in GCP Research Theme components.

The Subprogramme Leader for Crop Information has overall oversight of the IBP project. The management of the existing IBP will apply to the GIB Service until 2013: a Platform Manager to provide overall leadership; an Informatics Coordinator to lead development of informatics tools and applications; and a Service Coordinator to provide user support in accessing high-throughput facilities.

After 2013, the management of the GCP Research Theme components will be transferred to the respective Theme 3 crop megaprogrammes and the management of the GIB Service will be adjusted based on the needs of the crop megaprogrammes.

10.3 Monitoring and Evaluation (M&E)

M&E is conducted through various internal mechanisms and regular external reviews by donors and the CGIAR Secretariat. These mechanisms will remain in place during Phase II, and will apply to the GIB Service.

The foundational Integrated Breeding Platform has a Scientific and Management Advisory Committee (SiMAC) for strategic guidance and monitoring, with a core group of six, and a 10-member Specialist Group consulted on a need basis for their expertise. Several other Research Themes have an advisory committee along the lines of SiMAC. GCP also has one advisor on genomics and another on capacity building.

In 2013, an external review commissioned by the CGIAR Consortium Board will assess GCP Phase II and its transition into the Genomics and Integrated Breeding Service. After 2013, oversight of the GIB Service will follow the procedure that will apply to crop megaprogrammes in Theme 3, but taking into consideration that it is a service rather than a research programme.

11 Potential Risks

A major risk is that the GIB Service does not attract enough new users to make it relevant and sustainable once it is opened up to a broader community in 2012. Converting the use cases into successful integrated breeding projects will help to attract new users by creating incentive and buy-in. The bottom-up approach employed in the design and development of the Service further mitigates this risk by addressing expressed needs and engendering ownership.

The prevailing inward-looking institution-centric mindset and work style of researchers and breeders in the public domain is another potential risk that might jeopardise the co-operative approach promoted through the GIB service. Having supportive and active molecular breeding CoPs for different crops, as well as participatory professional networks to nurture a collaborative and outward-looking spirit of community, will be essential to stimulate the interest of new users.

Logistics-related risks such as crop failure at the field sites due to excessive or insufficient rainfall can compromise the success of the research components, as can unique risks implicit in molecular breeding, such as sample mix-ups, and poor phenotyping due to the nature of a trait or the limited skills of the technicians. Other risks are related to feasibility issues, such as the complex logistics behind the number of crosses, plants and environments that molecular breeding requires.

12 Transition of the Genomics and Integrated Breeding Service in 2014

In 2013, GCP ends, and – as proposed in this document –ongoing research projects will be incorporated into appropriate crop megaprogrammes within Theme 3. We propose that beyond GCP's 'sunset', the GIB Service, that will have been established and deployed by that time, continues as a demand driven service, and this requires consideration of the points outlined below.

The GCP team will oversee and coordinate the development and implementation of the Service up to 2013, and lay a sound foundation for its long-term sustainability. The *modus operandi*, governance and financial arrangements of the GIB Service after 2013 will be defined during this transition phase. We suggest that a working group composed of lead scientists in the crop megaprogrammes in Theme 3, GCP management, potential users outside the GCP (eg, NARS and SMEs) and representatives of private seed companies be formed soon to address these issues.

The implementation of a business plan to address the sustainability of the service will also need to be discussed. The idea that the GIB Service could eventually operate, partly or entirely, by full cost recovery will have to be explored. A membership model for defrayment of support service costs should be explored, with other services proposed to be provided on a charge-back basis. NARS, SMEs and universities could form a community for molecular breeding which would be hosted by the GIB Service, supported by a paid membership that provides access to all support services. The costs of data curation, development of suitable databases, hardware, etc incurred by each Crop Lead Centre could be borne by respective crop megaprogrammes.

The governance and management of the GIB Service should be considered once those of the crop megaprogrammes in Theme 3 have been clearly defined. The key objective would be to reduce both transition and transaction costs without jeopardising efficiency and flexibility. Three governance options might be considered: i) that the GIB Service remain an independent service under Theme 3 with its own governance structure; ii) that it be integrated into one of the support service platforms under the Consortium Board; or, iii) that it be placed under the governance of one of the crop megaprogrammes.

13 Timeframe, budget and budget strategy (2011–2013)

This document presents a workplan based on a timeframe of three years leading up to the end of GCP's lifetime, building on a set of focused research projects and an integrated breeding service component during its second phase. The workplan was approved by the GCP Executive Board and is being implemented through ongoing contracts with GCP grant recipients. It is in keeping with the recommendations of the very positive External Programme and Management Review of 2007.

The logframe for this three-year period is presented in Appendix A. The eight Research Themes and the Service component have been approved based on detailed proposals. All our proposals are presented in the same format, detailing outputs, products and outcomes, and milestones along a timeline over the entire duration of the project.

The overall budget for GCP to operate and support its research activities and develop the service component over the coming 3 years (2011–2013) is presented in Table 1. The largest portion of this budget is distributed to partners who are running the different research and service activities (research budget line 5 in Table 1). GCP is also directly involved in some research activities, especially for the GIB Service, and these are included in the budget line 3. The appropriation of this research budget by type of partner is presented in Chart 1.

As illustrated on the chart, the largest portion of the budget goes to developing-country programmes, and includes significant amounts for capacity building that is inbuilt in the research activities. The percentage of this allocation progressively increases over the three years of the transition, continuing a trend established over the last few years. This budgetary trend illustrates how the roles of the different kinds of partners have evolved over time, with scientists from developing countries getting more involved, and increasingly taking on project leadership. In the early years of the Programme, only about 25% of the research budget was allocated to NARS, as compared to a projected allocation of 42% in 2013. This increase has been balanced by a decline in appropriations to advanced research institutes who are moving from leadership roles to advisory and supporting roles. The budgetary allocation to CGIAR Centres has remained at about the same level (30–40%) over time, as some of the resources reported in Chart 1 under GCP will support activities conducted by the Centres. They continue to actively participate in most GCP projects, providing leadership in their mandate areas.

Research budget appropriation for GCP activities in Theme 3 and the GIB Service is illustrated in Chart 2. As indicated on the chart, about 40% of our projected resources will go into the development and implementation of the GIB Service, while about 60% will go into the eight Research Theme components, with the largest allocation to support research in legumes. As has been explained in this document, these research activities are embedded in the respective crop MPs and are included in their budgets. To avoid double budgeting, the resources allocated in the MP budgets for these GCP research activities are reported as *Current Restricted Project supported by GCP Funds*. This is additionally in keeping with the concurrent decision that these research activities will be managed by GCP until 2013.

As indicated in Table 2, about one third of GCP's projected income for the period 2011–2013 (USD 5m per year) is restricted funding from the Bill & Melinda Gates Foundation, dedicated to two projects. GCP therefore needs to secure an additional USD 10m every year from 2011 to 2013 to support the other project activities in our workplan for that period, and meet our contractual obligations to grant recipients both within and without the CGIAR. In previous years, this sum would have been directly raised from various CGIAR donors. However, as from 2011, these donors will disburse most of their funding through The Fund. Though GCP will continue to seek funding from alternative sources, GCP and partners hope to have the support of the CGIAR Board to access resources from The Fund to help bridge this annual budget gap of USD 10m.

Indeed the budgetary gap for 2011 is in reality 12.4m, but GCP will be able to cover 2.4 million (basically contractual obligations from previous years) from carryover funds. However, after these adjustments, GCP will be left holding just USD 4m, of which 3 million constitutes our reserve.

If deemed appropriate, some ongoing GCP research activities may be extended beyond our sunset in 2013. Such extended activities shall be managed by the megaprogrammes as part of their overall strategy, including providing the requisite funding to sustain them. As described in previous sections, the financial arrangements for the GIB Service after 2013 will need to be discussed and agreed upon by service users and allied stakeholders.

Table 1. Projected budget: Expenditure for 2011–2013

GENERATION CHALLENGE PROGRAMME (GCP)

	GCP Transition Strategy
Bilateral 'non-CG Fund' Investors:	Bill & Melinda Gates Foundation
Estimated starting date :	All projects assumed to be 1 Jan 2011 at present.
Project Duration :	**All Project budgets to be for first 3 years**

Project Cost

Cost group	Description	Year 1 Amount (US$)	Year 2 Amount (US$)	Year 3 Amount (US$)	Project Cost Amount (US$)
		'000,000	'000,000	'000,000	'000,000
1	Personnel Cost	0.598	0.641	0.687	**1.926**
2	Travel	0.150	0.150	0.150	**0.450**
3	Operating expenses (see definition)	0.926	0.986	1.181	**3.093**
4	Training / Workshop	0.576	0.235	0.723	**1.534**
5	Partners / Collaborator / Consultancy Contracts	14.074	12.369	10.274	**36.717**
6	Capital and other equipment for project	0.050	0.050	0.050	**0.150**
7	Contingency	-	-	-	
	Total	**16.374**	**14.431**	**13.065**	**43.870**
8	**Institutional Overhead (as a % of Direct project cost)** Av 7%	**1.050**	**0.943**	**1.050**	**3.043**
	Total Project Cost	**17.424**	**15.374**	**14.115**	**46.913**

Table 2. Projected budget: Income 2011–2013

Project Funding — **Investor contribution per year**

Description		Year 1 Amount (US$)	Year 2 Amount (US$)	Year 3 Amount (US$)	Project Cost Amount (US$)
Funding		'000,000	'000,000	'000,000	'000,000
	CGIAR Fund - (Window 1 & 2)	12.414	10.39	10.364	**33.168**
	Current Restricted Donor Projects				
	Bill & Melinda Gates Foundation	5.010	4.984	3.751	**13.745**
	Donor B				
	Current Restricted Donor projects "cofinanced by unrestricted funding"				
	Donor A				
	Donor B				
	Other Income				
Total Funding		**17.424**	**15.374**	**14.115**	**46.913**

Chart 1. Budget projection by type of partner

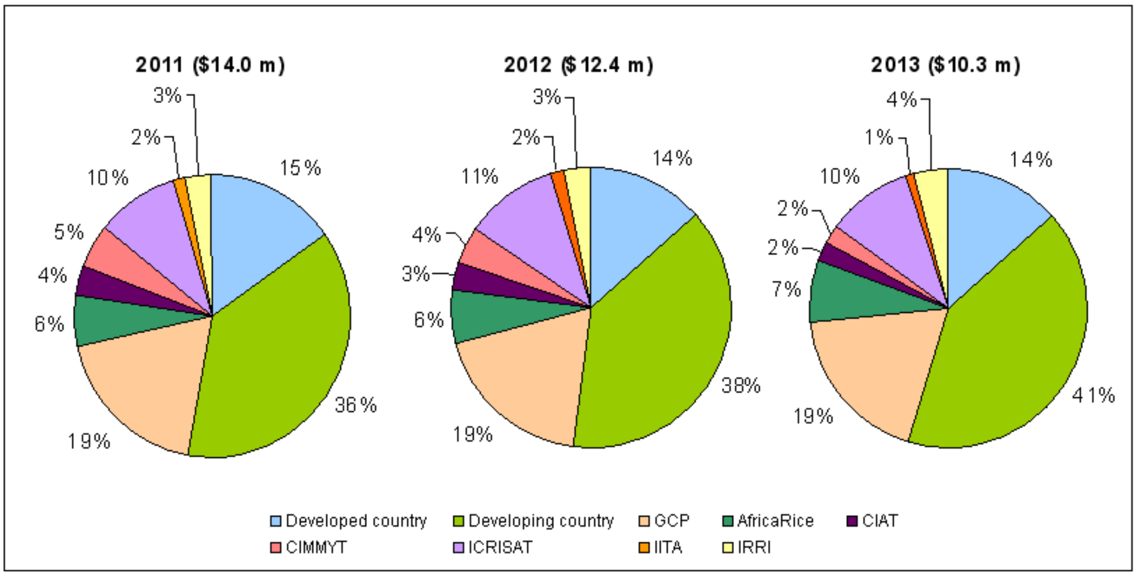
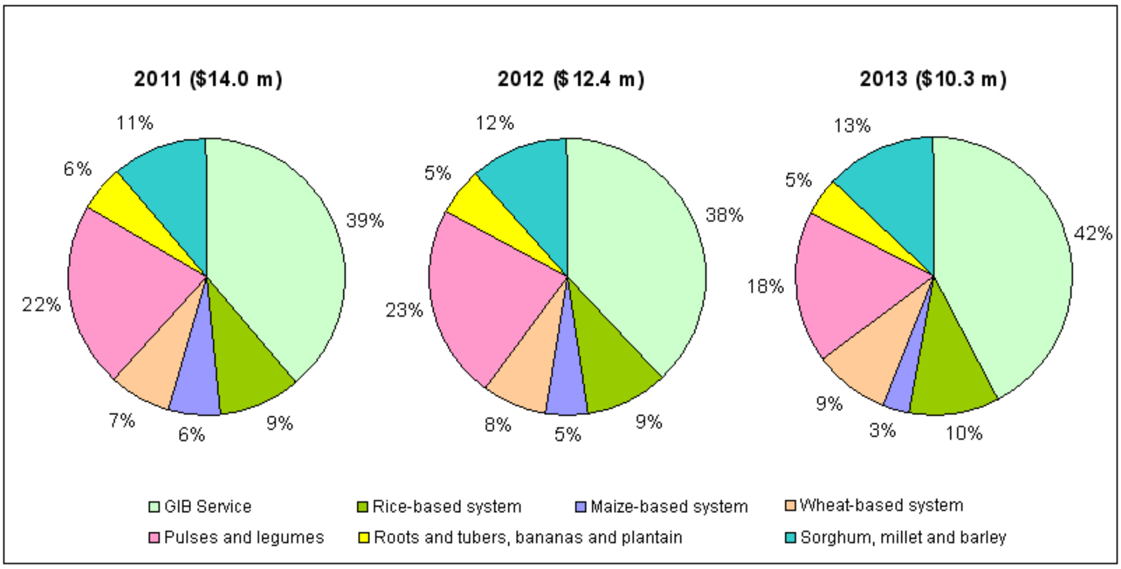


Chart 2. Budget projection of GCP research activities within Theme 3



14 Appendixes

14.1 Appendix A: Logframe overview

Project title	Output(s)	Outcome(s)	Impact
I. Service component			
Genomics and Integrated Breeding Service (GIB Service)			
This service is comprised of the 4 Modules described below	Efficient and demand-driven Web-based service providing single-point access to a broad set of tools, technologies, resources, and support services for genomics research and integrated breeding activities	Enablement and/or facilitation of molecular breeding and genomics by CG Centres, National Programmes, Advanced Research Institutes and Small and Medium Enterprises	• Improved capacity to conduct molecular breeding in a wide array of crops in developing countries. • More efficient development of new cultivars for marginal environments, leading to increased yields • Enhanced farm household incomes and improved livelihoods • Improved food security in developing countries
Module 1: Communications and access	• A web portal to access genomics and integrated breeding resources and services, established and managed • Easy single-point access to public crop information and informatics applications by plant scientists, including breeders, to conduct successful genomics and molecular breeding projects	• A collaborative environment for sharing information and knowledge • Genomics and molecular breeding project needs of plant scientists and breeders fulfilled via the Portal	• Shortened germplasm improvement cycle due to higher efficiency in plant science research • Germplasm improved for the target environments in developing countries through molecular breeding
Module 2: Genomics and molecular breeding informatics service	• Enhanced tools for: management of germplasm lists, pedigrees, IP and passport data; and management and analysis of phenotypic and genotypic data • Configurable workflow system integrating data management with a data analysis pipeline. • A critical mass of informatics resources and expertise on hand offering support for research data management – including quality control, analysis, modelling and simulation across crops.	• Harmonisation of the management and publication of research and breeding data and information within and across Centres and partners to maximise quality, access and integration • Enhanced data accuracy and reliability • Increased data sharing between partners • Enhanced quality control and standardisation procedures in research data management	• Highly efficient data and information management in the CGIAR and partner organisations • Higher research efficiency resulting from better information management leading to improvement of programmes • Better-informed choice of breeding material and design of breeding programmes
Module 3: Services and support for genomics research and breeding projects	• Operational Genetic Resource Supply Service • Updated database of the Molecular Marker Toolkit for marker-assisted selection • Responsive support services and Helpdesk to facilitate access to all tools and resources of the GIB Service	• Increased use of the cost-effective high-throughput genotyping laboratory services facilitated through the GIB Service • Cost savings by Centres and partners from not having to invest in genotyping lab infrastructure • Reduced time investment by developing country breeders and researchers in the legal and administrative complexities of accessing high-throughput services • Developing country breeders trained in, and supported to use molecular breeding	• More breeders in developing countries using molecular breeding, increasing the efficiency of their crop selection programmes • Enhanced progress in cultivar development by developing country breeders

Project title	Output(s)	Outcome(s)	Impact
		methodologies	
Module 4: Service communities and product delivery	• Operational professional molecular breeding networks and communities of practice (CoPs) • High-quality research products packaged, and delivered to target stakeholders and promoted in communities of practice • Tailor-made capacity development programmes	• Appropriate human capacity development and infrastructure needs of partners addressed • Increased use of the GIB Service • Enhanced access to, and use of, crop research products through CoPs and and professional networks • Increased adoption and practice of innovative breeding applications and support services by developing country institutes • Propagation of best practice through sharing of information and peer mentoring	• More advanced plant science research conducted in developing countries • More and better crop varieties for resource-poor farmers created by breeders in developing countries addressing the challenges of marginal environments

Project title	Output(s)	Outcome(s)	Impact

II. Research Theme components (8)

Project title	Output(s)	Outcome(s)	Impact
6.2.1 Improving drought tolerance in rice for Africa	• Improved infrastructure and more qualified staff in national breeding programmes • 3 F3 biparental breeding populations adapted to the target country and improved for drought tolerance and biotic stresses, (eg. RYMV resistance)	• Increased capacities of NARS to conduct accurate phenotyping and run molecular breeding experiment. • New African rice cultivars with improved performance under drought conditions	• Enhanced food security in lowland African ecosystems • Improved breeding methodologies for rice in Africa.
6.2.2 Drought-tolerant maize for Asia	• Double haploids extracted from BC1C2 and BC2C2 • 4*200 double haploids of 4 MARS-improved populations between 2 DT CIMMYT lines and 4 Asian adapted elite maize inbreds • Effective joint partnership between private companies and public institutions	• Asian national programmes benefit from the large effort made in Africa and Latin America for improvement of drought tolerance. • Drought-tolerant lines and hybrids identified and made available to farmers • SMEs exposed to molecular breeding	• Enhanced breeding programmes of Asian SMEs due to the use of molecular breeding • Maize yields enhanced in Asia through a molecular breeding approach • Enhanced farm outputs, incomes and livelihoods
6.2.3 Improving drought tolerance in wheat for Asia	• A functional crop data management system for China and India implemented • Improved field infrastructure for wheat screening under drought condition in China and India • 20 to 30 recombinant substitution lines improved for drought tolerance	• More efficient crop information exchange across breeding Institutes at the National and international levels. • New drought-tolerance QTLs transferred, validated and used for breeding in Indian and Chinese germplasm • New wheat varieties for India and China with improved performance under drought conditions	• Increased selection efficiency of Asian national programmes and SMEs thanks to the adoption of molecular breeding • Enhanced farm outputs, incomes and livelihoods
6.2.4 Improving tropical legumes productivity for marginal environments in sub-Saharan Africa and India	• Improved infrastructure and more qualified staff in national breeding programmes • New genomics resources for legumes developed • New germplasm material (e.g MAGIC, synthetic) available for genetic studies and pre-breeding in legumes • Molecular breeding projects implemented for selection and recombination of drought tolerance loci in targeted populations of groundnuts, beans, cowpeas and chickpeas	• Increased capacities of NARS to conduct accurate phenotyping and run molecular breeding experiment. • New germplasm and improved breeding programmes for tropical legumes in SSA • Improved germplasm for resource-poor cropping systems obtained	• Better-balanced diets for resource-poor people living in drought-prone areas in SSA and India • Increased yields in small scale farmers' fields in marginal cropping systems • Increased incomes due to improved local varieties of legume cash crops
6.2.5 Improving cassava yield in Africa's drought-prone environments	• Identification of main drought tolerance QTLs in South American populations • Validated markers to improve biotic stress resistance in cassava • Improved African cassava germplasm for cassava mosaic disease (CMD) and cassava brown streak disease (CBSD)	• Through an established community of practice, increased capacities of NARS to conduct accurate phenotyping and run molecular breeding experiments. • Major loci involved in drought tolerance pyramided in elite cassava cultivars • Molecular breeding for biotic stress operational in African national programmes • Cassava cultivars with improved productivity under marginal environments grown by farmers in SSA	• Capacity built in African national programmes to use molecular breeding to increase the efficiency of their breeding activities for both biotic and drought stresses • Enhanced food security in drought-prone ecologies through improved cassava cultivars

Project title	Output(s)	Outcome(s)	Impact
6.2.6 Improving drought tolerance in sorghum for Africa	• 20 specific, exotic, donor parents, 10 each from IER and ICRISAT, 11 common, diverse, donor parents, and two locally adapted recurrent parents used to develop BC1F4 populations by backcross nested association mapping (BCNAM) • Key genomic regions accounting for performance in target environments in the genetic background of the adapted parent, identified	• Availability of improved sorghum genotypes for marginal environments in SSA • Higher productivity of adapted cultivars produced through molecular breeding and based on broad genetic variation • Improved, near-elite, diverse breeding materials for marginal environments cultivated in West Africa	• Increased sorghum productivity by enhancing the capacity of national breeding programmes to widen use of diverse germplasm and deploy molecular breeding approaches
6.2.7 Yield improvement of sorghum in Africa through MARS	• MARS protocols developed and tested for sorghum improvement in Africa • Improved lines selected from successive cycles of recurrent selection in two populations • One PhD thesis on modern breeding by a Malian scientist • Effective joint partnership between private and public sector	• Increased capacities of NARS to conduct accurate phenotyping and run collaborative molecular breeding experiments in West Africa • Sorghum yields enhanced in West Africa through a marker-assisted breeding approach developed and applied through North-South collaboration •	• Better food security for farmers in marginal environments in Sahelian West African countries through improved sorghum cultivars • A new paradigm of co-operation between the private and public sectors towards food security
6.2.8 Comparative genomics to improve cereal yields in high-aluminium and in low-phosphorous soils	*In sorghum:* • Minimum of one validated marker for Alt_{SB} • Minimum of two validated markers for *Pup1* • Minimum of two target materials introgressed with Alt_{SB} for both Niger and Kenya	• New loci for tolerance to phosphorus and aluminium deficiencies available for sorghum breeding programmes • Comparative genomics approach for orthologous gene identification validated in sorghum	Varieties of sorghum that are better performing under poor soil conditions (phosphorus and aluminium deficiencies in acid soils) grown in target countries
	In maize: • At least one pair of markers flanking the Alt_{S} homologues or Al tolerance QTLs polymorphic between donor and receptor lines from Brazil, Kenya and Zambia • At least one pair of markers flanking the *Pup1* homologues or P tolerance QTLs polymorphic between donor and receptor lines from Brazil, Kenya and Zambia	• New loci for tolerance to phosphorus and aluminium deficiencies available for maize breeding programmes • Comparative genomics approach for orthologous gene identification validated in maize	Varieties of maize that are better performing under poor soil conditions in Africa (phosphorus and aluminium deficiencies in acid soils) grown in target countries
	In rice: • Major QTLs associated with Al toxicity tolerance identified • Al-tolerance QTLs identified in parallel projects validated in Indonesian varieties	• New loci for tolerance to phosphorus and aluminium deficiencies available for rice breeding programmes • Comparative genomics approach for orthologous gene identification validated in rice	Varieties of rice that are better performing under poor soil conditions in Asia (phosphorus and aluminium deficiencies in acid soils) grown in target countries

14.2 Appendix B: Service and Research component summaries

I. Genomics and Integrated Breeding Service components

Module 1: Communication and access to services – This will provide access to all the tools and services of the GIB Service via a web-based portal through which users can select and download tools and instructions, order materials and procure laboratory services and training. A helpdesk will support the use of the portal and provide access through CDs and other offline media to users who cannot use the web-based interface. The portal will be a collaborative environment for sharing information and knowledge.

Module 2: Genomics and Molecular Breeding Informatics Service for crop megaprogrammes and partners – The Informatics Service provides tools and support for the logistics of genomics and breeding projects and for data management and analysis. Existing tools are being improved to meet user needs and built into a configurable workflow system which will integrate data management and an analysis pipeline. This configurable workflow system will be both accessible via the internet and also downloadable for local installation. The Informatics service will support the curation, integration and publication of crop information through an informatics network, facilitating the choice of breeding material and the design of breeding programmes.

Module 3: Services and support for genomics research and breeding projects – The first objective of this module is to provide access to germplasm, genomic technologies, markers and trait services required to conduct genomic and molecular breeding projects. It will provide a gateway to facilitate access to specific germplasm and related information, in close collaboration with the CGIAR and NARS genebanks. The GIB Service will provide a set of options for users to access different genomics and marker service laboratories in the public and private sector with clear contractual conditions. It will also link with laboratories willing to quantify specific traits, such as metabolite profiles or grain quality parameters. Laboratories will be selected on the basis of competitive cost, quality and delivery efficiency. The Service will foster the integration of the information flow from these laboratories with the informatics system of the GIB Service.

The second objective is to provide support services, including training and other capacity building of NARS breeders, to deliver improved germplasm through marker approaches. These support services will help breeders address and resolve technical and logistical bottlenecks by providing backstopping and training in a broad set of complementary disciplines that support the use of various breeding services.

Module 4: Service communities and product delivery – This module will support and coordinate the development of professional networks and communities of practice (groups of people sharing a concern or a passion for their common work, learning how to improve their work through regular interactions), as well as provide the means to ensure that project products are evaluated, packaged, promoted, delivered and deployed according to specific plans. Two professional networks are envisaged. The Network for Agricultural Genomics would link all CGIAR genomic researchers and those from our current Consortium into a community sharing information and tools for genomic research. It would have a portal indexing all genomic and bioinformatics information available in the public sector. The Research Informatics Network would link the statisticians and data management specialists into a network sharing information and tools; it would encourage standardisation and quality control, support best practice in research data management, and provide knowledge and training in statistical analysis and interpretation. Concomitantly, the module will support the development of molecular breeding communities of practice by connecting appropriate groups of crop researchers, mainly breeders involved in the use cases and willing to share experiences and information on modern breeding methods and best field practice.

GCP's approach to product delivery, promotion and packaging is summarised in Section 5. The service communities will shape product development, delivery, evaluation and impact assessment with a view to promoting the successful use of the products by participating breeding programmes. *Ex ante* impact analyses will be conducted for selected, successfully packaged and delivered products. Such analyses will evaluate their long-term usability and their contribution to CoPs cohesiveness and expansion.

II. Research Theme components

6.2.1. Improving drought tolerance in rice for Africa: Rice yield in rainfed lowland ecosystems in Mali, Burkina Faso and Nigeria is affected by drought due to erratic rainfall and suboptimal water management. Within four years, the rice theme project proposes to: (i) establish drought profiles of target environments; (ii) identify traits of interest for target environments, using novel phenotyping methodologies for efficient separation of genetic and environmental effects; and, (iii) integrate information on drought profiles with novel phenotyping methodologies in a marker assisted recurrent selection (MARS) scheme to develop better adapted germplasm for each major target environment.

6.2.2. Drought-tolerant maize for Asia: The acreage under maize in South and Southeast Asia is expanding by 2.2 percent annually. Over 80 percent of the maize is grown under rainfed conditions and is prone to drought. Building on progress in breeding drought-tolerant maize in Central America and eastern and southern Africa, this project proposes to apply marker-assisted selection (MAS) to achieve a similar goal in Asia. MAS will be applied within pedigree breeding or through backcrosses between drought-tolerant source inbred lines and a minimum of four elite Asian adapted inbred lines. Additional lines will be included through self- and donor-funded MARS projects by both public and private partners (primarily SMEs).

6.2.3. Improving drought tolerance in wheat for Asia: The wheat theme project aims to assemble and integrate into breeding programmes genetic diversity for water-use efficiency and heat tolerance from key sets of genetic resources (including drought-adapted cultivars, advanced lines, elite landraces, products of inter-specific hybridisation, from China, India, CIMMYT, ICARDA, Australia, among others). This project will combine known genomic regions for performance under moisture stress in elite Chinese and Indian backgrounds using a combination of empirical selection for yield, MAS for genomic regions and selection for relevant physiological traits. The target regions will be combined using MARS and backcrossing strategies. Validation of selected germplasm will be conducted concurrently under managed drought stress in China and India.

6.2.4. Improving tropical legumes productivity for marginal environments in sub-Saharan Africa and India: The Tropical Legumes theme project focuses on improving the productivity of four legumes of high importance to food security and poverty reduction in sub-Saharan Africa and India. Its overall objective is to improve the productivity of groundnuts, cowpeas, common beans and chickpeas through modern breeding with genetic resources and genomic tools from the project's Phase I. This project will conduct high-quality phenotyping, and improve human resources and local infrastructure. The long-term objective (7–12 years), to be achieved through a sister project, Tropical Legumes II that deals with seed multiplication and distribution, is to double grain legume productivity. Doing so will generate additional income for farmers of USD370, 160, 220 and 250 per hectare respectively for groundnuts, cowpeas, beans and chickpeas for each crop cycle.

6.2.5 Improving cassava yield in Africa's drought-prone environments: Cassava is an important staple for over 200 million people in Africa. It captures more energy per unit area than any other crop in drought-prone ecologies, making it an ideal crop for food security. The GCP cassava theme project is driving crop improvement strategies based on marker–trait association to enhance breeding efficiency through quantitative trait loci (QTL) mapping for pest and disease resistance, and trait components of yield and drought tolerance. The best haplotypes will be identified and recombined in a MARS scheme for rapid genetic gain and improved productivity in dry environments through development of elite varieties. The previously developed cassava reference set will be further refined to capture more genetic diversity through molecular characterisation of new accessions. Output targets of the cassava theme project are to fast-track development of improved varieties and, through an established community of practice, increase capacity of country programmes in molecular breeding strategies.

6.2.6. Improving drought tolerance in sorghum for Africa: The project is an integrated programme to develop improved sorghum germplasm in Mali that balances local agronomic and grain quality preferences with incorporation of well-characterised drought adaptations and exploration for cryptic valuable alleles. Activities include population development, genomic analysis, phenotyping components and two molecular breeding programmes. The project will result in the development of modified backcross-based nested association mapping populations (BCNAM) that will be of long-term value in relating sorghum traits to their corresponding genes.

6.2.7. Yield improvement of sorghum in Africa through MARS: Sorghum is one of the most important cereals in West Africa. However, its yield is low and has not really progressed during the past 20 years. Sorghum production in West Africa is principally based on traditional, low harvest index cultivars and breeding efforts over the past 40 years have had limited impact. This project proposes to associate recent approaches on sorghum breeding that have been developed at L'Institut d'économie rurale (IER, Mali) and methodologies for MARS that have significantly improved breeding efficiency for complex traits, especially in the case of maize. It will illustrate the value of the MARS approach for sorghum breeding through a private–public partnership.

6.2.8. Comparative genomics to improve cereal yields in high-aluminium and low-phosphorous soils: This research component covers rice, sorghum and maize and leverages knowledge from model species or crops to facilitate gene discovery. The main objective is to build on the Phase I characterisation of the Alt_{SB} gene (that confers tolerance to aluminium toxicity in sorghum, a problem encountered in acid soils) and the *Pup1* gene (that improves phosphate uptake by rice in poor soils) to identify orthologous gene(s) for aluminium tolerance in rice and sorghum, and to improve phosphorus uptake efficiency in sorghum and maize. It is expected that in the course of Phase II, elite alleles for these new orthologous genes will be tested in adapted germplasm under local conditions, and gene-based or linked markers will be deployed for breeding in GCP target environments.